Intensive Livestock Farming

Edited by

W. P. BLOUNT
T.D., PH.D., F.R.C.V.S., F.P.H., F.R.S.E.

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To

THE LORD COLE

Chairman, Unilever, Ltd.

Printed in Great Britain by Alden & Mowbray Ltd at the Alden Press, Oxford

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PREFACE

The farming of livestock in Britain and in many other developed countries is growing more intensive each year, and as this is a field about which few texts have been written it is not surprising that the publishers decided that this would provide them with pastures new. What is surprising is the fact that they gave me the opportunity to act as editor, since my association with agriculture today relates almost solely to that of the poultry industry. Perhaps this in itself is some justification, as 'concrete farming' has been applied more to poultry than to any other species. In this respect it has received both brickbats and bouquets, and it is to the former that I hope parts of this book will make an effective reply. I have endeavoured to answer Ruth Harrison whose outspoken criticism of intensive farming created such great interest 3 years ago, and who has just been appointed a member of the Standing Advisory Committee (recommended in the Brambell Committee Report), whose chairman is Professor H. R. Hewer. And here I must thank the publishers Vincent Stuart Ltd. for permission to quote various passages from her book *Animal Machines*.

However, in addition to poultry matters I have had the privilege for many years of working alongside many agricultural specialists, and I consider myself particularly fortunate to have obtained their most helpful co-operation. They are experts in a variety of fields—animal physiology, nutrition and feeding systems, stock management, agricultural economics and marketing, fish farming, the role of computers and last but by no means least research. In all, eighteen colleagues have collaborated with me in producing this book, which it is hoped will appeal both to members of the veterinary profession and agriculturalists, particularly as eight of the contributors are themselves veterinary surgeons actively engaged in disease control or research.

Intensive livestock farming obviously covers a very wide range of subjects, but feeding and disease control form two of the most important, that is why they have been covered in greater detail than some other aspects of the problem. Doubtless some readers will feel that the text as a whole is somewhat disjointed, but to have dealt with all its important facets would have at least doubled its size. In spite of this obvious defect, one hopes that the average purchaser of the book will consider that his money has been well spent.

Acknowledgments and Thanks

As far as possible I have tried to give an adequate list of references and therefore apologise for any inadvertently missed.

On a number of occasions I have drawn freely upon the Agricultural Notes published in the *Financial Times, Daily Telegraph* and *The Times*. I have much pleasure in acknowledging these and in doing so would thank not only the editors concerned but also their special scientific and commodities staffs for the way in which they keep their readers in daily touch with events of agricultural importance.

I wish to thank the Ministry of Agriculture, Fisheries and Food for permission to use the photographs illustrating B. S. Hanson's article on the 'Diagnosis and Treatment of Poultry Diseases'. Also Messrs. Butterworth, Inc., Washington, D.C. for permission to reproduce illustrations from *Physiology of Digestion in the Ruminant* as follows:

'% of total stomach tissue contributed by each compartment for calves and lambs at several ages', from 'Anatomical development of the ruminant stomach', by Warner, R. G. and Flatt, W. P. and 'Factors which influence the balance of bacterial species in the rumen', from 'Possible factors influencing the balance of different species of cellulolytic bacteria in the rumen', by Kistner, A.

In addition the editor-in-chief (Ernest O. Herreld) *Journal of Dairy Science* and Dr. L. A. Mabbitt of the National Institute for Research in Dairying, Shinfield, Reading, for permission to use the Figure 'Amounts of digesta found in the reticulo-rumen of Shorthorn cows receiving various diets' from 'Weight Changes in Dairy Cows', C. C. Balch and C. Line, *J. Dairy Res.* (1957), **24,** 11–19.

I am also indebted to the editor of *Medical and Biological Illustration* and to Dr. P. F. Newell for permission to use Figure 9, and quote freely from *The Nocturnal Behaviour of Slugs.*

My best thanks go to all the contributors, who are listed separately, for the excellence of their several contributions. In addition I want to thank Jim Morton for kindly collating the work of my three colleagues Pat Bichan, Paddy Walsh and Peter Wilson whose combined contributions cover Calves and Cattle; also Bill Marshall who heads the Company's Farm Buildings Advisory Service, and who has supplied a variety of plans and drawings. It will be obvious to most readers that no single person could write effectively on such a wide subject as Intensive Livestock Farming, hence my gratitude to all the other contributors.

The permission to involve twelve of my scientific colleagues in the preparation of this book was readily given by Mr. C. A. C. de Boinville, Chairman of both the Unilever U.K. Milling Group Administration and of The British Oil and Cake Mills Ltd. That for my associates at the Unilever Research Laboratories, Colworth House, Sharnbrook, Beds., was given by Mr. J. K. D. Dow, B.Sc., M.R.C.V.S., Head of the Nutrition Dept., and to them both I am immensely grateful.

Finally I am particularly grateful to Miss H. R. Fraser for typing the text with speed and care, and to further secretarial assistance from Miss W. M. Buckley, who has dealt with the not inconsiderable correspondence. My assistant Miss M. M. Martin, M.A., F.P.H., has very kindly prepared the index, read the proofs, and given other invaluable help.

January 1968 W. P. B.

FOREWORD

Sir John Ritchie, C.B.

LL.D. (h.c.) (Ed.), D.V.Sc. (h.c.) (Lv.), LL.D. (h.c.) (Tor.), B.Sc., F.R.C.V.S., D.V.S.M., F.R.S.E. Principal and Dean, The Royal Veterinary College (University of London), Royal College Street, London, N.W. 1.

I am glad to have an opportunity to write a foreword to this book on intensive livestock farming edited by W. P. Blount.

The subject is still a controversial one and it is useful to have information on so many of its aspects collected into one book. Indeed, the range which is covered is extremely wide, covering all the food animals and including a very useful chapter on fish farming, an enterprise which has been so little exploited here but has been very successful in several European countries.

Nutrition is given a prominent place throughout and this is obviously of great importance with animals which require all their food to be provided for them.

Whatever system is used in the management of animals disease will occur but the disease patterns and the disease potential will vary. If the possibility of disease is great under intensive conditions, this is balanced by the opportunities for the successful application of preventive medicine.

Intensive management is not new but more animals of several species are now maintained in this way than ever before. Under conditions of reduced acreage and economic stress clearly intensivism has come to stay.

Some 40 years ago I was employed in the City of Edinburgh and my main task was to inspect the cows in over 100 dairy herds within the City boundaries. Freshly calved cows were bought into the dairies from markets in the north of England, they were not bred again and never left the cowshed until their milk production had dropped to an uneconomical level and they were ready for slaughter as fat cows. On occasion their lactations lasted for over two years yet these animals appeared to be in good health and to maintain a good level of milk production.

The fact that animals maintained under intensive conditions do remain apparently contented, healthy and productive may not be sufficient scientific evidence for concluding that no element of cruelty exists in this practice but in the absence of evidence to the contrary it is surely a good enough starting point upon which to base our judgment of their welfare and to build further and more precise evidence. Many aspects, particularly of animal behaviour, still require study. It is essential to ensure as far as possible that animals kept for the production of milk, meat or eggs enjoy freedom from pain and stress, and this book will help us to make a rational approach to the problems associated with such animals kept intensively.

3 January 1968 J. N. RITCHIE

AUTHOR BIOGRAPHIES

A. W. Ashby, B.Sc., M.Sc., graduated at the University College of Wales, Aberystwyth, specialising in agricultural economics, and working on farms in Wales during vacations. Subsequently he did post-graduate work at Cambridge and at Cornell University, U.S.A. before becoming a Lecturer in Agricultural Economics at Nottingham in 1950. Three years later he moved to the Institute of Agrarian Affairs, Oxford, where he carried out research, also editing work in the field of agricultural economics. From 1955 he has been in the Economics and Statistics Department of Unilever Limited.

Subject

THE IMPACT OF BRITAIN'S ENTRY INTO THE COMMON MARKET ON INTENSIVE LIVESTOCK PRODUCTION

A. O. Betts, M.A., Ph.D., M.R.C.V.S., received his professional education at The Royal Veterinary College, at the University of Cambridge and at Cornell University. After a brief period in general practice he joined the staff at the Cambridge Veterinary School where, apart from 2 years in the U.S.A., as a Commonwealth Fellow, he remained until 1964 when he was appointed to his present post of Professor of Veterinary Microbiology and Parasitology, The Royal Veterinary College, University of London. His research has been concerned largely with enzootic pneumonia of pigs, viruses affecting the respiratory and digestive tract of pigs and cattle, and the production and use of S.P.F. pigs and calves. In 1961 he was adviser in Yugoslavia on pig health control under the Anglo-Yugoslav Technical Assistance Scheme, and he has also advised and lectured on the control of diseases by S.P.F. techniques in the Netherlands, Switzerland and Germany.

Subject

S. P. F. ANIMALS

P. I. Bichan, B.Sc., who was born and brought up on a small mixed farm in the Orkney Islands, graduated at Aberdeen University, following which he spent 2 years with the Animal Breeding Research Organisation before joining B.O.C.M. Barlby Farm in 1953.

Barlby Farm has been concerned with Dairy Bull Progeny Testing, Sire Performance Testing, producing beef from dairy bull progeny and calf rearing. Work has been undertaken to investigate various systems of housing and managing purchased calves; intensifying grazing of both milk and dairy stock and comparative trials in various pure and crossbred animals for beef and milk.

Subject

TRENDS IN CALF PRODUCTION

W. P. Blount, T.D., Ph.D., F.R.C.V.S., F.P.H., F.R.S.E. Qualifying in Edinburgh in 1928, he held the James Tindall research scholarship and Centenary Fellowship whilst working as an assistant in the Dept. of Anatomy, Royal (Dick) Veterinary College, later concentrating on haematology. After a short spell in practice in Folkestone the editor decided to concentrate on poultry at the suggestion of the late Sir Frederick Hobday. One year was spent at Weybridge under T. M. Doyle and N. Hole, before moving to Hamilton's Poultry Pathological Research Laboratory, Goring, Oxon. The following year he set up the Poultry Health Laboratories at St. Leonards-on-Sea in conjunction with a veterinary practice. Four years later he was appointed Chief Veterinary Officer to the East Sussex County Council, joining the T.A. in 1937 and transferring to the R.A.V.C. in 1941. Until the end of the war he worked mainly at the Chemical Defence Experimental Station, Porton. Since 1945 he has been Poultry Adviser to the British Oil & Cake Mills Ltd., being appointed a Director of the Company in 1957. He is Honorary Veterinary Consultant in the Faculty of Medical Sciences, University College, London, and a Vice-President of the World's Poultry Science Association.

Subjects

Housing Systems and Controlled Environments for Poultry; Poultry Nutrition, Foods and Feeding; Poultry Diseases and other Problems of Doubtful Aetiology which have been linked with Nutrition; Rabbit Production; Health and Disease Problems; Factory Farming and *World Food Problems.*

E. T. Cantle began his career by studying human pathology, specialising in morbid anatomy. He left his studies to join a large commerical poultry company to gain knowledge of applied genetics. Although planned as a 'sandwich course' his interest in animal production was so aroused that it proved to be the start of his working career. In the 1950s he joined a partnership in poultry husbandry and breeding, acting as consultant to many of the well-known poultry breeders. During this time he became interested in the interaction of genetics/environment, and disease-inhibiting factors and in 1960 was given a chance to apply these theories in practice. After 1 year he was appointed to the staff of the company (now the Cobb Breeding Company) as Research and

Development Director. He has a keen interest in futuristic ways of producing protein.

Subject

A DEVELOPMENT IN MODERN SHEEP PRODUCTION

R. Coles, B.A., Ph.D., M.Sc., D.Sc., D.V.Sc. Graduated at King's College, London, following which he took his higher degrees at the Institute of Education, University of London, and the London School of Economics, University of London. In 1934 he joined the Ministry of Agriculture, first with the Markets (Eggs and Poultry), then the Fertilizer Divisions. In 1945 he was appointed Superintending Officer, Poultry Advisory Service, and in 1946 became Chief Poultry Adviser N.A.A.S., the post he still holds. He is a Past President of the W.P.S.A., the W.P.S.A. European Federation, the W.P.S.A. U.K. Branch and the Poultry Education Association. He was awarded the Jelf Medal (University of London), the Queen's Medal, the P.A.G.B. Medal and the B.O.C.M. Poultry Award. He has had publications in *Poultry Science*, *British Poultry Science*, *Journal of Agricultural Science*, *The Empire Journal of Experimental Agriculture*, *Nature*, and the *Journal of Science in Food and Agriculture*.

Subject

THE STRUCTURE OF THE POULTRY INDUSTRY OF ENGLAND AND WALES

D. G. Filmer, M.A., Dip.Agric. (Cantab), B.Sc. (Agric.), N.D.A. Coming from a well-known farming family in Kent he attended one of the first 3-year Agricultural Technical Courses in the country commencing 1944, later obtaining a first-class certficate after a further year at the Kent Farm Institute. He then graduated B.Sc. at Wye College. With a Ministry of Agriculture award he went to Cambridge University to study Animal Nutrition and Husbandry, Statistics and Field Experimentation. In 1956, after National Service, he returned to Cambridge where he was appointed to the staff of the School of Agriculture. In 1961 he was appointed Animal Nutritionist to R. Silcock & Sons Ltd., and is concerned with the formulation of their range of poultry, pig and ruminant diets, and research leading to the development of improved and new animal foods.

Subject

NUTRITION OF THE INTENSIVELY MANAGED PIG

M. J. Gaisford, B.Sc. (Agric.), hails from Wiltshire where his father farmed for many years. He graduated at Reading University, then joined F. & G. Sykes Ltd. where he was mainly concerned in poultry housing, husbandry and breeding in the Genetics Department. In

1963 he joined B.O.C.M. as Assistant Farm Manager of their Demonstration Farm, Stoke Mandeville, being appointed Farm Manager in 1966. He is particularly interested in the housing and husbandry of poultry under controlled environment conditions and in the measurement of egg shell quality.

Subject

BATTERY CAGE EGG PRODUCTION

C. M. Gould, M.A., B.Sc., M.R.C.V.S., graduated as a Veterinary Surgeon at Edinburgh in 1954, and is mainly concerned with farm practice, with particular interest in grassland and other management problems of cattle, sheep and pigs. In the B.V.A. he is one of the Committee concerned with the initiation and the organisation of Information Services for Veterinary Surgeons.

Subject

THE FUTURE RELATIONSHIP BETWEEN THE VETERINARY SURGEON AND THE LIVESTOCK FARMER

B. S. Hanson, M.R.C.V.S. After graduating at The Royal (Dick) Veterinary College in 1942, he returned as an assistant to the agricultural practice in Devon where he had previously seen practice. The following year he joined the R.A.V.C. and served in the Middle East, Italy and Germany over a period of four years. On demobilisation he spent 1½ years in a London horse and small animals practice and a similar period as Veterinary Adviser to P.A.G.B. He joined the field staff of Animal Health Division, M.A.F.F. in 1951, took charge of the diagnostic section in 1962 and was transferred to the Veterinary Investigation Service in January 1967. His work has been associated with the diagnosis and investigation of poultry diseases, and also lecturing. Outside his normal duties he is serving on the TS.65 Working Party, the Chicken House Panel, R.A.S.E., and is an examiner for the N.D.P. Board. In 1964 he was awarded the B.T.F. Goodchild Trophy.

Subject

DIAGNOSIS AND TREATMENT OF POULTRY DISEASES

J. F. Harbourne, M.V.Sc., M.R.C.V.S. After qualifying at Liverpool in 1950 he went into private practice as an assistant in Cheshire and then in the West Riding of Yorkshire. In 1952 he joined the Ministry and spent all his time at the Leeds Veterinary Investigation Centre as A.V.I.O. until he took up his new appointment as V.I.O. at the Thirsk Centre in October 1965. A good deal of his earlier effort was devoted to the study of the epidemiology and control of fowl typhoid, and some of this work formed part of his University of Liverpool's M.V.Sc.

degree thesis. His later work has been devoted mainly to respiratory diseases in cattle.

Subject

DISEASES OF INTENSIVELY HOUSED CATTLE, PIGS AND SHEEP

A. B. Harker, B.Sc. A graduate in Agriculture from the University of Aberdeen, he has had practical experience on farms, (including a short period of farming on his own account) in Devonshire, Shropshire, Norfolk and Denmark. He joined B.O.C.M. in 1956 and, following appointments in the south-east of England, became Agricultural Adviser for B.O.C.M. in Scotland in 1962.

Subject

SHEEP HUSBANDRY

K. J. Hill, D.V.Sc., M.R.C.V.S. An Animal Health Trust Scholar at Liverpool University he qualified M.R.C.V.S., B.V.Sc., in 1948. After 3 years as an Assistant Lecturer in Physiology at Liverpool (during which he was awarded M.V.Sc., for his thesis on gastric function in ruminants) he joined the Agricultural Research Council's Institute of Animal Physiology at Babraham, Cambridge, where he continued research on ruminant digestive physiology. In 1955 he was a Kellogg Foundation Fellow at New York State Veterinary College, Cornell University, where he worked on the problem of bloat in ruminants. Awarded D.V.Sc., for published work in 1961 and in 1962, he joined Unilever Research Laboratory, Sharnbrook to set up a section of Animal Physiology. The work of this section relates to the requirements of the Animal Feedstuff Industry for detailed information on the digestive physiology and biochemistry of all farm animals, particularly in relation to intensive livestock production.

Subject

THE PHYSIOLOGY OF RUMINANT DIGESTION

W. M. Justice. A Grammar School boy he joined J. Sainsbury Ltd. in 1930, and has progressed through various appointments, including Fresh Meat Buyer, merchandiser, to his present position as Director responsible for Fresh Meat, Eggs and Poultry. He has *inter alia* been connected with the Broiler Industry in Britain almost from its inception. His responsibilities with one of the leading distributors of perishable foodstuffs has brought him into the closest contact with agricultural interests.

Subject

THE IMPACT OF INTENSIVE LIVESTOCK PRODUCTION ON FOOD CHAIN ORGANISATIONS

R. Kenworthy, B.V.Sc., M.R.C.V.S. He qualified in Liverpool, 1951, and went into large animal practice as an assistant. The ensuing 7 years were spent in three agricultural practices in Buckinghamshire, Pembrokeshire and Salop, dealing mainly with dairy and beef cattle, sheep and pigs: being extensively involved in the tuberculosis eradication programme of M.A.F.F. as an L.V.I. In 1958 he went to the Central Veterinary Laboratory, M.A.F.F., Weybridge, as an Assistant Veterinary Investigation Officer, 2 years later taking up a research appointment at the Unilever Research Laboratory, Colworth. He has spent the past 6 years studying the influence of bacteria in general and *E. coli* in particular, on the intestinal tract of the young pig.

Subject

INFLUENCE OF BACTERIA ON ABSORPTION FROM THE SMALL INTESTINE

P. Matthews. Prior to joining the Queens Royal Regiment (afterwards transferring to the Royal Army Veterinary Corps) he spent 4 years as a technician in the laboratories at Weybridge in the T.B. and poultry diagnosis departments. He continued as a laboratory technician during the war, first at Aldershot then later at the Chemical Defence Experimental Station, Porton, Wilts. Afterwards he spent 2 years in the Middle East as a meat inspector.His return to Weybridge after the war was short lived as he joined B.O.C.M. at Stoke Mandeville in 1947. There he managed the company's demonstration farm for 19 years, before being appointed Poultry Farms Management Consultant.

Subject

A SELECTED SERIES OF POULTRY PRODUCTION PROBLEMS INVOLVING MANAGEMENT FACTORS

J. L. Miles. After 1 year gaining general farming experience and National Service, he entered Bristol University Veterinary School in 1958, leaving 3 years later. In 1962 he joined B.O.C.M. and after 3 years practical poultry experience at Stoke Mandeville he worked on Poultry Costings until 1966 when he was transferred to the field staff.

Subject

POULTRY COSTINGS

I. T. Miller. After receiving training at the Moulton Farm Institute he took charge of the litter testing and other pig demonstrations at Stoke Mandeville where he remained for 5 years. Next he became a pig specialist in the B.O.C.M. south-western area, and in 1962 was transferred to Glasgow as the Company's Scottish Pig Food Sales

Manager. Much of his time is now spent in the field tackling problems of management and organisation.

Subject

THE HUSBANDRY OF PIGS HOUSED INTENSIVELY

J. Morton, B.Sc. He graduated at Glasgow University, and obtained practical farming experience in Scotland and England. The posts held by him included Livestock Husbandry Officer, N.A.A.S.; Asistant Livestock Editor *Farmer and Stock-breeder*; and Chief Livestock Officer Milk Marketing Board where he was responsible for a stud of some 800 bulls. His present position is Public Relations and Marketing Development Officer with B.O.C.M. Ltd.

Subject

PART AUTHOR AND CO-ORDINATOR OF THE SECTION ON CATTLE

W. H. Naish. A member of the W.P.S.A. and Poultry Education Association, he is now National Poultry Foods Marketing Manager for B.O.C.M. Prior to taking up this appointment in 1964 he was for 15 years Poultry Food Sales Manager of the company's Bristol branch. Recently his work has taken him to France and South Africa.

Subject

INTEGRATION AND AGRIBUSINESS

W. E. Pearson, B.Sc. (S.A.), B.V.Sc. (Pret.), M.R.C.V.S., M.I. Biol., F.Z.S. Associated with agriculture in one form or other since 1946 (in South Africa, Nigeria, Italy and the U.K.) he has covered most species but, in particular poultry and fish. He received his veterinary training at Onderstepoort, previously having taught for 6 years. In South Africa he spent 3 years as Veterinary Research Officer in the Cape Province, and then left to teach Pathology and Bacteriology at the Veterinary School in Nigeria. After a short spell in Italy as Veterinary Consultant to a large farming operation, he joined Unilever Limited where he has been engaged in research for the past 11 years.

Subject

MODERN INTENSIVE FISH FARMING

S. A. Richards, B.Sc., Ph.D. After taking his B.Sc. in Zoology he worked for a period in Australia with the Department of Agriculture and Stock, being concerned with the ecology of fruit flies in Queensland citrus orchards. On returning to this country he obtained a Ph.D. in Agriculture at Wye College (London University) in avian physiology.

Many of his experiments were concerned with the assessment of pain in chickens in relation to modern procedures of electrical stunning and slaughter. This work has been published in the *Veterinary Record* and *Research in Veterinary Science.*

Subject

PAIN PERCEPTION IN ANIMALS, WITH PARTICULAR REFERENCE TO POULTRY

P. Roberts, B.Sc., A.R.C.S., D.I.C. After graduating in mathematics at Imperial College, London, he specialised in statistics, taking the college diploma in that subject. In 1950 he joined I.C.I. as a statistican at their Agricultural Research Station, Jealotts Hill, where he worked mainly on statistical problems connected with fertiliser and pesticide investigations. Appropriate methods of statistical analysis of long-term field experiments were also investigated as well as others involving grazing animals. Later he was seconded to the Sudan Government as Statistician to the Agricultural Research Division, spending 2 years in the Sudan Gezira where he analysed some long-term agronomic experiments on cotton. Another subject to which he made some fundamental contributions was that of entomological field experiments. He joined Silcocks in 1961 where, in addition to the mathematical problems of a modern business such as linear programming, he has worked on the design and analysis of experiments in intensive animal husbandry. A large part of this work is with poultry and pigs, but there has also been the opportunity for a revision of experimental methods with dairy cows.

Subject

THE ROLE OF THE COMPUTER

W. P. Roberts, B.Sc. Educated at Hereford Cathedral School he graduated at Reading University, staying on there to lecture and carry out research into the economic problems of the small farmer. Prior to graduation he had gained considerable practical experience in many capacities from farm pupil, head cowman to farm manager. He is now Chief Agricultural Economist to the B.O.C.M. and his work ranges from an appraisal of national economic trends and their effect on agriculture, to the organisation of the Company's Farm Management advisory work and costings schemes.

Subject

THE ECONOMICS OF INTENSIVE LIVESTOCK PRODUCTION

D. H. Shrimpton, M.A., Ph.D. The son of a country miller (Provender Millers Ltd., later Wharf Mills Ltd., Winchester), he graduated in biochemistry (Nat. Sci. Tripos with Chemistry, Botany and Zoology), and had post-graduate training in chemical microbiology, both at Cambridge. From 1951–55 he was at the Rowett Research Institute, working primarily on vitamin nutrition in poultry; but also with rats, pigs and sheep in respect of vitamin B_{12}. He has also undertaken a study of animal feedstuffs in respect of protein quality and the provision of B vitamins. From 1955–65 he was at the Low Temperature Research Station, Cambridge, a joint University and Agricultural Research Council Laboratory for the study of food science. During this period he was also a demonstrator in the University School of Agriculture (1956 and 1957). Since 1965 he has been a member of staff of the Animal Research Division of Unilever Research Laboratory, Colworth House.

Subject

RESEARCH IN RELATION TO INTENSIVE LIVESTOCK FARMING

I. R. Stalberg. After service with the Royal Artillery in the Middle East he returned to farming, taking up an appointment in 1949 with the Air Ministry as land adviser. He was successively farm manager with Northumbria Farms Ltd. (1957) and the Plymouth Co-operative Society (1960), joining the British Beef Company in 1963. There he was responsible for establishing and managing the company's beef units at Stowmarket. In 1966 he emigrated to South Africa.

Subject

A 2-YEAR STUDY IN OPERATING A LARGESCALE INTENSIVE BEEF FATTENING UNIT

J. P. Walsh, N.D.A. Following 4 years farming experience he took the Diploma Course in Agriculture at the University of Leeds 1932–36, joining Unilever as an Agricultural Adviser in Yorkshire in 1938. From 1942–46 he served with the Royal Navy. In 1948 he became an Adviser to the O.C.O. Feed Company and in 1952 Area Agricultural Adviser for B.O.C.M. Southern Branches. In 1960 he was appointed Chief Cattle Adviser to the U.K. Milling Group of Unilever Ltd.

His duties entail supervising the advisory work of approximately 100 University Graduates or holders of the N.D.A./N.D.D. who are employed by B.O.C.M. to give advice to farmers on livestock husbandry, nutrition, budgeting, breeding, etc. In this work as close liaison as possible is maintained with the N.A.A.S.

He is responsible for the cattle policy on the three Company farms in Essex, Yorkshire and Scotland where they conduct Danish Bull Progeny Tests, Beef Sire Performance Tests, commercial intensive beef production, multiple rearing of store calves, early weaning work with dairy and beef calves and commercial milk production.

Subject

INTENSIVE SYSTEMS OF MILK PRODUCTION

R. W. Widdowson, N.D.A. After leaving the Royal Agricultural College, Cirencester, where he was awarded the Ducie Gold Medal, he joined B.O.C.M.'s Bristol Branch. From 1955 to the present day he has been Assistant Pig Adviser to B.O.C.M. and has become more and more involved in the improvement of British pigs by applied genetics. He presented the first British paper on the use of ultrasonics in pig breeding and performance testing, and has also published a paper on progeny testing using split-litter techniques. He is currently in charge of the Company's Pig Breeding Scheme, and responsible for giving recording and genetic advice to a number of weaner groups which have taken shape in the last few years.

Subject

SCIENTIFIC AND PRACTICAL ASPECTS OF IMPROVED PIG BREEDING METHODS

H. Ll. Williams, B.Sc. (Agric.), M.Sc., Ph.D., N.D.D. He was born on a dairy farm in Carmarthenshire (where his father was a master breeder of British Friesians, establishing the GROVE herd in 1912) and educated at the University College of Wales, Aberystwyth, where he took a degree in Agriculture (Animal Husbandry), a College Diploma in Dairying and the National Diploma in Dairy Husbandry. In 1951 he joined A.B.R.O. to supervise the initial stages of the cyclical crossbreeding experiment (dairy cattle) at their Staffordshire Field Station. In 1956 he was appointed Lecturer in Animal Husbandry at the Royal Veterinary College, London, where in addition to lecture courses for undergraduates he gives post-graduate courses on Agriculture and Livestock Production. He is also concerned with the reorganisation of the 300 acre R.V.C. Farm, to demonstrate modern methods of livestock production. In 1960 he obtained his M.Sc. (London) with a thesis on 'Taste Acuity of Calves', and in 1966 graduated Ph.D. (London) with a thesis on 'The Intensification of Sheep Production'.

Subject

THE ONSET AND THE MODIFICATION OF THE BREEDING SEASON OF SHEEP

J. Wilson, B.Sc. was educated at King's College, University of Durham and graduated in 1951 with B.Sc. Honours in Animal Husbandry. His practical training was on mixed arable and stock farms in Northumberland. For the past 15 years he has been engaged in formulation/development/advisory work in the compound feeding-stuffs industry, and his present position is Chief Nutritional Adviser with Lever's Feeds Ltd. He is responsible for the quality of raw materials used in manufacture, their formulation and the finished products;

also for the progression of new research information, through development experiments and field trials, into new or modified company products, or management systems. He maintains close contact with the Animal Research Division of Unilever Ltd. and uses his Company's farm as a vital development link between research work and the final field-testing stage.

Subject

SOME RELEVANT STATISTICS ON THE U.K. POPULATION AND TRENDS; BEEF PRODUCTION

INTRODUCTION

Whilst agriculture has a fine record, like every other segment of industry, increases in output must clearly be sufficient to meet rising costs, otherwise net incomes will fall. Whilst the range of incomes is necessarily wide and for all types and sizes of farms, there is little question that those who have introduced intensive methods of husbandry are certain to be in a better position to weather the economic storm through which we are passing. Production is now valued at £1800 million, with upwards of £200 million being invested annually.

Between 50,000 and 60,000 acres of farmland have been lost during the past 10 years, indeed at the British Association meeting last year Professor W. Ellison predicted that nearly 4 million acres would have been taken away from farming for non-agricultural purposes by the end of the century.

In Britain between 1954 and 1960 the annual growth in labour productivity in agriculture was about 4 per cent, rising to 6 per cent by 1964, yet industry is absorbing thousands of agricultural workers annually. This remarkable achievement has resulted from an absence of restrictive practices amongst farm workers whose skill and adaptability, linked with mechanisation, calls for sincere congratulations.

Since 1945 *nearly* 300,000 *workers have left British agriculture*, but the U.S.A. is losing farmers at the rate of 35,539 a year. Statisticians have in fact calculated that the last farmer will disappear at 24 minutes past 2 on June 9th, 2101! (Zumbro 1966). Similarly it has been estimated that only one organisation would remain for the production of eating eggs somewhere between the years 2050 and 2075, at about which time only one hatchery would exist for the 316 million hatching eggs needed!

There is more than an element of truth in these U.S. assertions, as can be seen from the reduction in the number of flocks in the R.O.P. programme. These fell from a peak of 480 in 1947 to sixty-four 10 years later, and none should have remained theoretically by 1963, whereas there were nineteen!

Increased mechanisation and automation in agriculture automatically entails the use of more capital which is not necessarily easy to obtain, unless one is fully credit worthy, in the banking sense. At the present time banks are lending agriculture over £500 million, and merchant credit which amounts to about £150 million has risen by £70 million during the past 4 years. Long-term credit for the purchase of agricultural land (as a contrast to short-term credit) is something which the banks do not usually undertake, but farmers can use the Agricultural Mortgage Corporation for this purpose. The Government's plan to cure the U.K.'s chronic imbalance of payments, looks for a growth rate of the economy as a whole of +3 per cent (1964–74). This would appear to involve only a 1 per cent extra output of animal feeds, but a 3·6 per cent annual increase in agricultural output.

Looking at the whole subject of intensive livestock farming objectively farmers can be said to go intensive either to hold their own or to make a greater profit. They do not normally house their stock in this relatively expensive manner for any other reason. Farmers are not usually thinking that the extra milk, eggs or meat they produce should be made available for export, to benefit some under-developed country where some of the population may be on the verge of starvation. Nor are they laying out capital with the object of providing their stock with a more comfortable environment, unless by so doing their animals become more productive, assuming that stress factors are not an obvious feature.

Like every other efficient business the owner of any livestock establishment must know his outgoings and income intimately which explains the current interest in farm costings. In practice one finds that many farmers fail to realise the necessity for checking very carefully all the data that is eventually going through the computer. In addition, unless appropriate action is taken at the farm afterwards many costings are wasted. It is here that the knowledgeable adviser can often proffer sound suggestions for helping to improve the profitability of the enterprise.

The role of the veterinary surgeon today is changing rapidly, and the treatment of single animals becoming of secondary importance. Flock and herd studies, in terms of veterinary preventive medicine, are now occupying practitioners far more than in the past, and this trend will undoubtedly continue, particularly if a suitable system of payment can be agreed upon between client and practitioner.

Chapter 1

SOME RELEVANT STATISTICS ON THE U.K. POPULATION AND TRENDS

J. WILSON

The cattle population of the United Kingdom, as at June 1966, totalled approximately 12¼ million, spread over seven main groups:

	U.K. (1966)	*England & Wales only* (1967)
Cows and heifers in milk	3,720,000	2,847,000
Cows in calf but not in milk	565,000	450,000
Heifers in calf with first calf	750,000	647,000
Bulls and bull calves for service	92,000	61,000
Other cattle—2 years old and over	955,000	690,000
One year and under 2	2,714,000	1,910,000
Under 1 year	3,478,000	2,423,000
Total	12,274,000	9,028,000

Together with a sheep population of 30 million, they utilise the output from 18 million acres of temporary and permanent grass, 18 million acres of rough grazings and the unsaleable by-products from 18 million acres of arable land.

Out of a total annual compound usage of 9¾ million tons the cattle population consumes 3·32 million tons plus a large proportion of the 3·8 million tons of home-grown concentrated feeds retained on farm of origin and the 3 million tons of concentrates sold annually in the form of straights.

By means of their unique digestive system they convert this colossal weight of bulky fodder and concentrated foods into an annual output of 2437 million gallons of milk and 860,000 tons of beef and veal. At this level of production the country is completely self-sufficient for milk for liquid consumption, 1643 million gallons, leaving a surplus of 794 million gallons for manufacture into dairy produce. Home-fed beef and veal accounts for 71 per cent of our total beef consumption of 1·2m tons which amounts to 52 lb. per head of population compared with roughly 26 lb. of pig meat (half of it pork), 23 lb. of mutton and lamb and 15 lb. of poultry meat.

Milk Production

The Milk Marketing Board recently carried out an investigation into the structure of dairy farming in England and Wales. Whilst it may be true that the Dairy Industry, in keeping with other systems of animal production, is moving towards specialised large units, both intensification and specialisation have a long road to travel.

A total of 108,000 producers were registered with the M.M.B. and of this number individual farmers made up 78 per cent and provided 70 per cent of milk supplies. Just under half of dairy farms were owner-occupied, the remainder were either rented (41 per cent) or part-rented. Companies comprised 3 per cent of producers and 7 per cent of supplies and partnerships accounted for the balance. Six out of ten dairy farms were less than 100 acres and only 6 per cent above 300 acres. However, this 6 per cent occupied over a quarter of the land area. As dairy farm size increased, the proportion of land given over to cereals increased, but that of permanent grass declined. Some 40 per cent of dairy farms carried sheep and the same proportion had fattening pigs. One-third kept breeding sows and half had laying hens.

Half the farms had five or more separate farm enterprises and there was little indication of simple farming systems. Two-thirds of producers were estimated to have an output of less than £5000 per year and only 12 per cent exceeded £10,000. Milk was the most important enterprise for 87 per cent of all producers. Standard output per acre was highest on small farms. There was a decrease in output per acre as size of farm increased up to 150 acres, but thereafter there was little change. Forty-six per cent of herds had fewer than 20 cows in 1963–64, but these accounted for only 21 per cent of the national herd. At the other extreme, 11 per cent of herds had over 50 cows, but these included 31 per cent of all cows. The average size of herd was found to be 26 cows. Thirteen per cent of herds kept no followers at all, but the average for all herds was 60 followers per 100 cows. Larger holdings carried a higher proportion than this.

Three-quarters of the nation's cows were milked in shed and this represented 86 per cent of herds. Parlour milking accounted for 11 per cent of herds and 20 per cent of cows. Bails, etc. covered the remainder. Three per cent of cows were hand milked and 69 per cent machine milked with bucket plants. The remainder, 28 per cent, were milked with pipeline or in-churn system. However, these systems were used for only 6 per cent of the cows milked in sheds.

Half the milk producers employed no hired help at all and another 7 per cent only employed part-time help. Family labour predominated on farms up to 150 acres and on farms of 150 to 199 acres family workers comprised half the full-time labour force. Almost 60 per cent of all full-time hired labour was found on farms over 200 acres. In total, farms worked solely with family labour provided almost one-third of milk supplies.

Output per worker rose markedly with farm size up to 300 acres. Thereafter, it was fairly constant around £2700 per year. Output per acre decreased rapidly up to 200 acres, but then steadied at around £44 per acre. The average number of cows milked per worker was 19, but in herds of 70 cows and over the figure was 47. Cows milked per labour hour average 12 for all herds, but in the biggest herds 21. Cows milked per worker in parlours averaged 39, with herringbone layouts averaging 43. In sheds, the rate was 16 cows per worker. In terms of throughput, parlours gave a figure of 20 cows per labour hour and cow sheds 11 cows per hour.

Over the whole country 46·8 per cent of total supplies in 1964–65 and 45·8 per cent in 1963–64 were produced in the winter 6 months. Winter milk production was highest in the Eastern Region and lowest in South Wales. Summer biased production tended to be the concern of older producers, those with small farms, those with low dependence on milk production, and those with a small output. There was, however, plenty of deviation from this generalisation.

In the whole of England and Wales 220 producers had over 150 cows and a monthly output of over 10,900 gallons. Thirty-four of these had over 300 cows and four had over 1000 cows. Companies predominated in this group and farming systems were very diversified. Dependence on milk was lower than average.

From these facts it will be seen that the Dairy Industry is still composed of a large number of relatively small producers. However, the trend is most definitely towards fewer holdings with larger herds. In the period 1960/65 the number of holdings with less than 40 cows fell from 126,000 to 97,000 and if the present rate of decline continues, this figure will be down to 46,000 by 1974. In the same period holdings with more than 40 cows increased from 14,000 to 18,000 and is likely to reach 25,000 by 1974.

Beef Production

Unfortunately, there are not such detailed data available on the beef industry. This no doubt will be rectified by the new Meat and Livestock Commission. The make-up of the beef industry, however, is different from dairying in that it is usually a secondary enterprise on the farm. Nevertheless, the value of beef produced in this country being worth nearly £300,000,000, is not negligible. But profitability to the individual farmer has always been, and still is, questionable.

U.K. beef production, as in most European countries, is closely linked to dairying. A large proportion of beef consumed comes from slaughtered cows, and a larger proportion from fattened cattle produced originally in the dairy herd.

The M.M.B.'s Structure of Dairy Farming in England and Wales estimated that just under one-third of all beef cattle in England and Wales are to be found on dairy farms. The U.S. Feed Grains Council's *Feeding for Beef Production* suggests that a little less than half of full-time farm holdings are involved with fattening cattle once they have reached the age of 1 year.

One thing is certain; the forecasts that were so freely made in the early 1960s that there would be a development towards large-scale feedlots in this country have not materialised, and are very unlikely to do so in the present profitability situation for beef production.

'Meat will have one of the most important parts to play in any selective expansion programme . . . the main emphasis must be on the expansion of beef and veal production, which will have to be increased to the full extent of the technical possibilities.' [Extract from the National Plan September 1965.]

Unfortunately implementing the sentiments expressed in the National Plan is not proving easy. There are two main problems. First, although the beef industry is the U.K.'s second largest agricultural enterprise, it is also one of the least profitable in terms of financial return to the farmer. Second, beef is usually a secondary enterprise on most farms. There is a lack of performance and economic data both on cattle of various breeds and crosses and on the different systems which are practised.

The Beef Recording Association now provides a weighing and recording service on individual farms. This service is available to commercial beef producers and the data collected, together with feed records kept by the recording farmers, highlight the variations in performance which occur within similar systems of production. The Chief Executive Officer of the Association recently quoted the following figures:

Range in daily gain (lb. per head per day)	0·1 to 3·0
Range in feed cost per lb. of L.W.G.	2s. 8d. to 10d.
Average daily gain (lb. per head per day)	1·7
Top one-third of farms—average daily gain	2·5 lb.
Average feed cost per lb. of L.W.G.	1s. 6d.
Top one-third of farms—feed cost	1s. 1d.

The profitability of beef production is not only dependent on systems or efficiency of production. The volume of imported beef also has a vital effect on producer prices as was only too apparent both in 1966 and 1967.

The beef consumption picture in Britain is very different from the world pattern in that over one-quarter of our total beef consumption is imported. This figure is very much above the world average. In fact, over 25 per cent of total beef consumed in the U.K. is imported. In contrast to this, only about 9 per cent of the production from so-called exporting countries was exported, and only 7 per cent of the consumption of so-called importing countries was imported. The rising standard of living in countries which have exported a high proportion of their beef production has meant a higher proportion of their supplies being retained for home use.

This all means that there is ample scope in this country for a big increase in home beef production.

Chapter 2

TRENDS IN CALF PRODUCTION

P. I. BICHAN

For the first time since the 1939–45 war beef producers in this country have been given a chance to plan ahead. The National Plan and the 1966 Price Review have guaranteed that the price of beef will be maintained to the producer until 1970. Even though this does not cater for the inevitable rising costs all farmers are likely to face, at least it is a step in the right direction.

In particular, the future beef production of this country relies on efficient calf rearing. Calf rearing does, of course, cover the rearing of dairy herd replacements but this aspect of rearing presents relatively few problems. Home beef production will depend to an ever increasing extent on the by-product of the dairy herd.

Trends in calf production from the dairy herd can be considered under the following headings:

1. Source—breeds and breeding
2. Housing and management
3. Feeding systems
4. Single suckling

1. Source—Breeds and Breeding

The A.I. services in 1965 bred over 1¾ million cattle and they gave the best guide to the breeds and types of calf for rearing of beef.

Breed	*Insemination (% of total)*		
	1964/65	*1965/66*	*1966/67*
Friesian	49·6	52·1	51·2
Other dairy breeds	12·9	11·1	9·8
Hereford	22·1	21·2	22·7
Other beef breeds	12·9	13·6	14·1
Dual purpose breeds	2·6	2·2	2·2

The trend is towards a National dairy herd predominantly black and white. The Hereford is the most popular for crossing, but the Charolais

(3·29) is increasing in popularity. Dual purpose breeds are now almost negligible and the numbers of pure dairy breeds, except for the Channel Island cattle, are continuing to fall for economic reasons. The Friesian is capable of producing the greatest quantity of milk and is the highest in weight gain ability of our British breeds, as well as being easy to rear.

Herefords can stamp a trade mark on their calves and when crossed with the Friesian leave the characteristic black skin and white faced animal capable of gains almost as high as the Friesian, and particularly suitable for grassland fattening systems. Profitability is associated with high liveweight gain and low losses in young calves and this is the prime reason why these two types of animal have become so popular. The use of the Charolais is increasing quite rapidly despite the more difficult calvings and difficulties in rearing in the early stages.

	Arrival wt. (lb.)	*5-week wt. (lb.)*	*12-week wt. (lb.)*
Charolais × Friesian	116	125	248
Friesian	95	120	229
Hereford × Friesian	94	120	219
Charolais × Ayrshire	98	118	194
Charolais × Jersey	87	113	178

So long as milk production continues to be the most profitable sector of cattle farming the National dairy herd will continue to expand in numbers. Two-thirds of home-produced beef comes from this dairy herd and there is scope for expansion. In the thinner fleshed dairy breeds there is scope for beef production but each time a beef bull is used on an Ayrshire or a Dairy Shorthorn this accelerates the decline of those breeds in number. In considering beef produced from this type of animal, extensive systems of rearing and fattening are of little importance. The trend is towards increasing intensification and even though barley beef has undergone a temporary recession this system will expand again. It has made farmers realise that in beef production liveweight gain and food conversion are of prime importance just as they are in the pig and poultry industries.

The evaluation of beef bulls by sire performance testing is gaining rapidly in popularity, and stations are planned by several of our major beef breeding societies. In addition it is providing a weighing and costing service for beef producers throughout the country. This approach to beef production, in which the sire's ability to gain weight is measured prior to its use, is correct, and it is already apparent that high liveweight gain bulls are capable of increasing the growth rate of beef cross calves.

In the same context it is evident that the thinner fleshed dairy breeds can be used as a reservoir for calves for beef production and that the Charolais breed has a definite value in this respect for crossing on them.

2. Housing and Management

Intensification invariably brings its problems, particularly with buildings. They have to be easy to clean mechanically, rather than by hand, and must be low in capital cost.

In rearing dairy herd replacements (small numbers throughout the year with peaks at autumn and spring) the buildings are rarely overcrowded, and although specific problems occur they are usually the fault of the individual farmer.

As dairy herds continue to increase in size more steer calves will be sold directly from their mothers at birth. The rearer looks for batches of uniform calves which will allow him to utilise his buildings fully, rest them for a brief period, and then re-fill them.

Intensive Housing. The adaptation of existing buildings is a field to be explored by most farmers, who should seek advice from their veterinary surgeons or other farm buildings experts, since the requirements for ventilation and insulation are critical for the continuous rearing of bought-in calves throughout the year.

The loose box with a pantile roof is eminently suitable since it allows free ventilation, and where half stable doors exist, provides draught-free accommodation with a free circulation of air. False ceilings constructed of netting wire (supporting plastic fertiliser sacks filled with straw) can be used to provide a warm kennel during the winter months without restricting the ventilation. In buildings with sealed roofs, the installation of an extraction fan is essential, preferably with a variable speed control.

Little information is available on the number of air changes required by calves but in general terms the temperature of the building (55–60° F) should be controlled by the speed of the fan during the first 3 weeks. When the rumen is fully functional, temperature is of less importance. [Sainsbury (1957) recommends 0·1 c.f.m./lb. winter ventilation and 0·25–0·5 c.f.m./lb. summer rates. Editor.]

Broiler house. The broiler industry led the way in providing controllable environments for livestock and it seems sensible to apply this method to calves.

In 1961 we started experimenting with a small broiler house (75 ft. by 40 ft.) for the intensive rearing of purchased calves, and to demonstrate an alternative source of income for the small producer who tends to be a good stockman and capable of giving the detailed attention required in rearing purchased calves.

Each section houses thirty-two calves in hurdle pens bedded on straw.[1]

[1] The plan of this building No. 8770 is available from the author [Editor].

Slatted floors without a covering of straw and crates are found to increase stress, and led to many losses in the first fortnight after purchase and were therefore discarded.

In one section a perforated tunnel was installed in the ceiling along its full length with a 15-in. extractor fan at the far end, controlled by a four-speed switch. The other section was used for experimenting with pressurised ventilation, which however has limitations during the colder months. A heater bank, in front of the fan, is necessary to prevent the cold air dropping straight down on to young calves. The extraction system appears easiest to control and gives the best results.

As a build-up of pathogens in buildings is usually significant, it is advantageous to house calves in hurdle pens (tied together with string) away from the walls, thus reducing the amount of laborious wall scrubbing required between batches. This method works extremely well.

During the winter months the temperature of the building is raised to approximately 60–65° F. prior to the arrival of the calves. A space heater is used, but rarely found to be essential once the stock has arrived, since the calves themselves help to maintain the level of temperature required.

Fan speed and the opening in the wall apertures are used to control temperature. Thermostatic controls are not used.

By the time the calves are weaned at 5 weeks, the ventilation system is just sufficient to cope with their rapidly increasing requirement for air. After 6 weeks of age the calves will grow very satisfactorily under more open housing conditions so long as there are no draughts and a good circulation of free air. A broilerhouse is a fairly expensive structure and should be used solely for the early critical period of rearing only.

Cheap Shack. Two of the cheapest materials available on the farm are baled straw and empty plastic fertiliser sacks. Straw is a good insulator and fertiliser sacks are impermeable and cheap. A straw bale shack formed for two opposing lines of calf pens approximately 2 ft. 9 in. to 3 ft. apart can be constructed easily. The walls are straw bales, the roof consisting of fertiliser sacks filled with straw and sheeted over with second-hand corrugated iron. The calves are housed in pens formed of hurdles so that each calf is in an insulated draught-free straw bale 'pit'. The passage between the rows is open and, therefore, affords good ventilation.

Liveweight gain and rearing results in this cheap housing system have been as good as that achieved in a broiler house. During the winter months, to prevent chilling, each calf is sheeted with a hessian sack, inside which is a paper bag. Although conditions are not as congenial for staff feeding the calves, such temporary, cheap housing (which can be destroyed after each batch), allows scope for calf rearing by the farmer to whom capital is not readily available.

Adaptations of the same principle, using straw bale and hurdle pens under a Dutch barn roof, have given equally good results at low cost. When the straw bale pens are knocked down at weaning at 5 weeks, the resultant space is adequate for carrying the calves on to 12 weeks of age.

	No. of calves	*Arrival wt. (lb.)*	*5-week wt. (lb.)*	*12-week wt (lb.)*	*Av. L.W.G. per day 0–12 weeks*
Straw 'shack'	115	95·9	125	227	1·55
Intensive calf house	256	99·6	130	221	1·44

6–12 Weeks. In the early weaning system of rearing, calves should have finished with bucket feeding by 5 weeks of age.

For several winters now we have found that from 6 weeks of age onwards, calves can exist in simple well-ventilated buildings so long as they are not subjected to draughts. The transference of calves from the broiler house or shack should take place at the 6th week and *not* the 7th. It appears that there is an increased risk of precipitating outbreaks of pneumonia or Salmonellosis when disturbance takes place at the 7th week.

Without question the *ad lib.* feeding of a palatable concentrate is essential from 6–12 weeks (when calves are destined for beef) because at this stage their ability to convert food is at its best, and gains of over 2 lb per day are easily achieved, the majority of the calves exceeding 220 lb L.W. at 12 weeks.

Extensive Seasonal Calf Rearing. There is considerable interest in the rearing of purchased calves at grass during the summer months, but this system should be approached with care.

Where purchased calves are turned directly to grass, even with access to shelters, and fed on milk replacements for 5 weeks, progress may be poor, probably due to a heavy infestation of internal parasites in many cases.

Where calves have been turned out after weaning at 5 weeks of age, the results have been much better and this system can be applied to the rearing of dairy herd replacements, provided the farmer attempting it has grassland which is clean and relatively free from parasites. If calves are turned into a permanent grass paddock near the buildings, which is commonplace, infestations with parasites can be very high, and results disastrous.

SUMMARY

Housing and management techniques must be such that they produce the highest possible liveweight gain at the minimum cost, and the degree of capital expenditure will depend entirely on the level of intensification the farmer proposes to attempt. The optimum would appear to be a controllable environment which is easily cleaned and provides the best working conditions for staff. Disposable accommodation constructed of cheap materials has a definite place in livestock enterprises where profit margins are not tremendously high anyhow.

3. Feeding Systems

It must be accepted at the outset that so long as milk averages over 3s. per gallon throughout the year, there is no place for whole milk feeding in an intensive calf rearing enterprise.

Recent research has shown that it is imperative that the new-born calf should have colostrum within 6 hours of birth and preferably 3 hours. This ensures adequate intake of colostrum at a time when the intestine is still permeable to the transfer of antibodies.

The normal early weaning system of calf rearing is well known. Briefly, it entails feeding a limited amount of milk replacement twice daily (3½ pints) and weaning during the 4th week of age or the 4th week after purchase in the case of bought-in calves. Dry food, water and hay are offered throughout, although there are indications that the offering of a dry concentrate should not take place until the calves have been 7 days at the rearing unit. During the 4th week the milk replacement is slowly withdrawn and by 5 weeks of age calves are fully on to concentrates *ad lib.* together with water and hay.

There are, on the market, a wide variety of milk replacements and indeed there are variations in formulation. The following trials carried out on our own farms refer to work using two typical milk replacers.

(*a*) The Medium Oil Level Milk Replacement of approximately 7½ per cent oil.

(*b*) The Hi-Fat Replacement of approximately 17 per cent oil.

PERIOD 0–5 WEEKS

L.W.G. (lb./day)			*Calfwena consumed (lb./calf)*		
17%	*7½%*	*Sig. diff.*	*17%*	*7½%*	*Sig. diff.*
0·84	0·79	0·12	47·2	46·0	8·5

In terms of liveweight gain, the majority of individual farm trial results show a slight improvement with 17 per cent fat milk replacement. There were no significant treatment × diets interactions. The mean for liveweight gain however showed no significant difference between 17 per cent fat milk replacement and 7½ per cent fat milk replacement.

In terms of Calfwena consumption in the mean result there was no significant difference in intake whether calves were on 17 per cent fat milk replacement or 7½ per cent fat milk replacement.

Liveweight gains and Calfwena consumption were very similar for both groups of calves during the period 5-12 weeks. No milk replacement was, of course, fed during this time and this result shows that there was no residual effect from treatment given in the first 5 weeks.

PERIOD 5–12 WEEKS

L.W.G. (lb./day)			*Calfwena consumed (lb./calf)*		
17%	*7½%*	*Sig. diff.*	*17%*	*7½%*	*Sig. diff.*
1·81	1·80	0·14	250·9	250·0	53·9

The results of these trials are, as was expected, namely that any advantage shown for the use of 17 per cent fat milk replacement would be slight when compared with 7½ per cent fat milk replacement, particularly under conditions of reasonably good management. The average liveweight gains were reasonable, particularly when one considers that many of the calves purchased for this trial were of poor type and small in size and included Ayrshires. Perhaps as a consequence of the type of calf, health upsets were encountered.

These upsets were twice as prevalent on calves fed the lower fat diet. However, in general the results lead to the conclusion that 17 per cent fat milk replacement is probably the safest diet to recommend for rearing the purchased calf, particularly since a number of trials have shown this diet to be associated with less looseness. Results on 7½ per cent fat milk replacement in terms of liveweight gain, however, are not in any way inferior to those obtained on 17 per cent fat milk replacement and either of these diets can be fed as desired.

No real differences between diets were noted in any of these trials either in condition of faeces or in appearance of calves. In general, both diets mixed well and were readily consumed.

Composition of Milk Substitutes. Milk substitutes are manufactured from various milk by-products—skim milk, buttermilk and whey—together with added carbohydrates to replace the fat, and minerals and vitamins, and are suitable for feeding to new-born animals after the initial colostrum feeding period. The carbohydrates used include lactose, glucose, sucrose and cereal starches—either raw, cooked, or pre-digested—all of which are of lower energy value than the butter fat they replace.

Sale of milk substitutes by national compounders started in 1936 and up to about 1960 the majority of replacers contained about 1 per cent fat in the dry matter. They consisted basically of milk by-products and cereal starches and consequently the calorific content of these reconstituted diets was only about half that of whole milk.

Interest in the use of fats for animal feeding has developed over the past 15 years as a result of improved methods of refining and stabilising against deterioration, together with improved manufacturing techniques employed by the compounder. At the same time, the surplus of animal fat, which is the result of the replacement of soap by detergents, has reduced its price to a level which compares favourably with that of milk powders. Various blends of fats and oils have been used in feeding trials and whilst tallow and lard have consistently proved to be satisfactory, results from the use of vegetable oils have been more variable. Milk substitutes containing from 8 to 20 per cent added fat are now offered for sale by a number of manufacturers and are steadily replacing the low-fat milk substitutes although there is evidence that the inclusion of some cereal starch may have a costive effect.

Various methods are employed for adding the fat to milk powders. The emulsified fat can be tipped, sprayed or blown on to the milk powder resulting in a product in which the particles of milk are coated with globules of fat which range from 1 to 100 microns, with the majority between 10 and 30 microns. Alternatively, the emulsified fat can be mechanically homogenised with liquid skimmed milk and then either roller or spray dried. Because of the higher cost of roller drying, the major supplies of filled milks are available in the spray dried form. This method gives a product in which the globules of fat are enclosed in a coating of milk power and are comparable in size to those of whole milk (1–4 microns).

In general, the smaller the fat globule the greater the rate of digestion and there is some evidence that homogenisation improves utilisation of fat. The spray dried homogenised product reconstitutes more easily than mixtures prepared by spraying the emulsified fat on to the milk powder. It also has superior flow properties which is important when the material is fed through an automatic calf feeding device.

Because of the higher calorific values of high fat milk substitutes intake of dry food by the calf during the liquid feeding period is lower than the levels of intake associated with milk by-product/carbohydrate milk replacers.

Additional fat soluble vitamins A, D_3 and E are provided, whilst vitamins of the B complex, C and K are also generally included, although there is some doubt as to whether the incorporation of these last three is in fact essential. Mineral additions generally include calcium, phosphorus, magnesium, manganese and iron.

The majority of milk substitutes are reconstituted at a concentration of 1 lb. per gallon of water resulting in a suspension of about 9 per cent dry matter. At a cost of approximately 1s. 3d. per gallon there is a strong financial incentive to feed calves a milk substitute in place of whole milk, which sells at prices ranging from 2s. to 3s. 6d. per gallon, depending on the season of the year. Higher concentrations of 1½ lb. per gallon (13 per cent dry matter) approximate more closely to the dry matter content of whole milk and result in better liveweight gains.

Milk replacements. Farmers must be educated to appreciate the value of accuracy in using feeds carefully balanced for young calves.

Manufacturing techniques and ingredients have now reached the stage where a milk replacement is easy to mix and remains in suspension in the liquid. Indeed trials have shown that calves do equally well on cold milk replacement, and rearing is now possible on a once-a-day feeding technique. Indeed it is likely that milk replacements will form the basis of rearing for at least 60 per cent of home killed beef in the future.

5½ day feeding. One of the major factors in causing digestive upset in a calf rearing unit is the relief stockman/tractor driver at the weekend. This man rarely knows the exact quantities to be fed, or the idiosyncrasies of individual calves. Digestive upsets created by the wrong feeding invariably lead to the development of disease. Realising this, trials were carried out comparing calves fed 5½ days per week on the bucket with those fed for 7 days. Calves only fed 5½ days received an increased concentration of milk replacement, approximately 2¼–2½ oz per pint for 5½ days and during the Saturday afternoon and Sunday received no milk replacement at all. They had access to concentrates, water and hay.

System	*No. calves*	*Arrival*	*Liveweight (lb.) 5 weeks*	*9 weeks*	*12 weeks*	*L.W.G. lb. and (lb./day) 0–5 weeks*	*5–12 weeks*	*0–12 weeks*
5½ day	42	97·40	132·51	179·23	222·77	35·11 (0·99)	90·26 (1·88)	125·37 (1·50)
7 day	42	97·34	132·60	182·80	228·54	35·26 (1·00)	95·94 (1·99)	131·20 (1·57)

All eighty-four calves used in the trial were Friesians, but work is now in progress to check the effect on smaller breeds.

It could hardly be expected that liveweight gain would equal calves fed 7 days per week but a small reduction in gain is of little importance and is likely to be made up by compensatory growth during the 7 weeks after weaning. The important aspect of this work is that the skilled stockman can be left to do the calf rearing on his own. In addition there is a considerable saving in overtime payments. The great saving in this system is in manual labour over the weekend, but it is still essential, as in all stock feeding enterprises, to inspect the animals during this period.

Once a Day Feeding. The shortage and high cost of skilled labour has also resulted in the introduction of a system of feeding in which the calf is simply fed its total daily supply of calf meal in one feed together with 24-hour unrestricted access to a high-quality dry food and water. Volume of water fed with the milk substitute is reduced by about 25 per cent, but the concentration of powder is increased by 50 per cent in order to maintain intakes comparable with the more traditional system of two feeds a day.

Of equal importance to the obvious saving in labour is the fact that the feeding time can then be moved to a time of day when the work load is easier. On every stock farm there is a congestion of work at either end of the day, and any system which helps spread it more smoothly over the working day is of benefit to both the stockman and the stock in his care.

The successful feeding of cold milk substitute to pigs and lambs has aroused interest in the possibilities of adapting the system for calves. Initial results suggest that the feeding of between 5 and 7 pints of cold milk substitute, either in one or two feeds per day, results in a number of refusals, particularly during the cold winter months. Much better results were obtained when the calves had 24-hour unrestricted access.

Machine Feeding. Automatic calf feeding machines have received considerable publicity, the Nursette and Cowmatic being two typical machines, although others are on the market.

MACHINE AND BUCKET FEEDING

Year		*No. of calves*	*Milk replacement consumed per calf (lb.)*	*Live wt. gain 0–5 weeks (lb.)*	*Live wt. gain 5–12 weeks (lb.)*
1965	Bucket 7	21	21	33	83
	Nursette L	18	40	35	81
	Nursette S	11	58	45	88
1966	Bucket 5½	32	22·5	28·87	88·63
	Nursette III	20	33·5	37·9	86·7
	Nursette IV	30	26·2	32·5	83·4
	Cowmatic I	20	44·0	36·9	79·9
	Cowmatic II	30	40·0	35·4	82·7

During the summers of 1965 and 1966 studies were carried out by Honours undergraduates from the Faculty of Agriculture of Leeds University at Barlby Farm. Although the results obtained are not strictly comparable, since they were carried out during different periods, the observations are a good guide as to the value of such machines in rearing calves intensively. In all trials calves were weaned from liquid feeding on the machines at approximately 5 weeks of age following which their rearing continued on an *ad lib.* supply of Calfwena, water and hay.

In the 1965 observations the machine was rarely idle with the larger group of calves whereas the machine was not in use more than 30 per cent of the time with the smaller. Individual consumptions of milk replacement ranged from 6 to 38 pints per day, with little or no sign of ill effect where larger amounts were taken. On the other hand, there was no resultant increase in weight gain with high consumptions.

In the 1966 observations, in the case of the Nursette, the larger number of calves resulted in approximately 20 per cent failing to obtain adequate milk replacement from the machine because of competition, and hence deriving the main part of their nutrition from Calfwena, water and hay. Since the Cowmatic delivers mixed milk replacement continuously through two teats, twenty calves were allowed access to one and thirty to the other. The continuous delivery of mixed milk replacement then allowed both groups adequate chance to obtain sufficient milk replacement. Indeed, in the case of both the 'twenty' and the 'thirty' group the machine was idle for 30 per cent and 20 per cent of the time respectively. In contrast the Nursette, which delivers feed on an intermittent routine, restricted the time in any 24-hour period when feed was available to the calf.

FOOD COSTS

Year	*System*	*No. of calves*	*Per calf to 5 weeks*	*Per calf 5–12 weeks*	*Total*	*Per 1 lb. L.W. gain*	*Wt. gain (lb.) 0–12 weeks*
			£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*	*s.* *d.*	
1965	Bucket 7	21	1 16 0	4 5 0	6 1 0	1 0½	116·4
	Nursette L	18	2 14 0	5 0 0	7 14 0	1 2½	122·4
	Nursette S	11	3 10 0	5 0 0	8 10 0	1 3½	126·3
1966	Bucket 5½	32	2 4 6	4 10 7½	6 15 1½	1 1¾	117·5
	Nursette III	20	2 13 3	4 15 9	7 9 0	1 2½	124·6
	Nursette IV	30	2 7 9	4 14 7	7 2 4	1 3	116·0
	Cowmatic I	20	3 4 6	4 12 0	7 16 0	1 4	116·8
	Cowmatic II	30	3 0 0	4 12 0	7 12 0	1 3½	118·1

In 1965 bucket fed calves received a controlled amount of milk replacement each day whereas in 1966, bucket feed was only given for 5½ days each week. This system is described in detail under the heading '5½ Day Feeding'.

The food costs per 1 lb. liveweight gained would have been lower for the calves reared on the Cowmatic machine, had large quantities of HiFat Baby Calf Food not been wasted when the calves broke the teat tubes allowing milk replacement to run onto the floor. In the machine this could be a fault, no safety device having been incorporated to prevent wastage where teat breakage occurs.

In all machine rearing of calves a high standard of stockmanship is essential since it is only by observation of the behaviour of the calves that it can be ensured that all are receiving adequate intakes of milk replacement. Digestive upsets, possibly triggered off by excessive intakes (or vice-versa) can lead to outbreaks of disease which can only be identified by careful observation.

Estimates of labour costs involved in observation of calves, cleaning and maintaining the machines, indicated that little or no difference existed between bucket and machine rearing in this respect.

In general, therefore, when it comes to deciding which system, it would appear to be very much a matter of personal preference between a machine system requiring high capital outlay (in the purchase of machines) or a cheaper bucket feeding system. Both can give good results.

Antibiotics

Many workers have demonstrated the beneficial effect of antibiotics in calf rearing and levels of 30–200 mg. of chlortetracycline or oxytetracycline per day usually reduce the incidence of scouring; they improve the growth rate by 5–25 per cent and improve the efficiency of utilisation of the feed. The inclusion of antibiotics in proprietary calf foods is forbidden in this country although their use—and misuse—on farms is widespread.

It is generally claimed that with good management and housing the routine use of antibiotics in calf rearing should be unnecessary, and should be confined to the treatment of specific outbreaks of disease. Unfortunately, on the majority of farms in this country, ideal conditions for the rearing of calves are the exception rather than the rule and a mortality figure of from 5 to 10 per cent is accepted as quite normal.

Antibiotic treatment of the 'purchased calf' should be arranged to take place prior to loading on to the cattle float, or as soon as possible after arrival at its destination. A total of 600 mg. of one of the tetracycline antibiotics, given under veterinary supervision over a period of 3 days, has proved of considerable benefit in helping overcome stress factors resulting from the journey and change of environment.

Wherever possible calves, both home-bred and purchased, should remain in the pen in which they are initially housed until they are about 12 weeks old. At this age they will have been on dry feed for some few weeks, thus breaking the cycle of disease build-up associated with liquid feeding. The next batch of calves coming into the pens will not then be subjected to disease organisms specific to the very young calf.

As with all intensive systems of animal husbandry, batch rearing, followed by thorough cleaning and disinfecting, and a rest period of 2–3 weeks between batches will help minimise disease build-up.

Stilboestrol has had no effect on the incidence of scouring or mortality, and only a slight but non-significant effect on growth rate of calves up to 3 weeks of age. Similarly, tranquillisers administered to the calves after a journey from market to rearing farm have had no significant effect on subsequent liveweight gains.

4. Single Suckling Herds

Can hill areas contribute a considerable amount towards the expansion in beef production? The suggested subsidy of £6 10s. 0d. in the last Price Review may have been aimed at increasing the number of suckler cows on marginal land, but it is doubtful if it will affect hill areas to any extent. Nevertheless, where single suckling is practised the system is low in output and low in profitability, indeed it is only the hill cow subsidy that maintains cows on the hills at all.

This system has a place, however, since it is the single suckled calf that provides most of our high priced meat used by the special restaurant and hotel trade. In order to survive, the industry must look at every possible means of intensification. On reasonable land output of single suckled calves must equate as near as possible with dairying or cereal growing.

At the moment the structure of the subsidy system forces the farmer to make enough winter keep to sustain his suckled herd when both hill and marginal land are barren in winter. But this is an ineffective use of land, and little is gained by using food during the winter to keep cows warm particularly when much of that food may be deficient in micro ingredients essential for the health of the cow and the unborn calf.

If this system is used on better land the farmer must think in terms of two cows and their calves per acre, so that grass is grazed where it grows and little or no conservation is attempted. In any event, conservation leads to serious loss of nutrients.

It would seem that cows should be housed in winter, even if only with the minimum amount of shelter, and that the feeding system should be based on the minimum quantity of concentrates to maintain health together with the cheapest possible form of roughage, such as barley straw. Such a system would allow the calf born in January to take advantage of the spring flush raising the dam's milk yield. By the time the grazing season has started the calf would be big enough to utilise grass, and if the cows themselves are assumed to function mainly for clearing the pasture behind the calves creep grazed forward, this system would have a future since liveweight gains of up to 10 cwt. per acre would be quite possible, i.e. two weaned calves. With such a method there would be much less chance of grass staggers and small under-nourished calves at weaning time.

On the hill itself there does not seem to be adequate scope for expansion in weaned calf production, although some Scottish farmers are now using concentrates extensively for their cows and deriving considerable benefit in the vigour and growth rate of the calves, partly due to their milk yields. Creep feeding, even on the hill, will continue to develop because this method of supplementing the falling level of nutrition (which occurs on all hill land from July onwards) is the only means of ensuring reasonable sized suckled calves capable of growing thereafter. Again, as in production of beef animals from the dairy herd, the interest of farmers lies in increased size and weight gain potential, as is evident in the spread of the Hereford throughout England and Wales and well into Scotland. Undoubtedly, too, the Charolais will expand in the same way so long as calving problems do not occur requiring special management of individual cows on the hill.

SUMMARY

There has been a continuous downward trend in the number of calves slaughtered at birth from over 1 million in 1956 to less than 250,000 in 1965. The British farmer engaged in beef production has been quick to realise the potential of the by-product animal from the dairy herd, as a consequence imports of foreign meat have fallen to less than half their pre-war level.

In this development the calf rearer has become selective in the type of animal he purchases, emphasis being placed on an ability to survive adverse rearing conditions, plus fast growth. This has led to the predominance of the Friesian and the Hereford × Friesian, and more recently to an interest in the Charolais.

New rearing and intensive finishing techniques have led to a reappraisal of bull selection practices, in which growth potential and food converting ability take precedence over showyard type.

Hardening economic conditions in the agricultural industry have led to a search for cheaper and more effective calf feeds and feeding systems. Rearing on milk replacements within the practice of early weaning has become the rule, and the natural suckling of calves the exception. Milk replacements are now fully efficient in their ability to promote growth and maintain health.

In the housing of young calves conditions which reduce losses and increase weight gains are needed. Simplification and low-cost housing are both possible and practicable for the rearer who cannot afford to invest in specialised buildings.

The future expansion of calf rearing will ultimately depend on better disease control; losses on a national basis now exceeding 5 per cent.

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Chapter 3

INTENSIVE SYSTEMS OF MILK PRODUCTION

J. P. WALSH

1. In milk production the United Kingdom can be said to be entirely self-sufficient in that the full liquid needs of the nation are fully met, together with a comfortable surplus of 25 per cent over requirements for manufacture.

The difference in price between the quantity sold to meet liquid requirements, and the surplus sold for manufacturing purposes, is such that any considerable excess over the 'standard' quantity (meriting higher payment) considerably reduces the pool price. This has had the effect of stabilising the industry to some extent, rendering futile any mass expansion in output.

As a result there is room for manoeuvre in increasing income only by increasing efficiency. Future trends will be towards intensifying output either by increasing the efficiency of land utilisation, or by increasing the performance of the individual cow, or by steps in both directions.

Land utilisation improvement can come about by increasing the efficiency of the conversion of grass into milk. The fact that too little progress has been made is painfully obvious to plant breeders, soil chemists, fertiliser manufacturers and agricultural economists alike, though their combined efforts have increased the production or output of grassland appreciably in recent years.

Nevertheless far too little of the potential has been exploited. It is estimated that permanent grassland produces about 15 cwt. starch equivalent per acre per annum of which 10 cwt. is utilised by stock. It has recently been stated (Barber 1967) that in spite of the fact that 80 per cent more nitrogen, 50 per cent more potash and 25 per cent more phosphate has been applied to grassland over the last 10 years, the utilisation of starch equivalent from grass has increased by only 3·8 per cent.

2. It is desirable that increasing the intensity of milk production will be accompanied by a marked improvement in grass utilisation. Already the temporary ley with perennial ryegrass to the fore has made a potential of 60 cwt. of starch equivalent per acre an attainable goal, and some experts believe that this level may be approachable with top management of permanent grass.

The key to the situation is considered to be the application of more nitrogen, and the movement is forward from an estimated average of 100 units per acre (5 cwt. of fertiliser containing 20 per cent nitrogen) to several times that amount; accompanied where necessary by phosphate and potassic fertiliser applications.

Grassland intensified in this way provides more low cost milk per acre from grazings, and also more grass for winter conservation. A problem still remaining, however, is the gap between production and utilisation, and this problem is likely to remain because of the uncontrollable conditions created by rainfall and climatic variations. Also our inability to predict the necessary stocking rate in order to convert as much grass as possible into milk. Grass surplus to grazing requirements is harvested or stored as hay or silage but digestibility and respiration losses in storage reduce the value of these foods for an intensified dairy farms system.

Increasing the output of grassland by heavier fertiliser applications, the substitution of leys for permanent grass and heavier stocking rates in the growing season, create in themselves a problem because of the increased nutrition imbalance resulting from these practices. Many veterinary authorities are of the opinion that the lack of improvement in the fertility of the dairy cow and the marked increase in metabolic disorders in many herds, is due to a wide difference between the mineral requirements of the heavy milker and those present in grass, calcium excess all too often being accompanied by a marked calcium/phosphorus imbalance. When the very heavy intakes of kale and silage are considered in the self feed practices now in general use, it is easy to understand how these imbalances come about. There are also clear indications of severe deficiencies, or locking up of other minerals, which were not seen to the same extent under the pre-war traditional hay, roots and cake feeding régimes. Very often there is a shortage of manganese, and in certain regions deficiencies of copper and iodine.

Nevertheless the most efficient way of intensifying milk production (in association with sound grassland management) is to adjust the acreage of grass to enable a high stocking rate to be maintained over as long a grazing season as possible. (Young grass—topped and dressed repeatedly with nitrogen—and paddock or rotational grazing perhaps in preference to strip grazing.) A firm policy directed towards high quality silage or hay (as opposed to bulk at the expense of quality) is another in the right direction.

3. On mixed dairy farms where cereals are grown, alternatives to this are now available and the new technique of utilising barley straw in Fodderite and allied systems is economically clearly superior to complicated grazing and conservation policies. They also provide a much better breeding performance, and steadier, improved yields. The future will see top class leys utilised solely for grazing, with grass acreages provided for this one purpose—winter bulk food being provided by cereal straw, cereals and supplements.

Looking at the function of grassland under intensive milk production systems, there are of course alternatives to grazing, and those tried so far in the United Kingdom are based on 'zero grazing' with the herd housed all the summer and the grass cut and led in daily. The digestibility of the grass mown from paddocks for indoor feeding can be maintained over a longer growing period, and zero grazing is by no means to be disregarded especially where heavy wet land suffers from treading and poaching. It can operate with yarding and feeding arrangements (which also meet the requirements for straw maintenance feeding in winter), and can service very large herds in conjunction with cubicle housing and herringbone parlour milking arrangements. The system is not however for the smaller dairy farmer who cannot afford the capital for the harvesting machinery or the reserve tractor, for there must be no breakdowns throughout the cutting season. For him tight stocking after sensible nitrogen application, and the making of high quality hay or silage is the only solution; and if he has cereal straw to rule out the need for the latter—so much the better.

In the United States work has been going on for some years at the University of Wisconsin (1965) on evaluating storage feeding. Storage feeding consists of cutting a grass crop at the optimum stage of growth to give a fair yield whilst there is still a high degree of digestibility. Repeated cuts are filled into tower silos at intervals, and the herd self-fed in troughs, receiving supplies of wilted 'haylage' mechanically from the silos.

Although the final outcome of this work has not yet been reported, carefully controlled trials by Wisconsin University at their Marshfield Station suggest that storage feeding is superior to paddock grazing and strip grazing as a means of utilising grass grown efficiently. Unfortunately the cost of cutting and harvesting equipment and storage towers is beyond many farmers' means, and larger dairy farmers who grow corn are more attracted to straw maintenance feeding because of the labour saved and the added cereal acreage made available.

Summarising the position, intensive grassland utilisation for milk production implies (i) the employment of more advice on seed mixtures to suit specific areas, (ii) the employment of more nitrogenous fertilizers, and (iii) the development of paddock and rotational grazing with, if necessary, topping the grazings with gang mowers to maintain the digestibility of the grass. Where hay and silage has to be made the aim will be toward higher quality at some sacrifice of tonnage, but not of performance. Barn hay drying would appear to be economical considering the enhanced value of the hay.

Most dairy farmers agree that planning the seasonality of production (the incidence of calving) is an essential operation at the start, and they also agree that a high proportion of autumn calvers is desirable however good the grassland or the expertise in grass utilisation. The attraction of the higher winter milk price paid by the M.M.B. is still the

MONTHLY BASIC PRICES* PAID TO WHOLESALE PRODUCERS IN ENGLAND AND WALES—1965–66

The basic prices relate to milk with an annual average total solids content of 12·00 per cent but less than 12·10 per cent but with an average solids-not-fat content of more than 8·40 per cent
(Pence per gallon)

Month	*Northern*	*North Western*	*Eastern*	*East Midland*	*West Midland*	*North Wales*	*South Wales*	*Southern*	*Mid-Western*	*Far Western*	*South Eastern*
April 1965	36·23	36·58	36·76	36·61	36·25	35·96	36·17	36·83	36·42	35·94	37·13
May	27·55	27·90	27·83	28·18	27·82	27·53	27·49	28·15	27·74	27·51	28·70
June	27·67	28·02	28·20	28·05	27·94	27·65	27·61	28·27	27·86	27·38	28·57
July	31·84	32·19	32·12	32·22	31·86	31·82	31·78	32·44	31·78	31·55	32·74
August	36·02	36·37	36·55	36·40	36·04	36·00	35·96	36·37	35·96	35·73	36·92
September	39·11	39·46	39·39	39·49	39·38	39·09	39·05	39·71	39·30	38·82	40·01
October	40·01	40·36	40·29	40·64	40·03	39·74	39·70	40·61	39·95	39·72	40·91
November	39·72	40·07	40·00	40·10	39·74	39·45	39·41	40·07	39·41	39·18	40·37
December	40·94	41·54	41·47	41·57	41·46	41·17	40·88	41·79	41·38	40·90	42·09
January 1966	41·24	41·59	41·77	41·87	41·51	41·22	41·43	41·84	41·43	41·20	42·39
February	40·85	41·20	41·38	41·48	41·12	40·83	41·04	41·45	41·04	40·81	42·00
March	40·90	41·25	41·43	41·28	41·17	40·88	41·09	41·50	41·09	40·86	42·05

* Prices *after deducting ex-farm transport charges*, cost of sales promotion and publicity and Board's administrative expenses.
NOTE: The capital contribution of 0·16d. per gallon has not been deducted.

predominant advantage which the producer should never lose sight of. A high proportion of autumn calvers managed for high yields ensures that when the herd is turned out to graze in the spring the majority of the cows will still be giving over 3 gallons a day, and therefore convert most of the grass efficiently into lowest cost milk. It might be argued that spring calvers capable of 6 or more gallons would do even better on top quality grazings, which can provide the nutritional requirements for at least 4 gallons. This is true, but spring calvers are short lactation cows and the proportion of milk produced at winter milk prices is low, so that on a lactation comparison basis, the late summer, autumn or early winter calver has the advantage.

There is nothing new in this concept, but it is a fact which should always be borne in mind when planning a dairy operation, or indeed when discussing grassland policies.

The average calving index being nearer 400 days than 365[1], it is not possible to drop a calf every year and late autumn calvers often slip round to mid-winter calvers by their prime. For this reason an ideal situation would be to have heifers calving for the first time in mid-August or thereabouts, so that by the third calf they would still be calving with the bulk of the higher milk priced winter months ahead.

4 (*a*). On the basis of a relatively high proportion of milk in the lactation being produced in the winter months, the next essential to successful intensification is to plan to feed the herd for maximum output, at the lowest cost commensurate with fitness and health maintenance.

It is still customary in many herds to aim at covering as much of production as possible from cheap foods, but a limit is usually put on this by the very bulkiness of succulents like kale and roots, and high moisture grass products—silage. With reasonably high quality silage and hay, maintenance and 2 gallons are quite possible, but on most farms the first gallon is as much of the production as can be catered for, sufficient allowance must then be made for concentrates to satisfy the balance of production.

With winter fodder the imbalances mentioned earlier are considerably greater because of the effect of weather and season on growth and harvesting conditions; and also on subsequent storage losses—especially respiration losses in silage.

Technical laboratories offer a nation-wide service for hay and silage analyses, and many figures are available showing the seasonal effect on quality, as well as the variations in composition within each season. Study of these actual analyses (see Appendix 1) underlines the considerable variations in composition of hays and silage. In view of this and the fact that on the basis of an *average* of 2 gallons per day (plus maintenance from grass in summer and 1 gallon per day plus maintenance from bulk fodders in winter), appreciably more of the cow's energy requirements come from bulk foods. Indeed one of the reasons

[1] 389 days. United Kingdom (1965) (Milk Marketing Board).

for disappointing performances from well-bred cows is the simple disregard of this point. *Much* depends on the energy value of bulk foods grown on the farm, for whatever the quality of the grass or hay/silage combinations, variations in composition are considerable from farm to farm, and from one season to another.

In planning an intensified dairy unit therefore *ad-lib.* feeding of moderate to poor hay or silage has no place. A chemical analysis of the hay and silage used is strongly to be advised, and limiting bulk intake from these sources is a *must* if maximum yields of satisfactory quality milk are to be obtained. Concentrates must be put to optimum use, to enable the deep milking, willing cow to express her full potential.

4 (*b*). Most dairy farmers rely on purchased concentrates which are formulated on sound nutritional principles, but younger dairy farmers should profit from the mistakes made in the period of rationing (during the war) and de-rationing afterwards when the use of concentrates was discouraged on the score of dollar expenditure. The result of this policy was a very poor return per acre, because of moderate milk output and the extra acres required to service the herds. A large proportion of the energy content of concentrates now comes from home grown cereals replacing much of the maize and milling offals formerly imported as dollar purchases.

Dairy concentrates are still considered by some authorities to be unduly costly. Ladling out of a bag by the scoopful (instead of being weighed and issued according to yield), readily results in overfeeding which is a very costly form of mismanagement. Most milk producers are alive to this possibility, and the weight scale and recording sheet are now a 'sine qua non' in all properly run intensive dairy herds; concentrates being fed according to yield. Skimp the winter concentrates, use a cheap imbalanced mixture, or feed a correct mixture wastefully and the best of summer grazing expertise is completely unavailable if winter management does not match up.

That it pays to feed according to yield is clearly indicated in the following classification of performances by herds recorded in the B.O.C.M. Dairy Management Recording Scheme (D.M.R.): 1965–66:

Yield group (gallons/cow/annum)	700	700–799	800–899	900–999	1000–1099	1099
	£	£	£	£	£	£
Milk sales	105·7	119	134	149·5	165	184·2
Concentrate cost	24·9	31·2	35·1	41·5	47·2	57·5
Gap (= margin between milk sales and concentrate cost)	80·8	87·8	98·9	108	117·8	126·7
Margin per forage acre used	54·1	57	62·7	71·2	78·4	82·3

It will be seen that the higher yielding herds require a greater expenditure on concentrates, but the considerably greater income from milk sales not only offsets this, it increases the margin and thereby the sums of money to set against fixed costs.

As land values, labour and miscellaneous services continue to rise in cost, this principle again requires underlining: It pays to feed in order to express the maximum output per cow in winter, especially as the Table shows that high yielding herds do not require more acres to service them.

Has the efficiency of the purchased concentrate diet improved in recent years? Dairy 'nuts' look much the same as they did years ago but large scale research on the function of the rumen has revealed more of its mode of action, and also the effect of different nutrients on yield and milk composition.

As a result lower protein standards are possible for milk production, but the necessity for raising energy levels to meet the cow's needs also exists, especially under loose yarding and out-wintering conditions. The recognised standard is 2·5 lb. S.E. and 0·5 lb. P.E. per gallon, but this needs an uplift in energy to allow for exercise and exposure to winter weather conditions. Protein requirements for the ruminant, even for intensive production, need not include any animal proteins (Kon and Cowie 1961) and because of elaboration by the microorganisms of the rumen, complicated combinations of vegetable sources are no longer necessary. From the manufacturer's point of view, however, quality control, continuity of supplies and uniformity of composition are best assured by employing blends of protein of high quality and high digestibility, particularly where intensive production is based on high individual cow performance.

Today's dairy nut has a higher energy content than in the past, but starch equivalent is not a good criterion of this, furthermore checking starch equivalent is difficult under practical conditions.

Close studies have been made of the effect of different sources of energy on both milk yield and composition, utilising both oilcakes and cereals individually and also in different combinations. Individual fatty acids making up the oils—saturated and unsaturated—have also been added to oil free basal diets and tested for their effects. Cereals too have been compared, and maize at high levels has been tested against barley. Independent sources of oil (of both animal and vegetable origin) have been added to experimental diets and similarly tested for their effect on yield and quality.[1]

Work of a similar kind has been carried out in America by Shaw and Ensor (1959) where specific fatty acids have been tested in different diets. Commercial diets including these additives are now available, but the advantage of the British line of approach is that improvements (achieved by selection of superior sources of energy) have been obtained

[1] Unilever Research Laboratories, Colworth House, Sharnbrook, Beds.

by the use of natural fat sources at considerably lower cost. Furthermore we have established the optimum oil/carbohydrate ratio for maximum yields with no loss of milk quality.

New standards have been published by the A.R.C. covering ruminant requirements, and although some satisfaction can be gained from meeting them, we have also studied the effect of higher nutrient inclusions. Studies on calcium/phosphorus inclusions show that optimum performance from concentrates at high yield levels cannot be obtained if there is *ad-lib.* access to bulk foods carrying appreciable calcium excesses as well as phosphorus and manganese deficiencies (Burt 1966; Wilson 1966). Feeding on this basis should be restricted to low yielders and late lactation cows.

The outcome of all this is that the intensive milk producer can now have 'horses for courses'. For example a ration can be provided with a certain oil, carbohydrate ratio and mineral complex, which will aid a recovery in solids-not-fat. Another, with a specialised high oil inclusion, will increase butterfat. A third, because of its particular oil, carbohydrate and mineral relationship, will support maximum milk yield.

So that in terms of what the current range of milk production diets will do, better performances are now possible at no higher cost per gallon than that of less scientifically blended diets.

5 (*a*). What are the general policies to be adopted under intensive milk production?

The first two are clearly established:

(i) A deep milking cow. The work of the breed societies and the M.M.B., A.I. and 'non-Board' A.I. authorities more or less guarantees this. A large intensive dairy unit should preferably have on its staff someone with an interest in breed type performances, the contemporary comparisons of bulls, and the performance of A.I. bulls in particular through their first daughters. Improvements in performance are always possible if sound judgement can be brought to bear on breeding policy and care in selection of purchased replacements. No-one should underestimate the part that conformation also has to play. On the other hand many highly productive dairy units have been based on cows supplied by reliable dealers, or on the assiduous purchase of cows from markets.

(ii) A high proportion of autumn calvers.

(iii) High quality controlled use of bulk feeds in winter and productive grazings in summer: but care in placing nutritional value on lush autumn grazings—imbalance here can give disappointing results in late winter (Rowland, 1957).

(iv) The employment of high performance concentrates in conjunction with home grown foods for maximum milk output in winter, and overall high quality milk throughout the year.

The last requirement demands further elaboration because the key to successful performance with intensive milk production is high winter output. Advantage must therefore be taken of proven feeding techniques which enhance still further the performance of the cow. These involve 'steaming-up' 'lead feeding' and, for the man who is prepared to apply a higher degree of individual feeding, differential feeding.

5 (*b*). 'Steaming-up' is a well recognised practice which was originally proved by the late Professor R. Boutflour[1] and is a current practice in nearly all high yielding herds. Scientific authorities first questioned the necessity for steaming-up when the problem of oedema of the udder occurred. But this is physiological when calving is imminent, and a solution in the form of pre-milking is recommended when this condition is encountered. Authorities at the N.I.R.D. now endorse a sensible policy of steaming up, but this process must be used properly and understood thoroughly (Broster 1964).

It requires a reasonable dry period of 6–8 weeks. It also requires balanced dairy concentrates, to be introduced at about 2–3 lb. per day 6 weeks before calving with weekly rises until—with second and subsequent calvers—about 12 lb. a day is being fed. Some experienced feeders exceed this quantity with particularly high yielding cows by 50 per cent or more, but 12 lb. per day is usually adequate for cows, whereas for heifers caution is required. Steaming-up should certainly be employed, but in our experience a limit of about 6 lb. per day should be imposed—the actual level being dependent upon the heifer's condition. If, for example, she is very fit on particularly good autumn grazings—then no steaming-up will be required. Nor will it be necessary for cows which are in very good condition, although the stress of a previous lactation usually necessitates supplementary feeding during the dry period.

'Lead feeding' means that the cow is being led towards a high performance—her highest output of milk—by keeping her nutritional plane slightly ahead of her requirements, until peak output is attained.

5 (*c*). Following steaming-up, concentrates should be withdrawn during the calving period, and very gradually re-introduced a day or two after the calf is born. One of the problems associated with large dairy herds is that of applying the necessary management to newly calved cows at this time. Under intensive high output systems, management must ensure that concentrates are gradually introduced and increased according to the cow's ability to build up her appetite. The rate of increase will vary from cow to cow, but 2 weeks after calving she should be 'lead fed' or given an extra allowance over and above her yield requirement to encourage her to still further increase her milk output.

Traditionally lead feeding has been pegged at 2 lb. extra concentrates per day, but recently a system[2] of differential feeding has proved highly

[1] See list of references (Editor). [2] Details available from the author.

successful in herds where the management was capable of carrying out the simple but detailed adjustments to feeding rates. This involved feeding considerably more than the extra 2 lb. during the period up to peak yield (4–6 weeks after calving) but cutting back below basic requirements (when the cows are past their peak) and making up the daily food intake with higher bulk food allowances. The overall effect of this is to increase milk output with no higher cake consumption than the normal rate per gallon, and it occurs because the cow responds to higher feeding during the period of high stimulation.

5 (*d*). An extensive field trial covering forty-seven herds in 1965 provided useful information on the suitability of this system for general use. An economic evaluation of herd performance in the year before the trial feeding period, as well as during the experimental year in question, revealed a non-significant advantage over non-participating herds; but there was a cash advantage of 8·9 per cent (£8 6s. per cow) compared with the previous year.

Within this average lies the performance of many unsuccessful herds, but where the standard of management was high some particularly impressive economic improvements were obtained. It must be stressed that reasonably high individual cow management ability is necessary to get the best from this system, which is well worth considering in large intensively managed herds with qualified managers.

6. Bulk food feeding in winter presents the largest problem to the intensive milk producer, because the rival needs of feed economy and cow performance have to be met—the former involving bulk foods of variable quality, the latter a careful measure of bulk control and a certain degree of concentrate feeding expertise.

In simple terms the alternatives in the past have been (*a*) to grow kale and grass for silage, and some hay in the midlands, the south and certain semi-arable areas in the east and north-east; or (*b*) to rely largely on hay in the areas of poorer soils and higher altitudes in the north and north-west.

With moderate yielding cows it was possible to provide from these bulk foods sufficient nutrients to cover maintenance and 1 gallon or more in winter, especially with kale and hay available, followed later by silage and hay after the kale had been grazed off. In more northerly areas, relying mainly on hay, no more than maintenance could be covered, indeed in bad haymaking seasons it was difficult to find supplies to meet full maintenance requirements without subsequent adverse effects on yield and cow fitness.

The bulk food problem for intensive milk production would now appear to be in two directions, both with strong economic implications:

(i) the acreage to support part of production as well as maintenance, must be valued against alternative (arable?) uses;

(ii) the unbalanced nature of high bulk intakes does not support the high degree of individual cow performance sought under truly intensive conditions.

Where it is possible to make better economic use of land by growing arable crops, it is worth while examining the possibility of using arable by-products for bulk food for intensive dairy herds thereby liberating the grassland previously employed for winter conservation and utilising grassland solely for summer grazing and conversion in low cost summer milk. This is best described as straw feeding for maintenance, a practice now widely used throughout the United Kingdom. Barley, in coarse ground or rolled form is used to supplement barley straw which is fed *ad lib.* in conjunction with a proprietary supplement providing the necessary vitamins, minerals, protein and extra energy required to balance up the straw and barley. Basic management requirements of the system are that:

(i) straw is on free offer for at least two feeds a day (preferably more), especially when cattle are coming off grass in the autumn when four feeds a day are recommended for the first 3 weeks;

(ii) a daily allowance of equal quantities of ground or rolled barley and the Fodderite or allied supplement is given in amounts varying from 8 lb. per day for Friesians down to 6 lb. per day for Jerseys, according to liveweight;

(iii) the Fodderite/barley allowances can be fed on top of the concentrate allowance in cowsheds (in the feeding troughs);

(iv) the Fodderite/barley allowance must be fed separately from the concentrate feed in parlour units because of time limitations in the parlour;

(v) simple troughs or two lines of sleepers with a space to constitute a continuous trough should be used in the yarded area for loose housed cattle;

(vi) it is important that the trough spaces be limited to 1 ft. 9 in. to 2 ft. per head in order to secure equal time feeding and lack of bullying;

(vii) when commencing the system see that the herd is *gradually* introduced to straw feeding and that individual straw consumption is built up to the full daily allowance before the system *in toto* is commenced. This will be from 12 to 14 lb. for Friesians, 10–12 lb. for Ayrshire/Guernseys and 7–9 lb. for Jerseys.

The straw maintenance system (combination of straw and barley) has the virtue of a much greater stability in terms of all nutrients (with a favourable major mineral ratio), although it is admittedly deficient in energy, vitamins, trace minerals and some protein. It is however possible for a single feed additive to make good these deficiencies, thus providing a uniform stable maintenance diet. Concentrates may be added to this for production purposes without being involved in any maintenance feed imbalances.

Examples have been given of hay and kale and hay and silage maintenance diets, which often provide excess calcium and a deficiency of phosphorus, manganese and trace elements. The calcium/phosphorus ratio in fact often exceeds 3:1. The following are the data which support the view that barley straw is relatively uniform in general composition, irrespective of where it was grown, or the time of planting:

Region	*No. of samples*	*Crude protein*	*Crude fibre*	*Ash*	*Moisture*
N. England	11	4·0	43·1	3·8	10·0
S. and S.W. England	9	3·7	43·3	5·0	9·5
S.E. England	7	3·3	43·8	4·1	9·3
Midlands	6	3·9	42·2	6·0	10·1
Scotland	3	3·9	41·1	2·9	10·0
Not known	7	4·2	43·0	5·0	9·2

Sowing season	*No. of samples*	*Approximate analyses* Crude protein	*Crude fibre*
Autumn, 1963	5	4·1	42·7
February/March planting	4	4·2	42·8
Mid-season (March, April)	23	3·5	43·5
Late planting	4	4·7	40·6
Not known	7	4·3	43·0
Average		3·8	42·9

Eleven varieties were involved in these analyses carried out by Unilever Research Laboratories, Colworth House, Bedford.

Although the range in calcium is from 0·5 to 0·09 and the phosphorus from 0·28 to 0·05, the amounts taken in on an *ad-lib.* straw feeding basis are not high; and it is a simple matter to adjust the mineral balance of the supplement to make good the deficiency of phosphorus. This is assisted by the reverse ratio of calcium to phosphorus in the barley *per se*, the levels being 0·35 per cent phosphorus and 0·1 per cent calcium. In all, the combined allowance for a Friesian for example, of 12 lb. straw, 4 lb. barley and 4 lb. of Fodderite supplement will provide about 60 gm. of calcium and 25 gm. of phosphorus, covering the phosphorus requirements for maintenance with a satisfactory Ca/P ratio.

Opportunity is taken in this system to include a full range of trace minerals—copper, iodine, manganese, cobalt and iron, and also to include a vitamin supplement to make good the recognised limitations of barley and straw.

Many herds have responded to this more stable and fully balanced maintenance diet by steadier and often improved yields, and there are also indications of improvements in calving intervals although evidence of statistical significance will take a few more years to amass. The vitamin inclusions are also having beneficial effects on general fitness, tone, appetite and coat condition.

Whilst the basic cost of the maintenance diet (varying from 1s. 10d. to 2s. 7d. a day according to breed) is no cheaper than conventional feeding, there are two marked advantages:

(i) the ease of putting the system into effect. Herdsman/cowmen are well aware of the eased labour position through handling bales of straw and concentrate supplement which do not have to be weighed out individually;

(ii) a significant economic advantage can be gained by adopting a policy of independence from silage and haymaking, thus limiting grassland servicing acres to those required for the grazing season. This opens up the prospect of requiring 1 acre or less grassland per cow, as opposed to 1·5 acres in well managed herds requiring grassland for winter conservation.

The system has also proved satisfactory for replacement heifers as from 12 weeks of age, thus ruling out the need for hay or silage.

The fact that for the first time the whole diet of the dairy cow comes under control must have a favourable effect on overall performance. However even when the acres saved are diverted to cereal or cash crop growing a financial advantage does not always accrue.[1] Nevertheless the system is relatively easy to manage. If a genuine first gallon is obtained from home grown foods and no more than approximately 1⅓ acres per cow are already needed for servicing the herd then the employment of the Fodderite system may involve a small additional cost. This should be offset by better herd health and performance, and by easier working conditions. For the majority of farms a clear-cut financial advantage is likely (see Appendix).

6 (*b*). For many farmers there will still be the need to use hay, kale and silage. Straw may not be grown on the farm or available locally at a reasonable price—although the widespread increase in cereal growing brings barley straw within range of most farms in the United Kingdom.

If hay, kale or silage are to be limited to a highly organised intensive milk production unit, then steps must be taken to bring a greater measure of control over the total diet. Making good the deficiencies and putting a limit on the intake of those components which cause the greatest imbalance, i.e. kale and silage contributing excess calcium.

If these crops are used for winter feeding to cover maintenance and the first gallon of milk a degree of imbalance occurs which can be described diagrammatically as follows:

[1] See Appendix VII, Example 3.

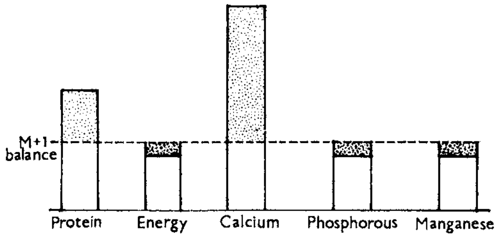

FIG. 2.

In practically all cases a surfeit of protein and a very large excess of calcium exists. In more cases than not an energy deficiency arises and in two cases out of three a deficiency of phosphorus and manganese will exist.[1]

In the animal feeding-stuffs industry these imbalances have an adverse effect on the efficiency of the balanced production ration. The lactating cow does not of course utilise maintenance and production diets separately. All too often well balanced production rations contribute nutrients to make good maintenance deficiencies, and suffer from t' 'nbalancing effect of excess calcium.

The British Oil & Cake Mills has conducted large-scale field trials on commercial dairy farms examining the effect of supplementary feeding designed to level off, as far as is possible, the imbalances in bulk diets: (i) by assessing the quantities of stored bulk foods; (ii) by carrying out chemical analyses of representative samples; and (iii) from an agreed uniform daily allowance of these foods calculating the nutrients supplied.

A supplement is then devised to level off the nutrient at a certain point of production, e.g. M+2 or M+2½, so that the use of balanced production rations can be made above this yield, knowing that the rest of the diet is properly balanced. The effect can be diagrammatically described as follows:

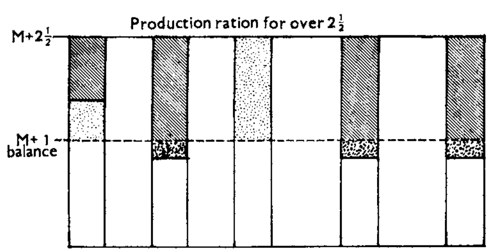

FIG. 3.

[1] Survey carried out by Mr. J. A. H. Castle, Unilever Research Station, Leatherhead.

In this example bulk foods provide the usual imbalance with calcium predominating and making provision for $2\frac{1}{2}$ gallons as well as maintenance, other nutrients falling short of this and not even covering maintenance in most cases. After analysis a formulation is devised to level off the nutrients at $2\frac{1}{2}$ gallons plus maintenance. This formulation would carry trace minerals and vitamins as an 'extra'. A flat rate per cow, of, in this case, about 6 lb. per day, would be fed—covering $1\frac{1}{2}$ gallons instead of the normal production ration, then normal balanced production ration for all other gallons according to yield.

The limitation of this exercise is the need to prescribe not only for every farm but for every change in bulk food allowance. On the other hand such supplement could be justified and indeed would be desirable for large-scale intensive dairy units where there would be some opportunity of standardising the maintenance diets.

7. Future systems. It has been strongly suggested that future milk production in the United Kingdom will move in the following directions:

(i) *Larger herds.* A definite move in this direction continues. In 1960 the average size in the United Kingdom was 20 cows. In 1964, 25 cows—varying from 19 in the western region to 40 in the south-eastern region.

In 1942 the average size of herd was only 15 in England and Wales. It was 26 in 1964.[1] The Scottish M.M.B. recorded an average herd size of 31 in 1942 and 44 in 1964.

(ii) *The change in the number of cows milked per man* or 'labour hour' is underlined more by the change of milking method than by other factors. Thus in 1964 in England and Wales the number of cows milked per man varied from 38 in abreast parlours to 50 in chute parlours—the relative numbers per labour hour were 19 and 24.

This gives an average of 39 per worker or 20 per labour hour in parlour systems compared with 16 and 11 respectively in cowsheds.[2] Obviously in future intensive methods loose housing or cubicles in conjunction with specialised parlour milking arrangements with correctly organised work cycle times will be the order of the day.

(iii) *Cotels.* This term derived from 'cow hotels' really only denotes 'large dairy units'. The larger the unit the more expertise is required, and if one envisages a return of town dairies with hundreds of cows in a unit then one will see management appropriate to the husbandry demands and the capital invested.

Presumably an overall qualified manager would employ shift milkers, part of whose income would be related to milk output, compositional quality and maintenance of herd health. The following special services would be required:

(*a*) specialist advice on soil fertility, cropping and grazing techniques;

[1] *Dairy Facts and Figures*, Milk Marketing Board, 1965.
[2] *Dairy Facts and Figures*, Milk Marketing Board, 1965.

(*b*) alternative advice on storage feeding or zero grazing;

(*c*) technical advice on alternative bulk diets such as 'straw maintenance' feeding;

(*d*) specialist 'balancer' diets to level up hay, kale and silage;

(*e*) veterinary control of health and milk hygiene;

(*f*) utilisation of strains of breeds or crosses to ensure uniform high quality milk earning premiums;

(*g*) possibility of large scale cream production in association with intensive milk production.

(iv) *Housing*. Developments of housing for intensive milk production must affect small dairy farms as well as large units. In the case of the former, rather than erect new buildings, any capital available will be very much better utilised purchasing more or better cows, and mechanising the chores in the cowshed rather than 'mechanising' the cows.

The proving of the efficiency of cubicles has, however, altered this situation as cowsheds can be utilised as the shell of the building with cubicles replacing traditional standings at low cost—capital still being necessary to install the parlour unit which is justified if the size of the business can be increased from say, thirty to fifty cows.

For large intensive units heavy capital commitments might be involved which may be justified by the efficiency of large-scale milk output. It is difficult to say at this stage if one can envisage all the nutrients being fed to yarded cows all the year round. The success of the Los Angeles Dairy land units of 200–800 continuously yarded cows is guaranteed by the climate—dung being dried in yards, bulldozed into heaps and sold for garden fertilizer.

The dung or slurry disposal problem is usually one of the biggest headaches facing the large intensive unit. Cubicles cut down straw expense by about £5 per cow but dung disposal problems remain. Straw maintenance feeding alleviates the slurry problem, but again grass or arable land must be available to benefit from heavy dung dressings.

Loose housed herds on a large scale will certainly require a series of yards in which very high yielders, high yielders, middle and late lactation cows as well as dry cows are separated.

Milking should remain a specialised operation with a finely calculated work cycle in the parlours. A flat rate of concentrates through the parlour to cover part of production—say 1 or 2 gallons—seems feasible, the balance of production being fed to numbered individual cows in yokes in the feeding area before or after milking. Similarly standard feeding levels to groups separated according to yield are a practical alternative.

The prospect of complete diets with bulk and concentrates combined —thus easing management still further—is an attractive prospect, but complicated by the varying requirements of cows at different levels of production. Further nutritional research and economic measurements are yet needed before such diets can be a commercial consideration (Mix & Lashbrook 1966). In the meantime the attractions of barley straw maintenance or supplements for succulents and hay can make real contributions to establishing uniformity of feeding, and as they are associated with group feeding, either trough, *ad lib.* or flat rate allowance can be fitted into the general housing picture envisaged for large intensive units.

(v) *What of the cow herself?* Specialised strains of breeds will give more milk of superior composition, high in total solids and with a better bill of health (less affected by mastitis or metabolic disorders) thanks to close veterinary supervision for health maintenance.

Crossbreeds such as Jersians may have a place. If the steer calf of this cross lacks a little in beef conformation it will still be useful because it will be standard in type and if it becomes established, available in quantity. Perhaps a feed programme can be designed especially for it.

There should be a movement towards earlier calving than the traditional 2½–2¾ years of age, because there is evidence that calving younger has little detrimental effect on later lactation performance. A recent example can be given of the performance of the final dairy bull progeny test at Barlby over two lactations in 1964–66. Forty-four Friesian heifers were inseminated from very young bulls (semen taken at 7–8 months), the heifers themselves being reared to calve at just over 2 years so that the time of progeny testing the bulls could be reduced to a minimum. (An accurate measurement of the bulls was obtainable after the first 90 days of the heifers' first lactation.)

The heifers were early weaned at 5 weeks and reared on a steady nutritional plane with growth rates as follows:

	Wt. on arrival (lb.)	*At service*		*At calving*			*Food cost*
		Age in months	*Wt. in lb.*	*Age in months*	*Wt. in lb.*	*L.W.G. day*	
Average of 4 bull groups	109·1	15¾	776·4	25	1001	1·17	£51

The performance in the 270-day test period of the first lactation of the four daughter groups was as follows:

Group	*No. of animals*	*Age at calving (months)*	*Yield (lb.)*	*BF (%)*	*SNF (%)*	*Days in milk*	*Liveweight after calving*	*End of test weight (lb.)*
Sullom Fort	11	25·9	8662	3·69	8·68	270	1019	1142
Castlerhydd Romeo Tudor	11	25·5	9340	3·74	8·85	270	967	1108
Pennine Vanguard	11	25·7	7536	3·68	8·79	270	983	1143
Eynsford Alycidon	11	26·0	7373	3·89	8·76	270	1042	1210

The second lactation was as follows:

Group	*No. of animals*	*Age at calving (months)*	*Yield (lb.)*	*BF (%)*	*SNF (%)*	*Days in milk*	*Liveweight after calving*	*End of test weight (lb)*
Sullom Fort	11	39·23	10278·27	3·51	8·61	270	1226·55	1321·27
Castlerhydd RomeoTudor	11	37·89	11187·32	3·41	8·81	270	1126·27	1249·82
Pennine Vanguard	11	38·10	8926·80	3·39	8·79	270	1202·40	1303·90
Eynsford Alycidon	11	38·98	9320·25	3·69	8·54	270	1271·70	1354·10

Thus there is no doubt that earlier calving is feasible for the large breeds, as well as for the early maturing Jersey calving at 2 years.

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Appendix 1

Hay Samples

	1st Jan.– 30th June 1965 No.	% of Total	Comparative figures Jan.–June, 1964 No.	% of Total
PROTEIN				
Samples under 8%	139	45	128	46
Samples 8–11%	153	50	125	45
Samples over 11%	15	5	26	9
Total	307	100	279	100
FIBRE				
Samples under 28%	26	8	35	13
Samples 28–33%	191	62	145	52
Samples over 33%	93	30	99	35
Total	310	100	279	100
ESTIMATED STARCH EQUIVALENT				
Samples under 25	5	2		9
Samples between 25 and 30	176	58	134	48
Samples between 30 and 35	86	28	85	31
Samples between 35 and 40	33	11	29	10
Number of samples over 40	3	1	6	2
Total	303	100	279	100

Silage Samples

	1st Jan.– 30th June, 1965 No.	% of Total	Comparative figures Jan.–July, 1964 No.	% of Total
DRY MATTER CONTENT				
Samples under 20%	108	36	134	35
Samples 20–25%	142	48	191	50
Samples over 25%	46	16	59	15
Total	296	100	384	100

	1st Jan.– 30th June, 1965 No.	% of Total	Comparative figures Jan.–July, 1964 No.	% of Total
PROTEIN IN DRY MATTER				
Samples under 12%	197	66	192	50
Samples 12–15%	84	28	147	38
Samples over 15%	18	6	44	12
Total	299	100	383	100
FIBRE				
Samples under 28%	5	2	19	5
Samples 28–33%	41	14	103	27
Samples over 33%	250	84	261	68
Total	296	100	383	100
ESTIMATED STARCH EQUIVALENT				
Samples under 7·5	86	29	59	15
Samples between 7·5 and 10	163	55	239	63
Samples between 10 and 12	22	7	54	14
Samples between 12 and 14	17	6	20	5
Samples over 14	8	3	11	3
Total	296	100	383	100

Hay Samples

	1st July– 31st Dec., 1965 No.	% of Total	Comparative figures July–Dec., 1964 No.	% of Total
PROTEIN				
Samples under 8%	573	47	426	43
Samples between 8 and 11%	574	47	473	48
Samples over 11%	69	6	89	9
Total	1216	100	988	100

	1st July–31st Dec., 1965 No.	*% of Total*	*Comparative figures July–Dec., 1964* No.	*% of Total*
FIBRE				
Samples under 28%	97	8	96	10
Samples between 28 and 33%	569	47	590	60
Samples over 33%	550	45	299	30
Total	1216	100	985	100
ESTIMATED STARCH EQUIVALENT				
Samples under 25	60	5	13	1
Samples between 25 and 30	751	62	556	57
Samples between 30 and 35	238	20	297	30
Samples between 35 and 40	139	11	110	11
Samples over 40	26	2	9	1
Total	1214	100	985	100

Silage Samples

	1st July–31st Dec., 1965 No.	*% of Total*	*Comparative figures July–Dec., 1964* No.	*% of Total*
DRY MATTER CONTENT				
Samples under 20%	201	39	158	40
Samples 20–25%	237	45	163	42
Samples over 25%	84	16	73	18
Total	522	100	394	100
PROTEIN IN DRY MATTER				
Samples under 12%	231	44	224	57
Samples 12–15%	220	42	136	35
Samples over 15%	77	14	34	8
Total	528	100	394	100
FIBRE				
Samples under 28%	27	5	9	2
Samples 28–33%	181	35	63	16
Samples over 33%	316	60	322	82
Total	524	100	394	100

	1st July–31st Dec., 1965 No.	1st July–31st Dec., 1965 % of Total	Comparative figures July–Dec., 1964 No.	Comparative figures July–Dec., 1964 % of Total
ESTIMATED STARCH EQUIVALENT				
Samples under 7·5	89	17	87	22
Samples between 7·5 and 10	307	59	235	60
Samples between 10 and 12	101	19	49	12
Samples between 12 and 14	16	3	17	4
Samples over 14	11	2	6	2
Total	524	100	394	100

Chapter 4

BEEF PRODUCTION

J. Wilson

Systems of Beef Production. Beef can be produced at any age from 10 months to 3 years, depending entirely on the system of feeding practised. As few farms in this country specialise in beef production, the problem facing most farmers is to decide how best to fit the beef enterprise into the whole farm economy.

A rough breakdown of the sources of U.K. beef supplies is:

Imports	30 per cent
Cow Beef	15 per cent
Home bred stores	55 per cent

Some 80 per cent of our home beef comes from the dairy herd in one form or another, which is rather surprising considering the number of tickets one sees in butchers' shops proclaiming 'best Scottish beef'.

Traditionally young stock are bred and reared through a store period on the grasslands of Ireland, Wales, the western counties and parts of Scotland. During this time they grow, without fattening, at an average rate of 1 lb. per day, which is less than half the rate at which they are capable of growing and fattening under good conditions of feeding and management.

The younger stores, weighing 7½–8 cwt., are then bought in the autumn, by farmers in eastern England and Scotland, for winter fattening on arable by-products of straw, roots, sugar beet tops and pulp, chat potatoes, tail corn and concentrates. Over an intensive fattening period of 4–5 months, the animals gain at the rate of 2–2½ lb. per day and are marketed for slaughter at about 10–10½ cwt. liveweight. Larger stores weighing 9–10 cwt. are purchased in the spring, by midland and northern graziers, and fattened during the summer on pastures renowned for their ability to fatten strong stores.

The profitability of this traditional system of beef production has always been questioned and what profits were made were frequently the result of the farmer's ability to buy and sell at the right time, rather than his ability as a feeder. The increasing use of sprays and artificial fertilisers reduces the need for cleaning crops and farmyard manure—the conversion of the former to the latter via the rumen often being the only justification for keeping beef cattle on many arable farms.

A comparison of the acreage required by animals slaughtered at various ages and the realisation that margin per acre is a governing factor in determining farm profits, presents a forceful argument in favour of a more intensive system of beef production.

An autumn-born calf finished at 2½ years after two summers at grass, requires about 2½ acres of grass during its lifetime, giving a margin of some £11 per acre. Feeding the animal well in its yearling winter will permit it to finish at 2 years off grass, but again the system requires 2 acres of grass giving a margin of perhaps £16 per acre. Under an 18-month system, each animal requires only 1 acre and the margin per acre is doubled to approximately £30.

Alternatively the question can be examined from the point of view of lb. of S.E. required per 1 lb. liveweight gain. The requirement for maintenance and production of a steer fed from 200 to 1000 lb. liveweight on a roughage system and gaining 1 lb. per day over-all, is 6·1 lb. of S.E. per lb. gain, compared with 3·9 lb. of S.E. per lb. gain for an animal gaining at the rate of 2 lb. per day. These figures illustrate the main weakness in traditional systems—too high a proportion of the food consumed is used for maintenance purposes and not enough for production. Furthermore, the policy of paying a £10 calf subsidy for each unit of production favours the replacement of old units for new as frequently as possible.

It follows, therefore, that unless the returns from grass-fed beef production equal or exceed the nett returns of other forms of land use on a per acre basis, beef is continually being squeezed off the better and more fertile land on to more marginal land, or into non-land intensive feed-lots and fattening yards. Compared with other forms of land use, only an intensive system of beef production gives comparable returns. Realisation of this simple factor has resulted in the development of two distinct systems of intensive beef production, one based on intensive grass production and the other on cereals, and known respectively as '18-month' beef and 'barley' beef.

18-month Beef. This is an ideal system for the high-rainfall, grass-growing areas of the country and for the dairy farmer with a limited amount of grass surplus to his herd requirements. It fits in with a policy of autumn calving when calf prices are at their lowest and animals are ready for slaughter at 16–18 months, when beef prices are at their highest. Calves should be reared to reach a liveweight of 2 cwt. at 12 weeks and 3–4 cwt. at turn-out, depending on month of birth.

In practice, this means feeding concentrates *ad lib.* up to a level of about 6 lb. per head per day, and then continuing at this level with some hay feeding for the remainder of the first winter. After the milk substitute feeding period, the aim should be a daily gain of about 1¾ lb. Feeding concentrates to the young animal when the maintenance requirement is low and growth is made most economical is of far more value than a much larger quantity of concentrates fed to the older animal.

In order to prevent the setback usually associated with turning cattle on to spring grass, it is advisable to start running the animals out from about mid-March and to allow a conditioning period of about 2 weeks. During this transitional period the animals should be housed at night and continued on full winter feed. Once a good bite of grass is available concentrate feeding can be discontinued and, except in very dry years, need not be introduced again until the quality of grass declines in late summer.

An early turn-out ensures that the animal is conditioned to a grass diet, thus enabling it to make maximum use of the spring flush of growth. If pastures have previously been grazed by older cattle the young stock should be dosed for stomach worms some 3 weeks after turn-out and again 2 weeks later. If there is any history of husk trouble on the farm it is advisable to use a vaccine before turn-out.

As previously mentioned efficient conversion of grass to meat is only achieved when cattle gain weight rapidly. Average daily liveweight gains of $1\frac{3}{4}$–2 lb. throughout the whole of the grazing season can be obtained by ensuring that the cattle always have access to freshly grown highly digestible grass. This necessitates periods of rest to permit maximum re-growth and pastures should be rested for about 14 days in the spring, increasing to about 30 days during the summer and autumn. This is achieved by strip grazing and the use of a back fence or by adopting a system of paddock grazing.

Liberal applications of fertilizer of the order of 250 units of nitrogen per acre is necessary and the grazing must be closely integrated with silage making and topping of uneaten herbage. The system developed by the Grassland Research Institute at Hurley is based on a $3\frac{1}{2}$-day moving cycle which requires the use of ten paddocks, half of which are grazed on a 14-day rotational basis from early April to mid-June, whilst the remaining five paddocks are cut for silage during the last 2 weeks of May. Thereafter, all ten paddocks are rotationally grazed at $3\frac{1}{2}$-day intervals with a nitrogen application after each grazing and topping when necessary.

With this system an over-all stocking density of 1·8 beasts per acre will be achieved throughout the year, but grazing intensity will be at the rate of 18 beasts per acre. Liveweight gains will be of the order of 3 cwt. per animal or approximately 6 cwt. per acre from grazing plus a considerable quantity of silage.

At such a high grazing intensity the animals may be subject to a considerable amount of stress with a consequent adverse effect on individual liveweight gains. Poaching may also be a problem in certain areas at certain times of the year. To help to reduce stress it may be advisable to work with small groups of no more than thirty animals.

Concentrate feeding should be reintroduced during August and the ration gradually increased from 2 to 6 lb. as the quality and quantity of grass declines until the animals are housed from late September to early November. This level of concentrate feeding should be maintained throughout the 4–6 months finishing period, together with 5 lb. of hay and *ad-lib.* feeding of the conserved silage.

Alternatively, should the high-quality silage be required for the dairy herd, the concentrates should be gradually increased to 14 lb. per day plus about 5 lb. of hay or good-quality barley straw. The animals will be fit for slaughter at about 900 lb. liveweight which should be reached at about 16 months of age, or they can be carried on to 1000 lb. at under 18 months depending on market requirements.

Intensive beef production, based on intensive grass production from spring-born calves, is less straightforward and less profitable than with autumn-born stock. After the liquid feeding period calves can be grazed on clean pasture, and with good feeding during the winter they can be sold fat off grass at 18–20 months of age. Alternatively, they can be housed throughout the whole of their life and fattened on an intensive system based on *ad-lib.* feeding of concentrates.

Barley Beef Production. In its simplest form the system consists of the *ad-lib.* feeding of a mixture of rolled barley supplemented with a protein mineral/vitamin mixture. It is, therefore, more suited to the drier grain-growing areas of the Eastern part of the country. The aim is to produce an 8–9 cwt. animal at about 12 months of age by a system of intensive feeding in which the animals never have access to grazing.

There is some controversy as to whether or not a small quantity of hay should be fed in order to satisfy the animals' natural desire for roughage and as a bloat preventive. Where hay is withheld animals will consume their bedding, both straw and sawdust, and it is therefore advisable to feed a daily ration of 2–3 lb. of hay or barley straw. Food must be available at all times to prevent too rapid intake with the consequent risk of bloat. A supply of clean water must also be constantly available.

Concentrate consumption will increase from approximately 8 lb. per day at 4 months up to 18 lb. per day at 12 months. Liveweight gain should average 2¾ lb. per day and the conversion ratio will increase from about 3¼ to 6 giving an average of 4¼ lb. over the whole fattening period. Total consumption of concentrates from 3 months to slaughter is under 30 cwt. per head.

Profitability of this system of beef production is predictable and is governed largely by the price of the calf, the price of barley and the price of beef. The system developed rapidly from 1962 to 1964 during which time calf prices doubled from £10 to £20 with no compensatory increase in the prices of beef. Consequently, barley beef has declined in popularity over the past year and although the situation eased in the autumn of 1966 with falling calf prices, the long-term prospects look none too secure.

It now seems likely that we will eventually become a member of the Common Market where the target price for barley in 1967 is

£33. 10s. 0d. per ton. The E.E.C. minimum or producer price next year will be £30. 16s. 0d. per ton and very few barley beef producers will be able to afford these prices unless the market price for beef rises steeply in compensation.

15-month Beef. Perhaps the answer to more profitable beef production lies in systems some way between 18-month beef and the full intensive barley system. One idea is to follow the 18-month system through to turn-out, when liveweights of between 400 and 450 lb. will be attained. Grass at turn-out is at its most digestible and grows fast during April, May and June, and initial stocking rates in this period could be stepped up from the usual two and four, to six beasts to the acre. By doing this each acre would yield a total liveweight gain of between 9 and 10 cwt. instead of the usual 5–6 cwt.

Immediately the grass quality begins to deteriorate, the cattle making the best progress are yarded. After a period on a change-over diet they are finished in exactly the same way as for barley beef. Another group of cattle can be yarded, say, in August, and finished at the same way as the earlier batches. The remaining cattle can remain on grass finished under the usual 18-month beef method, with supplementary feeding from mid-September to maintain growth rate until yarding. From one season's experience on Unilever farms with this system, the Managers recommend:

(1) Animals should be turned out immediately the grass grows, or as soon as possible afterwards.

(2) The heavier the calves are at turn-out the better they utilise the grass and the faster they grow.

(3) On wet land, precautions should be taken against foul-in-the-foot.

(4) Employ an efficient worming routine.

(5) It is essential to feed a correctly-formulated changeover diet (when the beasts come in from grass) to eliminate the risk of 'barley poisoning.'

A feature of the system—which fits in well on the average farm—is that cheap barley from early harvesting can be fed. Such barley is suitable for rolling and *ad-lib.* feeding because of its higher moisture content.

The results of the trial on two of our farms are given on the following page.

Unfortunately, the performance for cattle at Barlby was affected by a severe outbreak of husk. Because of the experimental nature of the trial the cattle were denied the usual husk protection injection.

Urea-Supplemented Concentrates. A number of urea-supplemented compounds and concentrates are now offered for sale for feeding to beef cattle. Urea is a nitrogen compound commercially prepared and containing 46·7 per cent nitrogen. The product has no energy value and is manufactured by fixing the nitrogen from the atmosphere. In theory

	Farm 'A'			Farm 'B'	
Date brought in off grass	14 cattle on 21st July	10 cattle on 7th Sept.	11 cattle on 17th Sept.	17 cattle on 16th July	24 cattle on 3rd Aug.
Age at slaughter	60 weeks	68 weeks	70 weeks	61½ weeks	66 weeks
Liveweight at slaughter	922 lb.	959 lb.	863 lb.	925 lb.	926·8 lb.
Carcass weight	495 lb.	537 lb.	478 lb.	503·5 lb.	500·5 lb.
Grading	12 'A' 2 'B'	All 'A'	10 'A' 1 'B'	3 'AQ', 5 'A' 2 'BQ', 7 'B'	16 'A' 8 'B'
Total food cost	£47 3s. 11d.	£53 11s. 3d.	£55 5s. 8d.	£59 13s. 10d.	£61 18s. 1d.
Margin over food cost	£35 9s. 1d.	£33 5s. 8d.	£24 9s. 11d.	£22 11s. 11d.	£21 12s. 9d.
Calf cost	£14	£14	£14	£12 10s. 2d.	£13
Margin over food and calf cost	£21 9s. 1d.	£19 5s. 8d.	£10 9s. 11d.	£10 1s. 9d.	£8 12s. 9½d.
Income per beast (including subsidy)	£82 13s. 0d.	£87 16s. 11d.	£79 15s. 7d.	£82 5s. 10d.	£83 10s. 10d.
No. days at grass	89	137	147	100	120
Daily gain at grass	1·6 lb.	1·68 lb.	1·35 lb.	1·36 lb.	0·97 lb.
Total gain at grass	146 lb.	299 lb.	199 lb.	136·5 lb.	119 lb.
Liveweight at yarding	644 lb.	626 lb.	519 lb.	589·5 lb.	512·5 lb.
No. days yarded	96	122	122	110	138
Daily gain while yarded	2·9 lb.	2·74 lb.	2·82 lb.	3·02 lb.	3·01 lb.
Total gain while yarded	278 lb.	333 lb.	344 lb.	332·5 lb.	414·4 lb.

Note: At Farm 'A' the cattle were moved out to grass on 21st April while at Farm 'B'—where there was a severe outbreak of husk after turn-out—the cattle were moved out at two different times—on 31st March and 15th April. All figures relate to an average per beast.

when urea and carbohydrates are supplied together, bacteria in the rumen combine them into bacterial protein which subsequently is used by protozoa and then by the animal.

Whilst the exact level of utilisation of urea nitrogen is still open to question, there is little doubt that at levels of protein supplementation currently practised in this country, urea nitrogen can constitute up to one-third of the total daily nitrogen intake without any detrimental effect to animal health or performance, measured in terms of liveweight gain, conversion ratio and carcass quality.

Ground Barley Straw. Whilst beef cattle are capable of converting cereals to meat they are relatively inefficient when compared with pigs and poultry because of losses in the rumen as a result of bacterial fermentation. They can, however, utilise roughages to a much greater extent than other farm animals and over the years many attempts have been made to improve the nutritive value of such products. The most recent attempt is the grinding of barley straw which is then compounded with cereals, proteins, minerals and vitamins to provide a complete diet in cube or pellet form.

Results from a number of research stations show that the nutritive value of barley straw and other poor quality roughages, for growing and fattening cattle and sheep, is considerably improved by grinding and pelleting. Estimates of the change in S.E. value of the straw, due to grinding, indicate values of 35–41 for ground barley straw compared with the theoretical value of 23 for long straw.

The increase in nutritive value is possibly the result of a shift in the volatile fatty acid ratio resulting in a reduction in the proportion of acetic acid and an increase in the proportions of propionic and/or butyric acids in the rumen liquor, together with a reduction in the time and effort required to ingest the ground and pelleted straw.

There is the further advantage that grinding and pelleting poor quality roughages results in a substantial increase in intake and liveweight gain. Vast tonnages of low-priced barley straw are available at harvest time, but problems of processing are considerable and it is unlikely that the process will be developed commercially whilst cereals remain at their present price.

Veal. During the first 3 months of life the calf has a much greater appetite for milk than for dry concentrates and much higher growth rates are possible with liquid feeding. There is also a considerable difference in the conversion of food to meat, in that over 80 per cent of the dry matter of milk is utilised for maintenance and liveweight gain compared with about 50 per cent of the dry matter intake from concentrates, which are subject to lower digestibility and to losses in the rumen as a result of bacterial fermentation.

Work at the N.I.R.D. Reading has shown that with liquid fed calves the weight of the alimentary tract plus contents is about 11 per cent of liveweight compared with a figure of 36 per cent for ruminant calves of 12–16 weeks on high roughage diets. Consequently, in veal production, calves are fed a liquid diet only in order to achieve maximum liveweight gain and killing-out percentage.

A high standard of feeding management is necessary if calves are to achieve maximum liveweight gains. The level of milk substitute feeding must be gradually but consistently increased, from 1 gallon per day at the end of the first week, until towards the age of 12 weeks when each calf is taking up to 3½–4 gallons per day in two feeds.

In the same way that opinions differ as to whether rearing calves should be housed in individual pens or group pens, so there are differences of opinion about veal calves. Results on both systems are equally satisfactory and both have their respective advantages and disadvantages.

On the larger units a small nursery, separated from the main fattening section, houses the calves in small groups for the first 2–3 weeks after purchase. When they are thriving satisfactorily they are then transferred to the main unit and housed in individual or group pens on slatted floors above a sloping concrete floor.

Calves reared for veal do not qualify for a subsidy or deficiency payments. The price of good quality Friesian and beef cross calves is increased on the strength of a subsidy at 8 months which is lost if the same calf goes for veal. Consequently, so long as beef production remains attractive the veal producer cannot compete for this class of calf in any great numbers throughout the year.

Quality veal is still considered a luxury in this country and the main trade is centred on Smithfield Market. Marketing is the major problem and anyone contemplating veal production would be well advised to organise a satisfactory outlet before going into production.

Bull Beef. Bull beef production is commonplace in a number of European countries. Yugoslavia, for example, has been exporting large quantities for some time, much of it to Britain and it has apparently proved quite acceptable here. In this country finishing bulls for beef is still a novelty.

Until recently the bull licensing regulations have effectively prevented this form of production and even today special dispensation is needed to keep bulls entire until slaughter. The main advantages of castration are that it:

(*a*) prevents indiscriminate breeding.
(*b*) improves carcass quality, at least where marbling is thought desirable.
(*c*) eases management by reducing aggressiveness.

The main disadvantages of castration are that it:

(*a*) causes stress.
(*b*) inhibits growth rate and food conversion.
(*c*) tends to induce waste internal fat.

Practically all the work on bull beef in this country has been done on housed stock fed liberal quantities of concentrates. The first nationwide trials in 1963–65 under Ministry and N.F.U. auspices involved forty-six farms on which bulls and steers were compared. Results showed consistently high liveweight gains for bulls. The improvement was in the order of 10–12 per cent for all breeds and crosses with a similar improvement in food conversion ratio.

There is general agreement that the carcases of entires have less waste internal fat than steers and less marbling. Their flesh is often darker in colour and the fat covering on a bull's carcass is usually thinner than that of a steer. Most of these characteristics intensify as the animal gets older.

The national trials referred to earlier showed that killing-out percentages were lower from intensively fed bulls than from steers and there were small reductions in the proportion of hind quarter. From tasting and analytical tests it was concluded that the public would probably like young bull beef because of its leanness. Two important questions, which at present have not been answered, are how bull beef measures up on the proportion of lean, fat and bone in the carcass and how does age at slaughter influence flavour.

Present Ministry regulations insist that bulls being fattened for beef must be housed from the age of 8 months onwards. A system of management which seeks to combine 4½ months grazing, whilst grass is at its most productive, with intensive fattening on high level concentrate feeding is now under investigation on one of the Company's development farms. Results from the first year's work are promising and the scope of the trial is now being extended to include various breeds and crosses.

Cow Heifer Beef. The production of beef by intensive methods results in lighter carcasses, the animals being slaughtered at a lighter weight. If, therefore, beef production is to expand appreciably there must be a corresponding increase in the supply of calves of the right type. As will be discussed later, the use of the Charolais bull on Ayrshire and Channel Island cows not required for breeding herd replacements could make an appreciable contribution and there is considerable scope for a reduction in calf mortality.

Twinning trials have been only moderately successful, but the more recent work on cow heifer beef is much more promising. The basis of the system is that spring-born beef type heifers are reared on a high level of nutrition to reach a weight of 5¾ cwt. at 15 months when they are put to the bull. With good feeding through the second winter the heifers will weigh 8½ cwt. before calving the following March. The calves are then bucket reared and the heifer dried off by inserting penicillin ointment into each quarter, and restricting water and feed intake for about 1 week. The heifers are then turned out to good pasture for 3 months grazing during the flush of growth before going for slaughter in June, at about 27 months of age and weighing $8\frac{1}{2}$ cwt.

With more intensive feeding the heifers can be served at 12 months, calved at 21 months, and be ready for slaughter at 2 years. Cow heifer beef is not eligible under existing regulations for deficiency payments and the system is still very much in the development stage. A number of management problems require further investigation and there is a risk that cow heifers may carry too much fat. The known ability of the Charolais to produce fast growing stock with a high proportion of lean meat in the carcass may make it the ideal crossing bull for the production of the right type of heifer.

Beef Sires. The trend towards intensive production methods emphasises the importance of high weight for age in beef cattle. Mention was made earlier that some 55 per cent of our beef supplies come from home-bred stores, a high proportion of which are a by-product of the dairy industry. The British Friesian is ideally suited for the intensive systems discussed, but of the total dairy cow population of the country approximately 20 per cent are in Ayrshire herds and a further 10 per cent in Guernsey and Jersey herds.

The use of beef bulls on those cows not required for breeding herd replacements must surely be the quickest and simplest method of increasing the supply of suitable calves for intensive beef production, while at the same time increasing the returns from sale of calves in the dairy herds. This will require an increased availability of top-class crossing bulls at A.I. centres throughout the country.

Until quite recently bull selection was based largely on pedigree and conformation—there being very little else on which to make the selection—even though it is known that the correlation between show yard type and performance is often very low. Liveweight gain and food conversion show a close correlation and in pure-bred beef bulls are highly heritable factors. Therefore, the recent announcement by the Milk Marketing Board that 'beef bulls of the major breeds will no longer be considered for the A.I. stud unless they have been performance tested' is a step forward.

Examination of published beef sire performance tests shows that within a group of ten selected bulls of one breed the difference between the best and the worst bulls on test was no less than 41 per cent for daily liveweight gain and 50 per cent for conversion ratio, measured in terms of lb. of S.E. per lb. liveweight gain. The animals on test were selected by three of the breed's most prominent judges and the bulls selected were considered by the Breed Society as good representative types of the breed suitable for crossing on dairy cows.

Charolais may still be regarded by some people as a vulgar French word, but the recently published report by the Milk Marketing Board of the Charolais cross-breeding trials highlights the superiority of the breed for beef production. Charolais crosses, out of all British cow breeds, grow faster and with a better food conversion rate than crosses by British beef breeds. At slaughter, Charolais crosses will have a slightly higher killing-out percentage, considerably more lean meat and much less fat.

It is not surprising, therefore, that Charolais inseminations continue to rise with an increase of 58·2 per cent over the same period last year. The Charolais is now the fourth most popular of the eighteen breeds standing at Milk Marketing Board A.I. centres. Only the demand for Friesian, Hereford and Aberdeen Angus, exceeds that for Charolais and only Friesian inseminations are up on last year. Charolais bulls have produced particularly good beef carcasses from Ayrshire and Channel Island cattle.

Marketing Requirements. Economic production of beef is one problem, satisfying consumer demands is another. An appraisal of market requirements should, no doubt, have appeared at the beginning of this section, but nevertheless may prove a fitting conclusion.

The meat market of this country amounts to 3½ million tons per year with a turnover of over £1200 million—a vast but competitive market. With a high proportion of the married women population at work, there is less time for shopping and food preparation in the kitchen. The reduced demand for traditional joints, on which there appears to be a price barrier of about 12s. for the average household, and the ever-increasing demand for steaks has resulted in the comment that a good butcher will cut steaks from any part of the animal up to a point just behind the ears!

According to market research the consumer buys beef on colour, tenderness, and flavour in that order. Fat meat of any kind is not favoured. These requirements can best be satisfied from an animal weighing about 1000 lb. liveweight, slaughtered at an age of 18 months after a summer at grass. This ensures a reasonable speed of growth to provide the right degree of tenderness whilst at the same time attaining a degree of maturity to provide the correct flavour. Fortuitously the most economic system of production provides the product most suited to market requirements.

Chapter 5

A 2-YEAR STUDY IN OPERATING A LARGE-SCALE INTENSIVE BEEF FATTENING UNIT

I. R. STALBERG

In endeavouring to start a large-scale feed unit, the following points require consideration:

(1) What types of Bobbie calves (those normally slaughtered at a week old) can be successfully used for beef production? How should they be procured and reared to 12 weeks of age?

(2) How should large numbers of cattle be handled in a confined area, from 12 weeks to killing?

(3) How to manage a feed-lot, and also to find a suitable method of livestock and accountancy control.

(4) What veterinary risks are there and what is the best method of disease control?

(5) Can cheap housing be used successfully?

(6) What is the best feeding programme for fattening cattle?

(7) What percentage gradings result from various crosses when fat; also their profitability to the butcher, expressed as sale value?

(8) The economics of large scale intensive fattening.

The following conclusions have been reached after a 2-year project involving nearly 10,000 cattle.

Calves

Bobbie calves of all breeds can be used for beef production, some pure and others suitably crossed, such as the Channel Island with the Charolais. The only points in which selection are necessary are (i) good health, and (ii) reasonable bone structure. Fortunately these two factors delete only a very small percentage of calves, since both pure and crossed breeds can be of equal value when fattened. We have consistently obtained equal sale values (both by deadweight sale and auction) using different breeds—(from pure Herefords to pure Ayrshires), provided the cattle have been fed to the same ration standards and received the same care.

We have come to the conclusion that to buy the entire calf drop from dairy herds is the best way to procure calves. Only in this way can correct crossing bulls be used for the various breeds and cow types within breeds. Local markets and dealers can provide any deficit to balance the weekly intake to rearers. We find no real difference between calves from dairy herds or markets as regards disease, which can flare up at the rearer's premises from both sources. Either calves or calf feeds are usually blamed for most disease troubles, but this is far from just. We find the real blame is on the rearers themselves (in nine cases out of ten) in allowing control to slip from them.

Success in rearing depends on the rearer.

The supposition that the value of a calf can be established at a week old, so as to be able to say that one particular calf is worth more than another, is just moonshine. Certainly one can give a good guess that the top ten will be excellent or the bottom ten useless, but the bulk cannot be graded for extra value. In our experience the economic value of calves is as follows: £10 a head for a heavy cross calf, £6 for a pure Ayrshire.

We have discovered likewise that the heavy calf over 100 lb. carries no financial premium. On delivery to a rearer this calf does not gain for a longer period than a lighter calf, say 75–80 lb. In fact, it lives on itself and puts on no more in 12 weeks than the lighter animal. It is also far from being a pointer to what the finished beast will have achieved in 12 months' time. In fact, as long as a calf is healthy and has a reasonable bone structure, it does not matter what it looks like, either in colour or shape. Conformation as far as the true commercial fattener is concerned means nothing. (Look at livestock judging results compared to deadweight grading at Smithfield to see the fallacy of this on what can be called excellent cattle.) Except of course that it is a pleasure to the eye to see one's favourite colour or type of cattle in the yards. But as this privilege costs money for no return, it cannot be justified economically.

Rearing Costs. The average cost of rearing to 12 weeks on batches covering mixed breeds is 1s. 8d. per lb. of liveweight, the average weight gain being about 120 lb. This feature caused us to alter our methods of payment—to 2s. 2d. for the first 100 lb., 1s. 8d. for every lb. thereafter. This is because, economically, we did not want calves to put on more weight than this whilst at the rearer's premises.

The main problem there is to provide separate accommodation (with plenty of fresh air) for each batch, which can be rested, and after 6 weeks given access to an open, well-sheltered yard. Controlled environments for our calves was definitely not allowed, since this only caused disease problems like virus pneumonia. In this connection we consider that an injection of vitamin A should be given into the rumen of all 12-week-old calves on arrival.

Density

We have found that cattle can be kept comfortable and clean in batches of ten, with an allowance of 24 sq. ft. per head. Under these conditions we have had no disturbance and the cattle have been extremely quiet and easy to handle. They can be fed and bedded easily and are easy to inspect for veterinary purposes and also for grading. When the ten are nearly finished, it has been found worth while to move two of them out. This is generally no problem since two usually finish earlier than the remainder. By using pens 20 ft. long by 12 ft. wide, and placing them in as long rows as possible, very large numbers of cattle can be handled easily and economically.

Management

The establishment of accurate cost accountancy is the first essential to good management, for which purpose a method of costing to one-tenth of a penny should take place every 7 days. This will entail a set of simple returns, starting with the sales invoices for the week-old calves, delivery notes to rearers, weights of calves at 12 weeks old (for delivery to units), check weights and pen allocation numbers on arrival at units. A feed return should be prepared each day to show the amount of feed sent to different yards. A similar straw return, a cattle movement form (showing deliveries of fat cattle for sale), a daily veterinary report and the fieldsman's report on rearers, and regular cattle weight sheets (by pens) are all essential.

With this detailed cost accountancy, it is possible to pin-point wastage of feed or straw, and to control feed rationing by giving the weight of feed to be fed to each pen. In fact to give detailed instructions to the head stockman, but this is only possible if it is based on accurate accountancy, the essence for this being the accurate returns mentioned.

It is important to make stockmen responsible for doing single jobs, and for the head stockman to see that the standard method of working is followed and that accurate returns of feed and straw used, cattle graded, etc. are sent in regularly.

Stockmen are wanted who either know their job or who can be trained to do it well. Men who can think and use their eyes, yet at the same time be prepared to do exactly what they are told. This is surprisingly hard to achieve, and it may be necessary to train one's own stockmen. The need for detailed and accurate instructions, and obedience to them, and for accountancy control, cannot be too heavily stressed since the whole success of the enterprise hinges on this.

Disease

This may not produce the amount of work expected, and the average duration of the veterinary round should not be more than 1½ hours a day, including a complete vetting of all pens. Mortality should not exceed 1½ per cent, including deaths from pneumonia.

Undoubtedly good ventilation was the chief reason for our low incidence of disease. Cattle must have a very high flow of unimpeded air; if not, airborne viruses or bacteria may bring a very high disease risk indeed. If there is an outbreak of disease such as virus pneumonia.

we would be inclined to blame the management for allowing it. It must be remembered that stock were designed by nature to withstand cold, not heat.

Housing

This must be cheap to keep capital costs to a minimum such as by the use of pole yards. Complete with all fittings and with water laid on the cost is about 2s. per sq. ft., or 72s. per head, including sleeper roads.

FIG. 4. Low cost feeding troughs can be constructed of galvanised metal nailed to a timber framework.

Low housing costs keep interest and depreciation charges to a minimum, which in our case has represented a charge of 19s. 5d. per head per year, written off over 5 years. This compares on the same basis with £3 10s. written off over 10 years for a more expensive concrete building, and the cheapest possible construction rate of £20 per head. (To these charges would have to be added of course any charges on land and other equipment.)

Pole yards are very practicable, easily maintained and cheap to install. There is still a large credit balance in their favour when all comparisons have been made and, when taking capital availability into account, it is much easier to get £10,000 than £70,000 for the same job!

Feeding

This is the heaviest charge in producing beef, covering some 70 per cent of total costs; the most important factor being the *Conversion ratio*.

All cattle must be rationed accurately (based on their body weight) and for the period 200 lb.–300 lb. up to 3·5 lb. of feed per 100 lb. liveweight may be fed, because at this time the feed conversion ratio is narrow. Over the rest of the fattening period it should not exceed 2·3 lb. per 100 lb. of liveweight.

FIG. 5. Cheap buildings are essential, such as simple pole yards with a sleeper road of sufficient width to take a site delivery truck. The open ridge pole yards at Brown Street Farm are 340 yd long.

It is again necessary to be precise in detailing the rations to be fed, and Table A shows the net energy method of assessing ration requirements for cattle at various weights. This table has turned out to be very accurate in practice, the actual liveweight gain being within a very small margin of the assessed gain. Accurate net energy figures of different feeds are available, and we find them invaluable.

Barley must be really thin, flat-rolled: if badly rolled it can lose up to 5 per cent of its value. Comparative conversion ratios for barley and maize we find to be as follows:

Barley	(rolled)	4·94–1 lb. of liveweight gain
Maize	(ground)	4·01–1 lb. of liveweight gain

We use both cereals, combining the two in a ratio of 50 lb. barley to 30 lb. maize. This lowers the feed conversion ratio, and at the same time produces very good quality fat carcasses.

There is also a sound case for using up to 5 per cent tallow in the ration, subject to suitable mixing plant and various adjustments to the basic ration. When using a high-energy tallow ration, we find that a full level of urea can also be used profitably.

Body weight (*lb.*)	*Total feed per day at 2·3% of liveweight* (*lb.*)	*Net energy needed for maintenance* (*Mcal*)	*Feed needed for maintenance* (*lb.*)	*Feed left for gain* (*lb.*)	*Net energy left for gain* (*Mcal*)	*Net energy needed per lb. gain* (*Mcal*)	*Expected gain/day* (*lb.*)
200	4·6	2·26	2·7	1·9	1·05	0·99	1·06
250	5·8	2·59	3·1	2·7	1·49	1·14	1·31
300	6·9	2·92	3·5	3·4	1·87	1·29	1·45
350	8·1	3·25	3·9	4·2	2·31	1·44	1·60
400	9·2	3·58	4·3	4·9	2·70	1.58	1·71
450	10·4	3·91	4·7	5·7	3·14	1·72	1·83
500	11·5	4·23	5·0	6·5	3·58	1·86	1·92
550	12·7	4·54	5·4	7·3	4·02	2·00	2·01
600	13·8	4·85	5·8	8·0	4·40	2·13	2·07
650	15·0	5·15	6·1	8·9	4·90	2·27	2·16
700	16·1	5·44	6·5	9·6	5·28	2·39	2·21
750	17·3	5·73	6·8	10·5	5·78	2·52	2·29
800	18·4	6·02	7·2	11·2	6·16	2·65	2·32
850	19·6	6·30	7·5	12·1	6·66	2·77	2·40
900	20·7	6·57	7·8	12·9	7·10	2·89	2·46
950	21·9	6·84	8·1	13·8	7·59	3·01	2·52
1000	23·0	7·11	8·5	14·5	7·98	3·13	2·55

We prefer to use a high energy fattening 'concentrate' which gives 0·8812 Mcal/lb. net energy for maintenance and 0·5738 Mcal/lb. for production energy, but we would not in the future use a 'concentrate' for more than 60 per cent of the total ration. Instead we would substitute either dry sugar beet pulp, or chopped straw in lengths of 1 in. or under (tallow sprayed to stop dust). This will cut the cost of the ration by ¼d. lb. The conversion ratio will be worse, but we consider that the cattle will do much better, and it is also cheaper. Complete concentrate feeding is wrong both economically and from the cattle's point of view.

Gradings and Income

The following represent our gradings from a variety of breeds and crosses:

Grade 1 Super grade	Minimum of ½ in. fat cover	30 per cent of kill
Grade 2 Commercial	½ in. fat cover down	55 per cent of kill
Grade 3 Lean Grade	No fat and plain	15 per cent of kill

Economically there is no advantage in holding cattle beyond a certain time in the feed-lot, and therefore each age-group is allowed to stay fattening for a maximum period, 260 days for heifers and 290 days for bulls. Every beast at the end of that period is slaughtered, regardless of finish: to ignore this is economically disastrous. The conversion ratio rises so fast that it increases the costs per lb. of liveweight gain unnecessarily. Cattle should not be fattened to any given weight, but sold as soon as they are 'finished', but without any excess fat.

Profitability tests on commercial cattle reveal the following:

Fore quarter	82 per cent saleable meat
	18 per cent rendering bones, fat and suet

Hind quarter	80 per cent saleable meat
	20 per cent rendering bones, fat and suet

with a general profitability of 22·8 per cent.

This is the necessary gross profit for a butcher to work on. We found no difficulty in selling these various crosses (deadweight and grade, or even in the auction ring), once the butchers realised the high quality of their carcasses. They have averaged 3s. 1¾d. per lb. deadweight over all carcasses.

Bull Beef

Beef from bull calves is definitely cheaper to produce, since the feed conversion ratio is less than that for steers. Furthermore the pure Ayrshire bull calf can be used, if it is of the flat-boned type, and cheap to buy. Provided a bull is never checked in its growth by bad feeding, there is never any trouble in fattening it.

Bulls should be slaughtered by 14 months, even though they do not colour in the carcass until about 18 months. The carcasses sell just as well as prime steers, and in fact most buyers cannot tell the difference between bulls and steers of this type. We would certainly produce no more steers ourselves, only castrating the odd awkward bull to quieten him.

Economics

Economics is the application of common sense to business methods and is the most important single factor to watch, with large numbers of cattle, for even a mistake of ¼d. a lb. liveweight can cost a fortune. This means working out a set of price costs at which the cattle will make a profit of, say, 7½ per cent net. The following data per lb. liveweight outline the main production costs:

Cost per lb. of liveweight gain	(pence)
Water	0·10
Labour	1·24
Sundries	0·22
Veterinary	0·35
Deaths, Culls	0·51
Depreciation	1·08
Finance (Interest)	0·86
	1·08
	5·44
Feed	13·00
	18·44
Straw	2·10
	20·54

These must be set against a sale price of 21·09d. per lb. liveweight (minimum).

These figures emphasise that agriculture must use the same economic basis of thought as any other business. The often-heard saying of farmers that 'I *must* buy some cattle' or some other commodity, in this day and age just will not do!

Production costs naturally vary from farm to farm. Some will be higher, some lower, but the overall figure of 20·5d. as the gross cost of producing a lb. of meat (liveweight) is a hard fact; and anyone who can find ways of cutting this cost further deserves commendation! Economies can only be effected on the feed side, by cutting the cost of ration below 2½d. a lb. (£23 6s. 8d. a ton), or by reducing the feed conversion ratio to less than 5·2–1. This figure is based on *all* feed taken into the unit and spread over the actual lb. of liveweight sold off the unit, and it therefore covers all feed fed to culls and dead animals, thereby representing the true overall conversion ratio.

It can be seen from the following data why we now say that heavy cross calves are worth a maximum of £10 apiece and an Ayrshire calf £6, with other breeds intermediate:

	£	s.	d.	
Heavy cross calf	10	0	0	
Rearing charge for 100 lb. gain	10	16	8	
Transport and charges	2	1	8	
	22	18	4	Cost to 12 weeks.

	£	*s.*	*d.*	
Ayrshire bull	6	0	0	
Rearing charge for 100 lb.	10	16	8	
Transport and charges	2	1	8	
	18	18	4	Cost to 12 weeks.

These charges, plus production costs, show the following gross costs per beast:

	£	s.	d.	
Heavy Cross	22	18	4	Say 200 lb. weight
Cost of gain at 20·5d. per lb.	46	19	7	Say 550 lb. weight
	69	17	11	Total weight 750 lb.

	£	s.	d.
750 lb. at 56 per cent K.O.			
= 423 lb. deadweight at 3s. 1¾d.	66	10	8¼
Subsidy 50 per cent heifer			
50 per cent male	9	2	6
	75	13	2¼

Net profit £5 15s. 3¼d.

The importance of economics can now be clearly visualised for any item not taken into account can easily reduce the net profit. Attention to detail and careful thought, and a realisation of what overheads can do to a gross margin of profit must be appreciated. These same thoughts apply to all types of fattening, grass and semi-intensive as well.

All calves reared at 12 weeks should be graded into three groups: (i) those for intensive fattening; (ii) those for semi-intensive (18 months); and (iii) those capable of going out to grass. It is in this correct allocating of cattle at the earliest stage than an indication can be seen where success may lie. This positive approach to production of cost per lb. of gain, coupled with buying to a price (for which the margin of profit is known) also includes the buying of stores by the cwt.

SHEEP

Chapter 6

'SHEEP HUSBANDRY'

A. B. HARKER

The 'Golden Hoof' of sheep is a description which has perpetuated through the centuries of British history and is indicative of the wealth which has resulted from sheep. Many areas owe their existence to the development of the marketing and weaving of wool. The actual hooves of sheep have also been praised for their contribution to land and crops in compressing soil in such a way unequalled by mechanical means. Such is the reputation of sheep which has done much to maintain its vast population in Britain today.

NUMBERS OF SHEEP IN THE UNITED KINGDOM
(thousands)

Year	*Ewes for breeding*	*Rams for breeding*	*Other sheep*		*Total*
			1 year and over	*Under 1 year*	
1939	10,975	317	3494	12,102	26,887
1960	11,232	322	3800	12,517	27,871
1965	11,976	339	3750	13,950	30,015

The population of breeding ewes is approximately equally divided between lowland ewes and hill and upland ewes and at 11 million sheep, Scotland is said to have more sheep than people!

But sheep have tended to live in the past and only in the 1960s has their place in the agricultural economy been challenged. The 30 million sheep are widely scattered and no less than 155,000 farmers are recorded as having sheep. Bearing in mind that this embraces both hill and lowland farmers, this class of livestock can hardly be described as either specialised or intensive. It is this fragmented nature of the industry and its very small flock size which is one of the problems causing farmers to re-examine sheep production in all aspects. The position is particularly urgent on lowland farms where land values have risen to £500 per acre and annual rents up to £12–£15 per acre. On such farms alternative systems of farming are present and their relative profitabilities are closely studied. With about one-third of the farming land in this country classified as mountain, hill or upland, the situation is no less acute—not so much because of increasing land values but because of the inflexible nature of the farming policy where sheep and cattle are virtually the only alternatives.

The interdependence of hill and lowland sheep farming is traditional practice stemming from apparent profitability and not co-operative motivation. With lowland sheep farming facing the closest economic scrutiny, it will certainly have repercussions on the stability and policy of hill flocks; but whether the latter can become independent is a matter for conjecture.

Traditional lambing during the January–April period (marketing in June–December) makes planned marketing on a contractual basis to wholesaler and retailer relatively unsatisfactory; not only in competition with other 'meats' for the housewife's purse, but because the ever present import of overseas supplies makes expansion difficult.

ESTIMATED MUTTON AND LAMB SUPPLIES TO THE U.K.
('000 tons)

	1954–8 average	*1957–61 average*	*1962–65 average*
Production	211·0	224·6	247·0
Net imports	*344·7*	*352·0*	*349·0*
Total supplies	555·7	576·6	596·0
% Domestically produced	38	39	41
Consumption mutton and lamb (per head lb.)	25·2	24·3	not calculated
Consumption carcass meat per head (lb.) excluding bacon and ham	N.A.	119 (in 1957)	118 (in 1960)

It is worth noting that of the 60 per cent of our imported supplies during 1962–64, 87 per cent came from New Zealand. But with a vast expanding market in Asian countries these supplies, primarily imported during January–June, are likely to be lessened. In 1963, the consumption of lamb per head in the U.K. was 25 lb. In France, West Germany, Italy and the E.E.C. consumption was 6·5, 0·5, 2·0 and 3·0 lb., respectively.

The U.K. market does nothing to guide the farmer in the direction of maximum returns. The market will absorb all sheep with which it is supplied. The result is lambs varying from 30–50 lb. deadweight, i.e. approximately 70–100 lb. liveweight. Some buyers prefer the heavier lamb and so the farmer has to gauge his chosen market requirements commensurate with his farm limitations. This confused situation is all the more surprising when viewed against New Zealand imports of a standardised 33 lb. deadweight lamb. The market is therefore a paradox of standardisation of weight and quality (from one breed in N. Zealand) on the one hand, with 'organised chaos' of weight and quality (from 40 pure breeds plus innumerable crosses in U.K.) on the other.

Economic Considerations

The sheep industry embraces both hill and lowland sheep, and although the two types are interdependent for marketing lambs, their particular problems are quite dissimilar. The hill imposes an extensive policy where there are invariably acres per ewe, relatively low labour input per ewe by present standards, i.e. 500 ewes per shepherd (N.B. at least 1000 ewes per shepherd in N. Zealand) and breeds tend to be few in number and pure bred.

The Scotch Blackface represents 25 per cent of *all* breeding ewes in the U.K. Under these hill conditions selection is largely based on tolerance to the environment and this restricts the injection of more intensive and productive aids, e.g. breeds. Nevertheless, whilst capital invested in land is less under hill farming conditions and also sheep are of lower value, the same economic arguments and limitations apply as under lowland conditions. Labour costs must be minimised, stocking density (number of ewes per acre) must be maximised as must also lambing percentage or litter size, lamb crops per ewe, longevity of ewe, and weight and quality of lamb per ewe. Furthermore, wool production per ewe must not be underestimated as a potential source of income. The farmer's attention is thus being focused on increasing output per ewe and output per acre, hence the present interest in intensive methods. Unless this is achieved on the lowland farm, sheep cannot hold their place as a profitable and therefore worthwhile enterprise compared with land used for the production of milk, cereals, other cash crops and even intensively grazed beef cattle. Grass margins (not profit) per acre frequently used for comparison are sheep—£12–£15, barley £27–£30, milk £35–£40.

On the hill farm alternative systems do not apply but the economic pressures are clear to see. Stocking rate is low, labour costs, which are aggravated by sociological considerations, are increasing and lambing percentages are more often under 100 per cent than above. Added to this predicament is the reliance on the vagaries of the store market being the main outlet for produce which clearly has resulted in the application of a ewe subsidy standing at 21s. per ewe per annum in 1966. There is little immediate prospect of fat lamb prices rising to relieve this situation since examination of average prices at Smithfield Market in 1958–60 and 1961–64 shows no upward trend—31 pence per lb. and 31¼ pence per lb. respectively. It is interesting to compare similar periods at the same market for N. Zealand lamb—25¼ pence and 25¾ pence per lb.

The following two Tables demonstrate the importance of output through intensification in order to contain costs.

DIRECT COSTS PER LAMB BORN—WAGES AND EWES PER SHEPHERD AND LAMBING % (Wilson 1966)

No. of ewes/shepherd	*250*							
Lambing %	*50*	*100*	*200*			*400*		
Shepherd's salary	£	£	£	*s.*	*d.*	£	*s.*	*d.*
£1500	12	6	3	0	0	1	10	0
£1000	8	4	2	0	0	1	0	0
£750	6	3	1	10	0		15	0
£500	4	2	1	0	0		10	0

No. of ewes/shepherd	*500*								
Lambing %	*50*	*100*			*200*			*400*	
Shepherd's salary	£	£	*s.*	*d.*	£	*s.*	*d.*	*s.*	*d.*
£1500	6	3	0	0	1	10	0	15	0
£1000	4	2	0	0	1	0	0	10	0
£750	3	1	10	0		15	0	8	0
£500	2	1	0	0		10	0	5	0

No. of ewes/shepherd	*1000*									
Lambing %	*50*			*100*			*200*		*400*	
Shepherd's salary	£	*s.*	*d.*	£	*s.*	*d.*	*s.*	*d.*	*s.*	*d.*
£1500	3	0	0	1	10	0	15	0	8	0
£1000	2	0	0	1	0	0	10	0	5	0
£750	1	10	0		15	0	8	0	4	0
£500	1	0	0		10	0	5	0	3	0

No. of ewes/shepherd	*1500*									
Lambing %	*50*			*100*			*200*		*400*	
Shepherd's salary	£	*s.*	*d.*	£	*s.*	*d.*	*s.*	*d.*	*s.*	*d.*
£1500	2	0	0	1	0	0	10	0	5	0
£1000	1	7	0		13	0	7	0	3	0
£750	1	0	0		10	0	5	0	3	0
£500		13	0		7	0	3	0	2	0

FIXED COSTS PER EWE IN PROPORTION TO LONGEVITY AND FECUNDITY (£ and nearest shilling)

No. of years ewes kept	2	3	3	4	4	5	5
No. of lamb crops	1	1	2	2	3	3	4
Fixed costs/ewe/life	£10	£11 13s.	£11 13s.	£13 7s.	£13 7s.	£15	£15
Lambing % per crop							
50	£20	£23 7s.	£11 13s.	£13 7s.	£8 18s.	£10	£7 10s.
100	£10	£11 13s.	£5 17s.	£6 13s.	£4 9s.	£5	£3 15s.
150	£6 13s.	£7 16s.	£3 18s.	£4 10s.	£2 19s.	£3 7s.	£2 10s.
200	£5	£5 17s.	£2 18s.	£3 7s.	£2 4s.	£2 10s.	£1 17s.
300	£3 7s.	£3 18s.	£1 19s.	£2 4s.	£1 10s.	£1 13s.	£1 5s.
400	£2 10s.	£2 18s.	£1 9s.	£1 13s.	£1 2s.	£1 5s.	£0 19s.

Based on following fixed costs per ewe:

	£	*s.*	*d.*
Labour		13	4
Food	1	0	0
Cost of ewe	7	0	0

Labour cost of ewe hoggs taken as half cost of breeding ewe.

Historically wool output was of major importance, but in recent years is very secondary to the output of lamb in placing the flock (particularly lowland) on a sound financial basis. Wool varies markedly in quality and a grading system is in operation through the British Wool Marketing Board. Mountain breeds of sheep produce wool clips ranging from 2 to 6 lb., e.g. Blackface, Welsh Mountain, Cheviot; but long wool breeds range from 7 to 18 lb., e.g. Border Leicester, Dartmoor and Wensleydale. The 1966 guaranteed price, around which the grading system is applied, is 54 pence per lb. Invariably the gross income from wool is nullified by the replacement cost of the ewe which is often too high. Wool value, therefore, should not be misunderstood or underestimated.

Biological factors affecting efficiency

It cannot be said, at present performances, that the sheep industry is efficient—efficient in leaving a satisfactory profit, but equally in utilising land or food.

Climatic Effects. Sheep, by tradition, are rarely housed and therefore are susceptible to climatic changes—wind, rain, heat and cold. Unfavourable weather is not usually considered a hazard except at lambing time and to a lesser extent some 6 weeks before and after lambing and perhaps at mating time on the hill. But work by Blaxter (1963) at the Hannah has demonstrated that small climatic changes can upset the apparent state of equilibrium. Heavy showers (producing 0·4 inches of rain per hour) are equivalent to a 10 m.p.h. wind, and at 45° F, with sheep in short fleece they can be lethal. A Blackface sheep in full fleece will withstand temperatures at freezing point, but if a 6 m.p.h. wind is applied the critical temperature rises to 50° F. Sheep turning their hindquarters into the wind reduce heat production by 25 per cent immediately. Thus climate can alter performance and efficiency of food use, so that attempts at controlling the environment are worthwhile when practicable.

Nutrition. Climate too influences production of grass, heather and other perennial foods leading to a summer surplus. Unfortunately, the winter period of shortage coincides with a critical period of the sheep's annual cycle of reproduction—mating from September to November and lambing during February to April. It is primarily this uneven energy supply which is responsible for performance per ewe being less than her potential, and also for her lamb's indifferent growth rate. The extreme of this situation is depicted by the Blackface ewe on the hill with 70–90 per cent lambing and twin lambs despised by the shepherd, whereas under lowland conditions the same ewe will lamb 140–160 per cent and rear twins reasonably well.

There is thus a need for greater control of the mating, pre-lambing and lambing periods if the breeding potential of the ewe is to be fully expressed. Adequate nutritional input at these times is critical. Work at the Grassland Research Institute by Spedding (1965) has investigated nutrition of the ewe on an individual basis through recording energy input and milk output measured by a milking machine. If ewes are to produce litters of viable lambs of which they are capable, knowledge of litter size is essential during pregnancy. X-ray is a feasible experimental technique but not under commercial conditions. If litter size is known the feeding pattern of a group of ewes can be controlled to produce lambs of desirable size, with a much greater chance of survival than at present. Mortality of lambs born alive is variously estimated up to 25 per cent. Much of this loss can be attributed to starvation after birth. Milk production of ewes with twins, triplets and quadruplets is often insufficient for survival. Reduction in mortality without even considering increased litter size would make an immeasurable contribution to efficiency and profitability. Improved nutrition clearly has a big part to play, but it is also necessary to provide better physical control of ewes at lambing with shelter and supervision.

Breed. By far the best way of improving efficiency is to increase output per ewe, both through litter size and frequency of lambing. Hurley have examined the efficiency of utilisation of food and its conversion into carcass meat. A lowland ewe with a single lamb is highly inefficient: a similar ewe of identical bodyweight with twin lambs is 50 per cent more efficient. The one ewe requires 40 lb. dry matter to produce 1 lb. carcass, the other requires only 27 lb. This improved efficiency is partly due to the fact that a greater percentage of the nutrients consumed by twin lambs is taken direct and not via expensively produced ewe's milk. Similar work has not yet been conducted with ewes lambing more frequently than once per annum but certainly the efficiency of food conversion into carcass meat would improve.

The weight of ewe is particularly significant since large ewes of 160–180 lb. liveweight will have a higher maintenance requirement than smaller ewes weighing 90–120 lb. Unless the former produce a larger litter they will be relatively inefficient compared with the smaller ewe; furthermore, the heavier ewe will also be stocked less densely.

Breed	*Approx. Liveweight of mature ewe (lb.)*	*Lambing % (range)*
Cheviot	130–160	141–158
Clun Forest	124	150–160
East Friesian	150–200	206
Finnish	110	200–400
Romney Marsh	180	131–142
Scotch Halfbred	160	176
Svanka	88	200–400 (twice yearly)

Wool. The conversion of food to wool is poor. Only 2 per cent of energy intake is converted to wool, and the production of wool from wether sheep is the extreme, in extensive low output sheep farming (Ryder 1963–64). The level of nutrition in the last two months of pregnancy and the first month after lambing can influence the wool bearing capacity of the unborn lamb. During these periods, nutrition has a major influence in the production of wool follicles, thus affecting future wool clips. Twin lambs have been shown subsequently to produce $\frac{1}{3}$ lb. less wool than singles. Wool growth is known to be seasonal, in that most growth occurs during July–November.

Thus whilst intensification in both sheep management and feeding will impose stresses which may reveal deficiencies or induce new disease patterns; this is a comparatively small price to pay for the many rewards which can be reaped from increased output and sheep efficiency.

Sheep Nutrition

In comparison with pigs and poultry, the nutritional requirements of sheep are imprecise, due to a lack of control over sheep as individuals or even in small groups. Moreover, only a small fraction of the total diet is hand-fed and thereby capable of measurement. In housed sheep, keen interest is being shown in the examination of input and output responses. Nevertheless, nobody contemplates as yet all the year round housing of sheep under commercial conditions. It is therefore true to say that sheep nutrition has a long way to go before theory is borne out in practice, and that as a contrast the dairy cow is well advanced in comparison.

The Agricultural Research Council published in 1965 their estimated requirements of ruminants in *The Nutrient Requirements of Livestock.* The details are complex and need careful study. They embrace requirements for all nutrients and take account of weight of sheep, type and stage of production (including months of pregnancy in the case of the ewe), litter size, rate of growth of lambs and type of wool produced.

PROTEIN

A biological value of 65 per cent is proposed for sheep. There is no evidence that animal protein is advantageous and therefore a variety of vegetable proteins is satisfactory. Non-protein nitrogen in the form of urea has a part to play, provided it is not included at more than 2 per cent in the concentrate supplement since above this level it may be toxic. Crude protein levels below 9 per cent may restrict voluntary food intake. In practice protein intakes are generally considered to be below the desired level in pregnant and lactating ewes, and in excess for growing and fattening lambs.

ENERGY

Energy is expressed nowadays in terms of Metabolisable Energy (M.E.) which takes account of both concentration and quality of the diet, as well as the requirements for different types of production. For basic maintenance the M.E. requirement is low thus permitting low concentration and quality, whereas for high growth rate the reverse applies.

High perrfomance, particularly pertinent in ewes carrying quadruplets, requires diets with high M.E. contents which, because of quality and concentration need high voluntary intake. These variants are not catered for in the starch equivalent system in satisfying and compiling total diets. The indication is therefore that traditionally sheep have been more than adequately catered for when maintenance only was necessary, but have been grossly undernourished with energy when anything other than minimum performance was the objective.

MINERALS

Deficiency of the major elements is remote. Phosphorus requirements of ewes vary from 3·7–5·8 gm. per day for 100 lb. ewe, but the figure increases 100 per cent during the first 3 months of lactation. The calcium phosphorus ratio is consistently 2:1. Magnesium supplies should also increase 100 per cent during lactation, from a maintenance requirement of 0·6–1·0 gm. per day. Potassium deficiency is rare and sodium and chlorine can be more than satisfied by 1 per cent common salt in a concentrate supplement. Trace mineral deficiency can occur so that mention is necessary of both cobalt and copper. Cobalt deficiency will lead to 'pine' and the recommended intake is 0·1 mg./kg. dry matter. Copper is also necessary at trace levels, but in excess of 20 p.p.m. in the dry matter can become toxic (see also Swayback).

VITAMINS

The principal vitamins which concern sheep are A, D_2 and E. The maximum requirements are 30 i.u./kg. liveweight, 5 i.u./kg. liveweight and 0·3 i.u./kg. liveweight respectively. 'B' vitamins are generally neglected because their production by rumen micro-organisms is usually considered satisfactory.

Feeding the Ewes. Feeding of ewes is of major importance as the prime productive unit. At weaning time they are in varying condition, dependent on whether they have suckled one or more lambs, and whether they are on the hill or lowland. Equalising of condition is desirable without achieving fatness. At mating some 2 or 3 months later ewes need to be 'thriving', in order that the maximum number of ova are fertilised. This state is often achieved by grazing a 'rested' field of grass or aftermath, and in some circumstances resorting to concentrate supplementation. The 3 weeks following conception is also critical since a nutritional check can cause complete absence or partial shedding of ova. It is customary thereafter to relax feeding control (other than to satisfy maintenance needs), but during the third and fourth months of pregnancy the plane of nutrition must be on a gradually rising plane. Any check can place the ewe's pregnancy in jeopardy and also result in loss of wool.

It is vitally important that attention is given to the feeding of ewes during the final 6 weeks of pregnancy. Knowledge of litter size at this stage would be invaluable since clearly a ewe with triplets requires heavier feeding than one with a single lamb. The aim should be to lamb the ewe down with strong viable offspring and the ewe herself fit to suckle. An over-large single lamb is as undesirable as weakling triplets. The Grassland Research Station are examining this stage of production with records both before and after lambing, and embracing weight changes in ewes.

Under traditional circumstances the ewe is outwintered on grassland. Supplementation of hay or silage is provided, particularly under adverse weather conditions of frost or snow. The quantities given during the later stages of pregnancy would be 4–8 lb. silage or 1–2 lb. hay.

Concentrate Feeds. Concentrate supplementation is necessary at this time, the quantities of which are based more on instinct than proven fact. Clearly roughage quality and quantity influences this decision, as also does climate, natural herbage and, not the least important, the condition of the ewe. With minerals and vitamins becoming of greater significance with increasing litter size, cereal supplementation alone is less favoured.

Compounded sheep rations or a 'balancer' for the cereals are now commonplace. Such rations contain about 15–16 per cent crude protein, and 60–65 starch equivalent. It is customary to commence this type of feeding 6 weeks before lambing giving ¼ lb. of concentrates per ewe daily, increasing this gradually to 1½–2 lb. just before lambing.

After lambing, it is economic and good practice to divide ewes and lambs into manageable groups according to litter size. Supplementary feeding and management can then be more correctly apportioned. This is of paramount importance immediately after birth, for unless lambs suckle within 2 hours their survival may be at risk. Large litters will require very great attention, even to the point of isolation from other ewes.

The ewe's milk output must be maintained at peak yield for 5–6 weeks. Yields peak 10–20 days after parturition and records show that this ranges from 1·7–4·9 lb. per day (Spedding 1965). The fat content of Dorset Horn ewes milk has been recorded at 5·8–8·3 per cent, however, factors influencing both milk and fat output are complex. Age, weight, breed, genetic make-up, litter size and nutrition (before and after lambing) all play a part. For many of these parameters, information is scant, nevertheless, nutrition plays a very important part, as more recent work at Hurley has shown. Concentrate supplementation should increase during lactation by 8–16 oz. per day. Succulents in the form of roots or soaked sugar beet pulp are also favoured at this time. The length of time supplementary feeding is applied will depend on time of year and litter size. The larger the litter the greater and the more prolonged will be the feeding, and if alternative feeding (e.g. the onset of the grazing season) is not to hand, this too will extend the feeding period. A requirement often overlooked at this time is the vital necessity for an ample supply of readily available clean water.

It is becoming increasingly common to house ewes during late pregnancy. In some circumstances ewes will be turned out to lamb but with close shepherding applied, or they will lamb and remain inside for an indefinite period. Space will often be the deciding factor, but the availability of grass, the prevailing weather or even the marketing date of lambs, e.g. the Easter market, will all have a bearing on this matter.

The complete control of feeding allows more critical nutrient input than under outdoor conditions. Hay, silage and even straw have all been successfully used as bulk foods, but unless these are of the highest quality they will not suffice alone. A ewe will eat up to 5 lb. hay per day, but during the 2 weeks before and after pregnancy this will voluntarily fall to about 3 lb. For high performance ewes, total reliance on hay is an unwarranted risk apart from other considerations. The use of silage with rarely more than 25 per cent dry matter is also open to question as a sole diet. Cubed grass or lucerne meal, and complete diets (embracing chopped roughage together with protein/energy fractions) are in experimental use, but are not yet a commercial proposition on any wide scale. It therefore remains for a combination of one of the three roughages mentioned to be fed in conjunction with a concentrate. Taking hay as an example, it would suffice to feed 2–3 lb. per day (dependent on size of ewe) and a ewe 'pencil' of 15–16 per cent crude protein and 60–65 S.E. at ½ lb. per day six weeks before lambing. This would be increased to 2 lb. at lambing time. After parturition, ewes with two or more lambs will require the concentrate portion to be increased to 2¼–2½ lb. daily. Underfeeding at this time can have devastating effects on the growth rate of lambs, particularly if housing is prolonged.

Lambs. Feeding of lambs is traditionally achieved through the ewe's milk and from any supplement they manage to find e.g. the ewe's concentrates or grass, but unless the ewe is suckling litters of three or more lambs it is an inefficient use of food to feed lambs in this way. Moreover few ewes with even twins have sufficient milk to grow lambs to their full potential. Lambs must therefore receive a supplement and owing to their body size and limited appetite, a really concentrated food is essential. A coarse cereal/protein mixture may be offered in a 'creep', out of reach of the ewes; or alternatively this may be compounded in pellet form. Such a ration will have a crude protein content of 16–18 per cent and 65–70 starch equivalent. Mineral and vitamin inclusions will ensure that there is no limitation on liveweight gain. Equally important of course is the necessity to see that the formulation in palatable.

Perhaps the three most important factors affecting the actual amount of protein required by fattening lambs are its ratio to energy, amino-acid make-up and digestibility relative to the rate of growth of the animal. Preston (1966) has summarised data which shows that the daily digestible protein requirements of lambs can be expressed by the following equation:

Digestible protein $2{\cdot}79 \times$ metabolic mass (kg.);
G being the daily gain (kg.), thus:

$$DP = 2{\cdot}79\ W_{kg.}^{0{\cdot}75}\ (1 + 6{\cdot}02\ G)$$

He has also shown that a protein to energy ratio of 22:1 is optimal for growing finishing lambs, i.e. digestible protein (g.) divided by digestible energy (megcal.)

The Feeding and Management of Ewe Hoggs. The breeding from ewe lambs is fast becoming an economic necessity, and there is ample evidence (both under controlled supervision and under practical farm conditions) that such management is complementary in every respect to the success of the flock. On the hill, however, where biological factors mitigate against good growth and condition in the autumn, it is still the practice in many areas to winter such ewe lambs with a view to breeding from them 1 year later. These ewe hoggs, customarily forming 25 per cent of the breeding ewe flock, are selected from the ewe lambs at weaning. It has been common practice to hire winter grazing, often on dairy farms, for the period October to March inclusive. The ewe hoggs rarely receive any extra feeding and rely on what they can scavenge, but under snowstorm conditions they may receive hay or silage at the discretion of the 'grazier', not the owner. Such treatment has a successful reputation in that the hoggs grow out in frame, mortality is rarely over 5 per cent and they respond well on returning to the hill on 1st April and subsequently make good breeding ewes. The system has been questioned in recent years for reasons of unavailability of grazing, cost, unnecessary mortality and rigidity of the wintering period. Some flock-masters have, by means of management reorganisation, arranged to provide similar winter treatment on the home farm, perhaps with limited concentrate supplementation to offset poorer land and more severe climate. Other farmers have resorted to indoor management. Under normal circumstances, the feed cost must be 10s. less per ewe hogg than the total away-wintering cost for the technique to be economically viable. In our experience this has usually implied a feed cost of 30–35s. per ewe hogg. The objective is much the same as before—to grow frame (not flesh) and to maintain condition, particularly with the fleece. Experience has shown that a liveweight gain of 4–6 lb. for a ewe hogg, regardless of breed, is adequate. This performance does not demand critical nutritive input and therefore availability of food, cost and convenience will dictate the system applied. Hay, silage, cereals and compounded ewe 'pencils' have all been fed with success. More recently a daily ration of barley straw (1 lb.) and a concentrate (8 oz.) have proved suitable. An example of feeding successfully practised for some years with Blackface ewe hoggs weighing 70 lb. liveweight, is based on hay and ewe pencils. The first 4 months—4 oz. ewe pencils and 1¼ lb. hay and the last two months—5 oz. ewe pencils and 1½ lb. hay.

Sheep, as a result of intensification, are becoming increasingly dependent on hand feeding which implies that the nutritive quantity and quality is more under control. The importance of food quality in relation to body size and voluntary intake has already been referred to, but because sheep tend to be more selective than other ruminants, there is a need to cater for this characteristic in the way in which the feed is offered. Silage and the larger type of concentrate cob are best fed on the ground. It is essential however that the feed is well spread out to allow equal access for all sheep and that clean ground is constantly sought. In this way poaching of land will be avoided as will wastage of food, and any disease risk or food infections minimised. Hay, ideally, is fed in a rack so that neither wind nor treading will cause wastage. If fed in very limited quantities at least 12 in. of 'feeding face' per ewe will be required so that bullying and uneven feed intake is avoided. Other foods will be fed in a trough where there is insufficient feeding space. Some 10–15 in. per ewe is necessary and the troughs should be frequently moved. Inverting of troughs between feeds is desirable in order to avoid soiling or collecting snow or rain. Overcrowding at feeding time not only ruins all one's carefully laid feeding plans, but with ewes late in pregnancy can be a cause of abortion.

Intensive Grazing. Ewes and lambs must be densely stocked on grass unless it commands a very low rental. If this is not done, the output per acre and the profit per acre will both be insufficient to cover costs and incomparable with other methods of land use. Such a requirement implies satisfactory grazing conditions—good well-drained land, good grass sward, adequate fertiliser application correctly timed and sound fencing. Stocking density in this context applies to the grazing season which must be of a high order if for the entire year a minimum figure of 3–4 ewes per acre is to be achieved. Hence, during the summer months 6 ewes and their lambs per acre is the base line of economic acceptability.

Fertiliser application will be commensurate with stocking requirements. Excessive nitrogen supplies will naturally be undesirable (in the absence of lime, phosphorus and potash) but in spite of traditional forebodings there is no evidence to suggest that the nitrogen is detrimental to either ewes or lambs. At Hurley up to 950 lb. nitrogen per acre has been applied in one season.

Perhaps the greatest barrier to be overcome in intensive grazing, is parasitic infestation, particularly with *Nematodirus* species. Management and therapeutic techniques of resting pastures and dosing of sheep now allow control of this hitherto difficult problem.

Grazing Management. In considering systems of grazing management sufficient grass has to be available in continual supply at optimum quality. Ideally the grass should be grazed evenly over the total sward without undermining the sheep's selective habit and without depressing performance of ewe and lamb. It must allow control of worm infestation and be easily applied. Above all, the system must be economic through achieving a given stocking density and an output of a given number of fat lambs in a given time schedule.

Set stocking implies ewes and lambs on a known acreage for a prolonged period. It tends to be inflexible and imposes uneven nutrient intake with progressively uneven pasture developing. Worm infestation can become a problem though it is possible that under this system a degree of tolerance by sheep is developed.

'Forward' and 'sideways' creep grazing were systems developed at Hurley with intensive stocking in mind. With both techniques, ewes are confined to a limited area of grass and by means of moveable fences in which 'creep gates' are incorporated, the lambs have access to ungrazed grass. Lambs are thus given the opportunity to have the best grass which is also uncontaminated by adult sheep and their worm infestations, but the system is complex and not readily managed. It is expensive in fencing, but permits dense stocking and gives good parasite control. The tight stocking of ewes often tends to depress milk yield through inadequate nutritive intake and the lambs suffer in consequence. The outcome is often one of too few fat lambs and too many store lambs.

Paddock or rotational grazing is a combination of creep grazing and set stocking, and it manages to achieve most of the virtues and few of the disadvantages. The grazing area is subdivided into paddocks, ideally about six which enables flexibility within a 4–5 day per paddock grazing pattern. The sheep have constantly fresh grass, provided by resting and judicious fertiliser application. Worm infestation is kept to a minimum and disturbance of sheep is not excessive. Surplus grass at peak periods of production can readily be ensiled. Stocking density can be 8–10 ewes and lambs per acre, but this must be reduced when conditions dictate.

Reference has been made to the critical balance between fat and store lambs; unfortunately density of stocking and proportion of fat lambs are often in inverse relationship. It is therefore advisable to apply, where necessary, concentrate supplementation to the lambs in a penned off 'creep', ewes with singles being segregated from those with 'multiples'. The single lambs do not justify additional feeding. The multiples, however, should be given a pelleted lamb ration *ad libitum*, with a crude protein of 14–15 per cent and an S.E. of 65–70 (Wilson and Hardy 1966). This feeding should continue to slaughter and in this way a stocking density of 8 or 9 ewes and their lambs per acre can successfully be achieved.

Housing Sheep

Sheep have been housed traditionally in Iceland and Scandinavia for many years, but it is only during the past 5 years that this technique has been adopted on a commercial scale in Great Britain, although inwintering was first practised early in the nineteenth century.

Housing sheep is a method of intensification which has advantages dependant on individual farm circumstances. It is complementary to dense stocking at grass in the summer months, in that the pastures are completely rested in winter and poaching is avoided. This produces an earlier growth of grass but (poaching effect excepted), there is some doubt whether the total grass production per acre in any one season is increased. The close shepherding afforded by housing ewes makes the labour task easier and should allow a greater number of sheep to be managed per man. Furthermore, housing eliminates climatic stresses particularly at lambing time, and reports indicate that lamb mortality is lessened which should increase lambing percentages. This will be most apparent in flocks which experience large litter size, or in hill flocks where mortality can be severe. The importance of longevity in ewes has been mentioned earlier. Ewes, unable to fend for themselves under outdoor conditions, could well extend their useful life by being housed for their final lambing.

Capital expenditure is perhaps the main disadvantage. Additional feed costs will occur, though it is difficult to compare these with those of outwintered sheep which obtain some or all of their nutrients from grass and other herbage at unknown cost. Suffice to say that hand feeding is apparently more costly under housed conditions.

It is also necessary to mention wool in this context, and on balance there is probably a 10 per cent loss in wool weight or quality; but reports are conflicting and some workers are adamant that fleece income increases with housing. Certainly the longer period of time sheep are housed the greater the risk to the fleece. The concern is primarily one of physical damage through rubbing (particularly at the neck and chest on troughs); and also when ewes are lambed inside through lambs climbing on ewes' backs. Careless use of hay or straw can contaminate fleeces, and bad ventilation may cause fleeces to sweat.

Disease Problems. Close confinement of sheep often results in disease problems, and housing intensively tends to highlight this reaction. Nevertheless commonsense and certain preventive measures lessen this problem. Pneumonia, pulpy kidney, orf, prolapse, copper toxicity, acidosis and foot rot are the major conditions which usually have to be faced. Any tendency to pneumonia in sheep under housed conditions is best controlled by adequate ventilation. Good air circulation with the indoor environment no warmer nor more humid than outside should be the aim. Indeed a sheep merely requires 'shelter' from wind and rain.

Measures can be taken before housing to prevent incidence of pulpy kidney. Orf or contagious dermatitis demands close observation by the stockman though prevention by vaccination is possible. Housing sheep in relatively small numbers (e.g. groups not exceeding twenty ewes, thirty hoggs or thirty fattening lambs) helps to contain the infection.

Footbaths containing 2 per cent copper sulphate solution used before housing and at, say, monthly intervals should give a trouble-free indoor period. This is certainly the case on slats but straw bedding will necessitate a closer watch.

Prolapse does not appear to be a problem specific to housed ewes, but too cramped conditions and too heavy feeding are associated factors.

Copper toxicity should not occur if a diet containing not more than 20 p.p.m. is used. The addition of sodium sulphate to the ration may reduce copper absorption.

Acidosis, a symptom of a lowered pH of the rumen, is a hazard which has arisen through the use of cereals, particularly barley, in *ad libitum* grain diets to the virtual exclusion of roughage. This condition, first experienced in barley beef production, is identical with barley lamb. The most critical stage is when lambs under outdoor conditions (regardless of diet) are placed immediately on an all grain diet. This change must be a gradual one and is best achieved by offering a concentrate ration (high in fibre—at least 15 per cent) for a period of not less than 7 days, before the barley ration is introduced. Hay or straw should also be on offer but this rarely exceeds an intake of 0·5 lb.

daily under these conditions, and is no substitute for the high fibre treatment.

The main stress period for ewes and thus the period of greatest losses, is the 2 months prior to the onset of the grazing season, usually coinciding with lambing. Any protection, individual management or feeding (all of which are possible through housing) at that time will reduce these losses.

Types of Housing. Housing is customarily considered in terms of breeding ewes, up to and after lambing. It is also used for ewe hoggs and fattening lambs either early weaned (from multiple litters at birth) or at a few weeks of age. Store lambs from both hill and lowland are also increasingly being fattened inside.

The types of housing to which sheep are subjected are numerous, but some conversions of cowsheds defy in their success the general principles of ventilation. Indeed some people submit that sheep on straw covered concrete, or slats with lateral protection (but without overhead cover) is adequate. Other people go to the extreme in sophistication with a specialised sheep house, incorporating slatted floors. Suffice to say, a wide range of housing conditions has been used satisfactorily.

Capital expenditure will often dictate the position, bearing in mind that a sensible approach will indicate that the system cannot afford extravagance when, under present methods of sheep intensification, few houses are utilised for more than the six winter months. Other uses must be found for the house in the summer, to carry the overheads, if much capital has been expended.

Another consideration in choice of housing system is that of labour. Generally, the easier that tasks under reasonably conducive conditions can be carried out, the better the results. Few men will relish tending sodden sheep in a bleak open yard with no cover!

The amount of space provided per sheep will vary. A roofed building with the sheep on slats will demand the minimum space—ewes 9–12 sq. ft., ewe hoggs 7–10 sq. ft. and lambs 5–7 sq. ft. The breed range shown by these figures would be depicted by a Welsh Mountain and Scotch Halfbred respectively. But it is important to realise that if ewes are lambed inside, the space requirement at and after lambing increases by 60–70 per cent to provide room for lambing pens, lambs and creeps.

Where straw bedding is used the space requirements may well increase by 25 per cent. Litter quickly fouls (especially under open conditions) and space is necessary to minimise foot rot and soiled fleeces. Straw utilisation varies but 2 cwt. per ewe in an enclosed house and 5 cwt. in the open should be adequate. This can be reduced by adding limestone to the straw. Part-covered yards should have a third of the area under cover.

Shelter walls should not exceed 4 ft. high in an enclosed building, and the eaves should be at least 7–8 ft. (Williams 1965). The intervening space is often left open though sometimes filled in with chicken netting to reduce wind velocity and encroachment of rain or snow. Pitched roofs are ideal, and a pitch of 18–20° is optimal. On no account should the ridge be closed; a 6 in. gap running the full length of the building is preferable.

Slatted floors will find favour more in the west where straw is expensive or unavailable. Slats are usually made in panels of 8×4 ft. and are supported on joists about 24–36 in. above the ground. The slat dimension is critical—$1\frac{3}{4}$ in. wide, $1\frac{1}{2}$ in. deep and $\frac{5}{8}$ in. gap between each. Too wide a slat and too narrow a gap lead to fouling of the pens. Slats are best fitted horizontal to the feed troughs.

Sheep pens are usually arranged on either side of the feed passage. Troughs are increasingly catered for by a copy of the 'Norwegian hay box'—2 ft. 2 in. wide, $11\frac{1}{2}$ in. high with rails above at 8 in. and 6 in. intervals. The hay is placed in the box, on top of which is a 'ladder' or weldmesh 3×3 in. strip, through which the sheep feeds but avoids wastage. Such a box into which concentrates can also be fed has the virtue of also forming the pen front.

Water must be in continuous supply, but water bowls are not favoured due to expense and therefore are rarely present in sufficient numbers and easily fouled. A water tank(s) is preferred, or alternatively a continuous half-glazed pipe running the full length of the building, from a header tank which flows continuously. Even temporary restriction of water can be dangerous—in ewes as well as fattening lambs.

Management Factors. Adequate artificial lighting must be provided for lambing, and in an enclosed house care should be taken to avoid frightening ewes when the lights are turned on.

Sheep, like other animals, can become accustomed to new environments such as confined buildings, but undue excitement and disturbance, particularly by strangers, should be avoided. There is no need to 'condition' sheep to housing beforehand. Some sheep settle better than others, but no breed is unadaptable as far as is known.

At lambing time individual penning arrangements are necessary either within the ewe pens or elsewhere. After lambing has taken place segregate the ewe and her litter for at least 24 hours. She can then be joined with another ewe and lambs and after 72 hours reunited with the lambed flock. Failure to do this may result in trodden lambs, mismothering and even hysteria in ewes.

Soon after lambing, a creep should be provided where lambs may have access to a special feed and water *ad libitum*. Easy entry and exit from the creep is necessary with two distinct sets of openings. If competition occurs, uneven growth of lambs will result. There should be no problem with the lambs' feet if the slats dimensions described earlier are used.

Artificial Rearing, Early Weaning and Intensive Fattening of Lambs. This subject is considered briefly under four headings:

(*a*) Orphan lamb rearing.
(*b*) Early weaning of lambs at or near birth from large litters.
(*c*) Early weaning of lambs at several weeks of age.
(*d*) Intensive fattening of early weaned lambs and of store lambs.

Orphan Lamb Rearing. Bottle feeding of orphan lambs has been practised with mixed success for generations when an emergency occurs. It is invariably a labour of love and the economies of the exercise are rarely questioned. Such lambs have quite often never suckled a ewe and in the absence of colostrum their chances of survival are limited. Various home concoctions, nearly all based on cow's milk (a poor substitute for that of a ewe) have been used:

	Ewe	*Cow*
% Solids-Not-Fat	11·3	8·7
% Fat	6·2	3·6

During the past three years properly designed milk replacers have been developed, which when reconstituted with water, closely approximate ewes' milk. The milk powder is usually mixed with water at 1½–2½ lb. per gallon.

Techniques in feeding these 'milks' differ from centre to centre and from farm to farm. Hurley, for example, choose to feed the liquid cold *ad libitum*, and in this way minimise souring of milk and also labour input. Furthermore lambs suck the milk through a teat which is syphoned out of a bucket sited outside a pen. Several lambs draw from one bucket. At Cambridge, on the other hand, the liquid is fed warm in set feeds—four times daily for the first 10 days, thereafter twice daily—and in bowls such that the liquid is drunk and not sucked. (Queen and Davies 1966). A lamb creep ration is offered *ad libitum* after 1 week and the lambs are weaned off the liquid at 25 lb. liveweight, i.e. at about 4 to 5 weeks of age. Good hay and water should be available from 1 week of age. Both systems work well but management and close observation in the early stages clearly have a major influence on success.

Using this feeding system large litters of lambs are now a manageable proposition, since any in excess of two per ewe may be artificially reared. Such a development opens new horizons in breeding for prolificacy, linked with a feeding programme at time of mating and through pregnancy to cater for large litters. Furthermore frequency of lambing can also be investigated, since no longer is there a restriction on the ewes having to suckle lambs to 12–16 weeks of age. It is interesting to note that the total litter weight of, say, three lambs at 6 weeks of age will be considerably greater if one or two lambs are artificially reared, rather than the entire litter left on the ewe. Lambs grow well and at Hurley ¾ lb. liveweight gain per day has been experienced and like all young animals lambs convert food efficiently. Up to 5 weeks of age the conversion ratio will be less than 2:1, and thereafter to 12 weeks about

3 or 4:1. Food cost to 5 weeks will be 25–30s., the cost mainly relating to the milk substitute.

Early Weaning. Not all farmers consider the risks from disease and good management necessary with liquid feeding justifiable, and therefore prefer to plan their future sheep development on a system of later weaning at 4–6 weeks of age at a time when liquid feeding is no longer necessary. In this context large litters of lambs are not feasible and unless ewes can be bred with more than two functional teats, three lambs is probably the maximum they will care for and nourish, even to 5 weeks of age. But increasing the frequency of lambing is still a feasible proposition. Surprisingly lambs can be weaned from the ewe at that age with no ill effect on the udder. Investigations have been made to even reduce the 'load' on the ewe at that stage by removing a triplet and/or a twin—again with no ill effect. The removal of a twin is of course a possible development under hill conditions where in many flocks management and feeding is not geared to the production of twins because they are considered worthless. For lambs to be weaned at 5 weeks, they need to have been accustomed to creep feeding beforehand. After weaning they may be housed, and continue on a mainly all-concentrate diet; or be at grass with or without concentrate supplementation. In the latter case grassland management must be of the highest order to ensure a constant supply of young fresh grass and at the same time to avoid parasitic infestation. Some straw-bale shelter will also be necessary.

One further application of early weaning concerns aged ewes which if culled at the traditional time in the late summer usually make little return. If, however, they are early weaned they may be sold fat on a more favourable market, thus, offsetting (if this is necessary) the additional feed cost to the lambs.

Intensive Fattening Programmes. Intensive fattening of lambs is a natural follow-on to artificial rearing or early weaning. Since liveweight gains are of paramount importance the diet will be largely grain with a protein, mineral and vitamin supplement. Such a mixture will have a crude protein of 11–12 per cent and an S.E. of 65–70. Barley is the usual cereal; oats tend to be fibrous and should not exceed 20 per cent; sugar beet pulp increases palatability, but if in excess of 15 per cent may cause looseness; maize is satisfactory but often too expensive. The ration should not be dusty and thus not ground or rolled too fine. Hay and water should be available. Down lambs fed in this way will put on 3–4 lb. per week and will convert the food at 4 to 5:1 ratio with acceptable carcasses.

Although it never became general practice, work by Burgess and Lamming demonstrated that stilboestrol implants in such lambs gave 33 per cent increase in liveweight gain, though some diminution in carcass quality was noted. More recent work by Lodge (1966) at Sutton Bonington concerned complete diets which included ground straw in partial replacement of maize. It was apparent that 10–20 per cent of straw was satisfactory but such feeding is still not a general practical proposition.

It is necessary to draw a comparison between intensive fattening methods and that of buying in store lambs, particularly lambs of hill breeds which are available September to November and are usually very cheap. They do not, unfortunately, grow quickly and 1–2 lb. per week is their expected performance regardless of size and quality. On grain rations they convert food badly—at least 6:1. Nevertheless there is often a profit in such a system if the lambs are healthy and bought well—say not more than 1s. 2d. per lb. liveweight. They should be carried through on a grain feeding system, at a maximum daily intake of 2½ lb., until the market price rises in December to March. It is the market prices at purchase and sale times which govern the economics of such a venture.

Breeds and Breeding

There are some forty recognised breeds and crosses in Great Britain. Each tends to be confined to a particular locality and one wonders whether such a wide range of genetical material is necessary. Breeds and crosses and sires of fat lamb tend to have their fashionable periods, but the justification for such trends is difficult to see. Records are very slowly becoming available, and it is clear that the variation within breeds or recognised crosses are as great as those between them. The likelihood is that the majority of sheep have yet to be extended to their full genetic potential.

Increasing intensification is beginning to identify the strengths and weaknesses of sheep and this has led to the development of new breeds for specific purposes. The Thornber-Colburn Ltd. '*Colbred*' has resulted from the most extensive use of progeny and performance testing, fully backed by the skilled application of genetic techniques and computer calculations. The Cadzow Ltd. '*Improver*' is another example, and more recently the Cobb Breeding Co. of broiler fame is becoming established in this new field.

These breeding developments have taken full advantage of the Finnish Landrace for prolificacy, the Westphalia for milk production and the Romanov for growth rate and carcass quality. The successful application of these ventures has yet to be proved, but as with the Charolais in the cattle world, they are undoubtedly acting as a spur to all sheep breeders and associated organisations.

In addition to work at the Animal Breeding Research Organisation, Edinburgh, there have been advances in out-of-season lambing and in the synchronisation of oestrus. This avenue will be particularly beneficial to the flock-master, since litter size has probably still some way to go. Furthermore, work by Rowson (1966) at Cambridge indicates that foetal mortality may well be considerably greater than realised and the mechanism, by which control may be effected, may shortly be much better understood.

Ewes, and also rams, vary in the period of sexual activity according to breed. Lowland ewes will commence in August through to October whereas hill ewes are active during October–December. Nevertheless in both cases activity coincides with declining daylight. Williams (1965) has carried out researches into this subject (See chapter 7).

This treatment conducted in February–March resulted in ewes coming on heat 6 weeks earlier than usual. There are obvious management difficulties with darkened houses for ewes, but simplification of the technique is being pursued. Such a system could allow one additional lambing in 2 years, i.e. three and not two.

One of the problems of shepherding is the spread of lambing over at least one cycle of 16–17 days. Concentration of lambing has many advantages, not the least of which is an even bunch of lambs. This objective has for some time been partly achieved by the use of vasectomised rams which were able to stimulate ewes to ovulate during the first heat when fertile rams were present. This development has been taken further by means of hormones—Progesterone and P.M.S. These have been used experimentally by injection, but such a system has as yet no farm application. G. D. Searle & Co. Ltd. (1966) introduced a vaginal sponge impregnated with progesterone. If the sponge is removed from the ewe after 12–17 days, she will come on heat within 48–72 hours (Wishart 1966). Invariably the first heat is not very fertile and it is often recommended that the rams are withheld until the second heat 17 days later. If, in addition to synchronisation, an attempt is made to gain a few weeks out of season, P.M.S. may have to be used by injection. The technique is only in its infancy but if successful would make a valuable and worthwhile contribution to the planning of more intensive shepherding.

Hill Sheep Farming

Hill farming by virtue of its land, climate and altitude is a most inflexible farming system. Cattle and sheep are its only products discounting, of course, forestry. Indeed there are some who would hand over all hill land to forestry and sporting pursuits. But hill farming land constitutes one-third of the agricultural land; half the sheep population is carried on it and the other two-thirds depend on it for store lambs and cattle.

There are many social problems and partly because of this fact government subsidies are provided without which hill farming would founder. Yet profitability is at a very low ebb and capital is desperately needed. The system is fraught with traditional practices and beliefs, and unless some of these are set on one side the future is even more difficult to project.

Perhaps the major problem is monetary output on each farm.

Although the litter size of ewes may reach 100 per cent, in many flocks it is nearer 50 per cent. Weather has such a major influence. Mortality is high—20–25 per cent of lambs born. This low output of numbers must therefore be corrected and in time, it is hoped, better quality will also command a better price per lamb. Nutrition is the principal controlling factor in output per ewe, particularly during the critical November–May period. But greater numbers of ewes will in themselves result in better pastures, or will encourage greater use of fencing, fertilisers and land regeneration. They will also help to reduce labour costs per ewe, and at the same time provide remuneration and facilities to lessen the sociological problems of the hills.

Housing of hill sheep in winter may well play a part for the prime purpose of increasing stocking density in the summer when herbage is plentiful. Winter housing would lessen the effect of climate on the ewes and careful feeding with more interdependence with lowland farms for supplies could overcome the 'hungry gap' of winter. An interesting experiment at the East of Scotland College farm is investigating just this philosophy and already on one section of the hill, the stocking rate has been increased by 50 per cent without any loss of individual performance (Cunningham 1964–65).

It is in fact climate and nutrition which are the stumbling blocks in hill sheep farming. Ewes culled from the hill to low ground conditions quickly show that their potential for lambs and wool has not been exploited. Fifty per cent more lambs and 1–2 lb. more wool are immediate rewards under such conditions. However hill farms have a value which must not be lost sight of, in attempts to intensify for profit motives. Artificialdom without some of the proven practices will surely falter. It is a case of blending the strengths of all new developments with the natural facilities of the hill environment.

Summary

In 1967 the British Sheep Industry is in the dilemma of change. The emergence of farm management techniques through which financial data is becoming more readily available, have revealed the weakness of traditional sheep husbandry—extensive, low output and high costs. Furthermore sheep compare unfavourably with other livestock and cash crops, in contributing to total farm income. The marketing of sheep products is confused to say the least and yet the future market gives cause for confidence. The complexity of breeds, the paucity of factual data and the intrusion of foreign breeds are warnings of the susceptibility of the whole business. Reorganisation on a planned basis is so vitally necessary.

And yet through a rather disjointed and diffused development background, new ideas are appearing. There is an awareness of the untapped potential of sheep and their unexpected adaptability to new techniques. Far from being merely a scavenger or at best a side-line, sheep can respond and be as relatively productive as a high-yielding dairy cow.

Much of the intensification and increased output of sheep will come from continually increasing knowledge of their behaviour, nutrition and physiology. Greater and better food input for larger and more viable litters, followed by the new realisation that milk secretion must be constantly encouraged if lambs are to grow at their maximum live-weight gain. Physiological development will enable greater output per ewe in her lifetime, through perhaps earlier lambing, out-of-season lambing and synchronised lambing.

But whatever technique or combination of systems is applied there will be the need to be conscious of increasing risk and therefore greater awareness of nutritional deficiencies, disease barriers and preventive medicine if the roundabouts are not to catch up with the swings.

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Chapter 7

THE ONSET AND THE MODIFICATION OF THE BREEDING SEASON OF SHEEP

H. LL. WILLIAMS

In recent years the relatively low gross margin per acre achieved from the more conventional sheep management systems has not compared favourably with other forms of livestock production. Since there is no particular reason for keeping sheep under lowland conditions the criterion of their suitability, as an alternative to other enterprises, should be based largely on productivity. Animal production is a complex operation and intensification may be achieved in a variety of ways involving one or more of the three major factors of production—land, labour and capital. In so far as the animal itself is concerned, intensification is interpreted as the adoption of a method or methods of production, which not only make heavier demands on one or more of the basic processes, namely reproduction, lactation, growth and development, but may also involve more control over the environment thus creating new ecological situations.

In most of the more intensive methods of production the choice of livestock is unrelated to their ability to survive and to produce under local conditions, which may well be severe, but is based very largely on their potential under conditions designed for maximum efficiency and a high level of performance. It is well recognised that a very important aspect of the production potential of sheep is their reproductive potential. It is their reproductive potential that delineates the future role of sheep in some intensive systems of production. Two important basic components of reproductive potential are lambing interval and ovulation rate. The first is to a great extent governed by the breeding season and the second closely associated with the breed, age and condition of the ewe and also the stage of the breeding season. The level of ovulatory activity sets the upper limit to the level of fertility attainable in any flock (Averill 1965).

The Breeding Season[1]

The restricted breeding season of most breeds of sheep kept in the higher latitudes is well recognised (Asdell 1946; Hafez 1952). The

[1] For information on the augmentation of fertility by increasing the size of the litter the following should be consulted: Wallace (1954), Pálsson (1962), Slee (1964), Newton and Betts (1966), A.B.R.O. *Ann. Rpt.* 1967.

establishment of a clearly defined breeding season is generally attributed to natural selection having taken place in an environment with distinct annual fluctuations. The correct timing of the season of birth resulted from a capacity to respond to a component of the environment which showed little year to year variation. Response to such fluctuations resulted in a fairly clear division of the calendar year into an anoestrous season and a breeding season. Although this rhythmic activity has long been known the study of the relative importance of the various factors contributing to its maintenance has largely taken place during the last 30 years. The effects of the ecological factors on fertility have been reviewed by Hafez (1965); in this discussion particular attention is given to the onset of the breeding season of the breeds and crosses of sheep found in Great Britain and to methods of modifying the seasonal pattern of breeding activity.

The Onset of the Breeding Season

In spite of the fact that the onset of the breeding season has such a profound influence on the flexibility with which flock-masters can time the lambing season there is only limited published information on the onset of the breeding season (Hafez 1952, Lees 1966, Williams 1966). This information is important in relation to the choice of method of advancing or synchronising the onset of activity.

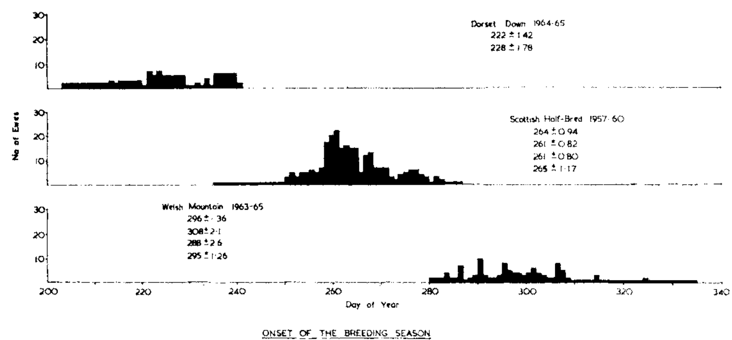

FIG. 6(a).

The pattern shown in Fig. 6 (a) taken from a recent study (Williams 1966) serves to illustrate some of the more important features connected with the onset of the season. The histograms represent the distribution of the first oestrus in groups of ewes, of three breeds, which had been given every opportunity from late spring of exhibiting oestrus. The mean date of onset given as day of year, for each year shows only slight variation between years. This is in agreement with the findings of Averill (1965) who found that the mean date of onset of ovulatory activity in Romney ewes in New Zealand was closely related to a calendar date.

The investigation of the effect of nutrition on the early stages of the breeding season in adult ewes has been directed at the improvement of fertility. There is no evidence to suggest that flushing can have a marked effect on the onset of the season (Coop 1966). Ewes transferred from high to low altitudes and showing a 10 per cent increase in body-weight between two successive autumns did not show an appreciable advancement in the onset of activity (Williams 1966).

Variability due to age applies more to the ewe lamb than to other age groups. In the case of ewe lambs the development of sexual activity is primarily a function of age but there seems to be a threshold of liveweight below which lambs do not exhibit oestrus (Hammond Jnr. 1944, Hafez 1952, Allen and Lamming 1961).

The interval from the spring lambing is unlikely to affect the onset of the breeding season. Techniques such as artificial rearing and early weaning of lambs may nevertheless have an important role in systems based on short lambing intervals. The date of the onset of the breeding season is of considerable importance in relation to post-lambing breeding activity. Lees (1964) has reported that, in a group of Clun ewes lambing up to December, conceptions took place about 6 weeks after lambing. In many breeds and types, pregnancy is as long or longer than the breeding season. It follows that the unfavourable seasonal changes in the photoperiod, which occur at the end of December, coincide with the latter stages of pregnancy and therefore it is difficult to separate the suppressive effect of the light environment from any delaying effect parturition, lactation and presence of the lamb might have. Where seasonal effects are eliminated the role of all the factors contributing to the 'umbrella' term lactation anoestrum, are of considerable importance and require greater definition. There is some evidence to suggest that the suppressive effect of lactation *per se* has been overestimated (Mauléon and Dauzier 1965). In general terms it seems unnecessary to separate lambs from the ewes prior to the fifth week and cannot be recommended as a practice simply to ensure uniform return to breeding activity.

Although it is generally acknowledged that rams are not as seasonal in their sexual behaviour as ewes, seasonal variations and breed differences have been reported (Hewlet 1966, Thibault *et al.* 1966). An adequate safeguard against a period of sexual rest in the ram is usually achieved by using more than one breed and by using a much higher percentage of rams relative to ewes compared with the accepted ratio for autumn tupping flocks.

Marked differences exist between breeds of ewes in the timing of the onset of the breeding season. This can be seen clearly in Fig. 6 (a); the breeds shown represent types which feature in the stratified pattern of production found in our sheep industry. The Down type has a mean date early in August, the crossbred in mid-September and the mountain breed in the last week of October. Although there is little overlap between the breeds illustrated, a more important aspect is the distribution of the onset within a group. It is this distribution that presents the problem of organising matings on a flock basis early in the season. It also suggests that members of a flock are not at the same hormonal status during the approach of the breeding season. The attainment of earlier lambing can, to some extent, be achieved by choice of breed, but is of limited commercial significance. A very high percentage of our breeding ewes are crossbred and as long as the present stratified system of sheep production remains, the restrictive influence of the seasonality of breeding will continue.

Methods of modifying the onset of the breeding season and of initiating activity out of season will have to be relied on to achieve greater flexibility in the timing of lambing and of attaining short lambing intervals consistently.

The modification of the breeding season

The ecological factors involved in the maintenance of periodicity fall into two main groups, those which are a part of the physical environment and those which are described as being a part of the social environment. In the former, the photoperiod and fluctuations in temperature and humidity are important; in the latter unaccustomed presence of the males and transportation have been shown to affect sexual activity. The climatic fluctuations experienced in Great Britain are such as to make them relatively unimportant. The importance of the social factors have not been adequately assessed. It is well established that they are of considerable importance during the transition from anoestrum to the cyclic phase; it is sometimes overlooked in the assessment of treatments applied during the approach of the breeding season. These factors, however, can only be considered where relatively slight advancement is required. The limitations of 'the entry of the ram' technique has been demonstrated in New Zealand (Edgar and Bilkey 1963).

Marshall (1936, 1937, 1942) placed the role of exteroceptive factors in the maintenance of reproductive periodicity on a firm foundation. Marshall assembled a wide range of evidence in these notable contributions to emphasise the dependence of the breeding season on environmental factors. He described the response to seasonal change as 'an outstanding fact' and that light must be regarded as 'the principal stimulus'. In so far as the modification of the breeding season is concerned, it is generally acknowledged that cyclic activity can only be achieved by the application of treatments simulating the exteroceptive stimuli and principally by the manipulation of the photic environment. Marshall presented data on the breeding behaviour of ewes subjected to transequatorial transfer (which is essentially subjection to a contrasting light regime) to support the concept that photostimulation results in the activation of the higher centres regulating reproductive phenomena. Since most of the evidence is of a presumptive nature, investigations involving photostimulation have been of an empirical nature but, nevertheless, serve to demonstrate the sensitivity of the ewe to such a stimulus and also permit an assessment to be made of their role in systems of intensive production (Yeats 1949, Hart 1950, Hafez 1952, Mauleon and Rougeot 1962, Thwaites 1965, Williams 1966, Wodzicka-Tomaskewska *et al.* 1967).

The more important information on the response of ewes, whose reproductive seasons are known to be under photoperiodic domination, may be summarised as follows: Gradual increases and decreases which simulate natural changes, are effective but not essential. A similar response can be achieved by using abrupt changes in the ratio of light to darkness. In the case of the former, the rate of change should exceed 15 minutes per week with a maximum of 18 hours of daylight at the point of change over. Where abrupt changes are applied the contrast between levels should be approximately 6 hours, with the lower level not exceeding 10–12 hours of light per day. The period of decrease or 'low level' required is governed by the reaction interval of the breed concerned. This is the interval from change over to the onset of activity and is the same for light treatments as it is under natural conditions (measured from 21st June). Breed differences exist under natural conditions and remain so for light treatments. The mean reaction intervals of most breeds originating in the higher latitudes fall in the range 60–120 days.

The fairly lengthy period of treatment limits the number of sequences which can be applied in a given period of time. Although it has been shown that a bi-annual rhythm based on sequences of 90 days results in two distinct breeding seasons in cyclic ewes, the duration of pregnancy, coupled with an allowance of 6 weeks between lambing and resumption of breeding activity, would curtail the number of sequences and also govern the period of favourable light phase. It is suggested that treatment should end by the sixth week after lambing.

In designing effective light treatments, it should be borne in mind that ewes treated on accentuated reversed seasonal light show almost complete reversal in their breeding season. Prolonged exposure to a particular level of light per day will not ensure a high incidence of breeding activity. In ewes maintained at 6, 9, 12, 13 and 24 hours of light per day, the pattern of seasonal activity became aberrant. Poor fertility, low intensity and irregular pattern of breeding have been reported in British breeds transferred to the equatorial regions. This has been attributed to the lack of photoperiodic stimulation.

Adaptation to improved light rhythms is also influenced by the fact that adjustment to a new light regime is only gradual and may in some circumstances be affected by a refractory period. Since the application of light treatments usually involve a windowless house their contribution to commercial systems must await the results of investigations, now in progress using supplementary light only. These treatments are applied during the winter period when there are other reasons for confining ewes.

There is little information on the effect on the ewe of successive lambing intervals of less than 200 days and on the capacity of the breeding ewe to respond to a recurring rhythm based on sequences considerably less than the normal 180 day pattern. A full assessment of the potential use of photostimulation in sheep production can only be made by the study of reproductive efficiency together with the economic implications of concomitant changes in flock management.

The use of hormones in the control of breeding activity is perhaps more widely known. Such treatments are designed to correct the quantitative and/or qualitative insufficiencies which exist during anoestrum. A variety of progestagens and/or gonadotrophic substances have been used to sensitise the tract and other centres and to stimulate the ovaries. The subject of hormonal control of reproductive phenomena has been exhaustively reviewed in two recent symposia in Nebraska and in Oregon, U.S.A. The responses recorded during intensive investigation of hormone treatments under field conditions have varied both in terms of percentage exhibiting oestrus and also effective conceptions, according to the method of treatment, the materials used, the state of the ewe and stage of anoestrum. Observers have found that dry ewes are more responsive than lactating ewes and that treatment is usually more effective when administered near to the onset of the breeding season. It appears that such treatments do not activate the centre controlling the release of gonadotrophins from the pituitary and so a series of cycles is initiated only when applied during the approach of the breeding season. The work of Gordon (1963), Crowley (1964) and Cullen and Shearer (1964) should be consulted on field studies, and of Robinson (1965) and Roberts and Edgar (1966) on the more recent types of progestagens and method of administration.

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Chapter 8

A DEVELOPMENT IN MODERN SHEEP BREEDING

E. T. Cantle

Not since the 'Agricultural Revolution' in the time of Jethro Tull, Coke of Norfolk and the 'father' of the 'Leicester' Robert Bakewell (1725–95) have there been real changes in the pattern of sheep production. The balance between grass, mixed and arable flocks has swung with the economics of cereal production, but no fundamental study of genetics, management and nutrition has taken place. There has, however, been steady progress in the veterinary field, and of course the use of fertilisers has done much to increase the productivity of extensive sheep farming.

In the last decade two new approaches have been made to sheep breeding by large chicken breeders of which Cobb is one. Whilst each appear to be making a different approach to the subject there are two factors they have in common. Firstly they are interested in productivity and secondly each, in various degrees, in applying scientific knowledge, not only of genetics but of other disciplines. Both poultry breeders concerned have interests and experience in other forms of animal breeding and especially chicken breeding. It is common knowledge how the standard bred chicken and its commercial first cross have been replaced by the hybrids in egg production birds, and the application of population genetics in the meat production birds.

Let us look closely at the approach being taken by the Cobb Breeding Company. Whilst it is not possible to publish details of their programme, if the philosophy behind the programme is analysed it will give some idea of the possible changes that the scientists from this Company hope to bring about.

As early as 1960 work was in progress on a pure bred flock of Dorset Horn sheep. This breed has a prolonged breeding season and under natural conditions it is possible to produce three lamb crops in two years. This flock was being selected for its consistent twinning factor and long breeding season. Two facts emerged from this early work—firstly the tremendous variation of breed type within a breed and the consequent necessity to select on an individual rather than flock basis, even though the flock is a closed one. Secondly, that environment asserted such an influence on the animal that it became impossible under outdoor conditions to make a factual evaluation of the sheep and their progress.

Even when large numbers are used the same problem exists, because although the geneticist has a large statistical sample, the fact that these animals, of necessity, are spread over several farms means that the environmental influence is increased. These relate to different grass, different management and even different disease spectrums. Thus the larger sampling factor is negated by the increase of unknown factors. Therefore it was decided that the only way to carry out a scientific research programme on these sheep was to house them intensively all the year round.

FIG. 6(b).

All the sheep in the Cobb breeding programme are now housed under strictly controlled conditions. Management, nutrition, lighting programmes, ventilation are equal for each set of animals, thus enabling data to be accurately assessed. The programme, however, had to be enlarged to undertake studies on management factors under intensive conditions. Other breeds and individual animals have been added to the programme, notably a large import of Finnish Landrace sheep; again these sheep were selected animals within the breed. One of the breed characteristics is the ability to produce large litters of lambs, up to nine lambs have been recorded and five lambs are common; however many Finnish Landrace only produce single lambs or twins.

It is obvious from the breeds being selected that fecundity is high on the list of improvements aimed for. Equally it must be remembered that fecundity is a trait with a low heritability, therefore it is necessary to have the highest possible reproducing factor in the basic stock.

Cobb workers have produced a drawing-board version of the type of sheep it is desirable to produce—embodying the following qualities:

1. Large litter size, not less than two lambs consistently, and preferably four.
2. Ability to breed all the year round—at least under intensive conditions.
3. The progeny to have fast meat growth, with good feed conversion and conformation.
4. The progeny to have a good meat to bone ratio, and to carry little fat.

It is certainly feasible that such a breed, or synthetic crossbreed, can be produced. However, not all these factors are going to be evolved in a short time. It is most likely that a process of evolution will take place, with increased reproduction taking priority. The second stage will be to increase the growth rate, and thirdly the redistribution of fat over the carcass.

Phase one is now well advanced and it is possible to breed ewes that produce two litters of lambs (utilising controlled environment and lighting patterns). Together with artificial rearing of lambs it is possible to produce two crops per annum. However, what is possible under a research programme may not be economically possible or desirable under commercial conditions. It may prove to be that three crops every 2 years under semi-extensive conditions are more profitable than four crops under intensive conditions. The need to know the answers to such questions is important, and the use of an economist to evaluate these factors is essential.

Phase two is involved to some extent with phase one, because the basic genotype for growth rate must be built into the breeding stock. However improvements in growth rate will continue for some time to come, so too will carcass conformation.

Phase three is considered by many experts to be the most ambitious, this is to develop the meat and reduce the fat distribution over the carcass.

Perhaps we are enthusiastic about this third phase because of the successful work which has been carried out on chicken relating to evisceration yield and meat-to-bone ratios. However, new techniques are being developed to analyse the body composition of live animals, and by making use of these tools it should be possible to influence a breeding programme.

One method of evaluating the meat content of a live animal is to measure the gamma radiation emitted by naturally occurring radioactive isotope potassium-40. It is also possible to estimate the meat to fat ratio by further variations on this principle.

Nutrition will play a large part in the success of these highly developed new breed types, therefore research into the animals' basic requirements has to be carried on at the same time as the genetic programmes. Interest at the moment is on the complete cubed diet, which obviates the need for feeding hay and other roughage which is often wasteful. By feeding a completely cubed diet it is more certain that the animal receives its correct nutrition, especially the pregnant ewe. The ewe producing a litter will have to be fed according to the number of foetuses she is carrying. This information can be obtained by analysing a small sample of blood from each ewe.

It will be obvious to the reader that many new techniques are being studied—some will without question be utilised, but others will not be necessary for commercial sheep farmers.

Whilst these research workers have deviated a long way from the old adage that 'sheep should never hear the church bells on two successive Sundays from the same field', they are still very concerned with details of management. When these new types of sheep are sold then the management advice will be sold with them.

Because it is visualised that eventually the farmer will require a package deal involving both ewes and rams (which will produce the market lamb but will not reproduce breeding stock), a close liaison will develop between the basic breeder, the flock multiplier and the farmer customer on all aspects of management.

Perhaps two of the findings from the work so far carried out will be of most interest to the conventional shepherd. First, that even under a research programme the workers have to admit that the problems of interference from varying management problems under outdoor conditions confuse a breeding programme. How many farm projects have had cyclic breeding results—one year showing an improvement and the next year just the reverse.

The second factor is that strains within breeds are more important than the breeds themselves. An argument has been carried on for many years on the value of so many breeds of sheep. It is just possible that the 'Cobb' ewe may be useful under many differing types of management, and both scientific and market research will be directed to this end.

The conservative farmer may be dismayed by these changes of breeds, systems and techniques which will certainly help to change a farming system which is more a way of life rather than that of a profitable business.

However, if our work is successful, the many farmers that take advantage of modern farming methods will find new outlets for meat production becoming available. Once lambs can be produced on a regular quota system all the year round, then the Supermarket and chain store outlets for meat will become interested. It should be possible to market lamb via processing stations in a similar way to pig meat.

One thing for sure is these workers envisage a new-look sheep industry and a *system* will be offered, rather than just an improved breed. Time and effort is being put into management research, which would make even the conventional sheep farmer envious. This, together with the possibility of continuous lamb production (attracting new market outlets), could change the sheep unit on a farm into a highly profitable enterprise.

PIGS

Chapter 9

THE HUSBANDRY OF PIGS HOUSED INTENSIVELY

IAN MILLER

Economic Factors

Pig production in the future is bound to see an increase in large-scale fattening units, particularly in the cereal-growing areas of the eastern counties of the British Isles.

Considerable capital investment in housing, mechanical handling of food and manure and complicated milling and mixing machinery will all be required. Automation will relieve the stockman of the drudgery and tedium of routine chores. The stockman himself will be a well-paid, qualified man who will be able to devote much of his time to management in the true sense of the word.

The rations used will be based on a protein concentrate fortified with the necessary vitamins and minerals. With an increasing world demand for animal proteins concentrate manufacturers are, and will be, devoting considerable research facilities to the economic use of new forms of protein both natural and synthetic. The rations fed on these specialised units will contain two, or at the most three, home-produced cereals.

Costings and forward budgeting will be on a very accurate basis, with the majority of the external requirements being bought on a contract basis. Possibly the most important item to be bought will be the pigs to be fattened. The unit manager will require to insist upon weaners of good health and capable of high performance.

Weaner Groups

Weaners will largely come from the west of the country where, in relatively small units, pigs will be produced by breeding specialists whose greatest asset lies in traditional inbred stock sense. Their output will be sold on an agreed price per lb. basis, with possible additional financial incentives to improve his weaners' economic potential.

In order to achieve the smooth movement of quality pigs, the pig weaner group will have an important role to play. For a group to achieve the necessary high standard of weaner required there must be strict control and guidance from the organising body. To remain viable in the future a group must embark on a stock improvement plan which will ensure a demand for its weaners and be a step ahead of its competitors. Breeders will be required to submit litters or individual pigs for both progeny and performance tests and any replacement stock will come only from approved tested sources.

The fattener will return performance details to the organising body so that improvement and its implementation will be dependent on both parties. In partnership the fattener and the group will go forward to meet and beat competition.

The group movement as operated in certain areas today will remain the basic framework for any improvement to take place.

The breeder will be required to provide certain minimum conditions. These will include an agreed minimum number of sows which will make the ownership of a boar feasible, and also allow for the economic collection of weaners. It would appear that this number should be around twenty. Correct feeding of the sows and litters will be under constant review to ensure optimum production. Farrowing accommodation will also have to meet certain minimum standards—although a weaner producer will be judged in the end by the quality of pig he produces.

Artificial insemination will become of great importance; at present there are certain factors which mitigate against an economic 'service'. Undoubtedly these current problems will be overcome and A.I. will have an immediate effect on improvement, but only if 'top' boars are used at stud.

One of the farmer's difficulties has been the inability to recognise a sow on heat, as well as the fact that semen cannot be stored satisfactorily for more than 72 hours. A well-organised group with a sow total of 6000 *could* be maintained by an A.I. service with only ten or twelve top-rated boars, and therefore livestock improvement could be vastly speeded up by the intelligent use of A.I.

In order to supply large-scale fatteners with the numbers required it is possible that groups will insist on batch farrowing on certain units. The future well-being of groups is going to depend increasingly on members accepting discipline since their future long-term security is dependent upon it.

Some authorities believe that the future is likely to lie more with self-contained breeder-feeder than with weaner groups. The basis for this thought being (*a*) disease control and (*b*) the possibility of reduced profit margins making it unlikely that the pig can stand two people's profit.

If this long-term thought is borne out in practice, many of the principles of stock improvement undertaken by groups can be equally beneficially utilised by a breeder-feeder. The purchase of tested boars, genetic recording and home gilt testing are avenues which can be followed to advantage. Indeed, many of the larger progressive units are embarking on these lines already.

Factors affecting Indoor and Outdoor Management Systems

The major factors governing one's choice of husbandry will be the best deployment of capital and labour. Building costs and the price of land are bound to rise which will lead to large-scale investigations of methods and systems to reduce costs.

In areas of low annual rainfall large-scale extensive systems will have an important place to fill. The 'Roadnight' system for outdoor farrowing and rearing is gaining in popularity, particularly in view of its low capital requirements, as far as housing is concerned.

FIG. 7. Outdoor early weaning Miller (Denny) pig ark. Plenty of straw bedding is essential for winter use.

The outdoor early weaning technique has proved to be a useful economic managerial tool in reducing costs and increasing output. Likewise production for the 'fresh' meat market, i.e. pork, cutters and manufacturing, can be carried out reasonably cheaply out of doors in certain areas. An increasing number of pig producers are using outdoor systems during the more favourable summer months in order to rest and thoroughly clean both fattening and farrowing quarters.

Apart from its low cost, the major advantage of any outdoor system is the health aspect, since disease build-up or spread is not usually a serious problem. Another attraction is that there are no dung-disposal headaches which frequently present difficult and costly problems.

Among objections raised are labour difficulties in adverse weather conditions, as well as the provision and maintenance of water, particularly during frosty weather. It is, however, today's economics which make it necessary to examine completely outdoor systems. The whole question of the ultimate profitability of a breeding enterprise revolves around the annual output of litters or piglets.

Three-week Weaning

Reducing the suckling period by earlier weaning enables sow output to be increased. On commercial farms it would appear that 3-week weaning is the earliest to be encouraged, although weaning at any age between 3 and 8 weeks will be advantageous. The following table illustrates the comparative output of normal versus 3-week weaning programmes:

	Litters/ sow per year	*Piglets/ sow per year*	*Output/ sow (£)*	*Food cost/ piglet (£)*	*Margin over food cost/sow (£)*
Traditional weaning	1·8	15·3	84	3·36	33
Early weaning	2·6	21·3	117	3·0	53

The figure of 15·3 piglets per sow quoted for traditional weaning is somewhat higher than the national average. Although increased output is clearly demonstrated with the early-weaning system, it cannot succeed if it is output at any cost. The following table compares fixed costs for the two systems and is based on experience from various costing schemes:

	8-week weaning		*3-week weaning*	
	£	*s.*	£	*s.*
Depreciation on breeding herd	8	0	8	0
Labour	7	10	9	8
Miscellaneous costs	2	8	3	0
Rent and buildings	5	8	3	12
Food cost per sow (inc. share of boar's food)	40	0	29	10
Total *fixed* costs per sow per annum	£63	6	£53	10

The major reduction in the fixed costs of an early-weaned sow is due to its lower food consumption. This arises from the fact that in early weaning she only requires 18·2 cwt. of food per year, compared with

25 cwt. for a sow that suckles her litter for the full 8 weeks. Whilst it is true that 6- and 7-week weaning is more widely practised today than hitherto, the economic argument for earlier weaning still holds good.

When comparing the systems on the ultimate profit basis a clear picture emerges. This table shows that the profitability of the most highly efficient producer using 8-week weaning only just betters the figure attained by the average early-weaning producer.

	Below average		*Average*		*Above average*	
	8-week weaning	*Early weaning*	*8-week weaning*	*Early weaning*	*8-week weaning*	*Early weaning*
Pigs produced/sow per year	14	17·5	16	20	18	22·5
	£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*
Fixed costs of sow per pig produced	4 10 5	3 1 2	3 19 2	2 13 6	3 10 4	2 7 6
Variable costs per pig produced	13 6	1 13 8	13 6	1 13 8	13 6	1 13 8
Total costs per pig	5 3 11	4 14 10	4 12 8	4 7 2	4 13 10	4 1 2
Profit per pig*	6 0	15 0	17 2	1 2 7	1 6 0	1 8 7
Profit per sow	4 6 0	13 2 6	13 15 2	22 11 8	23 8 0	32 3 7

* Assuming the value of an 8-week-old pig to be £5 10s. 0d.

Early weaning can be practised throughout the year, either entirely as an outdoor exercise or on an outdoor/concrete (winter) method.

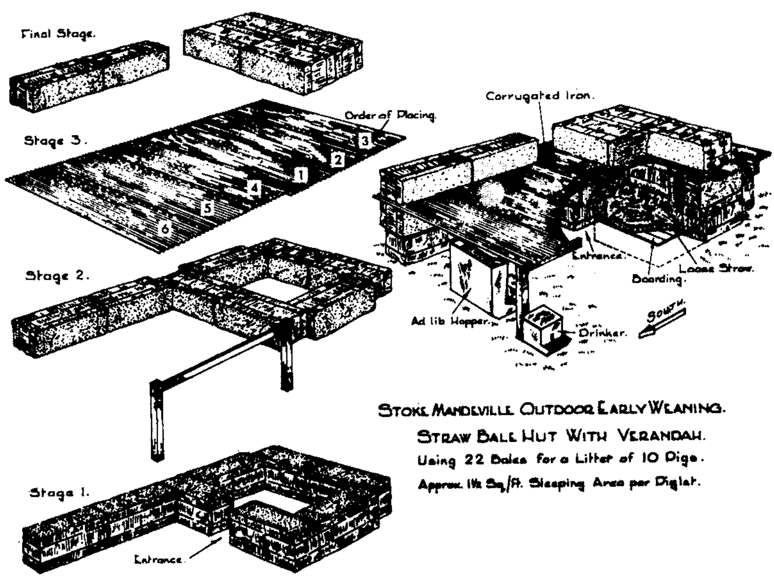

FIG. 8.

The most important points of management are these:

1. Wean when the piglets weigh 12 lb. (3 weeks).
2. Provide warm, dry, draught-free huts, arks or other cheap housing

Straw-bale housing is widely used where rainfall is not heavy, using twenty-two bales to form the walls and a few corrugated sheets for the roof. A really good depth of straw bedding is essential. (See exploded diagram for details.) After use the straw can be burnt on site.

3. Allow $\frac{1}{8}$ acre paddock for twenty piglets.
4. Fresh food and clean water should always be available.
5. Use the correct specially formulated food for the purpose.
6. Introduce the piglets to solid food prior to weaning.
7. Castration, etc., should be performed before weaning. Many veterinary surgeons nowadays castrate piglets at 7–10 days when there is less haemorrhage and less shock, and also a smaller incision.
8. Rest the paddocks every 12 months.

The following figures illustrate the average winter and summer results obtained from a carefully recorded group of farms during the period October 1961–October 1963:

	Summer	*Winter*	*All pigs*
No. piglets at weaning (3 weeks)	1374	1003	2377
No. at 8 weeks	1324	966	2290
Weaning weight (lb.)	12·7	13·3	13·0
56-day weight (lb.)	43·8	42·8	43·3

One development of this system that is taking place is the rearing of piglets from 3 weeks in huts raised off the ground, with an outdoor slatted veranda. This may become very popular as pigmen are not always keen to tend an outdoor system in inclement weather.

Indoor Systems

Turning to indoor systems we are likely to see fully mechanised units in blocks of up to 400 pigs with a common air space. The writer has seen as many as 2000 pigs in one unit in Sweden, but this is not recommended as the disease risk would appear to be higher in this country.

Indoor systems emphasise that management techniques and disease control have to be very carefully studied before embarking on any factory-scale exercise. It is feasible that with a well-organised layout a 300-sow unit (taking the progeny through to bacon or pork weight) can be run by two men and a boy. In such a unit sludge handling and automated feeding systems must be employed to the full.

Sow and Litter Management

The importance of providing adequate farrowing conditions is fully discussed in the section dealing with housing, but the stock themselves must be correctly managed.

A good practice is to thoroughly wash the sow with soapy water followed by a gammexane treatment to eliminate parasites such as lice and also mange prior to going into her farrowing quarters.

It is advisable to give the sow which is close to farrowing at least 5 days in which to become acclimatised to her farrowing quarters. This settling-in period is both for physical and bacterial considerations. The infra-red lamps should be switched on 2 days before the 'event' to ensure that the pen is dry and warm. The feeding of a bran mash incorporated in the sow food during this stage and for 3 days after farrowing has taken place is to be commended.

The question relating to the advisability of the presence of the pigman at the time of farrowing is a matter of opinion. In the majority of cases it is unnecessary to aid either the sow or piglets, although many pigs do owe their life to the attendant being on hand. It is wise to observe a gilt farrowing as it is a new experience for her and their reactions vary. With an aggressive or restless sow it pays to be near at hand. A bottle of beer an hour or so before farrowing can have a most soothing effect on a sow which might be troublesome. It is wise for the pigman to remove the afterbirth from the pen before the sow has a chance to eat it. Many stockmen clip the eye teeth of piglets to prevent damage to the udder, and also wounds to the face and ears of piglets fighting for teats. In many cases more harm than good is done by damage to the piglet's mouth and gums—although there are cases where it is necessary.

When the young piglets are 3 days of age it is essential to give them iron to prevent anaemia either as a paste, an injection, or crystals of iron sulphate. The injection probably has most to commend it as only one administration is required, and there is also no doubt that the piglet has received the full dose. Care must be taken to use clean needles otherwise one may encounter abscesses. The other methods mentioned have to be repeated, but are cheaper.

Creep feeds, which should be introduced at 10–14 days of age, normally contain iron, and therefore the danger period is over when feeding on solid food commences. The art of creep feeding is to encourage the piglets to eat the maximum quantity as this not only results in heavier 8-week weights, but also reduces the strain on the sow. The introduction of solid food should take advantage of the piglet's natural curiosity, and initially a small quantity should be sprinkled on the floor or shallow dish. It is a mistake to place a hopper or large container holding food and then expect the piglets to start eating it readily. In the early stages food given daily is the wisest policy. The aim should be to have an average creep feed consumption of 25–30 lb. per piglet to 8 weeks of age. The food conversion of pigs under 8 weeks of age is approximately 1·5:1 and therefore it is economically sound to take advantage of this and to produce maximum weights at weaning.

In the past there have been arguments against heavy weaning weights claiming adverse effects on carcass grading. The following table taken from a P.I.D.A. survey demonstrates the effect of weaning weight on grading and age at slaughter.

Weaning weight (lb.)	*Age at slaughter (days)*	*Grading % AA+AA*
Under 25	206	64
25–29	201	67
30–34	197	70
35–39	193	73
40–44	188	76
Over 44	182	79

From these figures it is abundantly plain that care taken over the management of creep feeding pays handsome dividends.

The correct age for the castration of male piglets varies between one pigman and another. It has been the practice on our own farms to carry out this operation between 3 and 7 days. Apart from the pig breeder, there is no reason why the commercial pig farmer should not have the task performed by the time the piglets are 3 weeks old. At an early age the young pigs are no bother to catch and hold and the wound heals much quicker too. The practice of spaying young gilts for fattening is rarely seen today as any advantage is slight.

Traditionally weaning has taken place at 8 weeks because in theory it is possible to produce two litters from each sow in 12 months. In practice this is rarely achieved and has led to widespread weaning at 6–7 weeks of age. Whichever age is chosen it is sound husbandry to take the sow from the litter to reduce any check which weaning itself may cause. Leaving the newly weaned litter in its accustomed surroundings for just 2 days can considerably reduce stress.

Irrespective of the weaning age oestrus will occur in sows some 3–8 days later, and in today's economic climate no commercial pig producer can afford to miss this period. Service should be supervised to ensure that the sow is ready and also that the boar performs satisfactorily. The practice of running a boar with a bunch of sows or gilts is not to be recommended. This latter method makes recording difficult as service is not always observed and the farrowing date is then unknown. Too often if two sows are on heat at the same time, the boar will only serve the one which stands most readily. With controlled service one is able to limit the amount of work each boar does and thus ensure that the quality of semen at each service is of a high standard. Boars should not have much more than 3–4 services per week when mature and fewer for younger males introduced into the herd. With young boars the first sow should be fully on heat and stand as steady as a rock. Nothing puts a youngster off quicker than the frustration of chasing a sow or gilt not fully on heat.

Housing. When considering housing it is fundamentally important to deal with the requirements of the pig, rather than build it around what mechanical devices or labour dictate. Mechanical aids to feeding, cleaning and ventilation are bound to become of far greater economic importance in the future, but not at the expense of pig comfort.

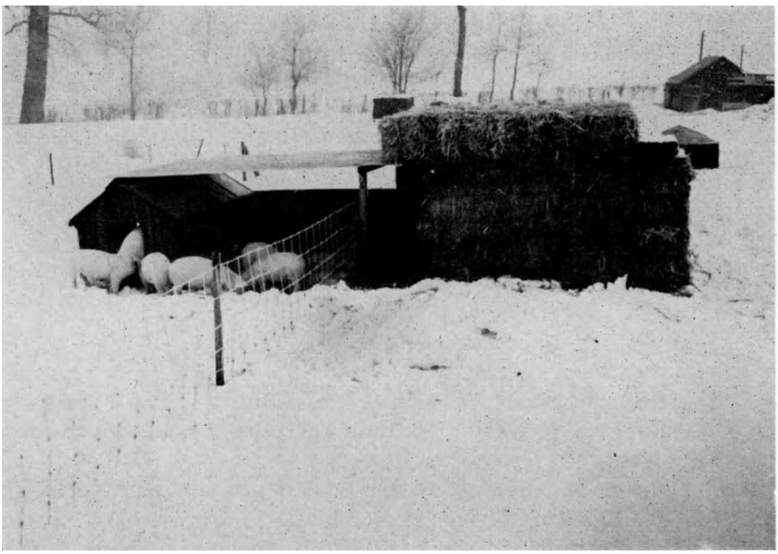

FIG. 9. A straw bale pig hut in conjunction with Sussex night ark as used at Stoke Mandeville during the winter of 1963. Note the healthy appearance of the stock.

Insulation. Heat loss must be kept to a minimum for efficient production—hence if pigs are cold a large percentage of their daily food requirement will be used as biological fuel. This can easily amount to half a pound of food per pig per day. The insulation required is as follows:

	'U' values
Floor	0·20
Walls	0·20
Roof	0·10

For calculation of 'U' values, see page 189.

Roof. It is usually necessary to insulate piggeries irrespective of their basic construction, but the cost when measured by improved performance is usually economical since 50 per cent of the heat loss is from the roof.

The usual construction encountered today is corrugated asbestos although aluminium is becoming increasingly popular and it has the advantage of easy erection due to its light weight and also lengths of 25 ft. are quite common. The conventional materials such as asbestos, galvanised iron, tiles, etc., are poor insulators and therefore require greater insulation.

The method of insulation will depend upon the height and pitch of the roof. In the case of high roofs a false ceiling is advocated.

Glass wool (2 in.) or polystyrene (1–2 in.) are excellent insulating materials, but a vapour seal to prevent warm moist air affecting these adversely is of the utmost importance. Polythene sheeting is adequate for this purpose, and should be placed on the 'stock side' of the insulation, directly above the inner lining, normally a flat asbestos sheet. Thus:

Corrugated asbestos sheet
Air space (2 in.)
2 in. glass wool
Polythene vapour barrier
$\frac{3}{16}$ in. compressed flat asbestos sheet.

This type of roof construction gives a 'U' value of 0·1. In a new building the easiest method is to buy or build this type of sandwich construction in one unit.

Walls. The most common materials used are concrete blocks and brick, but these have poor insulating qualities. In the modern 'package deal' houses, the outer shell may consist of exterior grade resin-bonded plywood. By the simple expedient of providing a cavity between the outer and inner shell the 'U' value will be reduced by approximately 50 per cent. For ease of cleansing and disinfection it is advisable to render the surface of the wall in contact with the stock.

Floors. With concrete floors insulation is advisable in the sleeping areas. A concrete floor without insulation has a 'U' value of only 0·7. By using straw bedding this factor is considerably improved, but when little or no bedding is provided an air space or other insulant must be incorporated in its construction. The materials suggested for this purpose are hollow tiles or insulation blocks, egg trays, polystyrene, etc. It is also important to lay a damp-proof course (to prevent moisture rising) consisting of polythene sheeting, roofing felt or a sealing liquid.

The build up of the floor is therefore:

Hardcore
Concrete
Damp-proof course
Insulation
Cement screed.

It is advisable to plan the fall of the piggery floor from the concrete stage; all too often tradesmen do not allow sufficient fall (1:36–72).

Ventilation. Much of the value of good insulation is lost if it is not coupled with efficient ventilation, and if this has led to any reduction in air space, this will mean warmer air with an increase in humidity. This may result in respiratory disorders, and only carefully thought out ventilation can overcome the problem.

It is better to calculate ventilation requirements by cubic feet per minute per 100 lb. liveweight than air changes per hour. The aim with pigs should be 20–25 cu. ft. per minute per 100 lb. liveweight: 250 cu. ft. per minute for a sow and litter. The natural method using chimney extractors has several disadvantages such as lack of control, need for frequent manual adjustments, siting of the building to ensure free external flow of air around the building and also height above the ground-level of the top of the 'chimney'. The ideal height above the ground being 25 ft.

Mechanical ventilation using correctly sited thermostats (as near pig level as possible) is more easily controlled and more reliable.

Hand in hand with the extractors must be well-spaced inlets, positioned as high as possible to avoid draughts, allowing 5 sq. ft. of inlet area to each 1000 cu. ft. extracted.

For fan capacities see page 193.

Roof Ventilation. There are several variations on the 'standard' ridge ventilation method. In intensive units with a large concentration of pigs in a given area, it is often more satisfactory to extract from the dunging passage, which can either be sited centrally or along the outer walls. With the central dunging passage arrangement, ventilation is simplified because the point of extraction coincides with the highest point in the house.

With the more traditional passages along the outer walls air can be brought in at the ridge by chimneys or central ducting. The ducting can be constructed of wood, light alloys, insulation board, polythene or calico-type material. It is essential that all ducts or extraction chimneys are well insulated to avoid condensation.

Pressurised Systems. Another method gaining in popularity is the fully pressurised system where air is 'pulled' into the piggery by a fan or fans placed in the centre of the gable end or normal chimneys. Where the gable-end method is adopted care must be taken to have good control to prevent draughts from the ducting, which is overcome by the use of calico ducting.

Houses with outdoor runs are generally easier to ventilate but it is often difficult to maintain an even temperature.

Humidity. The adverse effect of high humidity with poor ventilation has been mentioned previously. Little is known about the exact requirements for pigs but performance is usually satisfactory in environments varying from 60 to 80 per cent R.H. This measurement can be taken quite easily by means of a whirling hygrometer. From present knowledge it would appear therefore that provided the pigs are housed in a well-insulated and ventilated atmosphere humidity is not of great importance. However, Irish 'sweat boxes' seem to contradict this statement!

Room Temperatures. The relevant temperatures are:

Piglets up to 8 weeks	70–80° F.
Rearing 8–16 weeks	65–70° F.
Fatteners to bacon weight	60–70° F.

Although the temperatures quoted are considered to be ideal, the most important factor is to avoid serious condensation. This is where efficient insulation and ventilation play their part.

Farrowing Crates. According to P.I.D.A. figures, about 25 per cent of all live pigs born today are lost in the first week or so of life. In the majority of cases the losses are not due to disease, but to overlying by the sow, etc.

It is also well known that piglet mortality is dramatically reduced as the birthweight is increased; this can be brought about by correct feeding, breeding and the avoidance of bullying. Increased birthweights cannot overcome the fact that the sow weighs about 350–400 lb. and the baby piglets about 3 lb.! It is therefore necessary to provide conditions which are comfortable for the sow and also capable of protecting the piglets.

The wider acceptance of the farrowing crate or its modifications has greatly helped this problem. The normal crate is constructed of tubular steel, wood or concrete and is generally 2 ft. 6 in. wide where the sow lies. The space between the floor and the lower rail or partition should be 9–10 in. It is an advantage to have this lower rail adjustable so as to accommodate the varying sizes of sow. The crate need only be about 3 ft. high and the usual width between the top rails is 1 ft. 9 in. to 2 ft. The length of the crate should be governed by an adjustable gate at the rear which allows the length to be varied between 7 and 8 ft.

A creep area is provided along both sides of the crate which should be 1 ft. 6 in. to 2 ft. wide and of similar length to the crate. The total area required by each crate unit is approximately 6 ft. 6 in. by 8 ft. It is helpful to have a narrow passage along the front for ease of feeding the sow and a wider passage at the back for cleaning out, etc. A feed trough and water bowl are provided at the front of the crate. The dividing partition between each unit need only be 1 ft. 6 in. to 2 ft. high, constructed of wood, hardboard or some other light removable material. This ensures that the crate area can be thoroughly cleaned between farrowings. As such crates are rarely used for periods of more than 3 weeks by the sow and litter, it is not necessary to remove the sow for exercise. If the crate is to be occupied for a longer time the creep area should be of at least the maximum width suggested. Infra-red lamps

(250–150 watts) should be placed over the creep area to attract the piglets away from the sow. If artificial heat is provided in the farrowing unit the lower wattage infra-red bulb (150 watts) is sufficient.

In some cases farrowing crates are only used for the first few days, and then the sow and piglets are transferred to a more 'open' rearing pen.

The basic crate layout as described can be modified, adapted or improved upon. For example, the creep area can be covered with a ply-wood 'roof'; the chore of cleaning out can be reduced by use of slats; sloping sides can be installed so that the sow gradually eases her way to a lying position, etc. Under-floor heating by electric cables is also being investigated at the present time.

There are many efficient systems just utilising farrowing rails, gates, rings, voluntary farrowing nests or frames—the primary aim in all cases is the protection of the young piglets.

The follow-on rearing pen is generally of open design with 15–20 sq. ft. of creep area and about 60–70 sq. ft. for the sow. This accommodation should be maintained at a temperature of around 70° F.

Fattening Accommodation. This aspect of housing today is taking two basic forms—either totally enclosed 'controlled environment', or semi-fresh air housing.

The former type is most commonly found both in new constructions and in modernised existing piggeries. There are four basic designs in use today: the Danish piggery with dunging passages along the outer walls and a central feeding passage; the central dunging passage type with two narrow feeding passages beside the outside walls; the long narrow pen with a cat-walk between each row of pens; and finally the type which is virtually an outer shell with slatted dunging passages along the outside wall and with pen divisions of tubular steel or wood.

The Danish-type house which was introduced between the wars has been too readily decried, for so long as the ventilation and insulation are adequate, pigs usually thrive well in this type of house. It has two features which we are tending to overlook today—trough feeding, and a restriction to about ten pigs per pen.

There is increasing evidence which shows that as the number of pigs per pen is increased the performance tends to be poorer. The normal Danish house has pens which are 10 ft. long, 6 ft. wide with a dung passage of 3 ft. 6 in. and a 4 ft. feeding passage. The dunging area can be slatted to bring it into line with modern thinking.

The central dunging passage type piggery has the advantage of easier ventilation. Another point in its favour is that the outer walls need not be 'pig proof', as the stock never come into contact with them. On the question of cost—one wide slatted dunging passage is considerably cheaper than two. The requirement for the dunging area should be 2–3 sq. ft. per pig.

The long narrow pen is basically similar to the McGuckian style, but the division between the sleeping and dunging area is not always provided, as it may have a slatted dunging passage. There are factory-built houses of this type on the market divided into rooms with two pens per room. The cat-walk which has the trough down the centre is usually 1 ft. wide. This is wide enough for the stockman as the pen fronts slope inwards towards the pen, usually about 16 ft. long and 6 ft. wide. If floor feeding is desired, this design is worthy of consideration—it is quite simple to restrict floor space by the use of a hurdle across the narrow pen.

The final type of house which the writer thinks could have an important place to fill in the years ahead is one with no permanent internal fittings. Slatted dunging passages with water bowls placed along the outer walls and tubular or wooden divisions give the flexibility for varying pen size. This has the great advantage of being totally dismantled for cleaning when fattening is based on a batch system.

In nearly all new constructions slatted dunging passages are installed. The materials used for slats are mostly made of concrete, 'weldmesh' or metal T-bars. Wooden slats do not appear to be very practical. The gap allowed is either $\frac{3}{8}$ in. or $\frac{3}{4}$ in., depending upon the material chosen and the age of the pigs. There have been few piggeries constructed in this country with the whole floor area slatted, so that little information of value about this practice is known.

Slatted dunging passages will continue to gain in popularity in order to reduce the stockman's drudgery but considerable thought must be given to the handling of the dung itself from the pit or channel.

Low-cost prefabricated 'package deal' houses make a great appeal, but are dependent on a high stocking density in conjunction with floor feeding.

If the recommendations of the Brambell Committee are accepted much rethinking will be required. Their suggested sleeping area per pig will tend to increase the menace of pigs fouling the bed. There is much to be learned in the management of intensive floor-feeding units and the incidence of vices such as tail biting. One common factor in nearly every case of tail biting is that the pigs have no bedding, i.e. straw, but straw is not conducive to the efficient use of slats.

Sweat Boxes. Although opinions differ Irish 'sweat boxes' appear to have overcome many of the health problems previously encountered by this system's pioneer, Mr. J. Jordan.

In essence the house is an uninsulated shell 8 ft. wide and 16 ft. deep; ventilation is by means of a stable-door and a window on the front wall. There is no insulation in the roof, walls or floor. A slatted dunging passage is provided at the front of the pens and floor-feeding water bowls supplying either whey, skim milk or water. Both the temperature and humidity are constantly at a high level and the walls are generally wet from condensation. Management must be of a high order and it is generally true to say that many of those who have tried to copy Mr.

Jordan have failed to provide the optimum requirements. As labour is the all-important consideration today it is unlikely that there will be any widespread use of this system, which may have popularity in Ulster where unemployment is above average and odours less important.

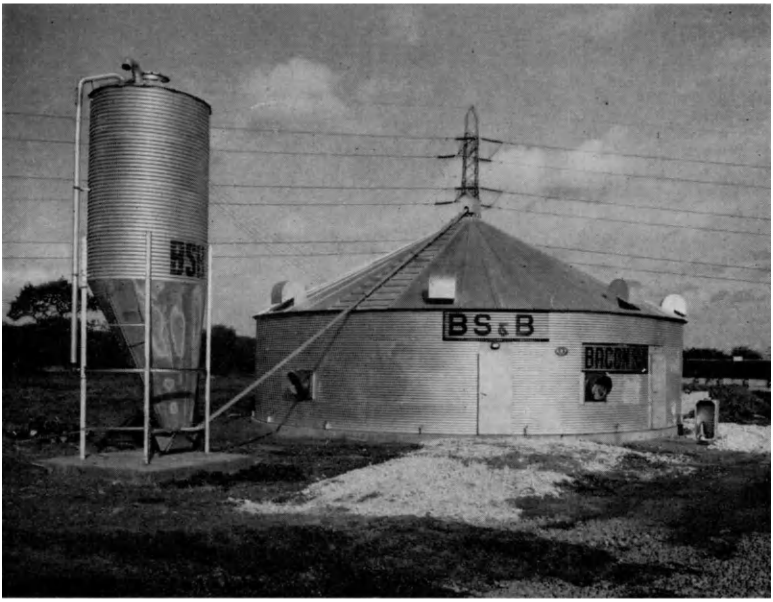

FIG. 10. *Bacon Bin.* The BSB 'Bacon Bin' has over 3000 sq. ft. of floor area with capacity for 46 sows and 437 other pigs of market weight. It is 48 ft. in diameter, has a fully controlled environment including automatic watering and feeding systems which complete the latter chore in 3½ min. The 3000 gallon manure trench can be flushed into a liquid manure tank in 4 min. The 10 ft. high walls are constructed of galvanised steel, insulated with Styrofoam. Internally the 'Bin' is constructed in two levels, each floor housing 23 pens averaging 60 sq. ft. It has 3 heating units including an electric unit heater with an output of 80,000 B.t.u./hr.; and to provide warm creep areas in the lower pens at farrowing time a hot water system is provided in the concrete floor. In the upper pens radiant heat lamps are used. Ventilation is by 5 × 24 in. exhaust fans each with an output of 27,000 c.f.m. The cost of the bin is between £9000 and £10,000 depending upon such local factors as preparation of foundations, site, etc.

Interesting developments into other forms of intensive housing are taking place at present, such as the 'Swedish' radial house. This is laid out like a wheel, the hub being a slatted dung area and pen divisions being gates. Experience of this system in Britain is as yet very limited, but the B. S. & B. '*Bacon Bin*' offers many very interesting possibilities.

Solari Housing. Turning to the semi-fresh air systems, these are likely to make the greatest appeal in grain-growing areas or where straw is freely available.

Whenever the pig has access to fresh air one has to be careful not to reduce the internal temperature of the house unduly. One development which overcomes this problem is the house devised by Philip Solari.

In essence it is a low wooden kennel under a Dutch barn roof. The temperature in the kennel is manually adjusted by means of the hinged lids. The kennels are normally 3 ft. high and the enclosed area 10 ft. by 7 ft. In the original design the dunging area was 10 ft. by 6 ft. with a 1 ft. 6 in. drop from the pen. The reason for the size and depth of the dunging area being such that the dung can build up through the liberal use of straw. A feeding passage is provided in the centre and feeding troughs placed along the passage wall.

There are several variations on this theme such as no troughs for floor or *ad-lib.* feeding; narrow dunging passages, slatted dunging passages and central dunging areas. This type of housing has the advantages of low cost, pig health, less disease spread risk and fewer ventilation problems. The major disadvantage is that it is difficult for the stockman to inspect the pigs. From a health and cost angle this method has much to commend it.

Where large numbers of pigs are kept under cover deep straw yards can provide the answer under skilled management.

Dry Sow Housing. The importance of individual feeding has been recognised for several years and most of the better types of sow yard have feeding stalls incorporated. A recent development has been the introduction of the sow stall. The idea originated in Scandinavia and was taken up by enthusiasts particularly in the north-east of Scotland. The stalls allow the sow sufficient room to stand up or lie down but not enough to turn round. The stalls are generally constructed of tubular steel, concrete, brick or wood. The normal size is 2 ft. 6 in. wide, 7 ft. long and 3 ft. high. A rear gate or chain keeps the sow in place and a food trough and water bowl are provided. Some provide a slatted area at the rear, others rely on daily manual cleaning.

Many pig farmers today who are convinced that the system is correct are awaiting the outcome of possible legislation following the Brambell recommendations. The Committee's major objection was that there was no provision for exercise. From experience to date there has been no reduction in sow output and no greater incidence of leg or arthritic conditions. In fact it is fair to say that the national sow herd loss through bullying would probably be reduced by the widescale use of such stalls, but in our experience it appears to be essential that the stalls are housed in a warm insulated building. In larger units the writer believes that mechanised feeding and cleaning will be worth the high costs involved.

Future Housing Trends. As skilled stockmen are getting fewer there must be greater developments to make their task easier. We are already

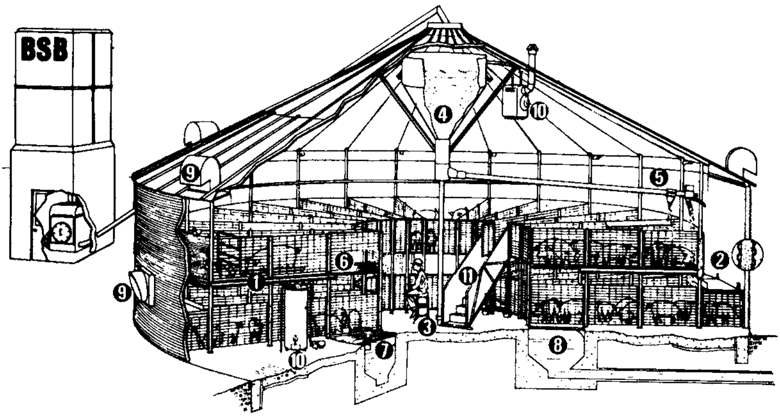

FIG. 11. Internal view of BSB 'Bacon Bin':
1, Wedge-shaped pens at two levels, with creep areas at the rear. 2, A walkway at the back of the upper pens. 3, From this vantage point all pigs can be viewed in conjunction with 2. 4, From this bulk hopper all pigs can be fed in 3½ min. 5, This rotating auger deposits feed into each pen. 6, A slatted floor section at the inner perimeter aids a high standard of hygiene. 7, Manure drops through to a circular trench below where it is agitated and homogenised. 8, The trench can be drained into an outside tank in 5 min. 9, Damper-controlled fresh air vents dilute odours and gases. There are five automatically controlled ventilation fans. All the air can be exchanged within 1 min. 10, Heating is by means of hot water pipes in the floor, plus a thermostatically controlled electric heater in the roof. 11, A movable stairway is used for transferring pigs from one pen to another.

seeing the increased use of slatted floor dunging passages, mechanical scrapers, etc., and this trend will continue. A considerable amount of thought is also going into food handling, both from the food store and into the trough. We are seeing an increasing use of the electrical time switch to govern the pigs' meal times. Systems such as (i) the dispenser which will drop a predetermined quantity of food on to the floor or into a trough, (ii) large mobile hoppers which are tripped to allow the food to fall in the correct quantities, and (iii) the wet pipeline, are all due to be tested on a large scale.

Any development which is not to the detriment of the pig and allows the stockman to use his managerial skills to the full is to be welcomed.

Chapter 10

NUTRITION OF THE INTENSIVELY MANAGED PIG

D. G. FILMER

Introduction

The last decade has seen a considerable advancement in pig housing, husbandry and disease control. At the same time improved methods of genetic selection have led to superior strains of pig now capable of faster and more efficient performance. It is felt that the pace of progress will increase during the next few decades with emphasis on hybridisation and intensive systems of production including controlled environment conditions. Big changes in the structure of the industry are likely to take place with an increasing proportion of the pig population in fewer and fewer hands.

Under such systems of intensive husbandry where high performances are expected and the risk of additional stress is increased, the nature of the diet fed at all the various stages of production becomes critical. Under less intensive systems with sows and weaners on grass with plenty of sunlight, fresh air and exercise, any nutritional deficiencies in the diet offered were often able to be made good by rooting. In this way pigs would ingest many essential minerals, vegetation and small animal and insect life as well as waste organic matter discarded or excreted by other classes of farm stock. Grazing itself can supply a good quantity of protein which in the spring is of high quality and which also contains relatively high levels of riboflavin (vitamin B_2) and carotene (the precursor of vitamin A). The action of sunlight on the skin in providing a reserve of vitamin D is well known.

In these circumstances the pig exercises its natural role as a scavenger and the diet fed is simply a supplement supplying extra energy and protein and balancing the mineral intake.

There is no doubt that such extensive systems, providing temperatures are reasonable, are very healthy particularly for breeding stock, but pressure of cost and availability both of land and labour are more frequently forcing a much less natural, if not unnatural, lifetime existence for the pig. Modern pig nutrition aims to supply in each diet the relevant quantities and balance of all nutrients necessary for the most economic performance of the pig for each stage of the productive cycle.

Available Nutrients

It is now universally accepted in technical circles that apart from the obvious facts that a diet must be palatable and non-toxic, the features which determine the suitability of the diet to the type and class of pig under consideration, are its content of available nutrients. Instead of regarding a diet as a mixture of raw materials such as barley, wheat offals, fish meal, yeast, chalk, etc., it is more meaningful to have regard to the available nutrient content of the diet. This may be described in terms of digestible and/or metabolisable energy (kcal./kg.), available amino acid contents (percentage of diet), and mineral and vitamin content (mg./kg. or p.p.m.). With regard to the last units it should be noted that milligrams per kilogram (mg./kg.) equals parts per million (p.p.m.), and that grams per U.K. ton (2240 lb.) is a close approximation to this since 1 U.K. ton contains just over 1 million grams (actually 1,016,047 grams). Thus expressing vitamins and mineral levels in the diet as p.p.m. or mg./kg., immediately gives the number of grams of the nutrient that must be contained in each U.K. ton. The mixed term mg./lb. should be avoided in this country for it is neither scientific nor does it help the formulator in translating requirements into practical diets. In the United States where the ton contains 2000 lb., the term may be of assistance to the practical nutritionist, but even there the adoption of metric notation is becoming more common.

The description of diets in terms of their nutrient content rather than their percentage raw material make-up has many advantages.

In the first place it takes into account the variability in available nutrient content that frequently takes place between batches of the same named raw material. For example the available lysine content of fish meal can vary from 3·5 to 4·8 per cent and that of meat and bone meal from 1·6 to 2·5 per cent. Obviously one formula, made up with the better quality fish meal and meat and bone meal, would be much more valuable to the animal than the same mixture of raw materials but from the poorer source. To obtain consistent performance it is more important to vary the percentages of raw materials in the diet whilst retaining the same levels of available nutrients, rather than stick slavishly to a formula when the nutrient values of raw materials are known to be variable. Formulating to an available nutrient standard allows for variability of raw materials; formulating to a fixed level of raw materials ignores it.

Secondly, it has been shown that providing texture and palatability considerations are taken into account and that no toxins are present, then all formulations containing the same levels of available nutrients but from differing raw materials will give the same performances when fed to pigs. Since this is so, it is important to the farmer that he supplies his pigs with the correct balance of nutrients in the most economic way. Using a fixed formula does not take account of this. Formulating to a nutrient standard allows flexibility to accommodate changes in analysis and market prices of raw materials, so as to provide a diet of constant nutrient content which shall always be 'least cost' to the user.

In addition it is apparent that progress in pig nutrition has advanced considerably since the basic amino acids have been considered, rather than the nitrogen or crude protein content of the diet. It is now known that some specific amino acids such as lysine have a considerable effect on the growth, efficiency and carcass quality of pigs, and this has led to the decreased use of low lysine protein concentrates such as groundnut products in pig fattening foods.

The construction of experimental diets differing only in levels of one nutrient has led to a much clearer understanding of the relationship between nutrient levels in the diet and resultant performance of pigs when fed these diets.

Lastly, having regard to available nutrients has led to a different approach to the economic assessment of diets. Normally of course, the cost of a diet is regarded as the sum of the costs of all raw materials in the formula plus milling and other charges. However since it is nutrients that stock need to perform on, it is relevant to see if the costs of a diet may be related to the nutrient content of that diet.

Once a 'least cost' diet has been calculated it is indeed possible to break down the total on-farm costs into the cost of energy, amino acids including lysine, methionine, etc., minerals such as calcium and phosphorus, vitamins, fatty acids, etc. The total of the costs of all nutrients taken into account in formulating the diet then adds up to the on-farm cost price per ton.

The cost of energy for example is the quantity of energy in one ton of food times the unit cost of energy, this being deduced in the calculation. Examination of these costs of nutrients, and more specifically the unit costs of nutrients, can be very helpful in planning research work, devising new diets etc. For example one can often find that the specified level of one nutrient may be very expensive to attain, whereas the specified level of another important nutrient may contribute very little to the total cost of the diet. A further important nutrient may cost nothing to include in the diet for, in satisfying the other nutrient levels, the required level of this further nutrient may automatically be satisfied. These cost/nutrient level relationships will be discussed in more detail later.

Nutrient Requirements

Having regarded a diet as a vehicle for the provision of available nutrients to stock, it behoves us to decide what levels of nutrients are appropriate to each class of stock. As far as pigs are concerned there is less published information available in this respect than with, say, poultry. This is due first to the fact that research with poultry is cheaper to carry out due to the individual cost of a hen and its housing being considerably less than a pig and its housing. Secondly, due to hybridisation, variation within a strain of hens is less than within a strain of pigs. Then there are management differences which often make it simpler for research on hens to fit in easier at a University or other research establishments rather than pigs. Again it is easy to arrange for several hundred (or thousand) day-olds to come onto an experiment together, whereas the organisation of even 50–100 weaners to start an experiment together is full of practical problems.

In this country there is no recognised publication which has summarised data on the nutrient requirements of pigs although a committee has been set up by the Agricultural Research Council to examine this subject and report. (This report is now available; *The Nutrient Requirements of Farm Livestock*, No 3, Pigs).

However considerable data have become available from British and Continental sources in recent years and the nutritional picture is much clearer now than even a few years ago. Nevertheless much work remains to be done.

In the United States, the National Research Council have produced tables in Publication No. 1192 *Nutrient Requirements of Swine.* This booklet summarises research to 1964 and had been used by many as a guide both inside and outside the United States.

It is important to realise that nutrient requirements relate to the pig and not the diet, and although this point may seem obvious, it is quite common to hear well-known figures in the pig industry talk of the requirement of the bacon pigs for lysine, say, as 0·75 per cent. What matters of course is the daily intake of nutrients per pig. These should be specified as calories of energy and weights of each amino acid, mineral and vitamin per pig per day. It is quite possible of course to provide the daily requirements of say a fattening pig in either a larger or smaller parcel of food. For example, a normal diet may provide sufficient nutrients for maintenance and a given rate of growth in say 5½ lb. of food per day, whereas by using higher energy raw materials and better quality proteins, including perhaps synthetic amino acids, the same quantity of nutrients may be packed into say 5 lb. or even 4½ lb. of food. This would of course require a greater concentration of nutrients by some 10 or 20 per cent respectively but it is important to realise that all three diets would provide the daily requirements of nutrients when fed at the appropriate levels per day. (Further one could dilute a diet by the addition of a non-nutritional filler such as cellulose, and, to obtain the equivalent daily nutrient intake, 6 or 7 lb. per day may be required.)

Nutrient Density

Thus it is impossible to dissociate nutrient levels in the diet with levels of feeding in order to arrive at the critical daily nutrient intake. The differences in concentration of nutrients within the above various diets is referred to as Nutrient Density and it is of interest to study the effects of increasing nutrient density of the diet, on costs of the diet and resultant daily costs of feeding.

Reference to Fig. 12 indicates that unit costs *of the diet* increase as nutrient density increases. However it will be noted that whereas unit costs increase slowly at first, they increase rapidly at very high nutrient densities. The nutrient density which provides the daily nutrient requirement at least cost is found by constructing a tangent to the curve passing through the cost origin. As this origin will be affected by milling and other costs which may be variable from one part of the country to another, as well as price differentials between raw materials which often vary, the nutrient density supplying the daily nutrient intake cheapest (optimum nutrient density) is subject to variation. However, for a

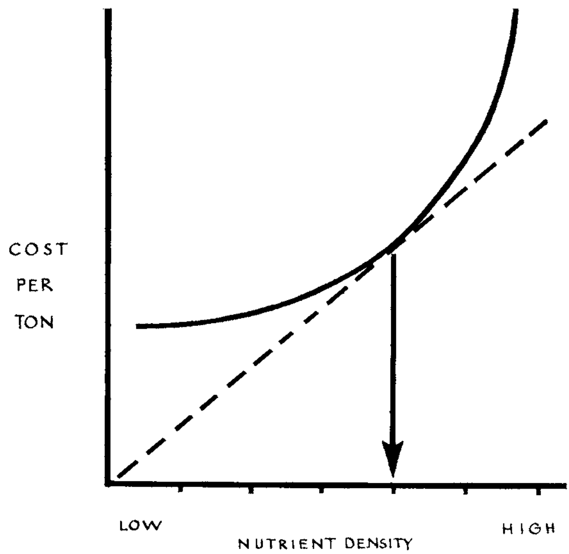

FIG. 12.

given product, variation is not normally great but could soon be radically changed if for example fats become economic sources of energy and synthetic amino acids become much less expensive. This would quickly alter the optimum nutrient density and the restricted use of a high fat diet, suitably supplemented by synthetic amino acids, could then become a very economic proposition.

The above discussion serves to illustrate one of the reasons why energy levels of commercial diets for similar classes of pig in the U.S.A. differ from those in the U.K. Apart from a difference in end product requirement (which may be more a result than a cause), commercial U.S. diets cost least per calorie when based on cheap maize and are thus high-energy diets resulting in fatter carcasses, but often quicker growth and certainly better conversions. Maize is less often economic on a calorie basis in this country than home grown materials, and optimum nutrient densities are likely always to be less in the U.K. than the U.S.A. For this reason one must be careful in translating the N.R.C. recommendations into British or Continental feeding and economic conditions.

Daily Nutrient Intakes

TABLE 1

DAILY NUTRIENT REQUIREMENTS OF GROWING AND FINISHING BACON PIGS

(extracted from N.R.C. publication 1192)

Liveweight (lb.)	10–25	25–50	50–75	75–125	125–175	175–225
Expected daily gain (lb.)	0·6	1·0	1·3	1·5	1·7	1·8
Daily *ad-lib.* food intake (lb.)	1·2	2·5	3·7	5·2	6·7	7·8
Crude protein (lb.)	0·26	0·45	0·59	0·83	0·94	1·09
Digestible energy (kcal.)	1920	4000	5400	7200	9400	11,000
Calcium (gm.)	4·4	7·4	10·9	11·8	15·2	17·7
Phosphorus (gm.)	3·3	5·7	8·4	9·4	12·2	14·2
Salt (NaCl) (gm.)	2·7	5·7	8·4	11·8	15·2	17·7
Vitamin A (I.U.)	1200	2000	2200	3100	4000	4700

Table 1 has been extracted from a table in the N.R.C. booklet and includes the levels of energy taken in when *ad-lib.* systems of feeding are practised. They mention that under such a system pigs will eat less of a high than a moderate energy diet and this has also been noted in this country. However with our present strains of pig, such feeding leads to excessive fatness in the carcass with resultant downgrading, and restriction of energy intake is necessary. In this case the N.R.C. point out that the same daily levels of nutrients other than energy should be fed. Simple calculation shows that if the level of feeding is restricted to 6 lb. per day then a 16 per cent protein diet is needed to 175 lb. liveweight. Using a high-energy, more efficient diet and restricting to 5½ lb. would require 17 per cent protein to obtain the 0·94 lb per day crude protein suggested to 175 lb. liveweight.

More important than total protein intake, of course, is the amino acid make-up of that protein, and much research remains to be done before a complete understanding of amino acid interrelationships and energy interactions are properly established. The N.R.C. quote figures which they suggest are 'minimum practical levels for normal growth and performance'.

It will be seen from Table 2 that the summary of American findings shows incomplete data for some classes of pig whilst no data at all are presented for sows, or growing pigs over 75 lb.! Moreover the definition of the term 'requirement' as 'minimum practical levels for normal growth and performance' raises the question of what 'normal' growth is, and whether performance means just food conversion or includes some aspects of carcass quality. One wonders whether these standards apply to fast and slow growing strains, lean as well as fatter strains, and to both sexes.

TABLE 2

ESSENTIAL AMINO ACID REQUIREMENTS FOR PIGS

(extracted from N.R.C. publication 1192)

	Baby pigs	*Growing pigs*
Weight range	5–10 lb.	25–75 lb.
Protein in diet	22%	18%
Digestible energy (Kcal./lb.)	1600	1500–1600
Arginine (%)	—	0·20*
Histidine (%)	0·28	0·20
Isoleucine (%)	0·76	0·55
Leucine (%)	1·25*	0·60
Lysine (%)	1·40*	0·75
Methionine (%)†	0·85*	0·55
Phenylalanine (%)‡	—	0·50
Threonine (%)	0·90*	0·40
Tryptophane (%)	0·18	0·13
Valine (%)	—	0·50

* This level is adequate, minimum requirement has not been established.

† Cystine can replace 50 per cent of the methionine requirement.

‡ Tyrosine can replace 30 per cent of the phenylalanine requirement.

Nutrient Responses—Response Curves

More recently important British work has been identifying and measuring, as precisely as possible, the effects of graded daily intakes of individual amino acids on specific production parameters, such as rate of growth, food conversion and percentage lean in carcass. This has been carried out at various universities and commercial research centres and the pattern that has emerged is quite clear-cut.

The method has been to select one amino acid in the diet which may be thought to be most limiting performance, and to construct a series of diets all containing the same levels of all nutrients other than the amino acid under examination. This amino acid is then included at a wide range of levels in the diet series and all diets fed to the same feeding scale. By means of carefully designed and replicated experimental work, the effects of these various levels are detected as they affect all aspects of production, and the results used to construct graphically the relation between daily intake of the amino acid and each measure of production.

These input–output relationships or response curves, can then be interpreted in the light of what measure of performance one wishes to maximise or optimise.

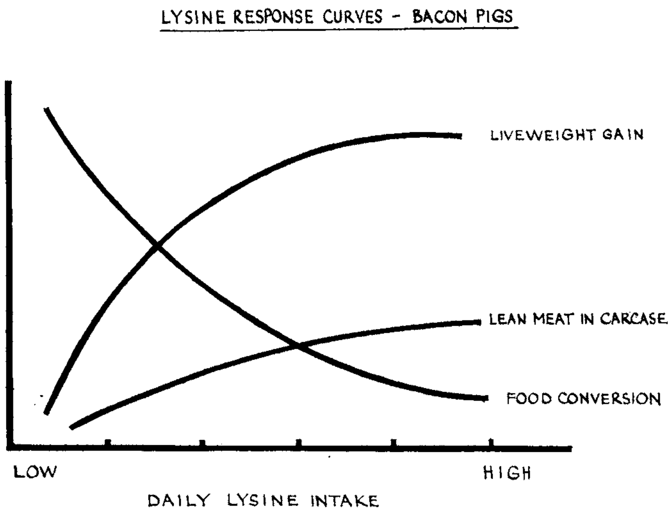

FIG. 13.

It will be seen that maximum liveweight gain is achieved before lowest food conversion is reached and that lean meat content of the carcass continues to increase even at very high lysine intakes well above those necessary for lowest food conversion. Moreover the responses to increased lysine are greatest at the lowest end of the scale, but the law of diminishing returns applies as levels of lysine are increased further.

There is thus no absolute fixed minimum 'requirement' for lysine for bacon pigs: different levels simply alter the performance of the pigs.

Interpretation of the above information is likely to vary dependent on the point of view and sophistication of the observer. The farmer presumably would like to obtain improved growth and conversion but would care little about extra lean meat provided his payment grading was good anyway. However the housewife and the meat processer would both be very keen to go to very high lysine intakes to obtain a higher quality end product. The attitude of the compounder could well vary dependent on whether he had a fixed or expanding market and whether he felt the extra performance at high lysine intakes could be readily demonstrated to his customers, for he would have to face the fact that the extra lysine would increase the cost of his compound.

Lysine Economics—Marginal Returns

A rational approach to the situation would be to refer to the unit costs of including lysine in the diet at the various levels, when it would be found that increasing lysine by a given small amount at the lower end of the lysine scale costs very little per ton of food (at this stage the return in animal performance is at its greatest). However at the higher end of the scale (when animal response is quickly diminishing) the costs of increasing lysine by the same given small amount becomes very high, as very concentrated expensive sources of nutrients have to be used. There is thus a level of lysine where the marginal cost of increasing the level by a small increment, is just balanced by the value of the marginal increment of animal response obtained (marginal return). This then sets an upper limit to the level of lysine which is economic and it should be noted that this level is going to depend on two factors:

(*a*) The unit cost of lysine. This can vary dependent on the relative price structure of the high lysine and low lysine raw materials, and can be subject to quite large changes.

(*b*) The value of the end product. If the average value of the finished pig rises, it will obviously pay to go further up the lysine response curve, to obtain a greater profit. The converse applies if the value of the pig reduces.

Because of these two variable factors, the upper economic lysine limit will fluctuate from time to time and it will either be necessary for the nutritionist to keep the level under constant review, or to build an automatic device into the diet specification in respect of lysine, which ensures that, taking the response curve into account, the right ECONOMIC level of lysine is included at all times.

Nutrient Responses—Response Surfaces

If one examines the lysine response curves in Fig. 13, it may be considered that the reason for the law of diminishing returns having effectively produced a maximum growth rate above which no further increase in lysine led to further improvement, is probably because at that stage a second nutrient became limiting upon performance. It is of interest from a research point of view to establish what is the second limiting nutrient and to consider how best to investigate it.

It is well known that amino acid auto analysers are now widely used in universities and commercial research centres for establishing amino acid contents of raw materials and finished diets for pigs and poultry. However it is less widely known that techniques are being developed to assay the free amino acid content of blood serum. The object of this is to identify which amino acids are in excess in the diet (shown by high peak levels in the blood serum of animals fed this diet), and those which are deficient, or limiting to performance (shown by very low peak levels in the blood serum). The ideal diet would of course lead to blood serum which had a very low level of all amino acids indicating that the end products of digestion were being produced in exactly the right proportions for the productive process.

The above method may be tried as a short cut to the determination of the second limiting amino acid(s), or more frequently the amino acid content of the diet may be determined (either by analysis or calculation from tables), and compared with estimated 'minimum requirements' obtained from the rather sparse literature. The sulphur containing amino acids, methionine and cystine together with tryptophane and isoleucine, are most likely to be second limiting amino acids in practical pig fattening diets.

There are two methods of investigating the second amino acid. The first is to formulate a basal diet at the same level of lysine as produced a high performance previously, and to formulate a diet series varying only in the second amino acid. This can then yield a response curve (provided a sufficient range is chosen): or secondly one can take say four levels of the first limiting amino acid at equal intervals, two either side of the performance peaks, and at each level include say four levels of the second amino acid. This produces a sort of grid of sixteen experimental diets, and with sufficient replication four response curves to both amino acids, one at each of the four levels of the other, will be produced. When cut out and fitted together, these then produce a response surface, and it then becomes clear whether the response to one amino acid depends on the level of the other. If so, valuable information as to the relationship or interaction results.

Lysine/Energy Interactions

The effect of increased energy in the diet of finishing pigs is well known in that it improves rate of growth, conversion and killing-out percentage when fed at equal daily food intakes; but decreases carcass lean and consequent grading. However when the diet is restricted so as to equate daily energy intake, then provided daily intake of other nutrients is similar, work has shown no increase in carcass fatness.

In order to obtain the benefits of normal level feeding of high energy finishing diets, many workers have examined the effects of increased protein or more specifically increased amino acid contents of the diet. Results have been somewhat variable, in part no doubt due to different basal diets and partly to different strains and breeds of pig involved. Work which we have done with 212 Large Whites taken to bacon weight, indicated that as energy in the diet is increased, the *ratio* of lysine to energy must be increased if normal rates of feeding are to be followed without prejudicing carcass quality.

Further work has confirmed that different lysine response curves exist when using a high energy diet than when using a more conventional energy level (both at equal daily food intakes); and that providing certain specific amino acid/energy ratios are increased, no harmful effect on carcass quality results. The adoption of such high nutrient density diets with suitable stock and management is a matter of economics.

TABLE 3

	A	*B*	*C*	*D*
Energy	normal	high	normal	high
Lysine/energy ratio	normal	normal	high	high
Weight at 20 weeks (lb.)	153·1	171·0	162·2	181·8
Conversion at bacon weight	3·09	2·87	2·97	2·75
Killing-out percentage	74·6	75·5	74·1	75·2
Percentage of pigs 'S' or 'Q'	32	19	42	32

Strain/Diet Interactions

There is no doubt that response curves yielded by fast-growing strains of lean pigs differ from those of more conventional stock. This is not surprising, for intensive selection over many generations has produced individuals and strains with greatly enhanced growth potential and capacity for very lean carcasses. However, these extra potentials cannot be fulfilled if the diet fed does not contain the wherewithal for extra tissue growth to proceed at an advanced rate. High nutrient density diets are readily utilised by such stock, in fact they cannot exhibit their true potential unless such diets are fed. One of the advantages of hybrid pigs is likely to be that they will be able to utilise high nutrient diets fed at higher daily intakes that would result in over-fatness and down-grading of more conventional stock. In time the ideal bacon pig may in fact be able to grow at a very fast rate and still produce a satisfactory carcass even on *ad-lib.* feeding of such diets.

There is also evidence that the two sexes respond differently to differences in energy and in nutrient density. Castrates respond more to high energy and higher nutrient density diets in general than do gilts. There is the probability that uncastrated male pigs, which may well become viewed with more favour for fattening purposes as time goes by, will also exhibit different responses. It is conceivable that different diets or feeding programmes could be devised for the sexes kept separately, which would be nutritionally sound and economically justified.

In the meantime it will become important for those engaged in the genetic selection of the advancing new strains of pig to ensure that they carry out their selection under a nutritional environment which gives the maximum chance for superior strains to exhibit themselves. No poultry breeder with a new light hybrid hen would today carry out his selection using a moderate energy diet, as the strain × diet interaction in laying stock is now firmly established. However 5 years ago similar comments with regard to the commercial as well as scientific importance of such interactions fell on many a deaf ear.

Trace Nutrient Requirements

Since currently much of the research into pig nutrition is concerned with energy and amino acid metabolism, the very important mineral and vitamin function has had less emphasis. It is also probably true that fewer symptoms of straight, nutrient deficiencies are seen now than formerly, due to a better application of available information. However, the nutritional disorders that occur may often be the result of a simultaneous lack of several nutrients resulting in a complex deficiency disease which can be detected only by carefully reviewing diets along with clinical symptoms. It should be noted that actual nutritional deficiency or insufficiency may exist without the appearance of definite symptoms other than lowered appetite and subnormal rate of gain. It is more helpful, perhaps, to envisage a dose-response curve relating level of a mineral or vitamin to rate of growth. Traditional symptoms are unlikely to occur unless a severe deficiency occurs, but a sub-optimal level could have a marked effect on growth, and additional levels could then result in increased economic performance. It should be recognised that high temperatures and other forms of stress can increase the requirement for both minerals and vitamins. The N.R.C. publication 1192 states 'Furthermore one should recognise that if a deficiency occurs it may be due to differences in nutrient requirements of individual animals, caused by genetic differences usually found in the average swine population. Thus the uncertainty of diagnosis of ration inadequacy must be recognised. A positive diagnosis should seldom be made on the basis of the observation of only one of the clinical effects expected to follow the deficiency in question.'

Mineral Requirements

Calcium levels in pig diets have been reduced over the past few years as it has been found that excessive calcium increases the levels of other minerals required in the diet, a level of 0·6 per cent is quite adequate for adult stock including breeding stock. Higher levels increase the requirements for zinc in the diet or risk of parakeratosis occurs. In addition phosphorus present as phytate phosphorus in grain, soya bean meal, etc., is rendered unavailable in the presence of excess calcium, but if the levels mentioned are adhered to, lower total levels of phosphorus down to 0·5 or 0·4 per cent of the diet are satisfactory. A calcium to phosphorus ratio (Ca:P) of 1·5:1 is now thought to be correct. Adequate vitamin D should also be present in the diet.

Cobalt is in chelated form in vitamin B_{12} and should be present either as the element or preferably in the form of the vitamin. Elemental cobalt is not required if sufficient vitamin B_{12} (cyanocobalamin) is present.

Iodine is an essential element in the diet of growing and breeding pigs and must be included in intensive diets or thyroid and fertility upsets will occur. Excess levels can adversely influence the growth of baby piglets.

Adequate iron and copper levels are important for haemoglobin formation, and shortages give rise to nutritional anaemia in suckling pigs. It is impossible to supply adequate iron via the sow's milk, as iron supplements to the sow's diet have little effect on the iron content of her milk. Ferrous fumarate has been shown to have the biggest effect so far, but even here levels of iron have been increased to only about 1 mg. of iron per litre of milk whereas young pigs each require about 7 mg. daily! Iron fed to the pregnant pig however can build up reserves in the livers of the developing embryos. Iron in the diet of the lactating sow can nevertheless be associated with increased iron uptake of the young piglets due to their picking up iron-containing faeces. Injection of young piglets with 150–200 mg. of any of the soluble iron preparations on the market at 1–3 days of age will prevent piglet anaemia. In the absence of this, housed piglets that become chilled, frequently exhibit symptoms of anaemia. This may be due to the chilling upsetting liver function such as when laying on, say, cold concrete, the livers become affected rapidly. Added iron is unnecessary in adult pig diets as the natural supply in feeding-stuffs is adequate, but iron can sometimes have an astringent effect on the dung.

British work has indicated that higher levels of copper in the diet of the pig can lead to improvements in performance of fattening stock and to some extent the response is similar to that obtained by the use of low levels of antibiotic in the diet (i.e. 10–20 p.p.m. or grams per ton of diet). It is not likely that a high level of copper (125–250 p.p.m. Cu added) gives a growth stimulant effect by nature of there being a nutritional response. Rather is it likely that in some way and under some conditions, the copper may have a beneficial effect on the gut flora, or perhaps assist absorption in some way. It is interesting to speculate why American research, in the main, has failed to substantiate British work. It is quite possible that with intensive management using S.P.F. pigs kept under hygienic conditions, both high copper levels and low level antibiotics will be ineffective. Certainly both of these additives seem to have less effect under field conditions now, than when they were first introduced.

Magnesium, manganese, selenium and molybdenum are all essential for efficient performance although the levels required of the last two are very low and often (although not always) provided by the basal diet. There is growing evidence of complex interactions which exist between groups of two, sometimes three elements, and factors which determine their availability to the animal and function in the body are being elucidated. This is an important field of study which could lead to significant improvements in economic performance of pigs.

TABLE 4

TRACE MINERALS FOR SWINE

(extracted from N.R.C. publication 1192)

	Requirement mg./kg. diet	*Tolerance level mg./kg. diet*	*Toxic level mg./kg. diet*
Copper	10*	100	250
Iron	80*	1000	4000
Iodine	0·2	—	—
Magnesium	400	—	—
Manganese	40	80	500
Zinc	50†	1000	2000
Selenium	0·1	—	5

* Baby pig requirement.
† High levels may be needed if excess calcium is fed.

Vitamin Requirements

The National Research Council suggest daily levels of vitamins which are equivalent to feeding diets containing the following levels at the rates of feeding indicated.

TABLE 5

(extracted from N.R.C. publication 1192)

	Weight range of growing pigs (lb.)				*Breeding*
	10–25	*25–50*	*50–75*	*75–225*	*stock*
Vitamin A (I.U./kg.)	2200	1760	1320	1320	3300
Vitamin D (I.U./kg.)	220	200	200	132	220
Thiamine (mg./kg.)	1·3	1·1	1·1	1·1	1·1
Riboflavin (mg./kg.)	3·3	3·1	2·6	2·2	3·3
Niacin (mg./kg.)	22	17·6	13·2	11	17·6
Pantothenic acid (mg./kg.)	13	11	11	11	13
Pyridoxine (mg./kg.)	1·1	1·1	1·1	—	—
Choline (mg./kg.)	1100	800	—	—	—
Vitamin B_{12} (mcg./kg.)	22	15·4	11	11	11

For growing stock the rates of feeding associated with the above dietary levels are:

10–25 lb.	0·55 kg./day (1·2 lb./day)
25–50 lb.	1·15 kg./day (2·5 lb./day)
50–75 lb.	1·7 kg./day (3·7 lb./day)
75–125 lb.	2·4 kg./day (5·2 lb./day)
125–175 lb.	3·0 kg./day (6·7 lb./day)
175–225 lb.	3·5 kg./day (7·8 lb./day)

For breeding stock the rates of feeding associated with the above dietary levels are:

Pregnant gilts	2·5 kg./day (5·5 lb./day)
Pregnant sows	3·0 kg./day (6·5 lb./day)
Lactating gilts	5·0 kg./day (11 lb./day)
Lactating sows	5·7 kg./day (12·5 lb./day)
Young boars	2·7 kg./day (6 lb./day)
Adult boars	3·4 kg./day (7·5 lb./day)

It is of course important that if lower than these rates of feeding are practised, then the concentration of vitamins in the diet must be adjusted upwards appropriately.

Vitamin A is extremely critical for brood sows. Deficiency can have serious effects particularly if a deficient diet is fed over 2–3 successive pregnancies, when a severe drop in pig numbers and the production of piglets with deformed or atrophied eyes result. It is also likely that sub-optimal levels can affect the health of developing embryos and subsequent piglets. However it must be pointed out that sows have a tremendous capacity to store this vitamin, and provided they have access to grass for even a limited part of the year, they can buffer very effectively the effects of a vitamin A-deficient diet. However where sows do not have access to grass at all (as is increasingly becoming the case), the vitamin A content of the diet is critical. High levels will provide the young piglets with a reserve of the vitamin in their livers, which may act as a safeguard against future disease hazards.

The role of vitamin D in stabilising the effects of adverse calcium and phosphorus ratios has been mentioned. The absence of vitamin D leads to rickets and unless pigs have free access daily to the ultraviolet rays of the sun, the diet must contain an adequate level. It should be remembered that pigs are able to utilise both vitamins D_2 and D_3 whereas poultry utilise only D_3. In commercial rations it is now usual however to use only D_3 in diets for all species.

Cod liver oil is a rich source of both vitamins A and D, but it is now more usual to use the stabilised vitamins which retain their potency in a mixed diet for a considerably longer period than does cod liver oil.

Vitamin E has long been thought to be associated with fertility in both males and females but the evidence for this is extremely slight.

However feeding a deficient diet can cause increased embryonic mortality and muscular inco-ordination in suckling pigs. Vitamin E is a natural antioxidant, and its action in the body is probably to protect some metabolites and body fats from oxidation.

Vitamin C is a further antioxidant but this vitamin is synthesised by the animal in sufficient quantities to meet requirements. However it is possible that with all these vitamins, sub-optimal levels may cause economic losses.

The B vitamins collectively are of great importance and low levels can cause the birth of pigs showing malformation of the appendages and nervous disorders characterised by trembling which may be so severe as to prevent suckling. Of most practical importance are B_2 (riboflavin), B_{12} (cyanocobalamin), pantothenic acid and niacin.

Vitamin B_2 enters into chemical combination in the body to produce flavo-proteins and these enzymes are involved in the metabolism of carbohydrates and proteins. The dietary requirements increase at low temperatures and also when fat replaces some of the carbohydrate as an energy source in high performance diets. Additional riboflavin is normally added to pig diets either as the pure vitamin or by the addition of dried yeast or liver meal.

Vitamin B_{12} occurs in animal proteins but not in vegetable proteins and is now considered to be the vitamin involved in the so called 'animal protein factor'. It contains about 4 per cent of cobalt, is a complex molecule and is concerned in the build-up of nucleic acids involved in protein synthesis. The importance of this vitamin is thus obvious even though minute quantities are required, the unit of measurement for B_{12}, namely microgram, being one thousandth of the measurement of the other vitamins which are assessed as milligrams.

The recognition of the value of supplementary sources of pantothenic acid in pig diets has been relatively recent. Pantothenic acid is found in the body as a constituent of co-enzyme A which is involved in the metabolism of carbohydrates and fats, and a deficiency exhibits itself in trembling in newborn pigs, and by locomotor inco-ordination in adults. This can often be recognised by typical goose-stepping of the hind legs. Maize–soya diets contain little natural pantothenic acid and many British type diets also need supplementation.

Niacin or nicotinic acid may be deficient in high cereal-containing diets, for although cereal grains contain this vitamin, it is in a bound form which is not readily available to the animal. The amino acid tryptophane is capable of conversion to this vitamin which is involved in energy metabolism. Thus the tryptophane status of the diet is important when assessing niacin levels. Niacin requirements vary according to protein and fat contents of the diet and the amount and nature of the carbohydrate metabolised.

Pyridoxine, choline, biotin, inositol, vitamin K and folic acid are all essential but are unlikely to be deficient in normal diets. However early weaning and orphan pig diets often need supplementation with these vitamins.

The Intensively Kept Sow

There are two main functions of the sow which involve different nutritional problems and may conveniently be discussed separately.

The first function is to produce the maximum number of viable piglets per annum, in order to defray annual depreciation and food costs of the breeding stock as much as possible. Secondly, the sow is expected to provide adequate supplies of milk to enable her litters to thrive and grow strongly so that they may become independent of her at an early age. The two functions are inter-related, for it will be apparent that number of piglets per annum is the product of the average number of piglets born per litter, and the number of litters born per year. The second function of the sow, if well achieved, may enable earlier weaning to take place and so afford the opportunity of reduction in farrowing index and an increase in litters per year.

The Pregnant Sow and Gilt

It is common for breeding stock to be selected on the basis of their growth and conversion to bacon weight. They are then selected and often placed on a restricted diet. It has been shown that provided this restriction is not below 60 per cent of full feeding, no adverse effects on subsequent breeding performance results. However the practice of flushing gilts, i.e. increasing their daily food intake 7–14 days before first mating, can give rise to an increased ovulation which may result in one or two more pigs per litter. This 'flushing' is likely to have its greatest effect on ovulation following a period of restricted feeding.

Puberty in the pig is primarily a function of age not weight and only extreme restriction of intake causes delay in first oestrus. There is some indication that protein deficiency which markedly restricts growth rate, delays onset of oestrus. Deficiences of specific fatty acids, vitamins A or B_{12} may also retard sexual development but within the limits of feeding practices and diets at present normally used, puberty is not likely to be affected.

Failure to hold to service is more likely to be due to managemental control of timing etc., rather than to nutritional problems, but complete embryo mortality at an early stage from nutritional inadequacy can take place. Experimentally, sows fed so as to lose 23 lb. during the first 28 days of pregnancy resulted in 25 per cent being non-pregnant at 28 days, whereas feeding which led to a gain of 6 lb. over the same period resulted in 100 per cent of pigs remaining pregnant. However, provided gilts and sows are kept to a steady increase in weight from conception there would seem to be little advantage from the point of view of embryo mortality of inducing heavy weight-gains. Nevertheless it has been shown that rate of feeding during pregnancy can influence litter weights, and 3-week weights.

Experimentally, sows given supplementary feeding in early pregnancy whilst at pasture showed larger litters, but this may have been due to the correction of a mineral or vitamin deficiency rather than an energy or protein effect. More recently, experiments in which either 3 or 6 lb. of a ration were fed throughout pregnancy, or 3 lb. for the first two-thirds of pregnancy followed by 6 lb. for the last one-third, showed that the higher level of feeding in the final stages improved litter weights. Of course the placenta and embryos have a limited demand on the sow early in pregnancy, but in the last one-third, demand becomes heavy and 3 lb. of a normal energy diet is not sufficient to allow of proper development. It is of interest to see that the N.R.C. publication No. 1192 states that sows during gestation consume more energy than required for maintenance and development of pigs during foetal life if fed *ad lib.* on high or medium energy rations. Energy intake must therefore be restricted and 8200 kcal. digestible energy per day for gilts and 9800 kcal. digestible energy per day for sows is suggested. This is equivalent to 5½ lb. and 6½ lb. respectively of a moderate energy diet.

One of the difficulties in carrying out experimental work with sows as to the effects of daily intake of nutrients upon size and weight of the litter, apart from large variability from sow to sow, is that the sow is such a very good buffer between the diet and her developing embryos. Deficiencies in the diet may not show up during the first or even after several pregnancies and thus one is cautious concerning the application of systems which advocate severe limitation of energy and protein during pregnancy. However one thing is quite clear and that is that excessive feeding during this stage leads to large body-weight increases in the sow of which a good deal is fatty tissue, and that this weight is subsequently lost rapidly during the following lactation. Over-feeding can also result in embryonic losses. Pregnant sows utilise their food much more efficiently than non-pregnant animals of the same weight and age but under-feeding can lead not only to lighter litters and 3-week weights, but can seriously prejudice the growth of a well developed mammary gland upon which the following lactation depends. In this respect it has been shown that mammary development is dependent on good nutrition from the early stages of gestation. It is generally accepted that a minimum of 4 lb. of a normal energy food per sow per day is necessary for normal reproduction, though many prefer to recommend slightly more than this in view of the limited evidence so far on long-term effects. However when considering weights of food per day, one should be careful to bear in mind that 4 lb. of a diet based on high energy cereals will provide similar levels of energy to 4½–5 lb. of a lower energy diet based on more moderate energy cereal offals. Such a diet may have the advantage of supplying bulk materials, so giving the animal a feeling of satisfaction on a relatively low nutrient intake and keeping the muscle tone of the gut in good order ready for the heavy demand made during lactation.

The Lactating Sow

It is well known that the colostrum produced by the sow after parturition is rich in albumin, globulin and also lecithin, vitamins, enzymes, phosphorus, calcium and magnesium. Colostral protein is also rich in leucine, valine and threonine which are constituents of the immune proteins or antibodies. The composition of colostrum changes rapidly soon after parturition and it is essential that each piglet obtains a reasonable quantity within a few hours. The nutrition of the sow appears to have little direct effect upon either the volume or composition of colostrum apart from the vitamin status. The importance of the vitamin make-up of the sow's diet has been referred to previously.

The colostral stage in the sow lasts for some 5 days during which time the milk composition changes rapidly to normal milk. The composition of sow's milk is much richer than cow's milk containing on average about 20 per cent total solids of which about 8·5 per cent is fat. It is of interest to note that the composition of this fat more closely resembles pig body fat than the milk fat of the cow and other species. There are also some indications that the metabolism of the pig is better geared to the utilisation of fat rather than carbohydrates. It is recognised that the fat content of the diet influences the fat content of sow's milk but little application of this fact seems yet to have been made.

The composition of sow's milk varies throughout lactation, the protein and ash contents rising steadily while lactose and fat reach a peak at 2–3 weeks and then normally fall. The yield of milk is greatly affected by protein and energy intake of the sow during lactation. Almost linear responses in milk yield to increased daily intake of digestible crude protein, within the range 250–750 g. per day, have been recorded although few workers seem to have paid attention to the amino acid intakes.

Increased energy intakes have also been shown to increase yield. High plane feeding increases peak yield at 2–3 weeks which is then maintained at a high level, whereas moderate plane feeding leads to relatively low peak yields which decline steadily from the third week. Twenty per cent increases in yield can be obtained by high daily energy intakes at this stage. On the basis of this type of work it has become more usual for high levels of feeding of high energy diets of good protein quality to be recommended during lactation, compared with moderate levels of moderate energy diets of lower protein level and quality for pregnant pigs. There is some evidence that lower levels of feeding whilst in-pig, increase the appetite of such animals, so they are able to consume more readily the higher quantities during lactation when the demand on their resources is greatest. Such a system avoids the inefficient transfer of energy to the pig via the sow's body tissue and thus prevents the wasteful process of successive gain and loss of weight in and out of pregnancy. This enables the young piglet to grow ahead rapidly, for sow's milk is very efficiently utilised, only 0·8 lb. of milk dry matter being required per lb. of gain.

The combination of a high birthweight and a plentiful supply of milk of high quality enables the young piglet to thrive rapidly and with good management, freedom from disease and a highly palatable good quality creep food, weaning should be able to take place around 30 lb. liveweight. However pigs should be eating about 1¼–1½ lb. of creep food per day before they are weaned if no setback is to take place. The complete transference onto solid food at an early age is to be aimed at, for although sow's milk is very effective in producing growth once the pigs are large enough, it is about twice as efficient to pass energy into the piglets direct rather than via the sow. The sow can then be weaned and returned to the boar, so obtaining an increase in litters per sow per year.

Earlier weaning systems than that suggested above, whilst having attractive features in reducing still further sow food and depreciation costs per weaner, have fallen down in practice due to disease incidence in all except outdoor early weaning. This latter system however does not lend itself easily to intensive systems of pig-keeping on a large scale. Nevertheless if the veterinary problems associated with very early weaning can be overcome, the importance of the lactation side of the reproductive cycle could become diminished, and complete diets produced suitable for the purpose. Although this is perhaps a distinct possibility, it is felt that systems of weaning similar to that outlined above are likely to replace traditional 8-week weaning, long beforehand.

Chapter 11

SCIENTIFIC AND PRACTICAL ASPECTS OF IMPROVED PIG BREEDING METHODS

R. W. WIDDOWSON

History

In the United Kingdom the pig, unlike other large farm animals, did not come under the influence of the eighteenth-century cattle improvers, the breeds forming localised populations; each population and type taking its name from the area in which it was developed such as Tamworth, Essex, Wessex, Gloucester Old Spot, Cumberland, Lincoln Curly Coat, Oxford and Sandy Black, Dorset Gold Tip, Welsh, Yorkshire (later Large White). Because of the lack of communications there seems to have been very little breeding between the populations, and cross-breeding as known today was unknown. The pigs had little national economic value, and were mainly kept to provide food for their owners, the cottagers and town dwellers of the new industrial areas.

The development, in the later part of the nineteenth century, of the breed societies made the breeds more national in outlook, but the societies seem to have done little for breed improvement. The starting of herd books was really no more than a method of giving the genealogy of any animal. At this time the show societies still do not seem to have acknowledged the existence of the individual breeds for as recently as 1872 the Highland and Agricultural Society of Scotland at their Dalkeith Show awarded a silver medal to William Ford of Harden Green 'for boar'.

This state of affairs continued and little real genetic improvement was carried out until the late 1920s and early 1930s when Price and Stubbs, Davidson and Duckham (1929) started the Buckinghamshire and East Anglian Pig Recording Scheme. This was the first recording scheme in this country and was designed to measure the fecundity of the sows as well as the 3-week and 8-week weight of the piglets. The 3-week weight was considered to be an estimate of the sow's milking ability, whilst the 8-week weight gave an indication of the farmer's management of his small piglets. During this same period British bacon factories, concerned at the poorness of the quality of the pigs for the Wiltshire bacon trade, and fearing the increasing competition from the Danish industry (which incidentally had as long ago as 1897 been progeny-testing animals), started to pay detailed attention to carcass requirements.

They laid down standards, and animals attaining these standards were paid for at higher rates. Some factories, such as Harris of Calne, actually advised on the breed of pigs most suitable for their trade.

On the outbreak of war, in 1939, the pig became a direct competitor with humans for food and in the early months of the war the pig industry in this country virtually disappeared. The few remaining animals which were left were fed on swill and other products which were unfit for human consumption. At the end of the war when meat was scarce the Government, realising the prolificacy and speed of growth of the pig, induced farmers to go into pig production, and any animal of a heavy weight was highly profitable.

Pig Litter Testing

In 1950 the British Oil & Cake Mills, realising that the quality of pigs would have to be improved eventually, started the first testing station of any type in the United Kingdom at Stoke Mandeville. Half litters of pigs were sent in to this station and their bodyweights and food conversion determined, as well as the carcass quality of some of them measured. The feeding of these pigs was *ad lib.* which allowed full expression of the genetic potential of the animals.

Boar Progeny Tests

In 1953 Stoke Mandeville began the first controlled progeny test run in this country on a national scale. The method of testing was similar to the Danish testing system, the main difference being the *ad-lib.* feeding programme. Under this test, a breeder sent in four teams of pigs, each team consisting of two hogs and two gilts, and the pigs were fed under an identical management system. The dams of the teams were unrelated but all pigs in a team had a common sire, and under this method it was possible to prove the sire. This work continued until 1958 when the Pig Industry Development Authority undertook to carry out boar progeny testing on a national scale.

Boar Performance Tests

At this stage the British Oil & Cake Mills turned their attention to the development of ultrasonics and the launching of boar performance testing. It was with this type of test, again the first in this country, that pig improvement was stepped up as sires were able to be tested before being used for breeding purposes. Theoretically no bad boar would ever be used in the National Herd. These tests were also taken over by the Pig Industry Development Authority who are now arranging under the Accredited and Elite schemes, to test about 7000 boars per annum.

Swedish Landrace

The tightening economic conditions which occurred in pig farming in the late 1950s had an influence on the use of genetic techniques in pig improvement, but undoubtedly the greatest impetus to the improvement of the native British Breeds was the importation in 1956 of pigs of the Swedish Landrace breed. A new herd book was started for these pigs, and the Society, unlike other herd book societies, ran its own boar progeny testing station. The success of the station, together with that of the Landrace breed in the show ring, and also in carcass competitions, caused the breeders of our native pig breeds, in self defence, to improve their animals genetically.

However, when one considers the effort which has been given to the development of genetic testing in this country, it is disappointing to note the poor results which have been attained and it is worth while considering the factors which have influenced this and which should be controlled to bring about more rapid improvement in the future.

Scientific Aids in a Modern Breeding Programme

1. **Mathematics.** A basic knowledge of the mathematics governing genetics gives an ability to understand and to make more certain that correct animals are selected as future breeding stock.

It is important to realise that all biological characters, for example height in man or food conversion in pigs, are controlled by many genes, each having an additive effect so that the animal with its inherited gene background if put into the right environment, can express itself to the maximum of its genetic make-up. It is quite obvious that the different genes which any animal inherits at conception will give it a different potential for various traits, e.g. height, length, or food conversion.

If data are taken of the weight, height or for that matter chest measurements of a large number of men, and then set out in graph form it will be found that the curve obtained is relatively uniform. This 'normal frequency curve', showing the distribution characteristic of data of this type, is well known and introduced into most textbooks on statistical methods. The example (Fig. 15) by Brookes and Dick (1961) relates to the frequency distribution of the weights of adult males born in the U.K. (1883).

If the population is large enough the curve is then completely symmetrical about the mean. By mathematical techniques, the distribution about the mean can be calculated, and this is known as the standard deviation for that population. It is calculated by ascertaining the mean for the population, calculating the difference of each observation from the mean, and squaring this difference, summing all the squared differences (known as the sum of squares) and taking the square root of the sum of squares divided by one less than the number of observations.

Example: Calculation of standard deviation of shoulder fat thickness in six pigs.

The standard deviation gives a measure of the distribution of the population and it is important because it is mathematically proved that about two-thirds of the total population which were investigated lie under the area of the curve given by ± 1 standard deviation and that

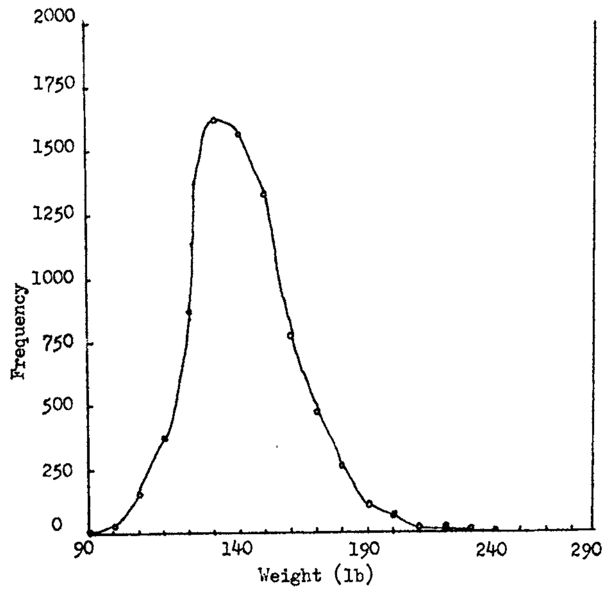

FIG. 14. Normal curve showing frequency distribution of weights of adult males. (Brookes & Dick, 1961.)

Back fat Thickness (mm.)	*Difference from mean*	*Difference from mean square*
24	−16	256
36	−4	16
38	−2	4
40	0	0
50	+10	100
52	+12	144
Mean 40		Sum of squares 520

$$\text{S.D.} = \sqrt{\frac{520}{6-1}} = \sqrt{104} = 10{\cdot}2$$

only 1 in 40 ($2\frac{1}{2}$ per cent) of animals is better than two standard deviations. Therefore, given the food conversions of a population of pigs fattened in a standard environment, it is possible to calculate (after testing many pigs) the standard deviation for that population, and the figure can be used for further selection within the population in that environment. For instance, let us say that the food conversion has been measured and the standard deviation calculated for 100 pigs and that it has been found that the average food conversion was 3·5 and that the standard deviation was 0·5. This would mean that two-thirds of the pigs in the population would have a food conversion between 3·0 and 4·0, but only 1 in 40 would be better than 2·5, and only 1 in 40 would be worse than 4·5. From a practical standpoint one would only be interested in animals which had a food conversion of 2·5 or better, which would only occur once in 40 times. Therefore, the selection level can be based on the laws of chance, depending on how many animals are required for herd replacement.

The problem, of course, is to get a constant environment, but it is possible to use the technique of contemporary comparison where actual figures are corrected on a moving average basis, and the average for each week's output is based on 100. This allows comparisons to be made over longer periods of time. It is important to realise that the character which has been corrected by the moving average will also distribute about the normal, and the same techniques of standard deviation can be used.

	Week 1		*Week 2*		*Week 3*		*Week 4*	
	F.C. actual	*On 100 base*	*F.C. actual*	*On 100 base*	*F.C. actual*	*On 100 base*	*F.C. actual*	*On 100 base*
	3·6	109	2·9	93	2·8	96	3·4	100
	3·2	96	3·0	96	2·6	89	3·6	105
	3·4	103	3·4	109	3·0	103	3·3	97
	3·5	106	3·2	103	2·9	100	3·2	94
	3·1	93	3·0	96	3·2	110	3·5	102
Average	*3·3*	*100*	*3·1*	*100*	*2·9*	*100*	*3·4*	*100*

Weekly Average. Environment can alter an animal's performance. If a litter of good 8-week-old pigs is put into a poor fattening house the result would compare badly with pigs of the same breeding, were these to have been put into better fattening accommodation. The latter would have grown well and been highly profitable. It is also very obvious that within a litter of pigs there exists a variation for practically every known character. This is partly due to inheritance, and partially due to the effects of the environment.

A pig may be small at 8 weeks because of its genetic inheritance, or it may be small because it received a bad milk supply from its mother and thus had not been able to express its genetic growth potential to the full. By using advanced mathematical techniques it is possible to split these sources of variation. Heritability (additive genetic) factors should ideally be calculated for every herd, but very often there is insufficient information available on which to make the calculation. Below is given the heritability (expressed as a percentage) of some of the traits found in British Large White pigs:

	%
Mid-back backfat	73
Loin backfat	70
Shoulder backfat	62
Carcass length	60
Food conversion	50
Area of flank fat	49
Daily liveweight gain	41
Eye muscle area	35
Litter size at birth	15
Litter size at weaning	10

As for example only 15 per cent of the observed variation of litter size at birth is due to the additive gene effects, the rest of the variation (85 per cent) is due to other genetic causes, as well as environmental and other effects.

A knowledge of heritability allows predictions to be made of the response which one should obtain from a planned mating. The following examples show that various predictions of performance can be made.

Expected Gains from the Use of Tested or Untested Stocks. By use of the formula—total selection pressure × heritability—the improvement which will occur using performance tested stock can be estimated within reasonably predicted limits.

(i) AVERAGE GILTS MATED WITH A TESTED BOAR

	Average gilt record	*Tested boar*
Daily liveweight gain (lb.)	1·25	1·60
Shoulder fat	50 mm.	42 mm.*
Food conversion	3·5	3·0*

* Boars carry about 7½ per cent less shoulder fat than hog pigs and convert about 10 per cent more efficiently. These values have to be corrected to give shoulder fat 45 mm. and food conversion 3·3.

Trait	*Selection differential*	*Herit-ability*	*Expected genetic improvement*	*Probable perf. of offspring*
Daily liveweight gain	$\frac{0 \text{ fr. gilts} + 0{\cdot}35 \text{ fr. boar}}{2} = 0{\cdot}175$	41%	0·07	1·32 lb./day
Shoulder fat	$\frac{0 \text{ fr. gilts} + 5 \text{ fr. boar}}{2} = 2{\cdot}5$	62%	1·6	48·5 mm.
Food conversion	$\frac{0 \text{ fr. gilts} + 0{\cdot}2 \text{ fr. boar}}{2} = 0{\cdot}1$	50%	0·05	3·45

(ii) SAME BOARS AS IN EXAMPLE (i) MATED WITH TESTED GILTS

Selected gilt record	
Daily liveweight gain	1·50
Shoulder fat	44
Food conversion	3·1

Trait	*Slection differential*	*Herit-ability*	*Expected genetic improvement*	*Probable perf. of offspring*
Daily liveweight gain	$\frac{0{\cdot}25 \text{ fr. gilt}+0{\cdot}35 \text{ fr. boar}}{2} = 0{\cdot}3$	41%	0·12	1·37
Shoulder fat	$\frac{6 \text{ fr. gilt}+5 \text{ fr. boar}}{2} = 5{\cdot}5$	62%	3·40	46·60
Food conversion	$\frac{0{\cdot}4 \text{ fr. gilt}+0{\cdot}2 \text{ fr. boar}}{2} = 0{\cdot}3$	50%	0·15	3·35

It is important to realise that the rate of response and improvement is increased considerably where both females and males have been performance tested, and in cases where sows give birth to a large number of pigs at one time, genetic progress can be speeded up by using as dams, tested females.

Farmers often enquire how one can ascertain the difference between animals which have been performance tested. It is obvious that economically there is a balance between food conversion, carcass quality and speed of growth, and excellence in one character can make up for poorness in another and still give the same profitability. It is desirable therefore to be able to score an animal on the basis of its economic worth. By a knowledge of the economic value of the characters, their heritability and the genetic correlation between them, it is possible to construct a scoring index. The animal with the highest score is potentially the best animal for producing offspring with maximum economic worth. The following index is based on 1965 values using equal selection pressure.

Index = 100+9·4 Daily liveweight gain (lb. per day)
−6·9 Food conversion (lb. per 1 lb. liveweight gain)
−0·27 Average fat thickness 2½ in. from centre line measured at shoulder, last rib, and loin (mm.)
—0·18 Shoulder fat thickness (mm.)
−0·19 Loin fat thickness (mm.)

It should be appreciated that as the index is based on biological measurements, it will distribute about a mean, and a standard deviation can therefore be calculated. If animals from a performance test are scored on an index, the standard deviation should be calculated and then, knowing how many animals are required as herd replacements, a decision can be taken what standard to take for the selection of future breeding stock.

In practice, selection at better than 0·5 standard deviation for females, and better than 2 or 2½ for males, should be obtainable.

2. **Ultrasonics.** When sound waves of a very high frequency pass through matter, some will be reflected if they enter matter of a different density. The time taken for the sound wave to travel from the transmitter back to the receiver can be recorded, and knowing the speed of sound through the medium concerned, it is possible to calculate the distance the different density media are away from the transmitter. This technique, using sound waves of an ultrasonic frequency, formed the basis of Asdic for submarine detection during World War II. Similar techniques were later developed for measuring flaws in steel castings, and work by Dumont (1957) in France showed the feasibility of using sound waves for determining the thickness of fat in a live animal. Researches at Stoke Mandeville developed this technique further, ultrasonic machines being used for measuring the back-fat thickness of the live pig. This was a great advance over the primitive probes which had been used in America, and for the first time allowed measurements of fat thickness in live animals to be carried out in conjunction with performance testing.

The technique is limited because the only sound waves which are received back by the transmitting receiver probe are those which strike the change in density interface *at right angles.* Those which strike at any other angle are deflected and therefore lost. Efforts are being made to overcome this defect, and the use of multi-probe heads have already made it possible to determine eye muscle areas in live pigs. Experiments to cut out the manual labour involved, and to carry out the work electronically are also in progress. If this is successful then a technique can be developed to find out depth of lean and fat in the ham, as well as eye muscle (*longissimus dorsi*) areas.

3. **Blood Grouping.** Development of the science of immunogenetics in pigs using red cell antigen and electrophoresis techniques has opened up a complete new field in methods of selection of breeding stock.

Already it has been established, using red cell antigen techniques, that there are certain groups which may have a deleterious effect on subsequent litters. Andersen (1963), working at Iowa, has shown that there occur in the pig haemolytic anaemias similar to those seen in man and the horse. Additionally there is an indication that certain sterility problems may be associated with blood groups.

Although various blood group factors are inherited in a simple Mendelian manner, certain combinations which should exist have very rarely been seen, and this leads to the question—do some blood groups have a lethal effect on developing embryos? The answer to this and other questions will have to await the results of a great deal more experimental work.

In the field of electrophoresis it is interesting to note the discovery of simple Mendelian inheritance of the haptoglobins, and certain enzymes, and it may be that science is on the verge of being able to read the genotype of complex polygenic inheritances such as food conversion, by typing the various enzyme and hormonal processes which go to make up the characters which are at present measured by costly performance tests.

Aids to Selection

1. PEDIGREES

Look first at a typical pedigree for Halesfarm, Champion Boy 7th. Born 13th September, 1958. (12—12)

Sire— Ardencote Champion Boy 469th 280015 (17—9)	Ardencote Champion Boy 311th 197231 (8—8)	Ardencote Champion Boy 200th 161813 (13—13)
		Ardencote Queen 23rd 490520 (9—9)
	Ardencote Lady Mollington 468th 701244 (10—9)	Ardencote Prince 10th 171805 (15—10)
		Ardencote Lady Mollington 291st 490434 A.R. (6—6)
Dam— Halesfarm Royal Catalina 184th 797218 (10—9)	Halesfarm Field Marshal 87th 223387 (12—11)	Thingoe Field Marshal 8th 181955 (12—8)
		Halesfarm Royal Catalina 13th 501774 (18—9)
	Halesfarm Royal Catalina 62nd 586430 (10—8)	Halesfarm Field Marshal 2nd 189133 (8—8)
		Thingoe Royal Catalina 79th 514804 (11—11)

What information does it give? It gives the family tree of the animal as well as the fact that the pig was out of litter of 12 born, 12 reared.

The real trouble with the pedigree is that it gives the purchaser no indication of the genetic variation experienced in the herd, nor is there any information given from which a standard deviation can be calculated. True some breeders give the average performance of a litter of pigs, but this is of little value if the spread within the litter is not given.

Consider in genetic terms a character governed by genes with an additive effect:

Let gene $A = 3$ units of quality
$a = 1$
$A^1 = 5$
$a^1 = 2$
$A^2 = 4$
$a^2 = 1$
$A^3 = 6$
$a^3 = 3$

then:

Sire with a genotype $A\ a\ A^1\ A^1\ A^2\ a^2\ a^3\ a^3$ has a value of 25

Dam with a genotype $A\ a\ A^1\ a^2\ A^2\ A^2\ A^3\ a^3$ has a value of 27

and Offspring No. 1 $A\ A\ A^1\ A^1\ A^2\ A^2\ A^3\ A^3 = 36$ value

Offspring No. 2 $a\ a\ A^1\ a^1\ A^2\ a^2\ a^3\ a^3 = 20$ value

Both pigs have an identical pedigree, but the one has a much worse combination of genes than the other. It is suggested that a pig's pedigree in the future should be written as follows:

Sire *Stoke Lad 3rd* 10B/10R—Own performance Index = 78
Average Index of all 60 offspring slaughtered = 76
With a standard deviation = 3

Dam *Stoke Lass 2nd* 8B/7R—Own performance Index = 75
4 litters of 9/8; 10/9; 12/8; 11/11
Average index of 30 offspring slaughtered 73 with S.D. of 5

} *Stoke Lad 10th 11B/11R* own Index 81

This type of pedigree gives all the information needed for selection. It gives the whole of the variation of the parents and also the animal's individual phenotypic performance; and indeed from the knowledge of population genetics it is established that the animal on offer is in the top one-sixth of both the sire and dam population. True, in the first assessment it will be necessary to find out how much the effects of environment (feeding, housing and management), of the seller may have allowed the animal to express its genotype and if the purchaser's management is not up to this farmer's management then a worse performance must be expected.

The present-day pedigree system can be criticised but it does assist in selection of such qualities as numbers born and reared which have low heritabilities. Examinations of pedigrees in particular reference to the cousins, uncles and aunts will make certain that these characters are not allowed to deteriorate, whilst selection for the more highly heritable characters are made. An animal is a dynamic entity and very often when selecting for one character, others which are not of immediate interest may deteriorate. How easy it is to refer to a pig absolutely superb in every character, but unfortunately it came from a litter of four reared. This adverse feature might be of environmental origin, but if it happened again in the next generation some concern would be felt from a reproductive performance standpoint.

Traditional pedigrees should give an honest record of an animal's parentage, and as such they are useful in selection for traits of low heritabilities, but they offer little help in the selection of characters with high heritabilities.

2. PERFORMANCE TESTING

Performance testing is the testing of animals under a standard environment so as to assess the speed of growth, efficiency of food utilisation (food conversion), and, by means of ultrasonics, the thickness of fat at the shoulder, loin and last rib, as well as the thickness of fat over the eye muscle. Those animals which show highly favourable values for these factors can then be used for future breeding stock. It has been shown earlier that the heritabilities of these factors are high and animals which give a good performance in these highly heritable qualities are likely to transmit them to their offspring.

Although performance testing in pigs has only been carried out in this country for about 8 years, there is nothing new in the technique. Breeders of racehorses and greyhounds have assessed their animals by performance testing them over the race-course. Those animals which could run a mile in the quickest time were used and indeed are used as the potential parents of 1-mile runners.

For pigs the test consists of selecting stock at 8 weeks which have come from a litter of at least 8 pigs born and reared, and which shows no obvious congenital faults. These provisos ensure that reproductive performance has not been overlooked. The animals are moved to a testing station where they are housed and fed under identical conditions. Their liveweight gains and food conversions are recorded over a definite period, say from 60 to 200 lb. and at 200 lb. liveweight their back fat at the shoulder, loin, and last rib, as well as over the eye muscle are determined by means of ultrasonics. The records for each pig are then processed to give the animal an index score. By comparing the animal's index with the sire and dam average index, and with a knowledge of standard deviation, the tested animal can be placed in the particular herd population. If the National breed average and standard deviation are known, the animal can then be compared with the breed population. Those animals with the highest index are the best potential breeding animals. However, it is most important to realise that once the animal has passed its genetic test it must be capable of living and performing well on a breeder's farm and so those animals acceptable genetically are put forward for visual appraisal. Stock must be culled irrespective of their genetic performance, if they show bad leg action, or any other physical character which would mar a useful working life.

Animals which then pass this visual culling test can be returned from the Test to the breeder.

3. PROGENY TESTING

Progeny testing, as the name implies, is the testing of progeny and deducing from their performance particular aspects of the genetic make-up of the parents. There is nothing new in the method and indeed the ancient Greeks fully understood the system. Varro 2000 years ago mentioned that 'one could know your ram by his get'!

Progeny testing is based on sampling. If one had a bag containing a large number of peas and beans and if it was not possible to empty the bag completely, an estimate of the numbers of peas and beans could be obtained by putting in a hand and drawing out a sample of the mixture and then counting separately the number of peas and beans. This would give some indication of the proportion of peas to beans, but it would not be very accurate because only one sample had been taken. If, however, the sample was returned to the bag, well shaken and another sample taken and counted, the knowledge about the split between peas and beans would be more accurate. And if this were to be done seven or eight times and the proportion of peas to beans in the samples averaged this would give the proportion of peas and beans in the bag with considerable accuracy.

Sire Progeny Tests. So it is with a progeny test, the genes are 'shaken up' by mating a sow and a boar together, a sample of the offspring is taken and assessed under a standard environment. The mating is repeated four times but with different sows. Half litters (consisting of two hogs and two gilts) are used as the sample teams; thus each team has the same father but the dams are different and not more closely related than half-sisters.

The best estimate of an offspring's performance ignoring heritability is given by the following equation:

$$\text{Offspring worth} = \frac{\text{Sire worth} + \text{dam worth}}{2}$$

$$\text{or sire} = 2\,(\text{offspring}) - \text{dam worth.}$$

If the dams are all of average genetic value then the sire's worth can be interpreted by differences between the offspring. Unfortunately, a major error arises from progeny testing because one cannot be sure that the dams are of average genetic merit. Indeed if the dams are not of the breed average, or are selected by the breeder with bias, then erroneous results will occur.

The following example illustrates the error which can occur where dams are not of the same genetic standard:

	Boar A	*Boar B*
Progeny test of offspring for food conversion	3·0	3·2
Dams worth food conversion	2·8	3·4
Boars worth (by deduction)	3·2	3·0

Published results could lead a purchaser (if he knew nothing of the dam's make up) to believe that boar A was the better, whereas once a dam's make-up is known it is discovered that in actual fact boar B is the better.

In this country to date farmers have been allowed to select the females who are to constitute the dams of the progeny test groups, and if bias has been allowed the progeny test result is likely to be invalid.

There is a further error which must be considered. The phenotype expressed by the progeny test group relates to the genetic make-up of the pig together with the environment. At the testing station, the environment is kept constant. However, the pre-test environment changes from farm to farm and if, for instance, the breeder can manage his pigs well, all his pigs will be well managed and all will get a plus, whereas if he is a bad manager, the effect will still accumulate, but be negative in direction.

Errors due to random selection of dams tend to cancel each other out—some will be better than the breed average, some will be worse—but the environmental errors will all work together in a positive direction.

Breeders are instructed to have tested four pigs which are average for the litter, but human nature being what it is, a bad pig is never sent. Therefore, the normal curves which have already been discussed are automatically biased and become abnormal, and this can easily lead to the calculation of erroneous values for standard deviation.

Notwithstanding the problems which can arise in carrying out accurate progeny testing, the technique, if conducted properly, is the only method whereby the genetic make-up of the characters associated with the carcass of the pig can be ascertained.

In an attempt to overcome the errors associated with biased dam selection and environmental effects, the British Oil & Cake Mills developed a new progeny test in which semen from two boars—one of which was proven—were inseminated into each sow. The resultant litter was split according to sire into two teams, and the progress of each team compared contemporaneously. (The sire identification of the pigs in the two teams was done by using red cell antigen blood grouping techniques.)

This test had the advantage that as the dams of the test litter groups were the same, any effects would fall on both the teams at random; but more important because the pigs experienced the same environment from conception to slaughter the errors due to this cause were eliminated.

SUMMARY

A sound breeding programme will depend on the following conditions being observed:

(i) The calculation of the means and standard deviations of the qualities for which the breeding programme is designed.

The use of an index based on overall economic value is a useful method of scoring animals.

(ii) The performance testing, of both males and females in the environment in which the offspring are to live. At the end of the performance a critical visual assessment of the animals is essential, to ensure that only those animals which have a strong constitution and a potential to stand the rigours of farm life are accepted into the herd.

(iii) The progeny testing of all stock boars at as young an age as possible. The progeny test to be conducted using as dams, females which are as near the herd average as possible.

(iv) The use of herd pedigrees, to check on characters of low heritability, but which nevertheless have economic importance.

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POULTRY

Chapter 12

THE STRUCTURE OF THE POULTRY INDUSTRY OF ENGLAND AND WALES

R. Coles

About a quarter of a century ago the poultry industry of this country was characterised by an absence of any marked difference in the concentration of laying stock over the country with one exception. That exception was Lancashire and the reason for the particularly heavy concentration there was that many workers in the textile trade had turned to poultry keeping on smallholdings in the depression following the 1914-18 War.

In addition to poultry flocks being distributed remarkably evenly throughout the country (apart from Lancashire) no great differences in flock size existed. About 98 per cent of our flocks were under 500 birds in size; over 80 per cent of the layers were accounted for by flocks of this calibre.

Today (1966) the number of layers has almost doubled and the number of flocks almost halved. In addition the density of the laying population manifests marked differences throughout the country. There is now a heavy concentration in the S.E. home counties and the middle N.W., i.e. near to the main urban areas.

Apart from the laying population the production of table chicken has become a major agricultural industry with an output for the United Kingdom of approximately 170 millions of broilers per annum. This industry did not exist before the war and since 1953 has largely superseded the former luxury roaster business which in pre-war days supplied only about 2 or 3 million table birds per year.

The turkey industry has similarly expanded and, like the broiler business, over 80 per cent of the market turkeys are supplied from around 500 farms—if 'farm' is now the correct description to apply to the 'poultry factory' of today. The annual turkey output has increased from well under 1 million in the pre-1939–45 war years to about 10 million in 1965.

The root cause of the dramatic changes in the structure of the poultry industry is to be found in the war-time conditions. But to keep matters in perspective it should be realised that the pre-war value of eggs and poultry products was 14 per cent of the total for all agriculture. Today it is between 15 and 16 per cent—although, of course, the value of the total agricultural industry has increased considerably over the last 25 years.

The main reason for the widespread post-war changes was the realisation by many farmers, forced to look more closely at the economics of livestock farming under reduced supplies of animal feed, that the poultry flock was a reasonably good economic venture. As a consequence many farmers took over the control of the flock from their wives and attempted to increase the size of the flock. This latter became possible with the successive stages in the relaxation over the control of animal feedingstuffs.

Since the same aim had occurred to many farmers expansion of the nation's laying flock proceeded apace. A natural consequence was a decline in egg prices although the guarantees in the 1947, and later, the 1957 Agriculture Acts prevented the full impact of the law of supply and demand. Nevertheless the highly profitable post-war years were passing and many continued to enlarge their flocks in the hope of maintaining flock income with successive falls in the guaranteed price of eggs.

It was at this stage—around 1950—that the beginnings of our modern poultry industry emerged and poultry keeping began to evince the pattern of factory farming. Three developments caused this change.

In an endeavour to check falling profits per bird a speedy move to intensive housing occurred in order to enable lighting patterns to be employed. At the outset this was the standard 14 hour 'day' of the old-time poultry specialist. But with the realisation that a *rising* light pattern was more stimulating than a standard 'day' the move towards windowless houses for layers and, in addition, intensive windowless houses for young stock began. Only by these so-called controlled environment houses could the newly defined light patterns from day-old to the end of the laying year be imposed.

By the introduction of light patterns egg output was stimulated but the almost standard house design with its completely intensive building began the association with the term 'egg factory'. The same term —'factory'—was applied to broiler production where a controlled environment house to ensure a constant dim light or short periods of light and dark was also essential.

The second development was an increase in house size. This took place as a means to secure lower housing costs through economies of scale. It will be appreciated that the difference in size with the modern fairly well standardised house only involves roof and side walls—and not the two end walls. Apart from the economies of scale achieved through larger housing, savings also applied to mechanised equipment since the larger the units the lower the cost per bird. The very large fully automated house (mechanised feeders, drinkers, manure cleaners and egg collectors) permitted a much more favourable man:bird numbers ratio. In many of these houses carrying 8000–12,000 head of laying stock one operator could manage 8000 birds. In some highly automated units this figure has been greatly exceeded. These ratios should be compared with the 1000–1500 birds regarded as the manageable limit per attendant for most range systems.

The third development was the introduction of more scientifically orientated breeding policies and the rise in popularity of the hybrid layer. Basically the hybrid is the result of the crossing (often in a complex manner) of unrelated inbred strains or breeds. Not only does the successful hybrid manifest 'hybrid vigour', i.e. high level performance to a marked degree, but the birds bred from the same strain or breed combinations evince a reasonably standardised production level. In effect the consistent performance of hybrids in the same batch and from the same parental lines reproduces the consistent quality associated with a factory made article.

This standardisation in performance did much to eliminate the need for culling and consequently two or more hybrid layers could now be housed in the same cage. In addition, some hybrid breeders had been concerned to breed a layer with a low maintenance ration. The result was the emergence of the light and medium heavy hybrids—birds with a liveweight of between 3½–5 lb. Admittedly this action caused some loss in egg weight since bird weight and large eggs appear to be antagonistically related. But the smaller birds enabled more to be housed in buildings formerly carrying an appreciably smaller number of birds.

These three developments promoted bigger flocks and larger houses. They stimulated the trend to fully intensive so-called controlled environment houses and, with some justification, attracted the description 'factory farming'.

The changes in size of flock did not apply equally to all engaged in the poultry business in the middle 1950s. The hybrid breeding policies necessitated large numbers of strains and breeds for early success. Considerable capital investment was essential. Some mergers took place between already large breeding establishments to economise resources. Many of the numerous independent breeders fell out either because they were outclassed by the quality of the new hybrids, failed because they were unable to supply in one batch the larger orders for D.O. chicks for the big commercial units, or were unable to compete against the intensive advertising of their big competitors. Nevertheless there are still today some three or four hundred independent breeders in existence. Their main market is the smaller poultry-keeper supplying a direct sale trade for big eggs and brown eggs. They supply about 15 per cent of the country's day-old chicks.

Many of the former independent breeders are now held within the franchise of one of the few huge breeding establishments and engaged in producing hatching eggs from parent stock supplied by the parent company. Some have turned to commercial egg production; others to pullet rearing; and several have retired from the field.

A somewhat similar pattern has occurred among the ranks of the commercial egg producers. The expansion described has led to an increased volume of egg output. Today the U.K. supplies about 97 per cent of her requirements for shell eggs. The actual output is about 105 per cent of the country's needs but about 8 per cent are broken out in attempts to stabilise the market by the British Egg Marketing Board.

The demand for eggs is inelastic (increased take-up can only be achieved by steep decreases in price) and the continued decreases in egg prices over recent years have caused the elimination of many high cost enterprises. In the main those eliminated have been the smaller flocks. Thus flocks under 200 layers have been showing an annual decline since 1957. Flocks between 200 and 1000 layers first evinced a decline in 1961 and flocks of 1000—5000 began to decrease in number in 1965. The annual loss of flocks—in spite of the generally rising size of the national flock—is around 13,000 per year with only flocks above 5000 layers continuing to manifest an increase (Table 1).

TABLE 1

CHANGES IN FLOCK SIZE (EGG PRODUCTION) IN ENGLAND AND WALES

Year		*Flock size*			
		1–200 layers	*200–1000 layers*	*1000–5000 layers*	*Above 5000 layers*
1957	Flocks	210,106	42,442	2,419	55
	Layers	12,847,476	14,723,275	3,882,920	469,463
1961	Flocks	164,628	43,114	5,464	266
	Layers	9,093,710	15,237,368	8,904,738	2,117,100
1963	Flocks	143,288	36,834	6,585	679
	Layers	7,694,597	13,503,192	12,001,572	5,907,150
1965	Flocks	124,931	25,544	6,392	1,235
	Layers	5,985,678	9,577,897	12,461,420	12,622,893

It would seem easy to forecast the future structure of the British Poultry Industry by projecting into the future those trends apparent from Table I. But it is already becoming clear that the egg-laying industry is developing into three separate forms of business and that poultry flocks are not now identical in form and design differing only in magnitude.

The small flocks of a few hundred birds seem now largely confined to holiday areas or in situations with access to main roads. Their main trade is direct sales and their dependence is upon the large egg and the brown-shelled egg and the belief by some sections of the public in the unspecified advantages of an egg 'from the farm' and a naïve assumption that they are produced on free range. The high cost of the small unit and high cost of producing fewer but larger eggs from the more traditional type of layer may be offset by the direct sale price exceeding packing station prices. In this trade the smaller folk are being increasingly joined by larger units trading in a more sophisticated fashion, i.e. market stalls and van to house delivery.

At the other end of the scale we have the large flocks of 20,000 layers and above (we still only have about a dozen or so units in excess of 100,000 layers). These units depend for survival on low costs secured by the scale economies of larger houses and automation. It seems a debatable point whether 20,000 is at all an ideal figure for survival. The argument embraces the rather disappointing performance levels of many big flocks compared with a really well-managed unit of 10,000–12,000 layers. Is this poorer level of performance due to a poorer standard of stockmanship often observed in the highly automated unit, or some aspect of animal behaviour with birds in contact with many of their kind and the absence of close association with human attendants?

It may well be that the large unit must become very large to offset a moderate performance level through the full exploitation of economies of scale including integration by way of home milling and chick hatching. With success in the fields of integration and excellent organisation their success seems assured so long as management does not lead to too low a level of production or scale economies do not reach a stage where an 'up-turn' in costs occurs. Both these faults have occurred in the U.S.A. accompanied by the speedy collapse of a few giant units (Fig. 15).

The middle sized flocks now seem to be concentrating in units of 12,000–15,000 layers. Those where superb management can ensure really high production levels may find their high income offsetting their higher costs compared with the giant unit. But in any case it is not in the nature of mankind to give up if he fails to equal the best—assuming in any case he knows the profit level of the best. Further, much will depend on whether the resources at present devoted to egg production can be more profitably directed to another activity.

Further expansion by any in the three categories will doubtless lead to the continued elimination of the less successful. Such competitive pressure may only relate to the one category, e.g. an expansion of big units supplying eggs to the public via the packing stations may not have any effect on the small flock owners maintaining a direct trade since their market does *not* seem influenced by prices or supplies of eggs in retail shops. But a move by big units from packing stations to direct sales could have some effect on small units.

The move to large highly integrated units observed in the egg industry has occurred with greater celerity in broiler production and been followed only a little less speedily in turkey production. Doubtless the absence of price guarantees promoted the speedier changes. We now have comparatively few breeders of turkeys and broilers and most of the existing breeding organisations are extremely large. The decreasing profit margins in both these sections of table poultry business have rapidly eliminated the small producer and the majority of the remaining

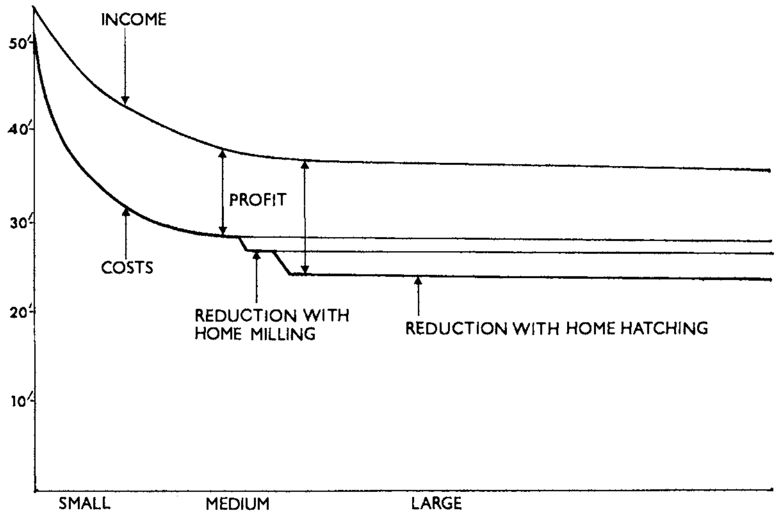

FIG. 15. Illustrating the effects of various factors on egg income.

TABLE 2
PROPORTION OF BROILER AND TURKEY UNITS SUPPLYING THE BULK OF OUTPUT

Year	*Total no. of flocks*	*Output*	*Flocks supplying over 80% of output*
		BROILERS	
1961	5310	140 m.	1086
1965	2790	170 m.	640
		TURKEYS	
1960	12,469	5·5 m.	495
1965	6463	10·0 m.	484

production units are not only large in scale but, in the main, integrated with either packer or breeder.

Today less than 500 turkey rearers supply over 80 per cent of our birds. About 600 broiler units produce a similar proportion of the country's broiler output (Table 2).

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Chapter 13

POULTRY COSTINGS

J. L. MILES

Chick Costs

Chick costs will vary according to the breed purchased, the time of year and any available discounts. The cost of house and equipment depreciation will also vary, depending upon whether a controlled environment house is being used, or old equipment on which little or no depreciation is charged.

The appetites of different breeds will influence the feed cost (0–20 weeks), which with a heavy breed could rise as high as 7s. 6d., compared with 6s. 0d., average to as little as 5s. 0d.

The age at which birds come into lay will depend on the natural maturity of the particular breed and the type of light pattern used. A delay of 2 weeks before they come into lay will increase the cost of the pullet by approximately 1s., but when the birds do start to lay their increased egg size will be greater initially due to later maturity.

As it becomes increasingly difficult to maintain profits in all branches of the poultry industry, more and more producers are becoming interested in recording and costing. The advantages of keeping records are that the exact level of profitability can be ascertained, efficiency of food usage and physical performance measured, and long-term planning of the existing business or its expansion can then be considered on actual performance figures. The essential information produced can be used as a guide to the management of the business.

Pullet Rearing

Pullet rearing has in recent years become more specialised and large numbers of birds may be reared on one farm for distribution over a very wide area. The following costs are for pullets of a variety of breeds costed during 1965 and 1966. (See page 158)

The cost of rearing pullets will depend on the cost of day-old chicks, their mortality, the age at which the pullets are brought into lay, the size of bird and their environment.

Egg Production

The problems of egg production are increasing every year, and it is in this sector of the poultry industry that regular records and costings are so vital if maximum profitability is to be achieved.

Recommendations on the correct method of costing for egg production have been provided by the Poultry Costing Advisory Council in its booklet *Standard Accounting for Egg Production.* A complete series of cards for on the farm costing has been designed by the Council and details of these are obtainable from *Poultry Farmer*, 33–39 Bowling Green Lane, London, E.C.1. Costing services are also provided by the National Agricultural Advisory Service and various Commercial Companies.

PULLET REARING COSTS	*1965*		*1966*	
Total birds reared	154,400		309,863	
Period (weeks)	0–20		0–19	
% Mortality	5·09		5·05	
Feed per bird (lb.)	21·02		19·68	
Costs per bird reared	*s.*	*d.*	*s.*	*d.*
Feed	6	6·07	6	0·27
Chick	3	7·52	3	5·77
Labour		6·59		7·89
Light and heat		3·98		5·05
Litter		1·09		1·53
Medication		5·97		6·11 (Including
Vaccination		3·02		vaccination)
Miscellaneous		2·50		6·20
Depreciation of house and equipment		8·56		9·44
Total	12	9·30	12	6·26

Records

Basic daily records should include maximum and minimum temperatures (night and morning), mortality and egg production. At monthly or weekly intervals feed consumption data, egg income and the actual financial standing of the flock should be assessed. In this way any errors can quickly be accounted for and corrected; and when the flock is no longer profitable it can be disposed of before any serious loss is incurred.

The following level of costs per bird are those which might apply to a laying flock, over a 50-week laying period, housed in batteries:

	£	s.	d.
Food	1	8	0
Depreciation of bird[1] (*See page 160*)		12	0
Labour		2	9
Light and heat			8
Miscellaneous costs[2] (*See page 160*)		1	0
Depreciation of house and equipment		3	0
Total	2	7	5

The following tables are an attempt to show the level of costs and profitability of an *above* average level of performance, and the effect of varying some of the production factors.

TABLE 1

COSTS AND PROFITABILITY PER 100 BIRDS HOUSED OVER 50-WEEK LAYING PERIOD

	£
19 doz. eggs at 2s. 11d. per doz.	277·02
88 birds at 3s. 6d.	15·40
	292·42
Less 20-week-old pullets at 16s. 9d. each	83·75
Gross output	208·67
Less:	
Food 4·9 lb. per doz. at £36 per ton	149·63
Miscellaneous	9·00
Labour	12·50
Depreciation: buildings 10s. per bird at 10 per cent	5·00
equipment 10s. per bird at 15 per cent	7·50
	183·63
Profit per 100 birds housed	25·04
Average capital per 100 birds	£
Buildings	50·00
Equipment	50·00
Pullet (half of cost)	41·88
	141·88
% Return on capital	17·65

TABLE 2

VARIATION OF PRODUCTION FACTORS

	Increase in Profit per 100 birds	*Increase in Return on capital*
	£	£
Increase of 12 eggs per bird	+14·64	+10·32
1d. extra per dozen	+ 7·98	+ 5·63
1s. less for cost of pullet	+ 5·00	+ 3·51
£1 less per ton of food	+ 4·17	+ 2·94
1s. per bird extra on buildings	− 0·50	− 0·35
1s. per bird extra on equipment	− 0·75	− 0·53

The cost of the point-of-lay pullet has been taken as that relating to its purchase at 20 weeks of age.

The levels of profit and return on capital are in addition to (+) or less than (−) the levels shown in Table 1.

The most striking feature of Table 2 is the dramatic effect which increasing the number of eggs per bird has both on profit and return on capital invested.

The increase in income received per dozen eggs will depend on current

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[1] Bird depreciation is the difference between cost at point-of-lay and the value of the carcass at the end of the laying year.

[2] Miscellaneous costs include repairs, light bulbs, medication and other small cost items.

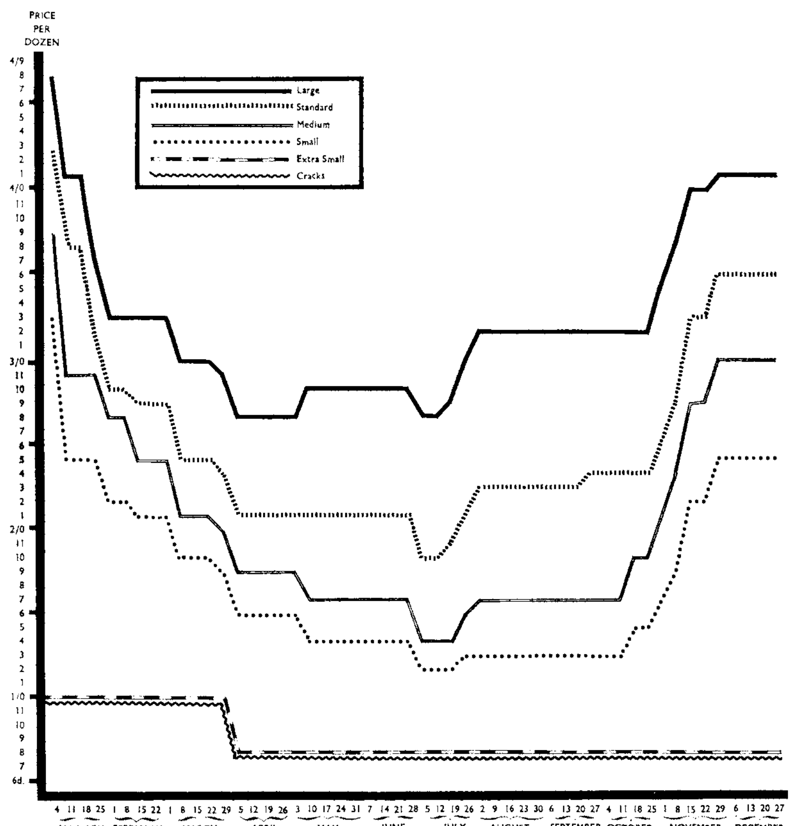

FIG. 16. Weekly average egg price chart, 1966 (to nearest penny). Based on egg returns from Dean Bros.' Egg Packing Station, Gubblecote, Near Tring, Herts.

prices paid by the British Egg Marketing Board, or received from sales at the farm gate or from an egg round. Income per dozen can be increased by an improvement in egg size, a reduction in the number of seconds, by careful planning of the pullet replacement programme and by obtaining maximum differential payment from the Egg Contracts Scheme. Brown eggs sometimes carry a premium over white eggs, e.g. at farm gate sales.

The following table shows the variation in egg income per bird depending on the month in which the birds are housed. The month listed indicates the month of housing and the same pattern of egg production and egg grading was followed in each case for 12 months. The prices used are the average weekly B.E.M.B. Egg Prices for 1963, 1964 and 1965:

	Egg Income per bird		
	s.	*d.*	*Order*
January	58	11·8	6
February	59	4·1	2
March	59	4·2	1
April	59	2·9	3
May	59	2·8	4
June	59	1·1	5
July	58	4·4	7
August	58	1·3	10
September	58	0·7	12
October	58	3·9	8
November	58	3·6	9
December	58	0·9	11

By housing pullets in March instead of September, egg income is increased by 1s. 3½d. per bird. In general terms it is more profitable to house birds at the beginning of the year, in order that they are laying more Large and Standard eggs when prices for these are at a premium during the period from July to January. An interesting discussion on this and allied subjects is to be found in E. S. Clayton's *Economics of the Poultry Industry* (1967).

The age at which to dispose of one's birds is generally a more difficult problem to solve. Any decision must depend upon the level of egg production and current egg prices on the one hand, and on the other the costs of production. Other considerations include the planning of replacement pullets and the effect of disposal of the birds on Entitlement for the next Contract Year.

If the net profit per bird has been decided on at 1½d. per bird per week then the sale of eggs must cover all production costs including depreciation and still leave this margain. When the level of egg production combined with egg prices falls below this level of net profit, and there are no other overriding factors, then the birds should be sold. Because so many factors affect the profitability of a flock, it is impossible

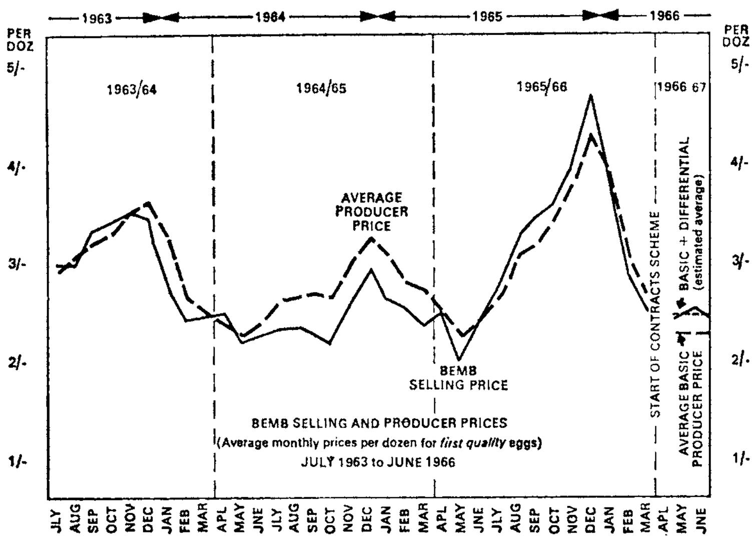

FIG. 17. B.E.M.B. egg prices 1963/64–1965/66.

to state categorically the optimum length of laying cycle. Each flock must be treated as an individual case based on the use of weekly records and a decision made at the most appropriate time.

White or Brown Egg Production

The comparative profitability of white and brown egg layers is frequently a subject for discussion. The following tables are an attempt to compare their profitability per 100 birds housed. The levels of egg production are above average for 50 weeks in battery cages, based on commercial costings. The income at 2s. 11d. per dozen is that which was received during 1965–66, and for the brown egg layers does *not* include any 'brown egg bonus'. The income for carcasses, levels of mortality and feed consumption are based on commercial results. The cost of the point-of-lay pullet is taken from the price list of a typical large commercial rearer. The costs of housing and equipment are taken at 2s. per bird higher for the brown egg layer on the assumption that more space would be required to house these birds. Under commercial conditions this does not necessarily apply, as many farmers now house as many brown egg layers to the cage as white egg layers. The larger appetite of some brown egg breeds means that point-of-lay pullets may cost more. Feed consumption during the laying year is higher, but to help to offset this feature cheaper feeds may be used and the income from the carcasses is higher. Fewer eggs are laid, but shell quality may be better than for some white egg breeds.

At these levels of egg production and costs the producer of brown eggs would need to make an extra 2¾d. a dozen to make as much profit per 100 birds housed, and an extra 3d. a dozen to obtain the same return on capital invested.

White egg layer	£
225 eggs at 2s. 11d. doz.	273·43
86 birds at 3s. 6d.	15·05
	288·48
Less P.O.L. pullet at 16s. 9d. each	83·75
Gross output	204·73
Less:	
Food 4·8 lb. per doz. at £37 per ton	148·66
Miscellaneous	9·00
Labour	12·50
Depreciation: buildings 10s. per bird at 10 per cent	5·00
equipment 10s. per bird at 15 per cent	7·50
Total costs	182·66
Profit per 100 birds housed	22·07
Average capital per 100 birds	
Buildings	50·00
Equipment	50·00
Pullet (half of cost)	41·88
	141·88
% Return on capital	15·55

A return of 2 per cent on capital invested for the brown egg layer is not a business proposition and therefore many egg packing stations pay a 'brown egg bonus' to cover the increased costs of production. In addition many brown eggs are sold at the farm gate for an additional amount, the consumer generally being prepared to pay extra for these.

Broiler Production

The production of broilers requires the keeping of careful records, and the results from one crop can be used to improve results and management for succeeding crops.

Many people still consider that the liveweight, feed conversion and feed cost per lb. liveweight are the only assessments necessary for a broiler crop. These factors are important but they must be related to overall profitability.

Brown egg layer	£
204 eggs at 2s. 11d. doz.	247·92
92 birds at 4s. 8d.	21·16
	269·08
Less P.O.L. pullets at 17s. 6d. each	87·50
Gross output	181·58
Less:	
Food 5·4 lb. per doz. at £35 per ton	143·44
Miscellaneous	9·00
Labour	12·50
Depreciation: buildings 11s. per bird at 10 per cent	5·50
equipment 11s. per bird at 15 per cent	8·25
Total costs	178·69
Profit per 100 birds housed	2·89
Average capital per 100 birds	
Buildings	55·00
Equipment	55·00
Pullet (half of cost)	43·75
	153·75
% Return on capital	1·88

The importance of a good liveweight can be seen from the following table of two crops killed at 63 days of age.

	Crop A	*Crop B*
Average liveweight (lb.)	4·10	3·60
Feed cost per lb. liveweight	9·96d.	9·94d.
Margin between income at 1s. 6d. per lb. liveweight and feed cost per bird	2s. 9·03d.	2s. 5·02d.
Other costs (except depreciation)	2s.	2s.
Gross profit per bird	9·03d.	5·02d.

In this example an increase of 0·5 lb. in liveweight increased the profit by 4d. per bird. At the same time the costs of production such as heat, litter, labour are reduced per lb. of liveweight produced.

Feed conversion and feed cost per lb. liveweight should be related to the cost of food per ton and the liveweight produced.

Stocking density varies depending on the age at which birds are to be killed. The general level of stocking is 0·55–0·75 sq. ft. per bird. If birds are to be killed earlier then producers should attempt to obtain the same weight from each square foot of house. In this way the income will not be reduced.

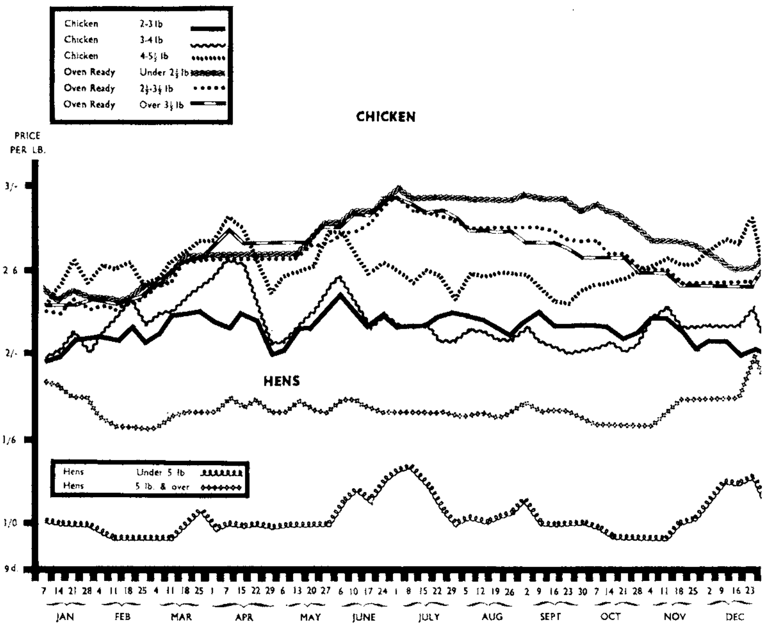

FIG. 18. Table poultry prices chart, 1966. (Comtel Reuter based on maximum Smithfield Market Daily Price List.)

The following are the level of the costs (other than feed and depreciation) relating to 3¼ million broilers, costed during 1965. Contrasted with this are the above average (best 50 per cent) results from half a million broilers costed during 1966 (average crop size 9061 birds):

Depreciation will vary depending upon the cost of house and equipment and the rate of depreciation, but it is generally around 3d. per bird. If this is considered an average cost then total costs excluding feed will be in the region of 2s. 3d. per bird.

Feed is the largest single cost item in broiler production and particular attention should be given to feed wastage. The installation of bulk bins can also lead to a useful saving in feed costs.

	1965		1966	
	s.	d.	s.	d.
Chick	1	3·14	1	3·62
Grit		0·06		
Litter		0·62		0·68
Heat and Light		1·88		2·06
Medication		0·93		1·23
Vaccination		0·81		
Labour		2·61		2·68
Water		0·11		0·12
Rates		0·73		0·63
Miscellaneous		1·15		1·11
Insurance		0·39		0·42
	2s.	0·43d.	2s.	0·55d.

Turkey Production

The principles outlined for broiler production also apply to turkeys. In both cases the use of first-class stock with a high level of performance increases profitability although the initial cost is higher.

The following costing is typical of those rearing poults to 16 weeks of age, and is based on three flocks totalling 31,434 turkeys (1966):

PERFORMANCE AND MARGIN OVER FEED COSTS

Average age sold	111 days
Average liveweight	13·16 lb.
Mortality	12·00%
Feed conversion	2·87
Feed cost per lb. liveweight	1s. 2·14d.
Feed cost per bird	15s. 6·13d.

COSTS OTHER THAN FEED PER BIRD SOLD

Poult	7s. 9·68d.
Litter	3·46d.
Heat and light	7·77d.
Medication and vaccination	2·22d.
Labour	1s. 2·43d.
Miscellaneous costs	1·87d.
Depreciation of house and equipment	1s. 0·90d.
Total	11s. 4·33d.

The importance of records and costings is being increasingly recognised in all branches of the poultry industry. Their continued increase in application and provision of useful accurate information should form a foundation on which many producers can build their businesses.

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Chapter 14

INTEGRATION AND AGRIBUSINESS

W. H. NAISH

The revolution in production, processing and marketing which has characterised the growth and development of broiler industries throughout the world has brought new thinking into the business side of agriculture. With it have come new terms, Agribusiness being one, meaning of course a study of the business of agriculture. It was invented by Davis and Goldberg (1957) of the Harvard School of Business Administration, and can be defined as the sum total of all operations involved in the manufacture and distribution of farm supplies, covering production, processing and storage operations, as well as distribution and marketing.

Amongst other matters it is concerned with many contracts and integration practices which result in lowered costs and improved marketing, and which automatically give greater stability to the industry.

Whilst the main concept of Agribusiness started with broilers, it has spread to the mass production of eggs and turkeys, and it can also be applied today to certain aspects of pig, veal and beef production too.

The multiplicity of small farm units which characterised Britain only a few years ago is rapidly giving way to larger, more efficient farm operations owned or managed by a limited number of consortiums, which are applying strictly business methods to their operations. In this context the introduction of automation in its many forms has released a considerable number of farm workers, many of whom have now left agriculture for good.

The aim, as always, is to find out what type of article is required and in what quantities and prices, and then to set about producing it 'at least cost' using computers and other aids when necessary. The scientist is able to supply a considerable amount of know-how, but many forms of research are necessary to keep ahead of one's competitors.

Integration within the U.K. broiler industry takes two forms—vertical and horizontal.

Vertical integration means that all operations necessary for the production of a given article are under the control of one individual or company, so that the whole is treated as one single enterprise.

The Nottinghamshire firm of J. B. Eastwood Ltd., provides a typical example of vertical integration. This company, of which Mr. J. B.

Eastwood, who exercises complete control, is chairman and managing director, is engaged in the production of broilers and commercial eggs. The company which first started with broilers, has plans to produce 30 per cent of the total U.K. broiler requirements, and 20 per cent of the commercial egg market. Eastwoods own and control breeding flocks, hatcheries, growing and laying units, feed mills and egg and broiler packing stations. Under such conditions the size of each operation can be accurately gauged to requirement with the result that all equipment, plant and housing is always working to full capacity at the lowest possible cost. To operate on such a scale calls for high standards of management in the day-to-day running of the various operations, for a breakdown in any one can disrupt the whole process by causing a chain reaction, and this would prove most costly. Provided the vertical integrator can operate according to plan he should always be at an advantage over the independent specialist packer or producer. The capital required, however, is such that it is usually prohibitive for the majority engaged in broiler or egg production to even contemplate vertical integration.

Horizontal integration allows an enterprise to retain its individuality but by co-operation with similar enterprises enjoys the benefits of volume trading. Producer broiler groups are a typical example of horizontal integration.

Some packers, however, operate under both methods of integration, in so far as they grow some of their own bird requirements, and purchase the remainder from independent growers. Most packers operating on this basis own their own breeding flocks and hatchery so that they can rely on a readily available supply of day-old chicks at a known price and quality. The hatchery is built to a size which enables sufficient chicks to be supplied to all the growing units operating within the packer's group, amounting to a total production equal to that of the total packing station processing capacity.

The importance of maintaining the hatchery output and packing station throughput at maximum is vital, as this has a great influence on costs. For example, if a hatchery with a total hatching capacity of 160,000 chicks per week is only hatching 80,000, then overall net profit per one hundred is reduced by 75 per cent. Similarly, a packing station working to full capacity at the rate of 100,000 birds per week will incur costs of 1s. per lb. to cover all processing, selling and advertising costs. If, however, the throughput should drop to 80,000 birds per week, then costs are increased by ½d. per lb., and if to 60,000 birds, by 1½d. As packers' margins are in the region of 1d. per lb., this can soon be lost unless full throughput is maintained. It is for this reason that packers have to integrate so as to be guaranteed an even and regular quantity of birds. Where packers own their own growing units, the phasing of production is comparatively easy, but when dealing with independent growers, careful planning and co-operation is essential.

Growers have to accept a certain amount of direction from the packer. Apart from having to maintain certain standards of management, they are told when to be ready to receive their day-old chicks, and also the date when the packer will be collecting the birds for killing. The advantages to the grower more than offset this slight loss of liberty, in so far as he knows he has a guaranteed outlet for his birds, at a price already agreed upon—packers usually announce to their growers each quarter the price they will be paying—and he also enjoys other benefits provided by the packer in the form of vaccination and general advisory services.

The formation of groups has not been initiated altogether by packers, some have been promoted by chick breeders, and others by broiler producers themselves. Regardless of the origin of such groups, the focal point is always the packing station, for it is from here that the final product will ultimately be sold.

Some packers accept responsibility for the purchase of feedingstuffs for their group and in so doing, through bulk buying, obtain price concessions which are passed on to their producers. In some instances packers make credit arrangements for producers whereby payments due from the producer for chicks and feed are made to the feed and chick supplier by the packer, at the end of each crop; the producer being paid the difference between these two items and the value of the birds sent to the packing station. Such a practice is known as 'crop credit', and whilst it has the advantage of helping producers over periods of financial embarrassment, as with all credit arrangements, additional cost is incurred as interest charges are always made.

The commercial egg industry is following a pattern similar to that of the broiler industry and egg packers, aware of the need of securing a regular supply of eggs to maintain full throughput and meet market demands, are entering into contractual arrangements with producers. These contracts usually stipulate the type of bird and brand of feed the producer must use, and also insist on the producer sending his total production of eggs to the packer. In return, the packer agrees to make bonus payments based on quantity, these being in addition to the current price for eggs as laid down by the British Egg Marketing Board. Packers with such contracts negotiate with chick suppliers and compounders to obtain special price concessions which are passed on to the egg producer either by direct payment or in the form of an additional bonus from the packer.

Many packing stations have been taken over by larger operators, and others have formed consortiums which enable co-ordination of their egg supplies. By this means negotiations with large buyers such as chain stores and supermarkets can be conducted whereas if each packer operated independently such trade would be unobtainable to him.

With the rapid decline in the number of egg producers in the country and with the growth of larger units, egg packers are in a most vulnerable position, and consequently have to find means of securing a reliable source of supply. They are doing so either by offering contracts as described, or by investing in laying flocks themselves. The cost of doing the latter on a large scale is generally found to be prohibitive, but the danger lies in the fact that some large-scale egg producers plan to build their own packing stations, and develop their own marketing outlets. As most of these producers already have their own breeding flocks and hatcheries, apart from the manufacture of their feed requirements, they would soon become fully integrated units.

One type of contract which is becoming more popular amongst commercial egg producers, is that being offered by national hatcheries and to a lesser extent by egg packers, in the form of a credit agreement. Producers usually have to sign a contract which requires them to agree to have a minimum size laying flock of 2000–3000 birds, and provide the necessary housing, labour and equipment. The contractor undertakes to supply the pullets, feed and advisory services. The birds remain the property of the contractor, who is responsible for their disposal at the end of the laying period. Pullets are purchased usually from approved contract pullet rearers, and are put into the laying cages at 18 weeks of age. The producer is paid at 4 weekly intervals, at a rate of £2 per every 100 birds alive at the beginning of the month in question. These payments provide working capital, but are debited to the producer's account, as also are the cost of pullets, feed, vaccination and insurance. All eggs produced have to be sold to a packer nominated by the contractor, who operates the scheme as one large consortium. Consequently the monies due for all eggs sold, are paid direct to the contractor by the British Egg Marketing Board, and these sums of money are credited to the producer's account, as also is the money received from the sale of the birds. At the end of the contract period, each producer receives a statement showing his position, and if this reveals a proft then this is sent to him. On the other hand should there be a debit balance, this is carried forward to the following year.

Under the government contract scheme which is administered by the British Egg Marketing Board, producers operating under contractual arrangements as described pass their entitlement to the contractor. Should, however, the producer wish to terminate his contract, then the contractor undertakes to return the entitlement to him. Whilst under contract, however, the producer still retains the right to vote during the British Egg Marketing Board elections.

National feed compounders have not yet allowed themselves to become too deeply involved in farm production. Although some have financial interests in broiler and egg enterprises, they do not as yet exercise complete control. The fact, however, that they have some direct financial stake in the industry puts them in a position, if ever circumstances developed which threatened the outlet for their feeds, to secure their markets by further investment, and become fully integrated themselves. From experience gained from America, compounders in this country would prefer to maintain their present position, but how long this can continue only time can tell.

From what has been written it will be realised that the poultry industry is rapidly ceasing to be a general farming activity. It must not, however, be underestimated that much of the country's production of eggs still comes from the general farm, and whilst big business may always constitute a threat, the small egg producer will continue to make a considerable contribution to the country's egg production. Such producers are usually general farmers who are able to keep costs of production very low by the use of family labour, and the adaptation of existing farm buildings. In addition they have the opportunity of joining local buying groups whereby they can purchase their feeding-stuffs, fertilisers and other essential requirements at most favourable prices.

Buying groups are co-ordinated by Agricultural Central Trading Ltd., which is a company sponsored by the N.F.U. Its main objective is to help farmers, who must be N.F.U. members, reduce production costs. To achieve this, A.C.T. Ltd. negotiate favourable terms with manufacturers under which their product can be made available to farmers who are members of a buying group.

The company, whose head office is at Chesham, employs a number of staff known as secretary agents. Their duties include dealing with the orders from group members, and attending group meetings which are held each month. Groups elect their own chairman, and at the monthly meeting the secretary agent informs the group of any price changes, and he will also take orders from members. Secretary agents operate from regional offices under the direction of a regional controller. There are ten regional offices in England and Wales spreading from Cornwall to Northumberland. A.C.T. Ltd. will open more as the growth of buying groups develops.

A buying group as mentioned is entirely directed towards reducing farmers' production costs. Unlike producer groups, no help is offered towards marketing finished products. Farmers, therefore, who have a problem in this respect can if they wish join a producer group, as membership of one does not necessarily preclude membership in the other.

The future will see groups increasing in size, either through recruitment of individuals, or by mergers with other groups. All engaged in the production of eggs, broilers or turkeys will not only have to be highly efficient, but also operate from strength. Integration goes a long way in helping to achieve both.

Agricultural Trading Societies

The co-operative movement in the U.K. was founded by the Rochdale Pioneers in 1844, the first Agricultural Trading Society being formed in

1867. There are now 500 such societies with a turnover of nearly £300 millions and a membership of 425,000. Mergers between different societies have taken place to meet changing conditions, and in England 75 per cent of the trade is now controlled by 22 of the 277 Agricultural Trading Societies.

Some co-operatives are engaged in the grading and marketing of eggs, others also being concerned with broiler processing and marketing. So as to ensure a regular supply of eggs some societies are directly involved in commercial egg production, and are therefore operating on a partially horizontal/vertical integrated basis.

Benefits from negotiations with hatcheries, feed compounders and appliance manufacturers are passed on to members supplying eggs under contract, who also receive certain premium payments.

The setting up by the Government, under the 1967 Agricultural Act, of the Central Council for Agricultural and Horticultural Co-operation, will undoubtedly result in more farmers operating under a co-operative partnership basis.

READING MATTER

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To give a concrete example of the way in which integration can be highly successful we would like to quote facts regarding the J. B. Eastwood poultry empire.

Eastwood's Vertical Integration Operations

J. B. Eastwood Ltd. (Warsop, Notts.) which was formed in 1959 as a holding company, represents Britain's largest fully integrated poultry concern, employing vertical integration methods to the full. Its output at present represents about 15 per cent of the total broiler production of the country. Likewise in egg production, with 1 million layers in 1967 rising to 12 millions by 1975, this too will represent about 20 per cent of the total U.K. figure.

The firm designs and builds its own houses—domestic, poultry, breeding and production, processing and packing, etc.—and owns more than 12,000 acres. Much of this is for grain growing for Eastwood has its own feedmills, transport, etc. So far as broilers are concerned it is definitely the largest fully integrated operation in the world.

Broilers

The company plans to have ten 'chicken cities', of which four are already operating in Notts., Lincs., Norfolk and S. Wales (two more are being developed in Yorks. and Scotland), with a current output of over 640,000 broilers weekly. The eventual figure could be 1½ million. Each self-contained site requires thirty-seven acres of buildings and an investment of £1¾ million. It has 4 × 25,000 bird breeding units (mainly Cobb, but Arbor Acres, Hybro and Starbro are under test); twelve broiler house sites with a total capacity of 1¾ million birds; an 800,000 egg hatchery with an output of 160,000 chicks weekly, and a feedmill. One man and two assistants deal with the routine work of 132,000 broilers, which are reared to 4-lb. liveweight in less than 10 weeks with a feed conversion of 2·5–2·6:1. (These figures are higher than usual due to the fact that Eastwood prefers to use cheap home-grown grain with a lower energy content than maize.)

Each processing station deals with 3500–4000 carcasses/hour, having a single shift capacity of 140,000 birds weekly. All carcasses are sold whole (eviscerated), polythene packed and quick-frozen. Before going into the tunnel freezer at 40 degrees below zero, the carcasses pass through a contra-flow chill tank, the temperature at the outlet being 35° F.

The finished products (*'Kentucky'* and *'Rufford'* are typical brand names) are distributed to about 100 wholesalers or supermarkets, many in company-owned vehicles.

Layers

So far as layers are concerned each Eastwood house now contains 30,000 birds in Californian-type cages; there are five laying houses per site and thirteen such sites represent one Unit. Thus each Unit has a laying population of around 1½ million birds.

Up to the present planning consent has been obtained for housing 12 million birds.

Experience to date indicates that a hen housed average of 220 eggs per bird during a 50-weeks laying cycle is satisfactory, with not more than 5 per cent second grade eggs.

As with broilers each Unit is self-supporting, having its own hatchery, feedmill and packing station for both eggs and birds (after they have finished their laying year). The breeding stock to supply the commercial layers are bought in as day-old pullets, every 14 weeks.

Following his initial training in the contracting and building business (Adam Eastwood & Sons Ltd.), John Eastwood sees to it that careful cost accounts are kept of all sections of the business, and it is as a result of the economies made and efficiency gained that the business has flourished where others have failed. In fact the company's profit for the year ending March 1967 was £1·75 million compared with £1·02 million for 1966.

Allied Farm Foods Ltd. provide another example of a highly successful, vertically integrated business, profits for the current year being £1·45 million compared with £1·00 million for 1966. The company owns six packing stations and six feed mills and the total weekly throughput of broilers now exceeds 600,000. A commercial egg-laying flock totals 150,000 birds, but turkey production is particularly extensive, the company having the sole franchise in Europe for the '*Wrolstad*' turkey. During 1967 production will amount to 650,000 poults, and plans are in hand to expand this to 2 million in 1968.

The Application of Econometric Techniques to Animal Production

The Americans use abbreviated combinations of words like Agribusiness, and in discussing certain aspects of housing farm livestock Professor E. I. Heady (1966) of Iowa State University recently introduced the subject of econometrics as applied to optimal planning and investment at a B.E.M.B. Conference. In this context production functions are equated with appropriate price ratios, from which calculations can be made which should indicate the optimal investment in alternative building arrangements and other inputs. Ideally these production functions should include temperature, humidity and other variables relating to environmental control. Equation of their derivatives with appropriate costs would then specify the economy and extent of environmental control, but much of the factual information required is often lacking.

One must agree that mathematical programming provides a powerful tool for econometric analysis, and that this should result in improved decisions in animal production. Investments in housing affect production costs partly because of the primary expenditure, but also through the non-fixed building components which will vary with the number of birds to be housed. This may be near-linear for rectangular buildings, or of a decreasing function for square-shaped structures. As a contrast variable costs (feed, labour, chicks, etc.) will alter directly with the number of birds. If several alternative types of housing are being considered, the total costs per annum (for any one of the systems) can be obtained from an appropriate formula.

Control over environment affects bird numbers as well as feed intake, and there is clearly an optimum amount which should be spent on this aspect of a housing budget. Furthermore, investment in buildings and equipment can also be a substitute for labour, due to the economics effected by mechanisation.

Simple cost curves for different housing systems can be computed, and as such represent an example of the rather simple econometric approach for a choice of optimum housing methods. Farm management economists, therefore, should be able to assist farmers interested in this subject, by assembling the requisite data to provide cost estimates for comparing different housing systems.

Similar mathematical exercises can be carried out for broiler production. Outlay of capital in relation to size and shape of house; degree of environmental control (quality of insulation; fan capacity; air filtration, etc.); floor space per bird; age and weight at killing (in relation to market requirements), feed intake, etc. All need careful study.

Are there worthwhile advantages to be gained for example by raising the standard of insulation from an average 'U' value of 0·15 to less than 0·10 by installing an extra inch or two of fibreglass in the roof, or by double-glazed windows? Will the incidence of infectious diseases be sufficient to offset the cost of installing air filters?

Increased numbers of birds (reduced floor space/broiler) should bring in a greater income, but only if the birds reach the estimated weight in the required time and are not subsequently downgraded. Here, then, there comes a point below which one should not go in terms of minimum floor space because, apart from all else, mortality will rise and cruelty may also result.

In terms of econometrics one determines the magnitude of the inputs (building investment, labour, bird numbers, feed, etc.) and then studies them stepwise. Ideally some of this data should also relate to weight gains, energy and protein intakes, space per bird, etc. From such data the production functions can then be estimated, and decisions based on the optimum results taken.

Similarly a prediction for the most profitable marketing weight, using all possible prices of the feeds and broilers could also be made. One can then attempt to forecast what will happen if there are fewer birds fed to heavier weights, or more birds marketed at lighter weights. Diminishing productivity of either feed or birds arises, if the one is increased and the other held fixed.

The least-cost combination of ration and birds (to produce a given gain) can be determined by equating an appropriate formula to the price ratio; cost of birds being divided by cost of the ration. (Costs of building space must also be considered when calculating per bird costs.) In this way one can make a more systematic approach to specification of resource combinations in poultry production, rather than the rule of thumb methods so commonly used.

Literature

For a detailed explanation of the methods and procedures in model formulation, the reader is referred to *Linear Programming Methods*, by Earl O. Heady and Wilfred Candler (1959), Ames, Iowa, U.S.A., Iowa State University Press. Also *Models for Production and Operations Management*, by E. S. Buffa (1963), New York, John Wiley & Sons, and *Linear Programming and Economic Analysis*, by R. Dortfman *et al.* (1960), New York. McGraw Hill Co.

For more information on Integer programming two texts should be consulted—*Linear Programming and Extensions* (1963) by G. B.

Dantzig, Princeton, U.S.A., Princeton University Press, and *Economic Theory and Operation Analysis*, by W. J. Baumal (1963), Englewoods Cliffs, U.S.A. Other models relate to risk and uncertainty factors. For a study of these and other econometric aids to poultry production *Agricultural Production Functions* by Earl O. Heady and John L. Dillon (1961), Ames, Iowa, U.S.A., Iowa State University Press, is recommended.

A new book, *Linear and non-Linear Programming in Industry*, by N. Williams of the Unilever Organisation Division, has been published by Sir Isaac Pitman and Sons, Ltd. at 35s. This too is obviously well worth studying.

REFERENCE

Heady, E. I. (1966) B.E.M.B. Conference, Harper Adams College, 'The Application of Econometric Techniques', 21st Sept.

Chapter 15

HOUSING SYSTEMS AND CONTROLLED ENVIRONMENTS FOR POULTRY

W. P. Blount

Many people think that to house poultry intensively today implies the sole use of fan ventilated, fully insulated windowless buildings lit by electricity, but this is not the case. Whilst these newer buildings offer the poultryman the opportunity to control the environment in terms of lighting, ventilation and temperature, we are still some way from judging which exact standards to adopt for optimum production. It is in fact still possible to obtain excellent results from layers and turkeys housed in buildings with windows and which are not fully insulated, although electric lighting is usually essential.

Free Range

Housing poultry on free range provides them with cheap food, but for productive purposes this is too bulky and it also requires supplementation with those nutrients which are lacking in grass, grain, insect life, etc. Although housing costs are low these are offset by much higher labour charges, but the picture is compensated to some extent by the free manuring of the pastures.

Confining poultry semi-intensively, to try to get the best of two worlds, was popular pre-war until disease build-up forced many producers to use more intensive methods; in addition to which the greatly reduced grazing area of the semi-intensive system automatically cut down the supply of cheap natural feeds.

Deep Litter, Wire and Slatted Floors

The American system of housing layers on deep litter became popular in Britain around 1947–48, some years later receiving Ministry approval for breeding stock. But the higher humidity of our climate and poorer standards of management soon showed that deep litter could not necessarily be used successfully when the stock were being given 3–4 sq. ft./bird of floor space. This provided too little body heat for wintry conditions, and resulted in many wet litter problems.

To overcome this farmers provided their stock with a slatted floor, sleeping compartment which automatically removed the nights droppings from the litter, thus allowing an increased stocking density. The slats covered about one-third of the total floor area, but it was not long before pioneers like Watkinson used *all* wire floors with communal nests. (This is one of the so-called 'Loose Housing' systems of the Brambell Committee.)

For several years slatted or wire floored houses appeared to be the most economic method for housing laying stock (allowing each pullet 1–1¼ sq. ft. of floor space), but whilst these heavier concentrations of

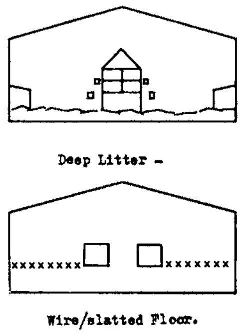

FIG. 19. Housing systems for poultry.

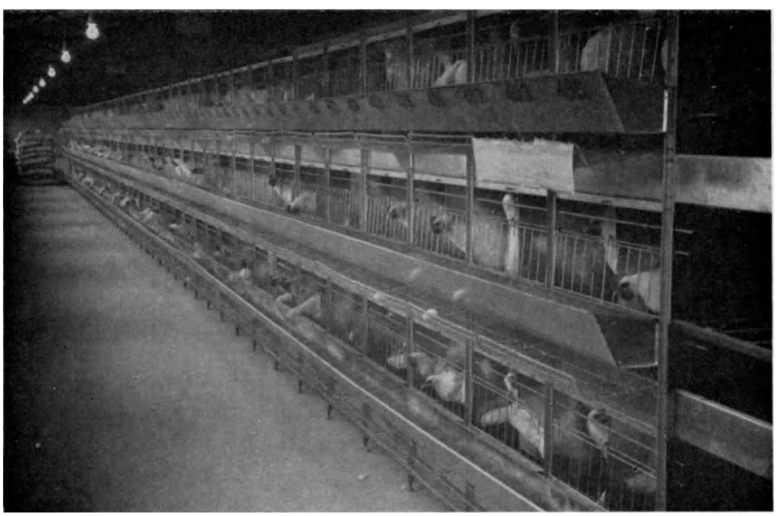

FIG. 20. Dunblane 3-tier unit laying battery cages with continuous feed troughing. Electric lighting is used at Stoke Mandeville to supplement daylight.

poultry sometimes overcame wet litter and temperature problems, nesting and egg collection complications occurred. Floor eggs increased and many new designs of nests were tried to entice pullets to lay in them. Today however many of these houses have been abandoned in favour of hen batteries, where control of stock is simpler and nesting problems no longer a feature.

Hen Batteries

Single bird laying batteries became popular soon after World War II, but after it was shown that 2, 3 or more birds could be housed together with little adverse effect on egg production, producers soon put from 4–10 birds to a cage, providing each pullet with little more than $\frac{1}{2}$ sq. ft./bird. In some instances cages were re-designed so that they would take from 20–40 pullets without any increase in mortality or decrease in egg production (Jennings 1965).

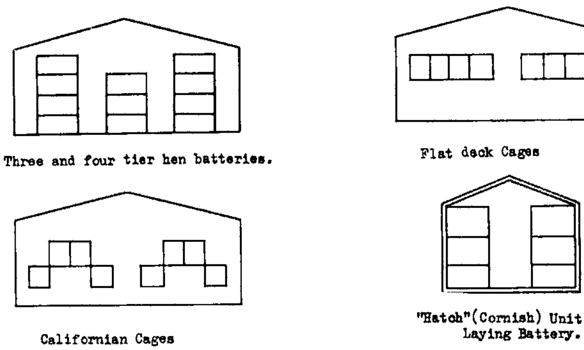

FIG. 21. Four popular layouts for laying batteries.

The Brambell Committee has since recommended that no more than 3 birds should be housed in a 20 in. (frontage) hen battery, an allowance which is considered to be far too generous and completely unjustified.

It was natural to try housing pullets in multi-bird cages and economic studies have convinced the majority of commercial egg producers that 4–6 birds per cage (allowing 4 in. of cage frontage per bird) is best although a small number of producers still favour the larger units.

Hen batteries underwent many other changes, for example numbers of tiers increased from two to six, but three or four-tiered units soon proved most popular. Water troughs were changed from galvanised iron to plastic, and later still from communal troughing to nipple drinkers, one of the latter serving the needs of 4–8 pullets.

At first pullets were fed individually by hand. Then came the use of continuous troughing which could be filled more quickly, followed by the introduction of cafeteria units operated mechanically, some of the latter moving continuously up and down or round the units of cages. Furthermore, instead of emptying bags of feed into the six individual hoppers of a three-tier unit, feed was augered from a main hopper outside the building holding 5–10 tons direct into smaller hoppers at the end of each row of cages. In a few instances the feed was metered in at the same time, so that a rough check could be kept on the amounts consumed daily in the belief that this would enable the poultryman to detect the beginnings of an outbreak of disease a day or two before any other clinical symptoms appeared. The wisdom of installing such equipment is, however, still in doubt because of the difficulty of interpreting the data.

FIG. 22. The latest method of supplying drinking water to fowls using nipple drinkers.

Controlled Environments

The move to a fully intensive system of husbandry took place gradually during the 'fifties, after it became clear that layers were more easily handled (thus reducing labour charges) and their egg production higher. Many reports showed that 30–40 extra eggs per bird was not an unreasonable increase to be expected from pullets housed intensively. B.E.M.B. (1966) statistics indicate that this egg production differential still applies—Free Range 168 eggs; Deep Litter 191 eggs; Hen Batteries 216 eggs; average 202 eggs/year.

This change in housing was accelerated by developments with broilers, because these just cannot be reared economically in any other way, and this industry, which only began in 1953, wisely adopted fully intensive housing systems. It was here that fully 'controlled environments' soon came into being, and their success encouraged egg producers to do likewise, but it has to be realised that the total cost of controlling temperature and humidity may be as high as 15 per cent of the total fixed capital invested (ffiske 1966).

In the case of turkeys, once it was seen that the Motley veranda

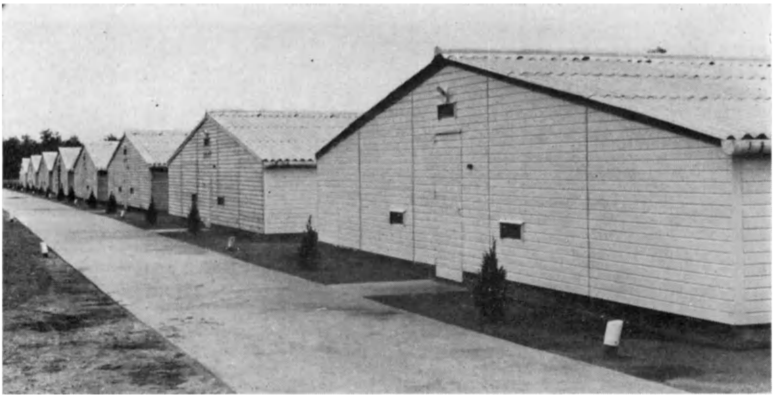

FIG. 23. Where land is limited controlled environment, intensive poultry houses are often sited close together; but with an all-in, all-out policy the risk of a build-up of infection is considerably reduced.

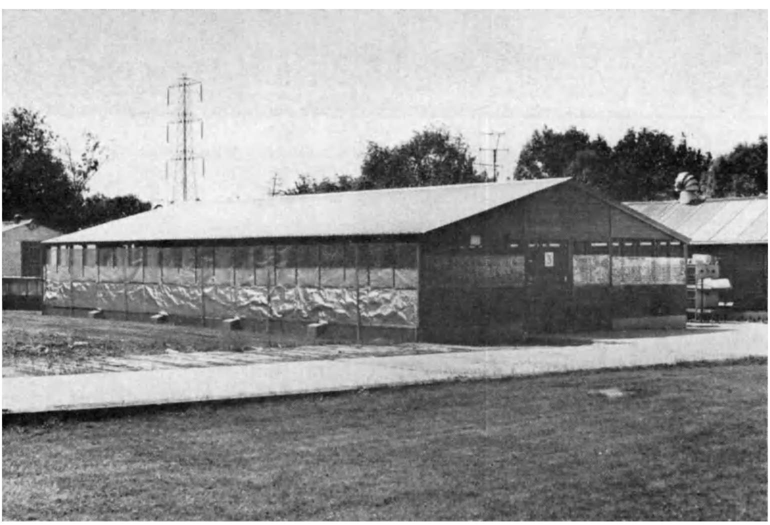

FIG. 24. Aluminium foil ('Sisalation') is invaluable in the summer months for protection against strong sunshine.

system could be improved upon, nearly all poults were reared indoors, and nowadays many flocks have fully controlled environments, at least during the brooding period. Once poults have passed the 8–10 week stage they can go outside if their rearing period coincides with warm weather (May–September); but it is false economy to keep them there when low temperatures are encountered (November–February). Their feed conversions rise sharply due to a combination of heavier bodyweights and colder weather conditions.

Those environmental factors over which farmers contrive to have good control are temperature and insulation, light and ventilation, humidity, density (floor space), noise, equipment (feeders and drinkers) and the control of certain diseases.

Temperature. A clear distinction must be made between brooding and room temperatures, the former starting at about 90–95° F for chicks and ducklings, and 95–102° F for turkey poults. A reduction takes place daily or weekly so that their brooding temperatures coincide with room temperatures at the time when the bird's feathering provides a good insulating layer. Ducklings feather more rapidly and may be taken off heat by 3 weeks of age (2 weeks in summer), contrasted with chicks at about 4 weeks and poults at 5 weeks.

Room temperatures should be around 75° F at first, but the regular reduction mentioned must be such that they don't fall below 60° F before stock (chicks and poults) are 6 weeks of age. Otherwise huddling will take place at night resulting in chilling, smothering and an uneven growth rate. Draughts must be excluded (air velocity over 70 ft./min.) from the brooding quarters (Payne 1961) or chilling will again take place. Whenever groups of young chicks or poults are seen massed together (instead of being more evenly spread) a careful survey of the brooding quarters should be carried out to check on errors in management.

Chicks have poor control over their body temperature during the first 7–10 days after hatching (related to their reptilian ancestry), hence their dependence upon, and need for, a broody hen or her equivalent. Therefore unless environmental temperatures conform to the physiological needs of the bird, the following reactions will take place: a desire on the part of the bird to make contact with something warm, e.g. huddling with other chicks; eating litter (instead of food); a loss of bodyweight, dehydration of the shanks and death. About 1 per cent of chicks die from this cause, characterised post mortem by a congestion of the lungs and kidney, unabsorbed yolk sacs, empty or semi-impacted gizzards, some containing only dark fluid extending into the small intestines. The source of heat for brooding purposes is important, because radiant heat (infra-red) rays do *not* warm the air and cannot be used for space heating purposes. The modern tendency is to use either hot air (room) brooding, or smaller gas brooders which combine an output of convected hot air with infra-red rays.

Few experiments have been carried out in this country to show the benefits of giving layers supplementary heat. The cost may be worth while from a cheap source (oil-fired), but electrically heated floors in deep litter houses do not offer economic advantages in our experience.

During 1966–67, to maintain room temperatures during the winter months cost about 10d. per pullet at Stoke Mandeville, the air being heated before filtration.

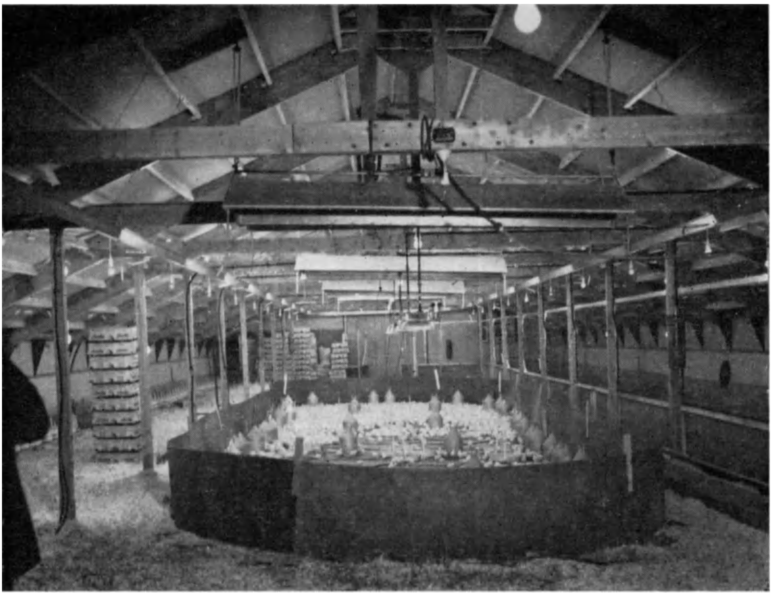

FIG. 25. Larger groups of chicks are now brooded together without adverse effects. In this unit 4500 broilers weigh 4¼ lb. at 8 weeks (mortality 2.78 per cent). Four gas brooding units were used with only one surround.

For layers whilst 55–65° F may be optimal commercially, anywhere between 48° F and 75° F is considered satisfactory. When room temperatures exceed 85–90° F panting occurs (particularly if humidity is high) as an aid to thermo-regulation by loss of latent heat of vaporization. Up to 10 gm./hour of water may be lost due to increased respiration (Lea *et al.* 1945). Payne (1966) has recently suggested that a fluctuating temperatue of 84° F by day and 65° F by night may give beneficial results. Weir (1966) has calculated that an increased gross margin of over 2s. 9d. per bird is possible with this practice.

Cost and Output of Different Fuels

Town Gas. Lower prices can be expected following the North Sea discoveries.

1 Therm = 100,000 B.t.u.

Various tariffs are available, but the Credit Block Tariff will suit the smaller user (cost 28·5d. for the first 100 therms/quarter), whereas large scale users will prefer the Commerical Heating Tariff (17·5d. per therm, plus £13 standing charge per quarter).

Bottled Gas (Propane). The cheapest sources relate to bulk quantities (1–5 tons) stored in pressurised containers on the farm. Prices range from about 4d.–7d./lb. (21,600 B.t.u./lb.).

Electricity. As with town gas various tariffs apply, ranging from 0·7d. off-peak tariff to 1·7d./kW for standard domestic use (3412 B.t.u./kW).

Oil. Domestic paraffin costs from 1s. 9½d. to 2s. 1d. per gallon, diesel oil (35 sec. gas oil) from 1s. 6d.–1s. 8d. The latter supplies 165,000 B.t.u./gallon.

Coal. Solid fuels differ in price according to quantities ordered, distance from coal mine, time of year, etc.

Household coal ranges from about £13–£16/ton; coke (2 in.) from £16–£19/ton and Anthracite from £18–£21/ton. (Output of coal 14,300 B.t.u./lb.) Comparative costs per 100,000 B.t.u. are as follows:

Town gas—1s. 3½d.–2s. 4½d.
Propane gas—1s. 1·8d.–2s. 8·4d.
Electricity—1s. 11·4d.–4s. 1·8d.
Oil (paraffin)—1s. 1d.–1s. 3d.
Oil (diesel)—9d.–1s.
Coal—1s. 0d.

Light. Whereas light has marked effects on the output of pituitary gonadotrophins and therefore on egg production, it is not a growth stimulant except for the fact that without it poultry cannot see to eat.

For *layers* both the intensity and duration of the light are important. Morris (1966) showed that less than 1 ft. candle (10 lux) does not provide optimum stimulation to the pituitary gland, and that higher levels are slightly more beneficial. Whilst the latter may not appear to be of any significance if there are only a few birds, when dealing with thousands of layers the result can be highly economic. A 1 per cent improvement daily on 20,000 eggs is 200, equal to the extra income obtainable from more than 16 dozen eggs, i.e. 50s. per day!

Forty to sixty watt lamps hung at 10 ft. intervals 6 ft. from the floor are generally used to provide the necessary 1–3 ft. candles at the level of the bird's head. Lower powered lamps (15–25 watts) often fail to provide the optimum stimulus. At the other end of the scale 1500 watt lamps can be used (to illuminate deep litter housed birds) for only one minute, since this appears to provide the same stimulus to egg production as 1 hour of ordinary electric lighting. No advantage is to be gained by layers from the use of particular coloured lights, eg. north (white), peach (pink), etc.; but red lighting has a slightly tranquilising effect. (Some producers prefer this to debeaking in order to quieten flighty pullets.) Poultry do not appear to see red objects clearly (e.g. blood) if a red lighting pattern is used. Fluorescent lighting is dearer to instal but cheaper to run, however plain incandescent lighting is more popular, and its intensity can be controlled cheaply by a variac dimmer. The duration of the lighted period is very important.

FIG. 26. A conventional intensive poultry house (Pilch grandparent stock) which contrasts with the more fully controlled environment house for similar breeding stock when particular lighting patterns are required.

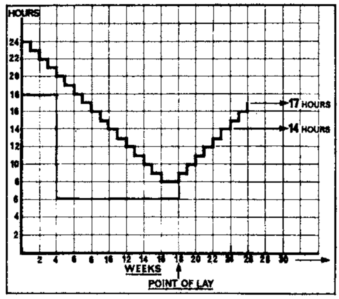

FIG. 27. Example of a step-down, step-up lighting programme for replacement pullets.

Pullet chicks should be started off with a long day, as little as 12 or as much as 23¾ hours, but after 3–4 weeks the light should be reduced to between 6 and 10 hours daily. At point-of-lay (about 18–20 weeks) when the first egg is laid light should be increased, and whereas some pullets reach peak production on a 12-hour day others require 14. To exceed this is seldom necessary, although later in the laying season a steady extension up to 17 hours a day may be beneficial in some cases. Unless the numbers of hours and correct intensity of light is provided at point-of-lay (e.g. 10 hours at 1–3 ft. candles) peak production will not be reached satisfactorily. Weekly increases of 15–45 minutes are commonplace, but it does no harm to start pullets off with 12 hours and even to jump them up if required to 16 hours in the case of stock which are not being housed in a controlled environment, to conform to daylight. Morris and Fox at Reading University have suggested a step-down, step-up system of lighting which is most successful.

Whilst no minimum standard has been set for the light intensity of *broilers*, if the poultryman can see the feeders and other equipment satisfactorily so will the chicks. This implies that there must be ¼ ft. candle (¼ lumen per sq. ft.) available. Many broiler producers believe that their stock benefit by being educated to an alternating lighting system using red or dull lighting for sleeping contrasted with brighter light for feeding, playing, etc. A suitable programme beginning at the end of the first week is 30 minutes white light, 90 minutes red light. This rhythm continuing both day and night.

This is one means of ensuring that the birds do not waste their energies unnecessarily, and it also means that producers do not require to debeak their stock. For students of animal behaviour this lighting programme offers many opportunities for research.

Insulation

Insulation helps to conserve heat so that room temperatures remain within the optimum range required; similarly it helps to exclude solar radiation in the summer which can raise environmental temperatures well above the level required. Heat to be conserved comes from the stock as well as any supplied artificially, and the less of the latter the better, because of cost.

Heat Losses. As hot air rises heat losses through the roof prove greatest which is why this structure must be insulated as completely as possible, particularly as its surface is considerably greater than that of the walls. The latter lose more heat proportional to the area of glass windows present, unless these have been double glazed. Heat loss through the floor is negligible if covered by a deep layer of suitable litter.

Three sets of data are required, (*a*) what range of temperatures is satisfactory, (*b*) heat input, and (*c*) sources of heat loss.

House Temperature Range °F

Chicks and Broilers	75–60
Growers	60–45
Layers	75–45

Heat Output (approx.)

Bodyweight (lb.)	*Direct Heat Output* (B.t.u./hr.)
0·5	10
1·0	17
2·0	21
3·0	27
4·0	35
5·0	44

Examples:

(i) 10,000 broilers weighing 2 lb. produce 210,000 B.t.u./hr., an output equal to 61·5 kW (3412 B.t.u. equals 1 kW).

(ii) 1000 × 5 lb. layers produce 44,000 B.t.u./hr. sensible heat, plus 11,000 B.t.u./hr. latent heat. (*Sensible* heat affects room temperatures directly. It contributes about four-fifths of total heat output when temperatures range between 40° and 70° F. Latent (insensible) heat plays no part in heating the air, but at high temperatures (over 90° F) latent heat loss represents about two-fifths of the total. *Note:* 0·018 B.t.u. are required to raise the temperature of 1 cu. ft. of air by 1° F.)

Thermal Conductivity ('K') is a specific property of a material and is a measure of the rate at which heat will pass through a material 1 in. thick when a difference exists between the temperature of its surfaces. ('K' = B.t.u./sq. ft./in./hr./° F.) Test materials should have been stored at 64° F, 65 per cent R.H., and to be classed as an insulating material it should have a 'K' value of less than 1·0.

Insulating material	*K value*	*Approx. relative cost per sq. ft.*
1. Asbestos cement sheet	1·5–2·0	7½d.
2. Breeze block (4 × 9 × 18)	4·0	11d.
3. B.P. insulation board (bitumen bonded)	0·39	6½d.
4. Brick (common)	6·9 outer 4·5 inner	11½d.
5. Celotex (½ in.)	0·35	6d.
6. Concrete blocks (4 × 9 × 18) solid (6 × 9 × 18) hollow	5·2–10·0	1s.
7. Expanded polystyrene (Poron) ½ in.	0·2	5½d.
8. Fibreglass 1 in. Crown 75 in.	0·26	2½d.
9. Foamed slag block (6 × 9 × 18) hollow	1·7–2·2	1s. 3d.
10. Gyplith (1 in.) (wood fibre)	0·57	7½d.
11. Gyproc (½ in.) aluminium bonded to one side	0·85	6d.
12. Hardboard (⅛ in. tempered)	0·53–1·0	3½d.–6½d.
13. Kimolo (asbestos) board	1·4	9½d.
14. Lignacite block	2·08	1s. 2d.
15. Paramount plasterboard (½ in.)	1·1	5½d.
16. Sisalation (reflective foil)		2¼d.
17. Stramit (2 in.)	0·6	1s.
18. Tentest board (½ in.)	0·34	6d.
19. Thermalite block	1·4	1s. 3d.
20. Wood chipboards (Novabord, Weyroc, etc.)	0·68	1s. 3d.

Expanded polystyrene has become very popular because of its thermal efficiency, cheapness and lightness. Newer products like Styrofoam (Dow) offer greater than average resistance to physical and chemical damage.

Standard hardboards are homogeneous fibre building boards compressed to medium or high density, i.e. exceeding 50 lb. per cu. ft. Tempered and oil tempered hardboards have been further treated to increase their strength and water resistance.

Fibre boards (*Tentest*, *Celotex*, *Insulite*, etc.) are made from wood or other vegetable fibre but the sheets do not go through presses, so the finished product is a light-weight, porous low-density board with low thermal conductivity.

Asbestos board, semi-compressed and flexible for curved linings or compressed and stiff, is specially valuable for all buildings where fire resistance is essential.

Sisalation, a 6-ply reinforced waterproof building paper to which is bonded on one or both faces a foil of burnished aluminium. It is used as a cavity 'split', radiant heat reflector of body heat from livestock, or as an outside reflector of solar heat.

Thermalite foamed slag and other blocks are made of various substances which seek to trap tiny air bubbles in the material: some need rendering.

Wood chipboards are solid boards of varying densities composed of resin bonded wood chips. Useful for partitions, doors, etc.

'R' Values

The 'R' value of a material (a term commonly used in the U.S.A.) is a measure of its resistance to heat flow, applied to any given thickness of the material. 'R' equals 1/K × thickness.

'U' Values

Thermal Transmittance ('U') is the rate at which heat will flow from one side to another of any given material or combination of materials. ('U' = B.t.u./sq. ft./hr./° F.) If building materials get compressed or wet they lose much of their insulating properties. Very careful watch is necessary to see that these matters receive careful attention during building construction.

Surface	*Absorbtivity value for solar radiation*
Black matt	0·85–0·98
Brick	0·65–0·8
Whitewash/paint	0·3 –0·5
Aluminium (dull)	0·4 –0·65
Aluminium (bright)	0·1 –0·4

In Britain the thermal transmittance ('U' value) is preferred as a measure of heat loss from buildings since this concerns air-to-air heat flow, i.e. a measure of the heat which will flow from the air on one side of a roof or wall to the other side. This considers therefore all materials and cavities in the construction of the roof or wall, and not just single materials ('K' value). 'U' value is the reciprocal of the 'R' value, e.g. 'R' = 2, 'U' = 0·5; 'R' = 4, 'U' = 0·25.

The 'U' value represents the number of B.t.u. flowing through 1 sq. ft. in 1 hr. for 1° F. difference in temperature between the inside and outside air (B.t.u./sq. ft./hr./°F). In practice 'U' values for poultry houses should be between 0·1 and 0·2, lower values (higher figures) mean greater heat losses. A high value for roofs is necessary to keep out the sun's rays, hence the special (emissivity) value of materials which reflect radiant heat, e.g. aluminium.

In practice *Snowcem*, aluminium paint, sheeting or foil (*Sisalation*) are commonly used to reflect the sun.

How to Calculate 'U' Values. The main requirements are, (i) 'K' values of the insulating materials, and (ii) certain 'resistance' factors, e.g. internal, external, surface-to-air and cavity.

Internal surface resistances

Walls 0·7
Floors/ceilings 0·6 (upwards heat flow)
0·85 (ditto downwards)
Roofs 0·6

External surface resistances

	Sheltered	*Normal*	*Severe*
Walls	0·73	0·57	0·43

(Different data apply according to whether the walls face, S, N, etc.)

	Sheltered	*Normal*	*Severe*
Roofs	0·4	0·25	0·10

(The resistance of corrugated roofs is reduced 20 per cent because of the larger surface area available for heat loss.)

Note: Under average conditions the external resistance is taken as 0·3, which with 0·7 for the internal resistance gives a combined air to surface resistance of 1·0.

Cavity Resistance

For unventilated cavities exceeding $\frac{3}{4}$ in. width a figure of 1·0 is taken, but if the surface is lined with reflective materials the value rises to 2·0. If less than $\frac{3}{4}$ in. width the value is 0·65, with reflective material 1·0.

'U' value for corrugated asbestos sheeting 1·40; corrugated iron 1·50; the resistance of a cavity between plain and corrugated surfaces 0·50.

Air cavities may be ventilated and enclosed with or without reflective materials. If ventilated the resistance value is lower but water vapour may thus be allowed to escape before it condenses.

Example. Wall construction = $\frac{1}{2}$ in. weather-boarding on a 2 in. studding, lined with $\frac{1}{2}$ in. fibre-boarding.

'K' value of timber	1·0
'K' value of fibre-boarding	0·35
Internal resistance of wall	0·7
External resistance of wall	0·3
2 in. cavity resistance (sealed)	1·0
Resistance of weather-boarding (1/K × thickness equals 1/1 × ½)	0·5
Resistance of fibre-board 1/0·35 × ½	1·43
Total air-to-air resistance	3·93
'U' value 1/3·93 equals	0·25

The inclusion of a 1 in. layer of fibreglass would halve the 'U' figure doubling the insulation value, thus:

'K' value of fibreglass	0·26
Resistance of fibreglass (1/0·26 × 1)	3·48
Total air-to-air resistance	7·77
'U' value 1/7·77 equals	0·13

The variety of materials used in building construction must be considered from many points of view apart from cost and 'U' values, such as load bearing (e.g. brick, concrete); fire and moisture resistance; dust holding properties; weight per cu. ft.; resistance to disinfectants, pecking or other physical damage; attack by vermin, moulds, etc.

Whilst a single brick wall (4½ in.) has no more insulating property than ½ in. of wood, an 11 in. cavity wall with glass fibre or Vermiculite or polystyrene infill makes an almost ideal wall with a 'U' value of 0·14 at reasonable cost if the depreciation is spread over 20 years. Next to fibreglass expanded polystyrene (e.g. *Poron*) provides one of the cheapest and best insulating materials, being available in the form of exceptionally lightweight sheets of every thickness, as well as hollow cylinders for water pipes, infill beadlets, etc.

Air is an excellent insulating medium, hence the use of polystyrene, glass fibre, air cavities, etc. The latter should be sealed whenever practical as the resistance factor is then 1·0 compared with 0·65 for a ventilated cavity. Glass allows the escape of much heat and to double-glaze windows improves the 'U' value from 1·0 to 0·55; cheap substitutes for glass are available such as nylon sheeting or polythene film, but the fitting of these to leave an air gap (sealed) of ¾ in. is important.

Special mention must be made of the need for vapour barriers at any sites where moisture may penetrate, especially roofs, particularly when aerofoil fans are blowing air into buildings under pressure. Also the use of builders' paper as a waterproof lining under weather-boarding. This subject and indeed most other aspects of housing relative to animal health has recently been the subject of a new text by Sainsbury (1967). It deals with both large and small farm livestock and will prove popular with veterinary surgeons.

Ventilation

Whilst fresh air is necessary to provide oxygen, it also functions as a diluent to bacteria, including P.P.L.O., viruses, etc., as well as to noxious gases such as CO_2, CO, H_2S, ammonia, methane, etc. From 1–2 cu. ft./lb. liveweight/min. represents the accepted ventilation standard no matter what species of poultry or type of controlled environment is employed.

Whilst few facts have been published defining the levels at which particular gases prove toxic, Selyanski (1966) considers that the maximum permissible level of CO_2 for poultry is 0·18 per cent, and for H_2S it is 0·02 mg./litre. (One mg./litre of H_2S has proved fatal.) Charles and Payne (1966) showed that over 38 p.p.m. of ammonia irritated the eyes, whilst higher levels (100 p.p.m.) reduced the growth rate of broilers; and in pullets caused conjunctivitis, lowered egg production and increased their susceptibility to respiratory infections. Ammonia may reduce respiratory volume and feed intake. Exposure to 50 p.p.m. for 48 hours increases the risk from Newcastle disease, whereas exposures for 6 weeks to levels below 20 p.p.m. have proved harmless.

Anderson *et al.* (1966) have reported that neither chickens nor turkeys exposed to 5000 p.p.m. CO_2 showed any damage to the respiratory tract after 8 weeks, but there was a slight lowering of the blood pH, although no increase in the respiratory rate. As a contrast Carlson and Clandinin (1963) showed that 0·01 per cent CO was harmful to young chicks.

Fan Ventilation

Since fans are used more and more their construction, installation and running are very important factors to be appreciated. The subject was discussed in detail by H. W. Prosser (1966) at the Agricultural Engineers Conference and Exhibition in Moscow. He stressed the following points.

Whilst four wing, *propeller* fans (being relatively cheap and quiet) are in general use for low pressure development, axial flow fans are essential for any ventilation system involving ducting or other resistance. The wings of the former are not adjustable, normally being fixed at one predetermined pitch angle. If a standard propeller fan is forced to operate above the working part of its characteristic (due to high-pressure resistance) the motor may burn out. This can also take place when dust builds up over a period on the linkage arms and bearings. Air enters the propeller fan blade from all directions and is discharged with both axial and radial components of velocity. At F.I.D.[1] the airflow is mainly axial whilst at cut-off it is almost completely radial. The air therefore leaves as a rotating, expanding column, the former being in the same direction as that of the impeller.

[1] F.I.D. = Free intake discharge. When a fan is operating without restriction to air flow.

Axial flow fans consist of a multi-winged aerofoil-section impeller, generally coupled to the shaft of the driving motor. Air enters and leaves the impeller in an axial direction. Whilst the pitch of its wings is adjustable (enabling a wide range of air volumes to be obtained), this cannot take place once the fan has been installed. The air leaving a single stage axial flow fan forms a spiralling column, rotating in the same direction as the impeller. It is directed into the building by way of a pegboard or other form of semi-open ducting, but calico bags may be preferable for this purpose. These require to be cleaned periodically, and their laundering on such occasions will cost about 25s. per 100 ft. length. When new they cost about 5s. per ft. (19 in. diameter) being obtained from Air Systems Ltd. Unsworth St. Radcliffe, Manchester.

PROPELLER FANS—SINGLE PHASE—RING MOUNTED

Manufacturer	*Fan size diameter*	*r.p.m.*	*c.f.m. free air*	*c.f.m. 0·2 ins. w.g.*	*Watts/1000 c.f.m. free air*	*Cost* £ *s. d.*
Woods of Colchester		900	750	—	66·7	19 7 0
Fenton Byrn		900	720	310	69·4	20 15 0
London Fan (Breeza)	12 in.	900	720	—	55·6	15 12 6
Vent-Axia		1170	916	—	85·2	24 0 0
Woods of Colchester		900	2550	1700	58·8	27 16 0
Fenton Byrn		900	2650	2140	45·3	30 10 0
London Fan (Breeza)	18 in.	900	2380	1550	63·0	25 6 0
Hydor		900*	2350	750	46·8	29 10 0
Woods of Colchester		940	6300	5500	79·4	33 12 0
Fenton Byrn		900	6200	5400	85·5	34 15 0
London Fan (Breeza)	24 in.	900	5750	5390	73·0	34 11 6
Hydor		900*	6200	3530	80·6	36 0 0
Smith	24 in.	940	6110	5530	540 (input)	32 0 0

* These fans have two speeds and can work on 900 or 450 r.p.m.

Choice of Fans. Having decided upon the type of fan required, it is essential to know the total number of birds the house can hold and also their maximum weight, in order to know what *capacity* or number of fans to order. For example, assuming the standard to be 1 cu. ft./ 1 lb./min., and that the house in question is to hold 10,000 broilers (maximum weight 4½ lb.) then the fans must be able to supply 45,000 cu. ft. air/min. The number of fans will relate to the size and shape of the building, but in general it is a good plan to divide the width of the house into its length and then place one fan in each 'square', so that ventilation will be as even as possible. This applies no matter whether the house is rectangular, L-shaped, square or circular, as shown in Fig. 28 on page 194.

Whether to use a large number of small fans or a small number of large fans is a matter to be decided in relation to the construction (strength) of the building, noise output (neighbouring dwellings), cost, etc.

It is very important that fans are chosen for their output of air against whatever pressures are likely to be encountered once they have been installed, and *not* on their F.I.D. performance. (Normally a static water gauge figure of 0·2 in. is chosen.) Appropriate tables should be consulted showing outputs, the costs of different size fans, working at different r.p.m. and also relative to their electrical performance in watt/1000 c.f.m.

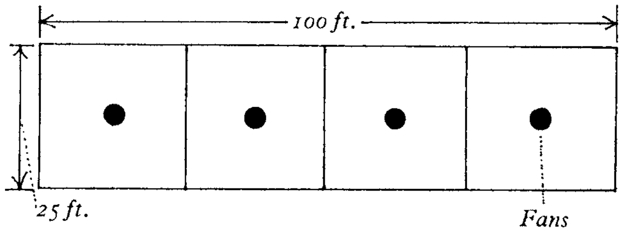

FIG. 28.

Pressure (Plenum) System. The chief use for axial flow fans is in those buildings where it would be difficult to distribute the air evenly using propeller fans (e.g. where there are several rows of hen batteries), but more particularly when the producer wishes to filter the air with the object of reducing dust and bacteria.

It is relatively simple to instal filters (consisting of fibreglass or those which have been specially medicated) at some convenient site prior to the air (heated or otherwise) entering the fan ducts.

Air Filtration

Whilst some filters can be purchased in 2 ft. square frames, most materials are available in rolls, present-day costs ranging from as little as 5d. per sq. ft. (1 in. thickness fibreglass) to about 2s. a sq. ft. for medicated filters. As an example of the latter *Permachem* (Fram Filters Ltd.) is impregnated with dialkyldimethyl ammonium chloride, tri-M-butyltin oxide and salicylic acid. Washable filters are also marketed, e.g. *Plipor* (Eaton Williams) costing £3 18s. and made from a porous foam medium.

If a filter of a given thickness removes 90 per cent of the bacteria, then a second similar filter superimposed behind the first will remove 90 per cent of the remaining bacteria; hence the value of double filters.

Whilst it is not easy in practice to decide whether to use plain or medicated filters, that they effectively prevent large amounts of bacteria-laden dust from entering the building is without question. When dirty, a *Versil* 20 in. sq. filter holds 3 lb. of dust equal to ten times the initial weight of the filter.

R. 50 fibreglass filters have been installed at Stoke Mandeville where we have studied the subject intensively, and the dust pick-up has reached 12·5 gm. after 10 weeks and 45 gm./sq. ft. after 20 weeks usage, allowing 3·5 sq. ft. of filter area per 1000 cu. ft. air input. Such filters stop at least 100 dust particles per minute, and so considerably reduce the risk of infection entering via the ventilation system. Bacteriological examinations show that the exterior of a dirty filter may contain 400 million organisms/sq. in. contrasted with 200,000 on the interior.

FIG. 29. The spread of infection downwind is a well recognised phenomenon in the poultry industry following many outbreaks of Newcastle disease. This aerial photograph shows the distance smoke from a bonfire was visible at Stoke Mandeville. The distance from A to B was $\frac{3}{10}$ mile.

All filters of course create physical resistance to air passage which necessitates the use of aerofoil fans and a manometer, for checking when the filters require renewal and also for determining the fall in fan efficiency. The following example relates to Woods 19 in., 1440 r.p.m. 20° aerofoil fans:

Free air— 3900 c.f.m.
0·2 in. w.g.—3600
0·4 in. w.g.—3200
0·6 in. w.g.—2600
0·8 in. w.g.— 0

With most filters the initial resistance will be 0·1–0·2 in. w.g. and they will require changing when the resistance rises to 0·5 w.g. which normally takes about 8-10 weeks.

Note: During foggy weather when air frosts are likely, the filter should be removed (if the incoming air has not been heated) or moisture particles in the filter will freeze, blocking the air flow and burning out the fan motor.

Air filtration is discussed in some detail by Rubbo and Gardner in *A Review of Sterilisation and Disinfection* (1965) Lloyd-Luke Ltd., 49 Newman Street, London. 35s.

Dust

Dust in poultry houses has a high protein (49–97 per cent) and low fibre (1–2·5 per cent) content and consists of fungi, feather and skin particles, wood dust, etc. Anderson (1966) showed that the airborne particulate matter ranged from 0·03–1·16 mg./ft^3, with a dry matter content of up to 90 per cent. Crude protein accounted for 60 per cent of this, fat 8 per cent and cellulose 5 per cent, but this would naturally differ with the age and type of litter used. In a 5-year study Howes *et al.* (1966) found a direct relationship between the humidity and ammonia levels, and that 25 p.p.m. of the latter was critical.

Removal of Moisture

Perhaps the most important difference between ventilating laying batteries and deep litter houses (for either layers or broilers) is the fact that the latter can only function satisfactorily if there is adequate removal of water vapour, whereas this is of much less significance in batteries. The state of the litter is dependent upon the evaporation of the faecal/urine excreta, and if this is defective wet caked litter results and the generation of ammonia is also a concomitant feature.

It is important therefore to know the water output (both excreted and exhaled) of fowls of different ages, and to realise that the water holding capacity of the ventilated air doubles with each 20° rise, e.g. from 40°–60° F the moisture content increases from 40–80 grains/lb.

Weight of bird (lb.)	*Total* water output (grains/hr.)*	*Water exhaled (grains/hr.)*
2	81	27
3	114	38
4	153	51
5	190	63

* One-third is exhaled.

Examples. 1000 × 5 lb. layers excrete 127,000 gr. moisture/hr., equal to 1·8 gallons or 43½ gallons daily (apart from a further 14½ gallons exhaled). It is this water which must be evaporated (into the ventilating system) if the litter is not to become wet. Fortunately hens also give out heat, in this case 44,000 B.t.u./hr. equal to nearly 13 kW.

For calculations involving moisture (relative humidity) psychometric charts should be used in conjunction with wet and dry bulb thermometers.

If humidity rises until the air becomes saturated with moisture the *dew point* is reached, this is a feature which occurs most readily when house temperatures are low because the water-holding capacity of the air is then decreased. Thus when warm air makes contact with cold surfaces (iron girders, glass windows, water pipes, etc.) condensation occurs, often with adverse effects. To make matters worse the incoming air in the colder winter months is often saturated with moisture vapour (high R.H.) and therefore it can hold no more moisture unless its temperature is raised. This should automatically occur within the poultry house, but if the stocking density is low there will be too few birds to provide the heat required, and wet litter will result.

Cold Weather Ventilation

When outside temperatures are around freezing point (25–32° F) a minimum 15° rise will be required to ensure that room temperatures are satisfactory for layers. Knowing the heat output of the birds, the U value of the building and the moisture content of the air, a calculation can be used to determine the ventilation rate required to remove the unwanted moisture and to raise the room temperature satisfactorily. The basic formula is:

$$\frac{H}{V \times W \times T \times N \times K}$$

where H = heat produced (B.t.u./hr.)
V = ventilation in c.f.m./lb.
W = average weight of bird (lb.)
T = conversion factor c.f.m. to c.f.h.
N = number of birds
K = specific heat of air. (The amount of heat required to raise the temperature of one cu. ft. of air by 1° F.)

Example (Relating to 1000 × 5 lb. pullets).

44,000 ÷ 5 × 60 × 1000 × 0·018 × 15 (deg. rise) equals 0·54 cu.ft./min./lb. or about half the normal rate of 1 cu. ft./lb. L.W./min.

Humidity

Standards for the humidity content of poultry houses are not well defined but below 40 per cent R.H. the air may get too dry and so help to irritate the tracheal mucosa. When humidities exceed 80 per cent R.H. it embarrasses the fowl's control over its body temperature in hot weather, because of an inability to lose heat satisfactorily. Panting takes place for this purpose (starting at about 80–85° F), heat being lost through the latent heat of vaporization. A special watch must be kept therefore in hot weather on the state of the litter, leaking drinkers, condensation droplets, porous walls (affected by driving rain), etc.

To check that the air flow in a poultry house is satisfactory, or when investigating ventilation faults, smoke can be injected into the ventilating system. The simplest method is to light a number of smoke pellets after which the currents of air can be followed easily. These smoke candles are obtainable from P. H. Thermal Products Ltd., Baildon, Yorks.

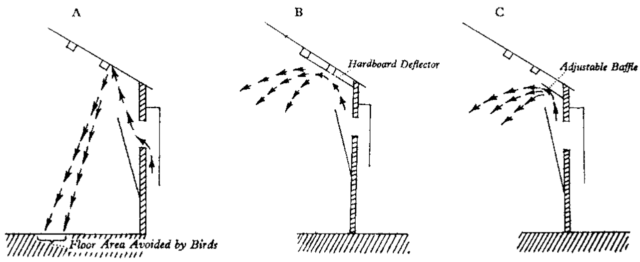

FIG. 30. Two methods for avoiding down-draughts from Tobins tubes.

Air Inlets

Having decided upon the number and siting of the fans, it is equally important to see that an adequate number of air inlets are present. These are usually placed equidistant around the walls, and preferably also at the ends, allowing from 3–5 sq. ft. per 1000 cu. ft. of air output. The lower figure relates to *free* air inlet space.

FIG. 31. It is always a good plan to site a row of intensive poultry houses end-to-end, across wind, with the object of minimising the spread of aerial contamination.

Floor space

The Brambell Committee recommended that broilers over 6 weeks old should be given 'at least 1 sq. ft.' of floor space, believing that this made life more comfortable for them. The boiler industry however uses 0·55–0·75 sq. ft. on the average, and therefore to accept the above proposal would reduce the present housing capacity by more than 35 per cent, and as there are over 40 million broilers on the floor at one time this would mean an extra capital outlay of about £7½–£10 million. But the Brambell Committee did not say how or why the chickens would benefit from this greater floor space, such as by better weights, feed conversions or a lower mortality rate, etc.

The figure of 0·75 sq. ft. ± 10 per cent was not arrived at scientifically, but by trial and error. Those who used 0·6 sq. ft. or less found that bodyweights were often not satisfactory and that mortality tended to increase as well as the percentage downgradings at the packing station. Others who used 1 sq. ft. sometimes obtained better weights (often due to the greater trough space available) but the monetary returns *per house* were lower. In fact 0·75 is a compromise between getting the best return per sq. ft. of floor space, and yet maintaining a good standard of management without cruelty or obvious discomfort.

The same is true of layers. On slats and wire floors whilst as little as 1 sq. ft. has been allowed pullets, the more successful producers found that 1½ sq. ft. was preferable, and on deep litter 2½–3 sq. ft. In cages, whereas the Brambell Committee recommend three birds per 20 in. cage, producers have found that four or five pullets are equally satisfactory on all counts. As a contrast seven pullets per 28 in. cage may give a definitely poorer return than six birds.

A trial in progress at Stoke Mandeville using 24 in. Dunblane laying battery cages, involving a total of 623 pullets (DeKalb, Nickchick and '606'), has given the following results to date, the pullets having been in lay 36 weeks:

	3 birds/cage	*4 birds/cage*
Numbers started	307	316
Deaths	26	25
Reproductive disorders, cannibalism, etc.	19	19
% Egg production	76·9	77·6
Eggs/bird	193·9	195·6
Feed/bird/day (oz.)	3·65	3·68
Total egg weight	398·12 oz.	399·73 oz.

There is thus no evidence at all to support the view that it is preferable to house three instead of four pullets in a 24 in. laying battery unit. (These cages are 20 per cent larger than those recommended by the Brambell Committee.) In practice of course commercial egg producers would house six birds in such cages (if of the light hybrid type), or five weighing at point-lay 4¼lb.

What farmers usually appreciate and laymen do not, is the fact that it is not so much sq. footage per bird which counts, as total weight per sq. ft. A 14–15 in. hen battery cage for example will hold two light/heavy pullets, or three light hybrid pullets because of the latter's smaller size and weight. Similarly broilers killed off at 8 weeks will be lighter (3 lb.) than those killed off 1–2 weeks later (3½–4½ lb.), the space they require is automatically less. Based on these weights, if broilers are allowed ¾ sq. ft. each, the weight per sq. ft. at 9 weeks will be 5 lb. This is an acceptable working standard to adopt for all ages thus:

Standard—5 lb. per sq. ft.

Floor space (sq. ft.)	*Bodyweight (lb.)*	*Approx. killing age (weeks)*
1	5	11
0·9	4½	10
0·75	4	9
0·60	3	8
0·50	2½	6

It had been suggested previously that growth rate decreases as population density increases, but Brooks *et al.* (1958) found that this inverse relationship had only small effects up to 9 weeks of age, with which statement most broiler producers will agree. The full criteria to consider are bodyweight, feed conversion, mortality, packing station downgradings, income per sq. ft. and state of litter.

Applying the same principle to layers in battery cages three 3 lb. lightweight pullets require the same space as two 4½ lb. pullets; similarly five of the former may equal three heavier hybrids weighing 4½–5 lb. providing there is adequate feed hopper and drinking space.

Equipment

Feeders

Assuming that the feed provides all essentials for growth or egg production, the next most important factor is feed trough space. Here again there is an optimum which can be obtained experimentally or by the trials and errors of producers. But any data obtained from the use of double-sided standard feed troughs cannot be applied to semi-continuous flow, automatic feeders which bring fresh food to the birds at regular intervals. Although earlier reports indicated that up to 2 in. of trough space per broiler was optimal, Hansen and Becker (1960), using trough spaces ranging from 0·75–3·75 in. per bird, found that growth was not depressed except at the lower allowances. Reed and Ringrose (1960) showed that ½ in. was satisfactory for optimal growth when the system provided continuously available feed. The British Poultry Industry commonly allows 20–30 tubular feeders/1000 broilers; 4–6 in. hopper space for layers and 1 in. troughing for turkey poults. The construction of tubular feeders is very important, because some waste less than 2 per cent of mash/crumbs, whilst others waste 13 per cent.

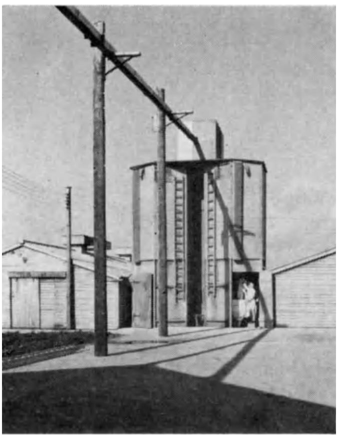

FIG. 32. This Cherwell Valley unit services 12,000 layers, the overhead conveyor leading from the feed mixing unit to two bulk bins, under one of which is shown a portable feed truck.

Drinkers

Water space allowances are equally important and although McClusky and Johnson (1958) found that 0·96 in. per bird was no better than 0·2 in., age of bird, type of drinker and the actual distance the bird has to travel to reach a drinker are important limiting factors.

Broilers should not have to walk more than 5–10 ft. to reach a source of water, and with a floor space of about ¾ sq. ft. per bird to 9 weeks of age, 720 in. of water troughing per 1000 broilers is adequate, i.e. six double-sided 5 ft. troughs. At day-old 10–15 × 1 gallon founts per 1000 chicks. When water troughs of the pan type ('Dewdrop') are used 8 per 1000 broilers should be allowed. For layers the allowance should be similar except that in the case of nipple drinkers, not more than six pullets should have access to any one nipple for preference. Units of nipple drinkers are now being manufactured for use in rearing houses, but great care must be taken to see that they are raised as the chicks grow taller or crossed beaks may result.

Noise

Noise is the result of the transmission of mechanical energy from a source to a receiver by mechanical vibrations of the intervening air. The receiver may be the human/animal ear or a measuring instrument. This latter can be designed to give an absolute reading of the sound intensity, i.e. the energy received per second in terms of say ergs/sq. cm./sec. or watts/sq. cm. Ridley (1967) has kindly provided the following facts about noise and its interpretation.

The sensation of loudness cannot be described adequately by a simple measurement of the amount of energy received by the ear. Although the ear is extraordinarily sensitive there is a lower limit of sound intensity—the threshold of hearing, below which sounds cannot be detected. As a first step to devising a loudness scale we accept as its base the intensity of the faintest sound that the ear can detect and relate the intensities of all other sounds to this. Thus the noise level is the ratio of the intensity of the given sound to the intensity of the faintest sound we can hear:

$$N = I/Io$$

thus where I is the energy content of the sound Io is the energy content of the faintest sound we can hear. On such a scale the lowest reading is $N = Io/Io = 1$.

But the ear is not only extremely sensitive, it is also able to encompass a fantastic range of sound intensity. The loudest noise the ear can tolerate being 1–2 million million times greater than the intensity of the faintest sound it can detect—a ratio of $1:10^{12}$. As such a scale would be cumbersome the logarithm of this ratio is used—log I/Io. In this way definition of the operating range of the ear as regards loudness is reduced from $1:10^{12}$ to 0:12 (log 1 = 0; log 10^{12} = 12).

The name given to the unit of readings is termed a Bell, and the definition of loudness becomes therefore $N = \log (\frac{I}{Io})$ bells. In order to avoid quite small fractions of the basic Bell unit, this is broken down into ten new units, decibels. Thus:

$$N = 10 \log \frac{I}{Io} \text{ decibels}$$

where I is the intensity of the given sound as measured by an energy measuring unit, and Io is the intensity of the faintest sound we can hear, so that the decibel scale ranges from 0 to about 120 decibels. Mathematically this implies that the perceived magnitude of a sound varies as the logarithm of its energy. The facing table will help to establish the general pattern of noise level.

Experience shows that poultry can adjust themselves readily to noises which are encountered regularly or continuously, or with relatively little variation. For example, in a controlled-environment poultry house where the air enters at one end (via fans and ducting) the noise diminishes with the distance from the fans, but stock at either end of the house grow at the same rate. Presumably the constancy of the noise—high, medium or low—from birth onwards plays an important part here. But a sudden clatter startles most poultry and the particular vocal response of layers to loud noises of this character are worth contrasting with those emitted by turkeys.

	Decibels
Threshold of pain or feeling	120/130
Aeroplane engine at 10 ft. Hammer blows on steel plate, indoors	110/120
'Supersonic' bangs	110
Pneumatic drill at 10 ft.	90/100
Very heavy street traffic	70/80
Ordinary traffic; noisy office	60/70
Average office	50
Ordinary domestic conversation	40
Quiet whisper at 5 ft. Rustle of leaves in gentle breeze	10
Threshold of hearing	0

The range of decibels from fans installed in poultry houses must be considered both in relation to the stock and to one's neighbours, or there may be well-founded complaints via the Local Authority!

The diameter of the fan and its r.p.m. both affect sound output, thus:

Fan type	*Fan diameter*	*Rev/min*	*Decibels*	*Classification*
Propellor	12 in.	900	46	Very quiet
Propellor	18 in.	900	57	Quiet
Propellor	24 in.	700	58	Quiet
Propellor	24 in.	900	61	Fairly noisy
Propellor	18 in.	1400	65	Fairly noisy
Propellor	30 in.	900	71	Noisy
Aerofoil	19 in.	1400	63*	Fairly noisy
Aerofoil	19 in.	2900	80*	Noisy

* Measured 3-fan diameters away from the impeller.

Intensity of noise is important also with baby chicks, because whilst they do not respond to the quiet pecking sounds of their companions, they do react to the much noisier 'tappings' of broody hens. This subject was recently investigated by Tolman (1967) who showed that tapping sounds motivate social feeding, operating through the mediation of a general arousal mechanism. The rate of tapping is also of importance, 120–240 per minute leading to larger feed intakes than lesser rates.

Particular communication ('talking') between pullets occasionally leads to panic, one frightened bird squawking in a special manner upsetting the whole of the flock. This can be overcome by installing a radio which plays continuously, at such strength that it drowns any possibility of alarm calls passing down the house from one bird to another.

High intensity sound from a gramophone record of a jet plane (110–135 decibels) has been used as a method for controlling broodiness in turkey hens (Jeannout and Adams 1960). The total non-laying number of days for the controls was 33·22, for hens injected with 5 mg. progesterone 23·35 days and 6·17 days for those sound treated.

Automation

A further example of the effect of noise on layers relates to automation. For example when scrapers or belts are first used in tiers of laying batteries, the noise emitted, plus the sight of the moving belts, etc. may frighten immature pullets considerably. This can be overcome by first cleaning out the droppings at night time (in the dark) when the birds cannot see the equipment in operation and when they may also be sleepy. Additional work for the poultryman, but well worth while in most cases.

Automatic feeders seldom offer stress, although in any batteries which have circulating feed troughs—moving up and down or around the unit—some pullets at first appear hypnotised, and although they lower their heads to feed, they may not do so far enough. This defect is quickly overcome when the affected birds copy their more sensible neighbours.

The highest pitch of efficiency for automatic equipment can be seen in the U.S.A., and those interested in this subject should read the U.S.D.A.'s latest bulletin—Misc. Publication No. 728 *Houses and Equipment for Laying Hens.*

Disease Control

If attention has been paid to all the previously mentioned factors (from temperature to noise) there only remains disease control including, of course, feed medication and vaccination.

Continuous medication using a nitrofuran or antibiotic is not recommended in spite of the work quoted by Dalton (1965) that 28 grams per ton of aureomycin is beneficial as a *continuous* feed additive for layers. This is partly because resistant strains of coliforms and salmonellae quickly develop, but also because of cost. Although bacterial resistance is not usually encountered with furazolidone, a healthy flock should not require continuous medication. If egg production is low (below 50 per cent), then attention should be paid to its causation, and if culling is carried out vigorously a more economic return will follow automatically. A short burst of anti-bacterial treatment (10–14 days) may be valuable on occasions, but *continuous* low-level medication is not necessary or advisable.

FIG. 33. The new look in a modern poultry breeding farm where freedom from P.P.L.O. infection is essential. Handling for body conformation, weighing and vaccination is carried out simultaneously.

Vaccinations against N.D. and I.B. are commonplace and thoroughly to be recommended, although the efficiency of I.B. vaccines does not seem to be as high as one would like. For fowl pox, I.L.T. and erysipelas (turkeys) vaccination is only recommended in those areas where these diseases are endemic. Although fowl cholera bacterins are obtainable, particularly from the U.S.A., their efficacy is sometimes lower than anticipated.

A special note is required concerning epidemic tremor vaccines which normally may only require to be administered once, about 4 weeks prior to pullets coming into lay. Whilst these are usually highly efficacious, in the absence of contact with live virus in the field, the resultant immunity may break down during the hatching season. A second inoculation should therefore be given about 5 months after the first.

Mixed vaccines based on two or even three inactivated viruses, e.g. N.D.+I.B.+I.A.E. are now being marketed and have proved very labour saving.

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Chapter 16

BATTERY CAGE EGG PRODUCTION

M. J. GAISFORD

Egg production in hen battery cages is one of the best examples of intensive livestock farming. Cages for pullet rearing are now also in common commercial use, whilst some turkey producers use cages for housing their breeding stock.

Commercially, battery cages for laying hens were first used in the U.S.A. in the early 1920s (Lee 1946), being produced in Britain as early as 1930 (Blount 1951). The most significant change in cage design from these early models, has been towards automation of feeding, watering, manure removal and more recently egg collection; together with an increase in the size of the unit, and also that of the individual cage itself. Until the early 1960s most cages held one or two pullets, now 4–7 birds are commonly housed together, while multi-bird cages with up to 40 birds are also in use. In addition environmental control has become more sophisticated. This permits a higher stocking density, each pullet being allowed 0·5–0·7 sq. ft. (cage floor area).

Cage Systems

Although the individual cage is basically the same for all units, batteries are commonly arranged in three ways:

Tier cages, Californian cages and Flat deck cages.

Most hen battery cages are arranged back-to-back in three tiers, although single-sided cages are also produced. The chief feature of the Californian or Stair-step system is that it permits a 12 months accumulation of poultry manure. This works best in warmer climates such as South Africa and parts of the U.S.A., hence the name 'Californian cages'. In Britain with our wetter and more humid weather, the manure does not readily dry out underneath the cages. Smells and flies can become a nuisance, although deodorants and insecticides may overcome them. One modification to this system is to allow the manure to fall into a pit containing water under the cages, and thus to collect the manure in a liquid form. In warmer climates Californian cages only require a roof to keep the direct rays of the sun from overheating the birds.

Flat deck (single tier) cages have many similar features and are very labour saving but a disadvantage of this lower stocking density is the maintenance of a satisfactory house temperature during the winter. Heat production from poultry is about 8–10 B.t.u.'s per pound body weight per hour, and this plays an important part in the maintenance of

FIG. 34. '*Big Dutchman*' flat deck cages. The 'pit' below the hen batteries may be 7 ft. deep to allow the accumulation of the excreta over a 2-year period.

a satisfactory environmental temperature in the battery house during cold weather. (The total heat output from a 10,000 bird battery house is equivalent to supplying about 120 kW of electricity per hour). Given a suitable pit beneath the cages the manure can be allowed to build up for 2 years or more which is another good feature.

Battery Cage Size

There is little variation in the depth and height of hen batteries marketed in Britain, whereas there is a wide range of cage widths. An average cage depth is 17 in. and height 17 in. at the front and 14 in. at the back, but their width ranges from a 9 in. single bird cage up to 72 in. holding twenty birds. The slope of the cage floor is 1 in 5.

The Brambell Committee's recommendations on cage size are as follows:

Minimum cage height	16 in.
Average cage height	18 in.
Cage depth	17 in.
Minimum cage width	12 in. (1 bird per cage)
Minimum cage width	16 in. (2 birds per cage)
Minimum cage width	20 in. (3 birds per cage).

These figures were not based on any practical study or experimental work on the subject, and no cage marketed commercially in 1967 is based on these specifications. The best guide to cage size is to allow 4–6 in. of cage front space per bird. This allows all birds in any size of cage to be able to feed together, assuming that the front of the battery cage is correctly designed.

Where birds are housed together it is common practice to debeak the lighter strains of hybrid pullets. This is a safeguard against feather pulling and cannibalism. An alternative is to maintain a low level of light intensity ($\frac{1}{2}$ ft. candle), but this way leads to depressed egg production. Even where a producer starts with a light intensity above 1 ft. candle on the bottom tiers this can soon fall if the light bulbs are not regularly cleaned. It is important to use bulbs of the correct voltage for a particular area. Over-volted bulbs although they will last longer do not have as high a light output as bulbs of the same wattage but with the correct local voltage.

One practical disadvantage of multi-bird cages is the difficulty of handling birds individually (for vaccination). Another is that should the birds become excited in multi-bird cages they stand a bigger chance of damaging themselves. This is because of the larger area in which to move around. However in a properly controlled environment these problems are less likely to occur.

A disadvantage of housing birds singly in a poorly insulated house is that the effects of low temperature will be greater than where several birds are housed together. Here heat generated by the individuals will not be lost so rapidly and will help to keep the group warm.

There is no 'best' number of birds per cage to suit all conditions, but between three and six birds per cage usually give good results and a minimum of management problems. Where birds are kept in larger groups they are sometimes overcrowded, which often explains the variability of their performance. Producers generally will welcome the suggestion that a Farm Animal Welfare Standing Advisory Committee be formed with powers of inspection and advice.

One interesting development is to rear replacement pullets in cages in small groups of ten birds, which at point-of-lay are split into two groups of five and re-housed in laying cages. Less stress should occur when such birds are moved, and their subsequent egg-laying performance should also be improved.

Battery Cage Components

A variety of materials are used in the construction of battery cages, although mainly in the form of wire mesh or thin sheet metal. Some makes have a timber framework, but a more recent advance includes an all plastic British battery cage. Reinforced glass, acid and alkali-resisting plastic sheeting, bituminous paper and asbestos are used as a base for the manure, with electric motors and gear units of various designs for the automation of the cleaning out and feeding systems.

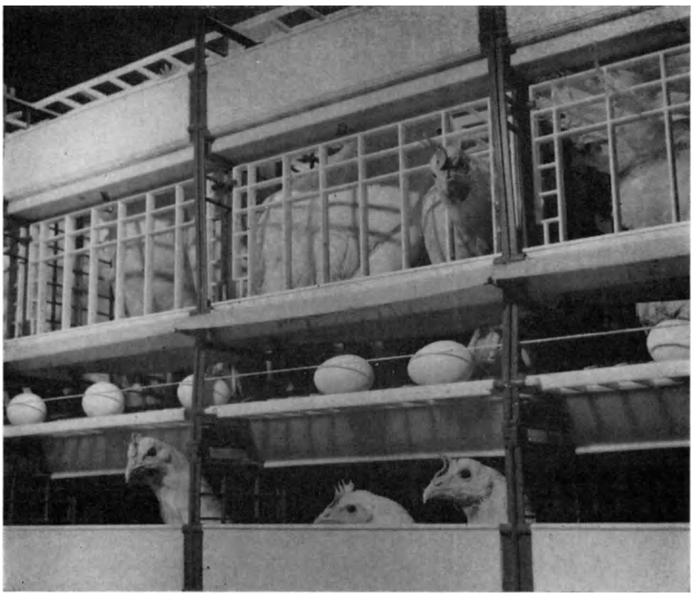

FIG. 35. The first all-plastic hen battery unit manufactured by B.E.C. from 'propathene' (I.C.I.). Continuous moving belts take food, collect eggs and remove droppings.

One's choice of materials when purchasing a battery cage will be influenced by several factors such as capital costs, corrosion, depreciation, ease of cleaning and maintenance, and these will be discussed under separate headings. Apart from cost, the first consideration should be—which materials will enable the bird to maximise her output?

Cage Fronts

Apart from the newer plastic units, cage fronts are manufactured as wire grids. They are either removable or adjustable to allow access to the cage, and designed so that the birds are able to extend their heads through the wire grids to reach the feed and sometimes the water too. For these purposes the vertical wire components of the cage front should be spaced $2\frac{1}{2}$ in. apart. This distance is critical as newly housed light hybrids are liable to escape from any wider cage fronts; and if it is only 2 in. wide, birds may not be able to feed comfortably.

There is however a wide range of cage-front designs sold by the twenty or so British cage manufacturers. Some incorporate a sliding cage front which makes access to the cage and removal of the birds very easy, as opposed to, for example, those that hinge inwards from the top of the cage which may make the removal of birds very difficult. Spacing of the vertical wires also varies, and although it is wise to have narrow spaced wires at the sides of the cage front to stop any intercage fighting, it is also important to have sufficient $2\frac{1}{2}$ in. spaces so that all the birds in that cage are able to feed comfortably.

If nipple drinkers are positioned at the front of the cage it should be ascertained that their position also coincides with the wide spacings of the cage front. Cage fronts and floors should also be designed so that the hens in the lower cages cannot eat the eggs awaiting collection in the ones above; or indeed reach under the feed trough to try to eat its own egg. (An egg guard is normally fitted to the bottom of the feed trough to stop this occurring.)

Cage Floors

The floor of a hen battery cage is the most important component of the unit, as it must support the hen, permit her to lay an egg on it which will not break as it rolls to the front of the cage, where it should be collected free from dust and faecal matter. To perform these functions adequately as well as allowing the droppings to pass below, the thickness and spacing of the wirework, the method of fixing and the slope of the floor are critical.

Most floors have a slope of between 1 in 4 and 1 in 6. Outside this range eggs are likely to either roll down too fast and break, or remain lodged on the floor (within the cage) where they may become faecal contaminated, broken or eaten by the birds. A 2 in. × 4 in. weave of wire of 14 gauge thickness is used for most floors, but 17 gauge hexagonal wire netting floors is used on some cages and gives rise to very few cracks, e.g. Grossmith cages. If heavier wire (10 gauge) (as recommended by the Brambell Committee) is used there is no elasticity in the floors and a high proportion of eggs will crack. Cage floors are not normally fixed to the framework of the unit, but are supported at the front and back of the cage. This gives them further elasticity, which helps to keep the number of cracked eggs to a minimum.

The front of the cage floor also calls for careful design to cushion the momentum of the egg which builds up as it rolls to the front of the cage. The floors may have upturned ends, strands of wire or strips of thin flexible metal, or plastic coated wire fronts or strips of foam rubber to check and stop the egg at the front of the cage. It is important that the floor protrudes far enough out to enable the poultrymen to collect the eggs readily without squashing his hand against the front of the feed trough. This is also important for preventing birds reaching eggs awaiting collection from the cages above them.

Cage Partitions

Side and rear cage partitions may consist of either sheet metal, wire mesh or a combination of both.

Wire mesh partitions offer less restriction to air movement through the cage unit, and they are easier to clean than solid partitions which have a greater surface area for faecal adherence. Light distribution is also more even in open wire mesh cages, but this is a debatable advantage in houses with a high light intensity where chances of cannibalism would be less of a risk with solid divisioned cages which would be darker at the back.

A useful advantage to cages with solid divisions is that if the birds at one end of the cage do become agitated for any reason this disturbance is less likely to spread down the block of cages as the birds cannot so readily see each other. Solid cross divisions every four or five cages can prove a useful compromise. With all types of divisions care must be taken to see that the birds do not squeeze their heads below them and so injure themselves.

Feeding Systems

A continuously available supply of feed in a trough at the front of the hen battery cage is normal practice. Cafeteria systems where the birds are fed intermittently from a food hopper which moves slowly round the block of cages have been tried, but are not now widely used.

FIG. 36. A 4½ cwt. electrically operated feed truck which travels down a 100 ft. length of Grossmith static cages, filling three feed troughs on the way down and the others on the return journey.

On some cages the troughs will be manually filled, but on many larger units today feed is distributed automatically. The commonest arrangement is a system of hoppers that run on a chassis above the cages, and fill the food troughs either daily or every other day depending on the capacity of the feed trough. These hoppers can in turn be filled automatically by auger from a bulk feed hopper positioned outside the battery house. Other cages have an automatic chain or auger feeder running along the front of the cage, while motorised trolleys which are driven along the gangways between the cages may auger the feed from them into the food troughs. These are particularly useful if Californian cages are used.

The design of feed troughs is critical if feed wastage is to be reduced to a minimum. Wastage in hen batteries is relatively low compared with wastage from tube feeders on deep litter which can range from 0·6–6 per cent, depending upon the design and setting of the feeders. The usual cause of wastage in hen batteries is overfilling of the feed troughs. It is also more likely to occur on those units which practise feeding every 3 days, as opposed to the more common practice of feeding daily. Where stock are fed only two or three times a week the feed troughs obviously need to be larger and filled to a higher level.

Pellets are not recommended for feeding to stock housed in cages except in single bird cages; normally either mash or chips are used. Pellets are very palatable and likely to be eaten too quickly, leaving long periods when the birds have nothing to occupy their attention; furthermore if supplied *ad lib.* the birds are liable to over-eat and become too fat. Feed consumption is higher with chips than mash, which is of particular value for light hybrids with their smaller appetites, enabling them to satisfy their nutritional requirements adequately.

If open water troughs are used with mash fed stock a proportion of the feed gets wasted in the water, having stuck to the outside of the birds' beaks and then getting washed off. Once a month it is a sound idea to let the birds completely eat out the food in the troughs, as this will ensure that a build-up of stale unpalatable food does not collect in the bottom of the feed trough, while some could also go mouldy.

Watering Systems

Water for poultry housed in cages is supplied *ad lib.* either from a continuous open trough running the length of the block of cages, or from individual drinking points adjacent to the cages.

Continuous troughs (metal or plastic) positioned either at the front or back of the cage will either be of 2½ in. diameter, half-round guttering, or V-shaped. Plastic troughing has overcome the old corrosion problem associated with galvanised iron. But if cages with plastic waterers are steam cleaned, the plastic can easily be warped unless excess heat is avoided.

Supply of water to continuous troughing is either by a drip tap at one end and an overflow at the other, or by a 'tipple' tank which fills the troughs at intervals. Troughing positioned at the back of a unit between two rows of cages) reduces capital outlay, but makes the water trough more difficult to clean. This should be at least a twice weekly routine procedure. Water consumption normally falls in the range 40–60 gallons per 1000 birds per day, depending on environmental temperature, rate of egg production and body weight of the birds. If water supplies are metered, peak demand is seen to be during the latter period of the day, during the 3 hours before the lights are switched off.

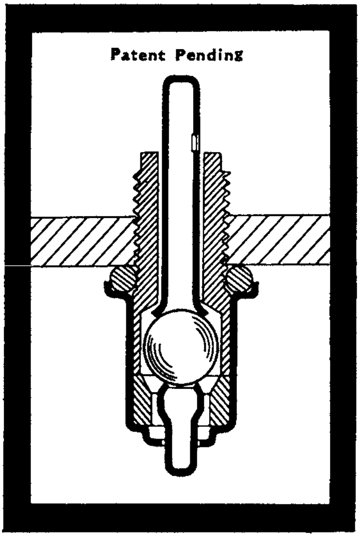

FIG. 37. Exploded diagram of an 'Aquasip' nipple valve drinker for poultry.

The second popular type of drinker used in cages is the individual 'nipple' drinker, e.g. '*No-Tro*' (Thornbers), '*Aquasip*' (Swifts) or '*Mono-flo*' (Listers). A plastic tube runs from a small header tank to each tier of cages. It is usually square in cross section and positioned at the top of the front of the cages, or down the centre of the block between two rows. Into this tube (which is upturned and open at the end away from the header tank) are inserted at intervals the nipple drinkers which cost about 2s. 6d. each. These contain a small rod (nipple) forming a valve with the stainless steel casing. This is pushed upwards by the bird's beak and a trickle of water flows downwards into the bird's mouth. The pressure of water in the tube is critical, and if too high will cause the nipple to leak. Water passing into the main tube should be filtered, so the chances of a nipple becoming blocked are negligible. If particles of grit, or dirt or rust enter the tube they are unlikely to interfere with the nipple, the interior entry to which is well above the bottom of the tube where any solid particles will accumulate. Leaking nipples may be a problem for a few weeks on a new installation, due to small pieces of plastic inside the tube becoming dislodged from around the holes that were bored in the tube to fit the drinkers. In such cases care must be taken to see that stale (wet) food does not accumulate at the bottom of the feed trough.

Corrosion of the feed trough directly under the nipples can be prevented by coating it with one of the anti-corrosion preparations commonly marketed. It is important that the birds can drink freely from the nipples (without reaching round wires or partitions) or they may damage their faces. Four to five birds per nipple is optimal. When pullets are newly housed in cages and have been used to other types of waterers, within a few minutes they can be seen investigating the shiny steelwork, and then once one or two birds start to drink the rest quickly follow suit. Pullets discover nipple drinkers situated at the fronts of their cages easier than those at the rear.

The advantages of this individual system of watering birds are, (i) that there is not any wastage of feed into water troughs, (ii) there are no drinkers to keep clean, (iii) much less wastage of water occurs compared with conventional troughing, and (iv) there is no requirement for drainage. One disadvantage with nipple drinkers is that the battery house must be well insulated because if the water freezes the consequences could be disastrous.

Manure Removal

This can be a daily, weekly or annual chore, depending on the system of manure removal employed, and can be conveniently classified into six main systems as follows:

1. Manual removal	4. Paper cleaning
2. Semi-automatic	5. Belt cleaning
3. Scraper cleaning	6. Long term accumulation.

Manual Cleaning. With this system the manure falls on to either a metal or asbestos tray underneath the cages. It is removed at 5–7 day intervals.

Semi-automatic. Tier cages using this system (e.g. Apex) have a 9 in. gap running down the centre of the block, so that the cages are not quite back to back. Once every 7–10 days the manure is pushed off the dropping trays centrally (between the blocks of cages) where it falls on to a moving belt positioned below the bottom tier of cages. It is then carried to the end of the block of cages and out of the house.

Scraper Cleaning. This is the most widely used system of manure removal, the manure falling on to a glass, metal or wooden shelf under each tier of cages. It is removed to one end of the unit by scrapers which are pulled through the cage unit automatically by wire or chain. Power to operate the scraper is provided by an electric motor and gear unit permanently fixed at the end of the block, although a few manufacturers produce a portable power unit which can be moved from block to block in the battery house. The scraper may be double-sided to allow cleaning out of both ends of the unit, or hinged so that when it is run in one direction it passes over the top of the manure awaiting collection. This permits the tier to be cleaned out in several 'bites' which is particularly useful on a long length of cages.

Wire breakages are the major cause of breakdowns on mechanically operated cages, and regular examinations for signs of wear or corrosion are advisable. To combat corrosion some manufacturers are using a wire which has been impregnated and coated with non-corrosive plastic.

Paper Cleaning. With this *Shepherd* system the manure falls on to bituminous paper which is rolled through the cage unit on a wire-netting base. The droppings accumulate on the paper and every 5–7 days the paper and manure are rolled out of the block together and replaced by new paper. The cost of the paper for this system is between 6d. and 1s. per bird per year, depending on the frequency of cleaning out and stocking density in the cages.

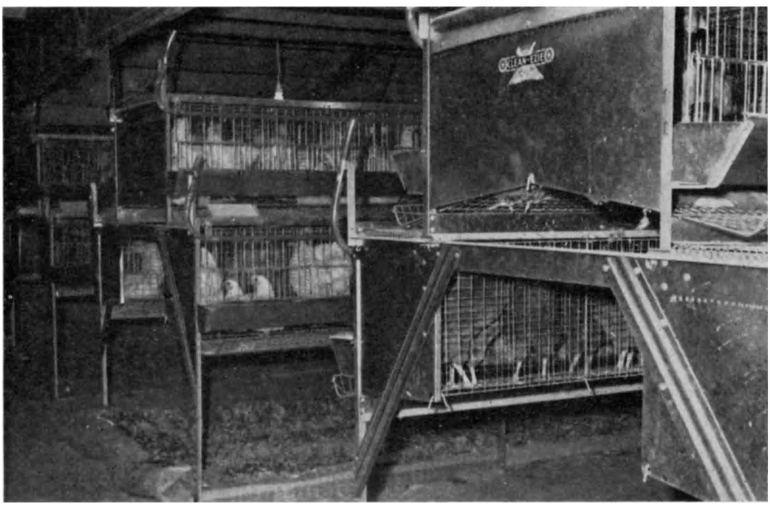

FIG. 38. Shepherd's '*Clean-ezie*' Californian unit built to 'Brambell' specifications, each cage being 20 in. wide for the holding of 3 pullets.

Belt Cleaning. A continuous plastic belt running under each tier is the feature of this Patchett system. The belt is run daily, transferring the manure to the end of the block of cages, afterwards the belt may pass through a disinfectant/detergent water bath, so that this system represents one of the most hygienic methods available. As with the paper-cleaning system, a further advantage is that the manure never comes into contact with any metal parts of the unit, thus reducing the problem of cage corrosion.

Long-term Accumulation. This method is used in conjunction with the Californian and Flat deck systems, the droppings accumulating over the whole of the laying year. In some battery houses the manure may fall into a water pit or 'lagoon' sited under the cages, and is eventually disposed of in a liquid form. Whether accumulated in solid or liquid form, some bacterial breakdown of the manure will reduce its volume, but the installation of a good ventilation system to remove ammonia, methane and noxious smells is very important.

Disposal of Battery Manure

Many of the larger battery installations utilise either a cross elevator or auger to remove the manure from the end of the blocks of cages to the outside of the house. From here it can be spread on agricultural land by manure spreader, or held in liquid form in tanks to be mixed with an equal volume of water before being spread. Liquid storage tanks are built to hold from 1–5 weeks output of manure from the unit, whereas disposal by a manure spreader is a much more regular chore.

Shortages of land for spreading manure on, and associated problems of disposal during adverse weather conditions have led to alternative methods of disposal. Although expensive and probably not justified on units of less than 30,000 birds, the artificial drying of poultry manure for use as a fertilizer is one method currently exploited. A typical analysis of such dried hen battery manure would be nitrogen 5 per cent, potash 2 per cent and phosphate 3 per cent. The cost of drying down to a moisture content of 10–15 per cent is in the region of £8–£10 per ton. This subject is discussed fully in our advisory publication *Poultry Manure and its Disposal* (1965).

Other methods of manure disposal such as incinerators, methane production by a 'digestion' process; feeding to fish, pigs and ruminants, and as a fuel source have also been investigated. The main problem is to find a regular, reliable and large enough market for dried poultry manure, since this competes with well-established artificial fertilizers.

Egg Collection

This operation is still performed manually on most farms, although cages with automatic egg collection are now available, and in the future as labour costs increase they are likely to become more widely used as in America. With many automatic systems the eggs roll on to a plastic or hessian belt and are transported along the front of the cages to an egg room at one end of the battery house. Here they can be graded and packed, although few units in Britain have yet reached this degree of automation.

Whichever method of collection is used, the aim is to market as high a proportion of the eggs as possible, naturally clean and uncracked. To this end it is important that the fronts of cage floors are dusted periodically to stop 'tramline' marks on the shell, and also that the eggs are carefully collected (directly on to 'Keyes' trays), when automatic systems are not in use.

Egg handling accounts for the largest proportion of the labour charge on most units, and the employment of part-time women workers assisting with the afternoon's egg collection is now common practice.

Egg Quality. After collection the eggs should be cooled as quickly as possible to 45–55° F., as this will enhance their keeping quality, and also minimise any loss of weight by evaporation through the shell.

The misguided conception that a free-range egg is better nutritionally and more tasty than a battery egg does not hold up to scientific investigation. Chemical analyses of both types of eggs for water, fat, protein and ash have proved to be similar. Where we have conducted taste tests on eggs from free range, hen batteries and deep litter, no significant differences have been found by the panels concerned. Yolk colour is a very variable factor in free-range eggs, being darker in summer when there is plenty of fresh green food containing xanthophylls, and paler in winter due to a lack of natural pigments. It should be stressed that yolk colour, like shell colour, has no nutritional influence on the contents of the egg. The nutritional composition of the egg is governed by the quality of the foods eaten by the hen, which may be very variable under free-range conditions, whereas in a hen battery cage the rations used are carefully formulated so as to enable the hen to produce top quality eggs consistently.

Daily Battery House Routine

It is important that the day-to-day details of running a hen battery unit efficiently are not overlooked; which is where the efficient stockman proves invaluable. Before entering a battery house, a good indication of efficiency can be found by a quick glance round the outside of the house. Its general tidiness, the state of any equipment and the construction of the Tobins tube air inlets are important. Air vents must not be choked with grass, cobwebs, feathers or dust. A maximum and minimum thermometer hung outside the building with others inside, all indicate that someone is taking pride and a careful interest in the running of the unit.

Once inside the house check the standard of ventilation, and note the house temperatures. If the fan shafts and inlets get blocked this will affect the ventilation rate. Is a routine record kept of room temperatures?

The light density (minimum 1 ft. candle) will also be apparent, but it can easily be checked with a light meter. What is the duration of light, and when was the time switch last checked to prove that this is so? Have the birds a satisfactory supply of food and water? Are the drinkers clean and the feed troughs filled to a level that is not causing feed wastage? In addition to checking these points, the poultryman should also glance at every bird in its cage daily, removing any which are sick.

The cage floor fronts must not be dusty, and the battery house floor should be swept clean each day. Cobwebs should be few and far between. Routine maintenance of the mechanical components of the battery cage is also important. Lubrication of bearings, checking the condition of scraper wires and blades and repairing immediately any tears in cleaning-out belts are examples of the points to watch for in battery house management. Occasionally faecal matter may get held up by the cage floors and this should be removed daily or it will increase the incidence of dirty eggs. This is normally less than 5 per cent, most having only a few marks on them which can be quickly removed with a sand-buffer.

Laying House Records

Record keeping does not appeal to many poultrymen, but the maintenance of a simple daily record of egg production, food consumption and mortality is essential, if the enterprise is to be run on efficient business lines. This can be particularly helpful in the rapid recognition of a disease outbreak, for example by noting a sudden fall in food or water consumption and checking on the state of the droppings.

Another aspect of disease prevention is that of controlling any external parasites. When housing pullets in cages, it is a useful routine to dust them with a suitable insecticide, as a precaution against a rapid build-up of mites or lice. A periodic examination of the birds for parasites at 2 to 3 monthly intervals during the laying year is also to be encouraged.

When newly housed, some strains of light hybrid birds become excitable, and the installation of a radio in the battery house may be helpful in quietening them. Cleaning out the manure daily may also upset them at first, and for the first few days this should be done after the lights have gone out.

Rodent control is another important factor with which the poultryman should deal effectively, particularly so when the house is depopulated and being cleaned, as at this time there will be no feed to attract rats and mice.

Either a steam cleaner or a pressure-hose washer are invaluable for the annual clean out and disinfection. At this time when the cages are being cleaned any major replacement of wires, belting, etc., should be done, and where possible a service by the cage manufacturers.

Economics

The basic reason for the rapid growth of the hen battery cage system for egg production, is that it is the most economic method for producing eggs on a large scale. Although egg production on deep litter can be successfully carried out on a large scale by some egg producers, the hen battery system has fewer problems of management, and all aspects of the battery system are under complete control by the poultryman. An absence of broodiness and parasitic diseases such as coccidiosis and worms, and egg cleanliness are examples of the superiority of the battery system of egg production. Furthermore the level of egg production from hens housed in cages is rarely attained by pullets housed under any other system.

The capital cost of housing birds in cages is currently 8s. to 14s. per bird to which must be added the cost of housing, which for a new house will be about 15s. per bird. Exact costs will depend partly on the quality of house and cages installed, but also vary considerably according to the stocking rate used. For example a 16 in. cage to hold four light hybrids may cost £2 apiece, or 10s. per bird. But under Brambell Committee recommendations this cage would only hold two birds, thus doubling the capital cost of the cage, per bird housed. A well maintained block of cages will last for at least 10 years, which would give an annual charge for depreciation of house and cages of around 2s. 6d. per bird.

When planning a new unit for battery egg production the size will basically depend on the capital available, but there are usually a number of possibilities regarding the layout of the unit, and size and number of houses that can be used. Most houses do not contain more than three blocks of cages side by side, due to the extra expense of extra wide houses and the difficulty of efficiently ventilating them. The length of blocks of mechanical cages rarely exceeds 100 ft., due to the big strain placed on motors, wires, etc., on very long blocks.

Where the farmer has his own rearing house, it is often practical to have three battery houses, so that each year the rearing house produces three batches of pullets to fill each of the laying houses in turn.

Other Cage Systems

Tier brooder cages for rearing chicks for the first 3–4 weeks of life have been used for many years. They may contain 50–150 chicks and use gas or electricity as a source of brooding heat. From these brooders chicks may be transferred to a variety of housing systems, including larger cages which will house them indoor or outdoors until they are transferred into laying cages at 16–18 weeks old.

More recently rearing cages with a brooding compartment at one end have been marketed, and the latest trend is to brood the chicks in only the top tier with a heater suspended above the top of the cages. With this system the birds are progressively moved into the middle and bottom tiers so that at about 10 weeks of age one-third of the birds are housed in each tier. These moves are normally planned to coincide with the dates of vaccination of the birds against Newcastle disease and infectious bronchitis. Having been reared together 'peck orders' are of little importance, but this new rearing system is not one to be undertaken without understanding the techniques concerned.

Apart from *Gallus domesticus*, cages are used on a more limited scale for other species of poultry, the next in importance being their use with breeding turkeys. They may house individual males and females, particularly where artificial insemination is commonly practised. Ducks can also be kept in battery cages for egg production, but particular care must be taken in the design of the cage floor, which must have a very smooth surface or it will damage the birds' feet. Probably the only other bird housed in cages in Britain for commercial purposes is the Japanese Quail (*Coturnix coturnix japonica*) which may be kept for both egg and meat production.

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Chapter 17

POULTRY NUTRITION, FOODS AND FEEDING

W. P. BLOUNT

Foods for Intensively Housed Poultry. Given access to range, poultry acquire various grasses, seeds, insects, beetles, worms and allied sources of animal proteins and in some cases they may obtain their vitamin B_{12} from dung heaps. This variety of feed supplies essential nutrients, carbohydrates and fats for energy, animal and vegetable proteins, and for much of the year vitamins, minerals and trace elements. There is of course a shortage of vitamins A and D_3 in the winter-time, and some of the minerals and trace elements are dependent upon the nature of the soil itself. The mixed diet of poultry on range supplies adequate nutrients for maintenance purposes but there is a shortage of some essential nutrients for high egg production or rapid growth.

Under intensive conditions practically all these natural sources of nutrients are absent, but a variety of effective substitutes can be obtained economically. Cereals provide ample supplies of energy, although even these may have to be supplemented by oils or fats for particular purposes, including good feed conversions. Fish-meal, whale-meal and feather-meals replace insects, worms and beetles, slugs and snails, and it should not be forgotten that the latter often act as intermediate hosts for tapeworms. Dried brewers' yeast is commonly used as a source of the B vitamins, except B_{12} which is freely available through the antibiotic industry which markets commercially B_{12} concentrates. For today's high producing stock supplements of minerals such as salt, calcium, phosphorus, manganese and zinc are often required and supplied in exact quantities. Most of the lesser elements like magnesium, iron, copper and selenium are supplied by the raw materials and therefore may not require to be provided as mineral supplements.

Poultry Nutrition

To the majority of agriculturalists and veterinary surgeons the nutrition of poultry is far from clear, because although they may have studied the scientific feeding of cattle and pigs, they are seldom taught the intimacies of poultry nutrition. Yet much more attention has been paid to this group of livestock than to any other, except possibly the laboratory rat.

Perhaps therefore answers to the following questions recently posed by a veterinary group will prove helpful to others: What food sources do you draw on when compounding poultry rations, both raw materials and countries of origin? How do you go about formulating feeds for poultry?

Basic Questions. First comes the question of nutrients, which ones are required by poultry and in what concentration relative to the age, sex and species? Then the source of supply of ingredients to provide these nutrients.

Apart from price perhaps the most important point concerns availability, because a national feed compounder is likely to need up to 1000 times as much of any one ingredient as a local merchant. Thus, small parcels of exotic ingredients, no matter how excellent their quality, are unlikely to appeal to those who may be manufacturing thousands of tons of compounded feeds weekly.

Regarding formulations, (i) Has the ration to be as good as possible, or must it be cheaper because it is in competition with locally manufactured feeds? (ii) Is the physical form of feed important—mash (meal), pellets, etc.? (iii) Has the feed to travel some distance, for example 60 miles in an 8-ton bulk delivery vehicle, before it will reach the farm? and (iv) Is the client/customer the sort who pays great attention to cost per ton, rather than cost per lb. liveweight or per dozen 2-oz. eggs? Is he usually impressed by the physical appearance of the ration, e.g. must the pellets be hard, firm, shiny and green?

It will be appreciated that there are various rations for different classes of poultry; that there are many different sources of ingredients and that one may have to consider the farmer, the animal and the transport system.

Literature. It is clearly valuable to study the available literature, which should include the following:

Bulletin No. 174, *Poultry Nutrition* (1964), Ministry of Agriculture, Fisheries and Food, 6s. 6d.

This gives a useful general account by Dr. W. Bolton O.B.E. of nutrients, their digestion and utilisation; formulation of poultry diets, composition of foods and other useful data. It includes valuable information about the physiology of the digestive and reproductive systems, subjects into which Dr. Bolton has himself conducted researches at the Poultry Research Centre, Edinburgh and elsewhere.

The Scientific Feeding of Chickens, 4th ed., 1961, 297 pp. by Dr. Harry W. Titus; published by The Interstate, Danville, Illinois, U.S.A. 32s. 6d.

Begun in 1936 and published in its revised, 2nd edition in 1955, this little book can be heartily recommended to budding poultry nutritionists. It is concise, complete, accurate and as up-to-date as was possible in 1955, and is particularly valuable because of its addendum which includes both Fraps productive energy and metabolisable energy data as well as a complete list of feed additives, etc.

Poultry Nutrition, 5th edn., 1963, by W. Ray Ewing, published by The Ray Ewing Company, 2680 E. Foothill Blvd, Pasadena, California, U.S.A. £6 15s.

Although expensive, this much larger volume (over 1400 pages) is an invaluable reference book, consisting of 64 chapters covering every possible aspect of poultry nutrition.

There are many other texts on animal nutrition which can be consulted, including *Recent Advances in Animal Nutrition* (1966), edited by Dr. J. T. Abrams, London, J. & A. Churchill, Ltd., 256 pp., 36s., and *Animal Nutrition* (1966), by P. McDonald, R. A. Edwards and J. F. D. Greenhalgh; Oliver and Boyd, 407 pp., 57s. 6d., but these texts in themselves are incomplete where poultry are concerned.

Special attention should also be given to *Poultry Science*, the bimonthly journal of the Poultry Science Association, U.S.A. and Canada; the quarterly *Journal of the World's Poultry Science Association* (London); *British Poultry Science*, etc. For the specialist the *Journal of Nutrition* (Official Organ of the American Institute of Nutrition), the *British Journal of Nutrition* (edited for the Nutrition Society) and *Nutrition Abstracts and Reviews*, etc. are invaluable.

Raw Material and Nutrients

As is customary these can be grouped into those chiefly supplying proteins, fats, fibre, carbohydrates, minerals, vitamins, trace elements, unknown growth factors and other nutritional or allied supplements, including medicaments.

Proteins

Whereas it was customary 20 years ago to divide these into animal and vegetable varieties (the former being considered of higher biological value) nowadays one considers them as a single group, each raw material providing a proportion of the total amino acids required. So that it is not a question of buying 1 per cent of animal or vegetable protein at the cheapest cost, but of determining which is the cheapest source of certain *essential* amino acids. A further complication is the fact that a proportion of each protein or amino acid will be unavailable to the host. So that *digestible* protein is more important than crude protein, and *available* lysine is more important to the feed formulator than total *lysine*.

The chief ingredients supplying proteins are shown on page 225.

Although urea and ammonium compounds may be used as sources of nitrogen (protein) for ruminants, they are not used commercially as sources of non-essential amino nitrogen in poultry rations.

Animal Proteins. White fishmeal has always been considered the best protein for compounded animal feeds, but supplies are far too restricted for general use. The annual production of all home-produced fish- and meat-meals is about 250,000 tons, of which one-third is fish-meal—white and herring-meal. In relation to the 9 million tons of compounded feeds manufactured in this country it falls far short of requirements, hence the necessarily large imports from Norway, Denmark, South Africa, Peru, etc. Indeed fish-meal developments in Peru during the

Average % crude protein	*Ingredient*	*Country of origin*
	Animal	
64	Fish-meal	Peru; Norway; Denmark; South Africa; Iceland; Canada and home produced
72	Herring-meal	Norway; Iceland; Denmark; Canada
56	Meat-meal	Home produced; U.S.A.
35	Dried skim milk	Home produced; Holland
13	Dried whey	Home produced
80	Blood-meal	Home produced
88	Feather-meal	Home produced; Holland; U.S.A. and Canada
63	Poultry offal-meal	Home produced
	Vegetable	
45	Soya bean-meal	U.S.A.; Canada; China; Argentina and Nigeria
50	Dehulled soya	U.S.A.
49	Groundnut-meal	India; Nigeria; Burma and Gambia
43	Sesame-meal	India
39	Sunflower-meal	India and Argentina
37	Cottonseed-meal	East Africa
37	Rapeseed-meal	Canada; Algeria; Italy; Chile and Argentina
44	Guar-meal	Pakistan and U.S.A.
	Others	
44	Dried yeast	Home produced; West Germany and Eire

past few years have been quite staggering, her annual production of anchovy-meal now exceeding $1\frac{1}{4}$ million tons (out of a world total of 4 million tons), despite the tidal waves last year (following an offshore earthquake) which damaged many Peruvian fish-meal plants. Her larger companies operate their own fishing fleets, comprising 83-ft. long, steel-hulled, 180-ton trawlers with nets which range up to 300 fathoms. And of course they have their own sonar devices for detecting shoals as far distant as 1500 metres. Although Peru now catches more fish than any other country in the world, her own *per capita* consumption of fish is amongst the lowest. At one time Peruvian fish-meal did not have the best reputation, but branded varieties are now first class.

Herring-meals have the 'stickwater' added back (after the removal of the oil) and such meals are termed 'full' herring-meals, being richer than usual in certain 'B' vitamins, and unidentifiable growth factors. The production of fat-extracted herring-meal began at Kopervik, Norway last May; its protein content is 80 per cent and fat 1 per cent.

Some sources of *meat-meal* are suspect, either because of (*a*) overheating, leading to a loss of amino acids like lysine; or (*b*) the presence of viable salmonellae (many strains are exotic).

Dried milk products are expensive (in contrast with other animal proteins), and therefore less used today than hitherto, although some manufacturers insist upon their incorporation in 'starter' feeds for 'milk-fed' table poultry.

Blood meal has never been a popular ingredient in poultry rations because of its unbalanced amino-acid content and relative unpalatability (see F.B.O. meal).

Feather-meals are increasing in popularity, but some sources are unsatisfactory due to inefficient hydrolysation or salmonella contamination. In combination with blood and offals (F.B.O. meal) properly 'cooked' feathers can provide a meal of good biological quality. Such chicken by-products meals are a recent introduction into British poultry rations, and those unfamiliar with their use should consult one of the U.S. publications on this subject, e.g. Bulletin 618, Maine Agricultural Experiment Station, *Use of Poultry By-products in Poultry Feed* (1962), edited by R. W. Gerry.

Vegetable Proteins

Soyabean-meal is the staple vegetable protein of the U.S.A. and Canada and is also much used over here. Its protein content varies between 44 per cent and 50 per cent and full fat soyabean-meals are also obtainable. These contain about 16 per cent oil instead of the usual 1 per cent in extracted meals.

Groundnut-meals have to be used very cautiously because of the risk of aflatoxin being present. Most national feed compounders have laboratory facilities to spot-check the level, using Lee's (1966) rapid test; but in practice *no* groundnut-meals are used in duckling, turkey or pheasant feeds. Only very low levels (2–5 per cent) of any G.N. products containing less than 1 p.p.m. of aflatoxin are used in other poultry rations.

Sesame, like soya, has a very useful content of lysine, but is somewhat richer in methionine, and is also in short supply.

Sunflower-meal can be a very useful ingredient so long as it is not high in fibre and sand, and also free from contamination with toxic weed seeds like thornapple (*Datura stramonium*).

Cottonseed is not a popular ingredient in layer's rations because of its gossypol content which lowers yolk quality, causing both a greenish discolouration and mottling. Iron salts can be added to neutralise the effects of gossypol, but now that glandless cottonseed-meals are being developed in the U.S.A. it may not be long before this gossypol hazard disappears.

Rapeseed is also not popular as an ingredient in poultry rations in this country, but it has recently been the subject of a Canadian (1965) review—*Rapeseedmeal for Livestock and Poultry*, edited on behalf of the N.R.C. Associate Committee on Animal Nutrition. The chapter on its feeding value for poultry is by Professor D. R. Clandinin, of the University of Alberta, and should be consulted by those interested in this subject. In some respects comparable to soyabean-meal, rapeseed-meal has the disadvantage of possessing goitrogens which may cause a dysfunctioning of the thyroid glands resulting in their enlargement. In addition mustard oils are present and rapeseed also has a high content of erucic acid which has other disadvantages.

During the past few years *guar-meal* has come on to the British and American feed markets, but its content of gums, resins and other unwanted ingredients makes it unpalatable to poultry unless 'toasted'. Its prime use in India, from which it originated, is for the production of gums for commercial use.

Dried Yeast. Although yeast provides a useful source of lysine, its high cost is against its general use as a source of protein. Most formulators, however, consider it a valuable ingredient because of its high content of B vitamins and unidentifiable growth factor(s).

Amino Acids

As poultry can only use effectively the nitrogen present in proteins in the form of amino acids, it is perhaps worth noting that whereas one normally multiplies their nitrogen content by 6·25 to obtain the crude protein (since a conventional protein contains 16 per cent nitrogen), for soya it is 5·71; for barley, oats and wheat 5·83 and for maize 6·25. (Some of the nitrogen in the protein will be in the form of non-protein nitrogen.)

Standards for the requirements of poultry for amino acids have been published by both the N.R.C. and the A.R.C., and these should be consulted. They do not differ greatly, except that whereas 0·15 g./100 g. diet of tryptophan is given by the A.R.C. (range 0·09–0·21) for chicks 0–4 weeks, it is increased to 0·2 in the N.R.C. table; and although the requirement for methionine+cystine is given by the A.R.C. as 0·7, it is listed as 0·75 per cent by the N.R.C. (1966).

Synthetic Amino acids. Calculations may show that it is cheaper to incorporate a synthetic amino-acid supplement, than to increase the percentage of a given ingredient such as fish-meal, e.g. for supplying lysine. Indeed in the U.S.A. the use of high proportions of soyabean-meal automatically necessitates the inclusion of methionine, but that is not necessarily the case in Britain where animal proteins of good quality are more freely available at mill sites. (The distance from coast to coast being a few hundred, contrasted with a few thousand, miles as in the U.S.A.)

Amino-acid supplements would be used more freely in many countries if their costs were not so high, but these will fall as their usage gradually increases. Methionine is available in two commercial forms, dl- and a hydroxy-analogue M.H.A. (Monsanto). Whilst both can be utilised by poultry, there are breed differences. Miller and Denton (1959) for example, showed experimentally that more radio-active methionine was converted to cystine-S^{35} by White Leghorn chicks than Australorps. Whilst some workers believe that these two forms can be considered equal nutritionally (on a weight-to-weight basis), it has to be remembered that M.H.A. is offered as a calcium salt (calcium dl-2-hydroxy, 4-methyl-thiobutyrate) and it is necessary therefore to calculate its molecular equivalency before deciding how much to use.

Commercial sources of lysine are available from Germany and Japan, but prices are still too high for general use. Other synthetic amino acids sometimes incorporated into poultry feeds include arginine and glycine; and both urea and di-ammonium salts have been used experimentally as sources of non-protein nitrogen.

Energy

Poultry obtain their energy either from cereals (carbohydrate) or fats, whichever is the most economic.

For a fuller understanding of the difference between the metabolisable (M.E.) and productive energy (P.E.) values of ingredients, the reader is referred to the N.R.C. (Washington) Publication 100 (1962), *Glossary of Energy Terms*. Tables listing both Fraps P.E. figures and M.E. data for most ingredients used in poultry feeds are given in Titus (1961), Tables 17–19. The unit of energy is a kilocalorie (kcal.), equal to 1000 small calories (cal.): a megacalorie is equal to 1000 kcal., known also as a *therm*.

The *total* or gross energy of a feed or ingredient can be determined in a laboratory bomb calorimeter. Having fed similar materials to chickens some will pass out undigested in the faeces, and this is known as faecal energy. The apparent digestible energy is the total energy minus that passed out in the faeces, but the *metabolisable energy* is the total energy less the faecal, urinary and gaseous energy. (Some feeds may release gases and some urine will be excreted without being admixed with the faeces. Both may contain oxidising substances, i.e. energy.) *Maintenance energy* relates to that used to keep the animal in energy equilibrium, the energy content of the tissues remaining static. *Production energy* is that over and above the maintenance requirement, used for the production of eggs, meat, feathers, etc. *Basal* *energy* represents the minimum amount required to keep the animal alive in a fully resting stage, in a thermo-neutral environment.

Energy is of course used in voluntary activities (movement) and to keep the bird warm (body temperature 105° F) when the environment is cold, but also to cool the bird (by panting, etc.) if the environment is above the zone of thermal neutrality. Fig. 39, page 230.

Carbohydrates

In many countries corn (maize) forms the main source of carbohydrate, but where rice is the staple cereal grown, then broken rice may replace maize. In Canada and Australia wheat has also been popular on the basis that wheat supplies 10 per cent less energy than maize, but the economic climate in Britain today favours barley, and in the U.S.A. much more attention is being paid to the use of milo than hitherto.

Oats are not a good source of energy, although groats or oatmeal would be if their price was not so high; and the same applies to sugar. On the other hand molasses is a cheap, economical source of metabolisable energy, and whilst very high levels (19–20 per cent) have been used in Hawaii without adverse effects, much smaller quantities are used in Britain or wet litter problems may follow.

Fats and Oils

Supplements of fats (greases and tallows) or oils (cod-liver) are useful whenever the routine ingredients do not provide enough energy, and also for the supply of essential fatty acids. The fowl is able to digest many sources of oils and fats readily, but tallows are not as well digested by young birds. In an experimental diet used by Combs of Maryland (which gave a feed conversion to 8 weeks of age of 1·1 : 1) the diet contained 40 per cent 'fats', showing their great digestibility.

Whenever 'fats' are used in poultry rations it is essential that they are not rancid, as this may result in off-flavours, e.g. in broilers. Fish oils and those in herring-meals may also give rise to 'fishy' tasting meat and eggs. (In some instances off-flavours appear more marked in cold than hot meats). As an aid to the prevention of rancidity, anti-oxidants like ethoxyquin (Santoquin 0·0125 per cent) can be added at a convenient stage during processing.

Under some circumstances cod-liver oil may provide economic sources of both calories and vitamins A and D_3, but on other occasions it has been superseded by cheaper sources of fats and synthetic vitamins.

Essential fatty acids (E.F.A.) have come into specific use in the poultry industry during the past few years, in connection with the production of 'large' eggs, high fertility in Leghorn cockerels, etc. Unless minimal levels of E.F.A. are provided fertility is decreased, but high levels of linoleic acid may have an equally adverse effect unless given in conjunction with either vitamin E or ethoxyquin. For optimum

- Food intake gross energy
  - 1. Apparent digestible energy
    - 1. Metabolisable energy†
      - 1. Net energy
        - 1. Production energy
          - A. Energy storage
            - a. Foetus and nutrient storage in female
            - b. Semen in males
            - c. Growth
            - d. Milk
            - e. Eggs
            - f. Wool
            - g. Fur
          - B. Work (part of this is expended as heat)
        - 2. Maintenance energy
          - a. Basal metabolism*
          - b. Voluntary activity*
          - c. Heat to keep body warm* (only necessary when below critical temperature and when more heat is needed than is supplied by the heat (increment)
          - d. Energy to keep body cool* (only necessary above zone of thermal neutrality)
      - 2. Heat increment
        - A. Heat of fermentation*
        - B. Heat of nutrient metabolism*
    - 2. Gaseous products of digestion
    - 3. Urinary energy
      - A. Food origin
      - B. Endogenous (body) origin
  - 2. Faecal energy
    - A. Food origin
    - B. Metabolic (body) origin

* These items are expended as heat.

† When metabolisable energy is corrected to nitrogen equilibrium it is known as N-corrected metabolisable energy.

FIG. 39. The utilisation of energy (conventional scheme).
(With acknowledgements to N.R.C. Publication No. 1040, 1962, Washington, D.C.)

hatchability and egg weight $2\frac{1}{2}$ per cent linoleic acid is recommended (Calvert 1965).

There may also be a disease control role to E.F.A. Ross and Adamson (1961) reported that chicks deficient in E.F.A. developed aspergillosis more readily than those fed a diet containing corn oil. More recently Boyd and Edwards (1966) showed that chicks receiving an E.F.A.-deficient diet were more susceptible to mortality from *E. coli* than chicks fed a corn oil supplemented diet, but the extent of the protection could not be correlated with its linoleic content. These and other experiments indicate two general theories for the function of E.F.A.—(i) as precursors of prostaglandins, and (ii) as integral parts of phospholipids in various coenzymes and lipoproteins of sub-cellular structure. Further studies are obviously required.

One egg producer recently gave his laying stock rations especially rich in E.F.A. in order to sell 'medicated' eggs (containing above average amounts of linoleic acid), some doctors believing that certain heart disorders may be prevented by E.F.A. One of the richest sources of linoleic acid is safflower oil, but this makes the final mix very oily which may make the meal unpalatable to layers. Cruickshank (1934) showed that the linoleic acid content of egg yolk could be increased from 19 to 49 per cent when 28 per cent of hempseed oil was added to the control diet. The percentage of linoleic acid in some common oils is as follows:— safflower—60 per cent (Indian)—78 per cent (German); Hempseed oil—68·5 per cent; Linseed oil—13·4 per cent; Palm oil—7·3 per cent; Mutton fat—2·2 per cent (Hilditch & Williams, 1964).

High Energy Diets for Poultry

Farmers have become specially interested in the use of *high* energy feeds, indeed some go to the extent of buying rations based on the level of energy, without knowing anything about calories. But what is a *high* energy diet? One can assume that over 900 P.E./lb is high, 850 is medium and under 800 low; their equivalents in metabolisable energy are 1287, 1215 and 1144 respectively. (M.E. = P.E.×1·43). But there can be little comparison between the energy data used by one company and another simply because there is no fixed value for any one ingredient. For example, the M.E. of maize ranges from about 1280 to 1780 Cal./lb., and the protein from 8 to 16 per cent. For these reasons some feed manufacturers carry out their own biological assays to obtain more accurate data, whereas others consult nutrient tables. Therefore rather than try to define the *exact* energy level in a feed, it is far better to classify it as being in the low, medium, high or very high energy categories.

High energy diets for poultry have arisen not as a gimmick, but because some of today's highly productive stock need them. Light hybrid pullets weighing about 3 lb. often consume less than 100 gm. feed daily, especially early in the laying season when they are still growing, when egg production is moving towards peak and when egg size is increasing. They will lay between 200 and 300 eggs in 336 days (48 weeks) and their egg size will average about 57 gm. (2 oz.). As calcium carbonate may form about 10 per cent of the ration the remaining 90 gm. or less must contain first quality protein and ample energy for maintenance and production.

Such pullets consume about 220 P.E. Calories per day, contrasted with 330 for heavier pullets. If they are to obtain this in 3½ oz. (100 gm.) of feed then such rations must contain over 900 P.E./lb. The value of ingredients specially rich in energy therefore will be appreciated.

Similarly with broilers, which today are expected to reach 4 lb. in 63 days with a feed conversion of about 2·35 : 1. Thus only 9½ lb. of feed will be consumed. It is for this reason that both broiler starter and finisher rations usually contain over 900 P.E./lb. And the same goes for starter feeds for as-hatched turkey poults, which commonly weight 9–10 lb. by 12 weeks of age, with a feed conversion of 2·5 : 1.

M.E. or P.E.?

For years poultry nutritionists used Fraps productive energy (P.E.) figures (Texas Agricultural Expt. Station, Bulletin 678), but more recently many scientists have preferred metabolisable energy (M.E.) data. Even so today's publications still show that some authors prefer P.E. data, and this may be due in part to an unwillingness to change to a new set of figures for which they have no counterpart in their earlier data. Although some workers multiply their P.E. figures by 1·43 to obtain an M.E. equivalent, it is not the same simple mathematical change as going from Centigrade to Fahrenheit.

Wheat however is one of the ingredients for which M.E. figures do appear preferable to P.E., based on numerous feeding trials, but like all cereals the energy contents of different varieties of wheat vary considerably. In British Columbia M.E. values have ranged from 1460–1600 Cal./lb. on a dry weight basis. (Soft wheats may contain only 8 per cent protein, and hard wheats up to 18 per cent.)

So far as fish-meals are concerned it is important to know whether they have been stabilised during manufacture by treatment with an anti-oxidant, since trials have shown that the energy content of treated *versus* non-treated fish-meals differ by as much as 300 Calories, e.g. 1500 *versus* 1182. M.E./lb. in favour of the treated fish-meals.

Fibre

The minimal level of fibre for chickens today is much lower than hitherto, since broiler feeds have been shown to perform perfectly well with as little as 2 per cent fibre. At the other end of the scale pullet replacement high fibre rations may contain from 14 to 18 per cent, and the only detrimental feature is an increase in feed intake. Therefore little attention is paid to fibre, unless one supports Bolton's view that the level of indigestible organic (I.O.) matter is important. In his book he lists the percentage I.O. matter in different feeds, and believes that chickens require about 13 per cent of the diet in this form (15 per cent for older stock), lower levels leading to watery droppings and scouring (Bolton, 1963).

Minerals

Chief are calcium, phosphorus, common salt, manganese, iron, copper, iodine and zinc.

All poultry rations contain adequate amounts of potassium and magnesium, and the fowl's requirement for cobalt appears to be met fully by vitamin B_{12}, the molecule of which contains cobalt in a chelated form (see p. 254).

Calcium and phosphorus supplements such as steamed bone flour or di-calcium products are used in Britain, but in other countries rock phosphorus or other forms may be used as a source of inorganic phosphorus. The fowl is unable to utilise phytin phosphorus freely, but from 33 to 50 per cent is usually considered available for chicks and adults respectively.

The cheapest source of calcium is of course limestone (calcite), but care is necessary to check that it has a high content (e.g. 38 per cent equal to 98 per cent calcium carbonate), and also that it is not contaminated with deleterious components. One sample we recently analysed contained only 58 per cent $CaCO_3$, nearly 10,000 p.p.m. magnesium, 43 p.p.m. lead and 30 per cent silica! (*Note:* Whilst many rations contain low levels of sand ($\frac{1}{2}$ per cent) which comes from raw materials grown in the soil, there is no evidence that silicon plays any part in poultry nutrition, except in the form of insoluble, flint grit.)

Whilst numerous experiments have been carried out to determine whether other forms of calcium than the carbonate are better assimilated or utilised by poultry (such as lactate), most compounders find carbonate best. If the sulphate is used, watery droppings may result.

The *salt* content of the ration will be derived partly from raw materials (e.g. fish-meal, containing about 1 per cent, soyabean-meal 0·45 per cent), but additions ranging from $\frac{1}{8}$ to $\frac{1}{2}$ per cent must be included whenever necessary. If excess salt is given thirst is created and following the increased water intake wet droppings may again follow. If water is not freely available excess salt becomes toxic.

Manganese is usually added as the sulphate, but cheaper, cruder forms such as the green manganese oxide are on the market and would appear to be suitable for poultry. As many wheat by-products however contain over 100 p.p.m. of manganese, as well as some limestone preparations, a supplement is not always necessary.

Quite high levels of *iron* are present in many raw materials so that iron sulphate is not an absolutely necessary addition to poultry rations, and the same applies to copper. Even so many feed formulators prefer to add 10 p.p.m. iron and 2 p.p.m. copper as a safeguard against

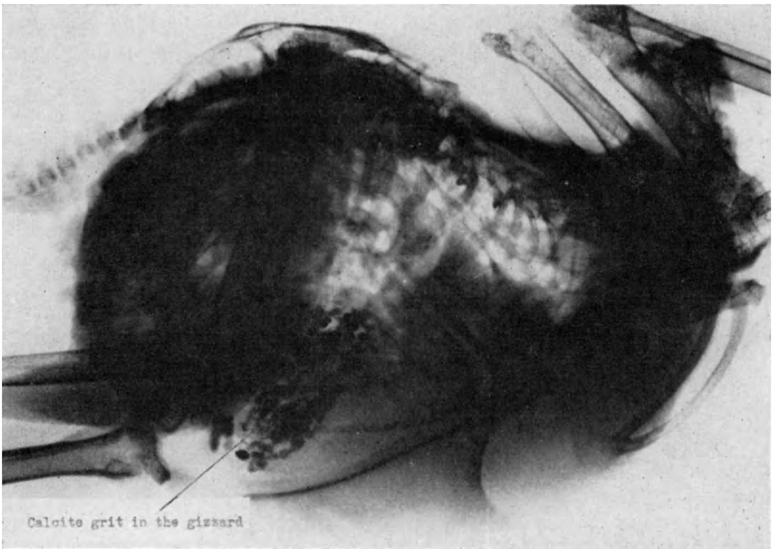

FIG. 40. The presence of calcareous grit particles in the hen's gizzard is physiological but a feature which is not seen when stock are fed on modern layers' rations 'complete for calcium.'

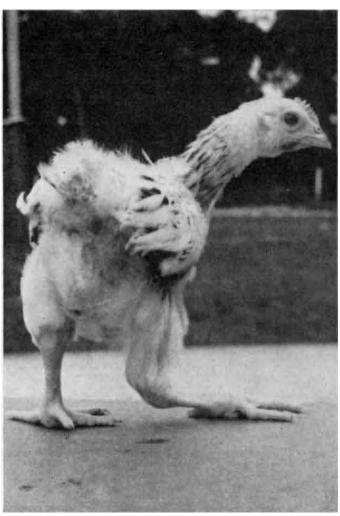

FIG. 41. Perosis in the chicken is commonly linked with a shortage of manganese in the diet, but in the turkey poult choline, vitamin B_{12}, folic acid and other nutrients may be involved.

anaemia, etc. (They may also add 0·2 p.p.m. cobalt sulphate.) Iron salts can also be used to counteract the adverse effects of gossypol (Ullrey, 1966).

Iodine is another nutrient which does not necessarily require to be given as a supplement, particularly when the ration includes fish-meals or molasses. Whilst potassium iodide contains 76 per cent of iodine, a stabilised form in a 10 per cent cerate base is more commonly used, particularly in breeder rations because of its beneficial effect on hatchability. Iodine is also given to counter the goitrogenic effects from the use of certain rapeseedmeals.

Kratzer and others (1959) showed that many poultry diets benefited from the inclusion of a salt of *zinc*, because rations containing high levels of soyabean-meal 'locked up' some of the zinc. As the carbonate or oxide, it is commonly included as a supplement in many turkey rations, and also in layers or breeders rations containing high levels of calcium (over 2 per cent). Chelates such as E.D.T.A. are being used experimentally for the release of the locked-up metals e.g. zinc.

Selenium. Selenium is normally regarded as toxic when present in any marked quantity (1–6 p.p.m.), but it is now known that it can function (when present in very small amounts) as a co-partner to vitamin E in relation to the prevention of exudative diathesis.

A report that seleniferous soils have been discovered in this country comes from Webb, Thornton and Fletcher (1966). They showed that certain areas of North Staffordshire, Derbyshire, Devon and Caernarvonshire showed from 5 to 60 p.p.m. molybdenun together with 3·9–9 p.pm. selenium. (Normal contents 2 p.p.m. molybdenum; 0·2 per cent selenium.) The possibility of associated animal disorders of a sub-clinical nature was discussed. This is the first evidence of the existence of seleniferous soils in Great Britain, although up to 324 p.p.m. have been reported in certain Irish soils (Walsh 1951).

In order to provide a minimum quantity of selenium, the sodium salt (Na_2SeO_3) has been used experimentally, and it has also proved of value in the prevention of 'white muscle' disease and 'stiff lamb' disease, where the natural selenium content of forage crops in the areas concerned was 0·05 per cent or below. Muscular dystrophy in chicks depends upon a simultaneous deficiency of vitamin E and sulphur-containing amino acids, whereas in the turkey poult selenium and vitamin E have additive effects, sulphur amino acids being valueless as a preventive.

Vitamins

The role of vitamins is well known, but several points, particularly in relation to chick nutrition require emphasis.

Different breeds have varying requirements, for example White Leghorns pass about 60 per cent more B_1 into their eggs than other breeds, and R.I.R. chicks require 12 per cent less pantothenic acid than White Leghorns, whereas the latter utilise B_2 better than do New Hampshires.

As many vitamins are water-soluble and others capable of being solubilised, there may be a place eventually for administering vitamins in cases of emergency in the drinking water, but cost in relation to wastage may decide the economics of this practice.

During incubation embryos synthesise some vitamins, e.g. nicotinic acid from tryptophan, but if there is any interference in this at a time when there is a rapid increase in cell division malformations may result. Thalidomide has this effect and its teratogenic properties are probably related to this feature.

Vitamin E is not so synthesised, and therefore that present in the baby chick's liver at birth is dependent entirely upon the vitamin E content of the breeders ration. This may play an important part in determining the onset of crazy chick disease, particularly as liver levels fall during the first 2 weeks no matter what the amount present in the starter feed. Whilst high levels of anti-infectious vitamin A can be built up in the liver (for use in emergency), there is little point in attempting this in the case of broilers which are to be killed at about 9 weeks of age. Their diet need only contain sufficient for day-to-day needs, and liver storage values can be used experimentally to determine when excesses are being given.

Excessive amounts of vitamin A given to layers may lead to pale yolks, lack of skin pigmentation and a fall in egg production; similarly a marked deficiency of this vitamin also causes egg production to fall sharply.

Breeds of poultry characterised by black feathering ('Harco') require much higher levels of riboflavin than most other breeds, and if this is not supplied to the parent breeding stock hatchability falls markedly. This condition occurs as a result of a recessive gene which expresses itself by altering the renal absorption mechanism for free riboflavin and not by riboflavin destruction. Thus riboflavin excreted into the urine (riboflavinuria) is not reabsorbed via the tubules. In such cases at least three times the usual supplement in the breeders diet should be given to overcome this defect (Beer, 1967).

Now that poultry are housed on fully intensive systems the necessity to check very carefully the vitamin levels of the rations used has been emphasised, and consideration is given to at least eleven, thus:—

Vitamin A (retinol). This is usually provided in a synthetic form, although there is no reason to reject the use of good quality fish liver oils. In the U.S.A., and elsewhere where first quality corn forms a high percentage of the diet (particularly in conjunction with alfalfa meals) there may be no need to use any supplements, because of their high content of carotene. But in Britain where No. 2 or No. 3 corn is used (age unknown) the use of a 'protected' form of synthetic vitamin A (beadlets) is practised. Such products should undergo less chemical deterioration than unstabilised powders, especially if the latter come into direct contact with oxidising agents such as salts of manganese or iron.

FIG. 42. The multiple pustules in the oesophagus (alongside the trachea), are considered typical of vitamin A deficiency in the fowl.

Vitamin D_3. The Russians still provide their stock with this vitamin daily by means of irradiation from ultraviolet lamps, others may use cod-liver oil, but most modern feed compounders use synthetic D_3 (activated 7-dehydro-cholesterol). In fact it is usual to purchase vitamins A and D_3 together in a ratio of 4:1 or 5:1 and in some cases vitamin E is added too. Unless adequate amounts are incorporated into poultry feeds, cases of rickets or osteomalacia are liable to occur. (*Note:* Calciferol (vitamin D_2) is not suitable for poultry since they require ten times as much compared with D_3.)

Vitamin E. Few ingredients are rich sources of vitamin E, other than the 'germs' of wheat and other cereals, and therefore synthetic alpha-tocopherol acetate is used instead. Whilst its function for poultry is not absolutely clear, a supplement is generally given in chick and broiler feeds to help to prevent the development of crazy chick disease; and also in breeders rations to aid fertility and hatchability, although there is not the same requirement here as an anti-sterility vitamin as for some mammals. Vitamin E is readily destroyed by rancid fats, so that an anti-oxidant is often included at the same time. (In fact it is claimed that *Santoquin* protects both vitamin A and E from oxidation.) Authorities differ as to the level of vitamin E in broiler feeds, these ranging from 2000 to 5000 I.U./ton.

Vitamin K. Most rations contain enough vitamin K (supplied by $\frac{3}{4}$ per cent alfalfa) to aid normal blood clotting, but because of the risk of outbreaks of haemorrhagic disease 1–2 gm. per ton of menadione sodium bisulphite (vitamin K) are often included. This is increased to 5–10 gm. in any rations containing sulpha drugs, or coccidiostats with a sulpha drug component, e.g. *Pancoxin.* The best natural source of vitamin K is green-food—fresh or dried (grassmeal).

Vitamin B_1 (Aneurin). Many ingredients like wheatbran contain small amounts of vitamin B_1 (thiamine) so that supplements are unusual, especially as no-one ever sees the classical deficiency symptoms characterised by polyneuritis. The richest natural source of B_1 is dried yeast which may contain 35 mg./lb. compared with 5–10 in wheat by-products and 2 mg. in barley.

Vitamin B_2 (Riboflavin). As a contrast to thiamine, riboflavin (vitamin G) is often deficient in poultry rations, unless special care is taken in the choice of ingredients (usually expensive) or synthetic riboflavin used. Soon after the war when the use of dried skim milk (5 per cent) was insisted upon in baby chick rations by the Ministry, riboflavin first came on to the market at a cost of about 6s. per gm. Today it costs less than 1d. per gm., the reduction being due mainly to the greatly increased usage by the feed industry. As a natural growth stimulant it is an essential component of 'starter' and breeder rations, but as dried yeast is also rich in other B vitamins some nutritionists prefer it to the synthetic product.

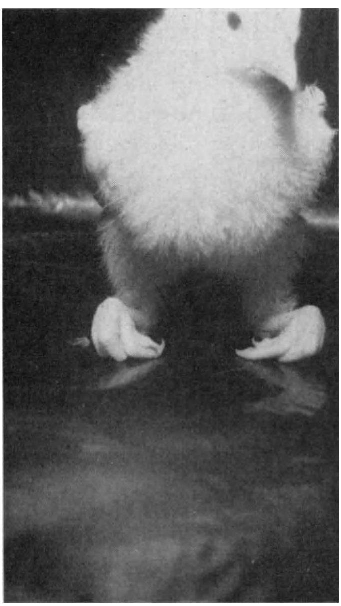

FIG. 43. Curled toes are typical of vitamin B_2 deficiency and generally respond to a supplement of yeast or synthetic riboflavin unless the lesions are very far advanced.

Vitamin C (ascorbic acid). The fowl has no requirement for vitamin C in its feed, because it can synthesise this, but only if the liver is healthy. Work in both the U.S.A. (California and Florida, etc.) and Israel has shown that a supplement of vitamin C may be of value to layers under hot weather conditions, at a time when feed intake is low. Trials in this country have not substantiated this use.

Nicotinic Acid (niacin). A member of the vitamin B complex, nicotinic acid or its amide is necessary for good feathering, normal growth and the prevention of certain hock abnormalities more particularly in poults. Wheat by-products, sunflower-meal, dried distillers and fish solubles, rice bran and dried yeast are all rich in niacin so that on many occasions no synthetic supplement is needed. Furthermore poultry can synthesise this vitamin from the amino acid tryptophan. Against this is the fact that much of the vitamin in cereal grains is 'bound'.

Pantothenic Acid. This B vitamin plays an even greater part in turkey rations than in those for fowls, primarily because of the much higher requirements of the former species for this vitamin—for growth, feathering and hatchability. So that whilst some poultry rations provide enough, others require a synthetic supplement, although dried yeast, groundnut-meals, dried milk products and most cereal grains all contain useful amounts. One form of dermatitis follows pantothenic acid deficiency, and in turkeys this may appear as a secondary aspect of moniliasis (crop).

Pyridoxine (vitamin B_6.) It is unusual to add synthetic pyridoxine to poultry rations although its presence is essential, particularly in 'starter' feeds.

Folic Acid (folacin: vitamin B_c.) Some years ago it was discovered that poults receiving compounded rations developed a flaccid paralysis of the neck and that they responded to folic acid. Up to that time it was uncommon to include this vitamin in poultry ration specifications. Today it may be included, particularly in turkey starter and breeder rations, but as the requirement is low (0·36 mg./lb.) only a gramme or two is necessary per ton.

Vitamin B_{12} (cyanocobalamin). Since the world-startling researches of Smith at Glaxo Laboratories and Rickes *et al.* in the U.S.A. in 1948, much has been discovered about the 'cobalamins' as nutrients in both human and animal rations. B_{12} has special properties in relation to red cell regeneration, and is used in man to treat cases of pernicious anaemia. Apart from an ability to maintain normal red cell development, B_{12} is also a growth stimulant and therefore of great importance in breeders rations, helping to raise hatchability. Whilst supplies normally come from animal proteins, cheap synthetic sources are also available.

Biotin (vitamin H). Biotin is another member of the B group of vitamins, made famous because it is destroyed by *avidin* present in raw egg white. Its function is not absolutely clear, but if there is a deficiency in the diet the growth rate may be poor, and perosis results as well as dermatitis (involving the feet and mouth). This latter requires differentiation from the dermatitis linked with pantothenic acid.

A combination of any six common ingredients in most poultry rations presumably supplies all the biotin required, particularly as dried yeast and grass-meals are rich sources. In any case synthetic supplements are expensive, costing about £2 per ton of complete ration.

Choline. The much higher requirement of the turkey for choline highlighted its use in poultry rations, and many feed compounders now check the level in layers and breeders feeds, as well as in *all* turkey rations. When shortages are seen to occur choline chloride is added appropriately, either in the liquid form or adsorbed on to a suitable substrate.

Choline is considered to be of special value for preventing one type of fatty degeneration of the liver in layers, and there may also be a link with the now well known *fatty liver syndrome* for which Couch recommends the use of a supplement containing 5000 I.U. vitamin E, 12 mg. vitamin B_{12} and 1600 gm. choline per ton.

Vitamin Levels. Many different levels have been suggested for satisfying the needs of poultry, but the following table outlines Scott's (1966) recommendations, alongside which are given the increased levels which he considers advisable when poultry are subjected to 'stress'.

SUGGESTED VITAMIN LEVELS FOR PRACTICAL CHICKENS FEEDS
(per kilo)

Vitamin	*Chicks and broilers (0–8 weeks)*		*Layers*		*Breeding hens*	
	Normal	Anti-stress	Normal	Anti-stress	Normal	Anti-stress
A	10,000	20,000	6,500	15,000	10,000	15,000
D_3	550	1,000	1,000	2,000	1,000	2,000
E (added mg.)	5	20	2½	20	7½	20
K_1	2	8	2	8	2	8
B_1	2	2	2	2	2	2
B_2	4	6	4	6	5	6
Pantothenic acid	13	20	5	10	15	25
Nicotinic acid	33	50	25	40	30	50
Pyridoxine	4	4	3	4	4	4
Biotin	0·12	0·12	0·12	0·12	0·12	0·12
Folic acid	1·2	1·5	0·35	1·0	0·8	1·5
Choline	1,300	1,300	1,100	1,100	1,100	1,100
Vitamine B_{12}	0·01	0·02	0·006	0·01	0·01	0·02

In addition to *anti-stress* rations containing the higher levels of vitamins recommended above, they may also contain high levels of broad-spectrum antibiotics (100–400 gm./ton).

Other Vitamins

Other vitamins or vitamin-like substances such as inositol, para-amino benzoic acid, glycuronic acid, etc. are occasionally used as supplements if special or experimental feeding trials have indicated their usefulness.

Unidentified Growth Factors (U.G.F.)

Many feeding experiments in the U.S.A. and Canada have shown that chick growth can sometimes be stimulated by unknown (unidentifiable) factors. Such U.G.F. are believed to be present in dried yeast, dried whey, grass juice, fish-meals, fish solubles (in addition to the presence of vitamin B_{12}), dried distillers and fermentation solubles. Some are derived from antibiotic fermentation residues e.g. *Vigofac* and *Fermacto* (Borden); others are nitro-chemicals such as *Payzone* (Pfizer) and may have an antibiotic-like effect on the intestinal flora.

Nutritionists therefore often include several sources, but not usually the 3 per cent originally recommended, particularly now that one is not always clear exactly how many U.G.F. there are. When used they are incorporated into 'starter' and 'breeder' rations, both for broilers and turkeys.

Supplements

The other supplements which are incorporated into poultry rations consist of (i) anti-oxidants, (ii) pigments, (iii) medicaments, (iv) antibiotics, and (v) miscellaneous substances.

Anti-oxidants. Approved anti-oxidants for animal feeds like butylated-hydroxy-toluene (B.H.T.) and ethoxyquin (*Santoquin*) are used at low levels in any rations where there is a risk that rancidity may develop. This normally depends upon the class of ingredients in the formulation, but when high levels of herring-meals, rice bran, Sussex ground oats, etc. are present, an anti-oxidant offers useful protection against loss of potency of vitamins A and E, and against the development of nutritional encephalomalacia (crazy chick disease). In 1954 D.P.P.D. was recommended as an anti-oxidant in poultry rations but it was later shown to be toxic to pregnant rats.

Pigments. The chief pigments used in Britain are *xanthophylls* for increasing yolk colour, but in parts of France and America where the housewife wants a golden shanked broiler pimiento and allied pigments may be used for this purpose.

The richest sources of natural xanthophylls for yolk pigmentation purposes are dried grass[1] or alfalfa-meals, maize and its by-products, and specialist preparations based on maize such as *Prairie meal.* American research workers have also shown the value of Mexican marigold petals and certain green algae for this same purpose, whilst more recently Roche (Switzerland) and Philips (Holland) have marketed synthetic 'xanthophylls' which strengthen either the yellow, golden or red tints. (In Italy paprika is also used for making reddy-golden yolks.)

None of these products is in the slightest degree harmful, either to the animals receiving them or to persons consuming the end products.

Seaweed-meal. Claims have been made (Guilor 1964) that seaweed-meal (kelp) is a valuable supplement for poultry rations, supplying a wide variety of trace elements. The author carried out feeding trials with chicks and layers, but no worthwhile benefits resulted. Presumably

[1] Although it was reported some years ago that dried nettles were the richest natural source of xanthophylls, these suffer from the same defect as grass meals, everything depends upon their age when cut and harvesting conditions. If the latter are unsatisfactory, their pigmenting properties decrease proportionately.

the success of incorporating kelp follows its use with formulations where trace elements are deficient. A full account of the chemical make-up of seaweed-meals is given by Black (1958).

Medicaments

Drugs other than antibiotics are available for combating the following diseases: coccidiosis, blackhead, hexamitiasis, rupture of the aorta (turkeys), *E. coli* septicaemia, Salmonellosis, etc.

Anti-bacterials. Furazolidone (*Neftin*—S.K.F.) and allied preparations like *Furasol* (given in the drinking water) are commonly used for controlling *E. coli* and Salmonellosis, including pullorum disease. A level of 0·01 per cent is used for prevention purposes and 0·04 per cent curatively, but the latter amount should not normally be given for longer than 10 days. (0·2% *Furasol* for young chicks).

Blackhead. *Entramin* and *Entramin-A* (M.&B.) have now been replaced on many occasions by *Emtryl*, since the latter preparation does not depress the growth rate or hatchability, and it is equally effective against *Histomonas meleagridis*. *Carb-o-Sep* (Whitmoyer Reed) containing as its active principle an organic arsenical (p-ureido-arsanilic acid) is also popular, and its use does not require a veterinary prescription in this country. *Hepzide* (Merck) is no longer available but *Histostat-50* is now marketed.

Coccidiosis. Following the use of sulpha drugs and the nitrofurans, e.g. nicarbazin, attention was paid to *Amprolium* (Merck) (sometimes used with ethopabate = *Amprol Plus*; or the latter with sulphaquinoxaline = *Pancoxin*); Zoalene (Dow) etc. (see also p. 286). More recently metichlorpindol *Coyden 25* (Dow), and buquinolate (Butoril (G.B.), Bonaid (U.S.A.)) have been marketed, and other specialist products are known to be coming along. e.g. *Statyl* (I.C.I.).

These drugs are incorporated, according to the manufacturers' recommendations, but the feed manufacturer cannot accept any responsibility that such medicated rations will prevent the disease in question, because management factors can play an equally important part in the control of coccidiosis.

Reserpine. The use of reserpine *Serpasil* (Ciba) for controlling outbreaks of rupture of the aorta in growing turkeys has become commonplace. It acts mainly by lowering the blood pressure of the male turkey aged 8–20 weeks. Its best use is as a preventive at a level of 0·2 p.p.m., but 5 times this strength can be given for 5–7 days curatively. It cannot of course assist any stock with advanced aortic lesions.

Antibiotics. Feed manufacturers in Britain are limited to the use of three antibiotics in rations for farm livestock—procaine penicillin, and special supplements containing either Aureomycin (Cyanamid) or Terramycin (Pfizer). The maximum level is 100 gm./ton, but such rations may not be fed to layers and breeding stock (or to ruminants).

Procaine penicillin is generally incorporated at levels ranging from 2½ to 20 gm./ton with the object of controlling anaerobic organisms which get a foothold in the caecal tubes and elsewhere within a few hours of hatching. These are believed to be the chief micro-organisms which depress the 'normal' growth rate, following their toxin production.

It is extremely rare to use higher levels of this antibiotic, which is relatively insoluble and therefore does not pass from the intestinal contents into the bloodstream.

Aureomycin (chlortetracycline) and *Terramycin* (oxytetracycline) are broad-spectrum antibiotics, so that some feed manufacturers prefer not to use them (as growth stimulants), but to hold them in reserve for the treatment of an actual disease such as infectious synovitis, pullet disease, pasteurellosis (*F. cholera*), etc.

So that whilst small quantities (10 gm./ton) may be used for growth promotion purposes (? followed by the development of resistant strains of pathogens), much more (100 gm./ton) may be incorporated into specially formulated *high level antibiotic* poultry feeds. These are also used for overcoming 'stress'—following transportation, vaccination, debeaking, dubbing, etc.; and also when it is believed that stock are suffering from sub-clinical disease, possibly linked with P.P.L.O. infections.

Other antibiotics like chloromycetin (*Animycetin*—Stevenson, Turner & Boyce), *Rondomycin* and *Landomycin* (Pfizer), *Eskalin* (S.K.F.), streptomycin and zinc bacitracin may not be used without a veterinary prescription, nevertheless their use in this context (for the medication of either feed or water supplies) is sometimes desirable. Broad-spectrum antibiotics can sometimes be potentiated by the use of an additive such as terephthalic acid, or by the use of low calcium rations, or those containing calcium sulphate.

Arsenicals (organic). Organic preparations of arsenic, e.g. *Progen* (Abbott) and *AS 101* (Whitmoyer Reed) (arsanilic acid), are now being used for the control of *E. coli* in broilers, but whether they have any direct effect against coliforms or only act as a 'tonic' to the gut is uncertain.

Some wholesalers in Britain refuse to buy table poultry which have received organic arsenicals, yet they are used almost 100 per cent in similar circumstances in the U.S.A., particularly 3-nitro-4-hydroxyphenyl arsonic acid in broiler feeds.

The law is such that British farmers do not require a veterinary prescription to obtain such arsenicals, and if they hand them over to a feed compounder he may legally incorporate them into any ration which is being specially made and supplied direct to the farmer in question.

Penicillins. Misunderstandings commonly occur over the nomenclature given to the penicillins. Straight penicillin is also known as penicillin G or benzylpenicillin, available as sodium or potassium salts which are freely soluble. The form which feed manufacturers are allowed to incorporate into certain rations is procaine penicillin, also known as procaine benzylpenicillin or procaine penicillin G. One mega-unit (1 million units) of penicillin is contained in 1 gm. of procaine penicillin; this weight of procaine penicillin is approximately equivalent to 600 mg. of benzylpenicillin. It is soluble in 200 parts of water.

If procaine penicillin is given by i.m. *injection* penicillin is slowly released, but in order to maintain an effective blood level for combating septicaemic conditions (e.g. erysipelas in turkeys), a combination of procaine penicillin and another sparingly soluble salt of benzylpenicillin, namely benzathine penicillin, is often injected (*Penidural*—J. Wyeth & Bros.). Serum concentrations in man may last 7 days, but no similar data have been given for poultry injected with this, or any similar long-acting, form of penicillin.

Miscellaneous

Enzymes. A number of enzymes have been recommended for increasing the digestibility of cereals (barley), some acting on the fibre content, others the protein or starch. So far their general use has not been approved, but in parts of the U.S.A. (California) western barleys have benefited greatly from the addition of 10 per cent malt, and the stickiness of the droppings normally associated with such barleys has been prevented by the use of the ferment *Clarase* (Osm, 1959).

Anderson and Warnick (1964) suggested that gum-splitting enzymes may play a useful part in increasing the digestibility of rations containing locust or guarmeals.

Pellet Binders. A variety of lignosulphonate compounds (derived mainly from the paper-making industry) and also bentonite have been used as binding agents in the manufacture of pellets. They have a very poor nutritional make-up however (some hexoses are present) and therefore the 3 per cent recommended only takes up valuable space, an adverse feature in high energy rations. Attention to the use of improved machinery at feed mills (temperature, pressure and output—at the point of extrusion) may pay greater dividends; especially if used in conjunction with more natural binding agents like molasses, groundnut, pea and bean-meals, etc.

Hormones. Chemical caponisation can best be carried out by the implantation of synthetic female sex hormones, e.g. *Hexoestrol* (Boots) or *Combestrol* (B.W.) but other oestrogenic compounds (Lorenz and Bachman, 1947) can be used in poultry feeds such as dienoestrol diacetate (0·0033 per cent). In America *Lipamone* (American Scientific Labs.) (from $\frac{1}{3}$ to 1 lb./ton of feed) is used for this purpose during the last 4 weeks of the fattening period, prior to a 48-hour withdrawal period.

Iodinated casein preparations like *Protamone* (50–100 gm./ton) are sometimes incorporated into duck rations to help to reduce fat deposition by stimulating the thyroid glands, especially in the summer months. Conversely, 0·2 per cent thio-uracil can be used in other species to aid fat deposition by depressing thyroid activity.

Synthetic progesterone-like compounds have been recommended for their effects on egg production and moulting, as also the I.C.I. antifertility compound 33828. This inhibits ovulation and has been used for forced-moulting purposes in the feed at a level of 0·01 per cent (Clayton and Sykes 1966).

Flavouring Agents. Although a number of flavouring substances, including spices and aniseed, have been sold for incorporation into poultry feeds, none is effective.

Dyes. To pander to some farmers' requirements certain feed compounders have added innocuous vegetable dyes to their feeds so as to improve their appearance. But a greater use of dried grass-meals would achieve the same object and provide a supply of nutrients at the same time as colouring the feed bright green.

Markers. To mark or tag particular ingredients, especially antibiotics or drugs, such substances as phenolphthalein or chromium oxide can be added to the feed. These can then be detected rapidly and cheaply by a qualitative method, proving that the ingredient concerned was present.

Antibiotic Potentiators. The best known is terephthalic acid (0·4 per cent) which doubles the blood level of aureomycin or terramycin. Although Pfizers have shown its economic value, this product has not yet received official approval in the U.S.A. and is protected by patent.

Water. Water is perhaps the most important nutrient, and three sources are available to poultry—what they drink, the natural moisture content of the food and that produced biologically.

The quantity which is drunk must make up for any deficiencies in the other two categories. For example, most compounded feeds contain about 10 and 12 per cent moisture and this would supply stock consuming 4–6 oz. of feed daily with about ½ oz. of water. Fresh greenfoods and roots, of course, contain much more, turnips and cabbage 90 per cent, grass 74 per cent, etc. The water of biological origin arises as follows: from the oxidation of fats 107 c.c. from 100 gm., 55 c.c. from carbohydrates and 41 c.c. per 100 gm. protein (Selyanski 1966).

The usual consumption figure for laying stock is given as 5 gallons/100 birds/day, but this changes markedly in hot weather. When temperatures are in the region of 20° C (68° F) a flock of 2700 laying pullets will drink about 125 gallons per day; equal to 4·7 gallons/100 birds. If the temperature rises to 27° C (80° F) consumption rises to 140 gallons daily. This represents a rise of about 18 per cent from 7·04 oz./bird/day to 8·3 oz.

Water consumption under temperate conditions shows a strong tie with feed intake, rising and falling *pari passu*. Normally fowls drink water to feed in the ratio of 1·5:1. its special importance to layers can be seen from the following B.O.C.M. experiment. When pullets were deprived of water for 6 hours little effect was noticed, but if no water was available for 12–18 hours then egg production fell from 77 to 50 per cent.

When water is absent for any long period the birds combs go deeper red, due to haemoconcentration; feed consumption falls and there may be a 30 per cent reduction in droppings output. Egg production may fall to as low as 10 per cent and egg size will decrease about 4 per cent. Once water is offered to such birds they drink continuously for 10–15 minutes following which some will vomit: afterwards their droppings soon appear wetter than usual. Bierer, Eleazer and Roebuck (1965) showed that week-old chickens deprived of water developed nephrosis and visceral gout, whereas adult layers developed signs indicative of pullet disease.

In turkey poults aged 15–22 days water deprivation resulted in high mortality (up to 28 per cent), most of this occurred after they received a supply of water (Marsden McKee and Crandall 1965). The rapid ingestion of water by young poults after a 48-hour period of deprivation gives rise to a distressing mortality (up to 86 per cent), the poults showing convulsions, huddling and shivering associated with a lowering of body temperature (Haller and Sunde 1965). These adverse effects are not seen in older stock aged 2–5 months.

Feed Formulations

Actual formulations must of course be based on the animal's requirements. They include protein and certain amino acids (in the case of particular species or age group); energy and E.F.A.; thirteen vitamins, eight minerals plus U.G.F. and other factors. The subject is therefore far too complicated to be described in detail; nevertheless in order to give specific examples lysine and calcium will be taken.

Protein and Lysine. Although 20 per cent protein is taken as the standard for young chicks, this is raised for the rapid growth rate required by broilers. If, however, a given amino-acid relationship can be obtained, lower protein levels will prove satisfactory for replacement pullet chicks. One can go as low as 12 per cent and the only disadvantage will be a much slower growth rate and poorer feathering. In practice baby chick rations contain from 18–20 per cent crude protein, broiler 'starter' feeds 22–24 per cent, whilst the protein content of a turkey starter ration will be from 26 to 30 per cent.

The level of the essential amino acids is given either as a percentage of the total ration, or as a percentage of the crude protein. Thus, if a ration has 20 per cent protein and 1 per cent lysine, the latter can also be expressed as equal to 5 per cent of the total protein. With an 18 per cent protein feed the lysine level would fall to 0·9 per cent, being raised proportionally, of course, with higher levels of protein.

In order to provide the correct amount of lysine, protein-rich ingredients may have to be used, i.e. those containing above average amounts of lysine. Fish-meals, dried skim milk and blood-meal are typical examples, but whilst these might all be included in chick formulations, they would not prove so popular for layers feeds, either because of cost or availability.

Soyabean-meal is a good source of lysine, but it has the disadvantage that it is relatively deficient in methionine. Therefore if high levels of soya are used (especially in company with maize or other cereals low in methionine) it is necessary to support it with a synthetic methionine supplement, or some other feed ingredient which is richer in methionine, e.g. sesame-meal.

Low Lysine Diets. Since 1964 low lysine diets have been used with potential broiler breeding stock since these check the growth rate and thus help to prevent the laying down of excess fat. From the normal 1 per cent present in starter feeds, levels as low as 0·45 per cent have been used successfully. Apart from a markedly reduced growth rate and possibly poorer coloured feathering, the chicks appear normal but they may call out plaintively.

Singsen *et al.* (1965) have shown that this system can be used without any adverse effect on subsequent egg production. Its effects on feed consumption and bodyweights can be seen from the following data:

	Feeding programme (weeks)	*Bodyweight (gm.) (weeks)*		*Feed (kg.) (0–21 weeks)*
		12	*21*	
D	0–21	1367	2577	12·26
N	0–12; D13–21	1793	2949	12·74
N	0–21	1793	2935	12·91

(N = normal diet; D = lysine-deficient diet.)

Although not exactly comparable the work of Gordon (1964) at Monsanto has shown that if chicks weighing 90–100 gm. are given a diet deficient in tryptophan they will gain only 16 gm. over a 200-day period, whereas controls will reach point-of-lay normally and attain 10 per cent production. Following the introduction of ordinary diets the suppressed chicks start to grow and lay normally, but if the original deficient diet is given to stock weighing more than 200 gm. (about 10 days old) it does not have the same dramatic effect mentioned.

We have confirmed Singsen's work with broiler replacement pullets, and also devised a feeding programme for commercial layers using rations containing less than 0·5 per cent lysine after the age of 12 weeks.

Thus it is clear that if a single essential amino-acid is provided in sub-optimal amounts it will have clear cut effects on growing stock, and in particular circumstances these can be put to good commercial practice. The same applies to the *Skip-a-Day* programme in which growers are given a full ration one day followed by a simple scratch feed of grain on the following day. Contrary to expectation, bullying is not a feature, but when the poultry-man appears on the morning after the day's semi-starvation diet he may need to protect himself from attack! Details of these various specialist feeding programmes have been published in B.O.C.M. *Quarterly Poultry Bulletins* 48, 52 and 53.

Calcium for Layers. A 2 oz. egg contains 2 gm. of calcium and therefore this amount must be supplied daily, when egg production is at a high level. When a *flock* averages 75 per cent production some pullets will be laying daily and others from 3–5 eggs a week, but as pullets are not fed individually all the essential nutrients must be supplied to *all* the pullets every day. This means 2 gm. of calcium, included as a calcium carbonate supplement, few feed ingredients being rich in calcium. The calcium contents of commonly used ingredients are as follows:

	Ca (%)
Calcium carbonate (limestone)	38
Sterilised steam bone-meal*	30
Dicalcium phosphate	27
Meat and bone-meals*	10
Fish-meal	4–9

* Some feed manufacturers will not use these because of the risk of introducing anthrax spores into the feed mill.

In practice good quality limestone or oystershell flour (containing up to 98 per cent $CaCO_3$) is used, but fowls do not normally digest much more than about 50 per cent of what they receive, so that if 5 gm. limestone is required to provide 2 gm. Ca, then 10 gm. must be given. If a fowl is only eating 100 gm. (3½ oz. approx.) of feed daily—as is commonplace with many light hybrids today—this means that 10 per cent of the total ration will be limestone. This takes up valuable space required for other nutrients, hence the necessity to use concentrated sources of energy, proteins, vitamins, etc.

If, however, a laying fowl were to eat 200 instead of 100 gm. of food daily, it would then only be necessary to include half the amount of limestone i.e. 5 per cent instead of 10 per cent. But 2 gm. of available calcium must be included in the day's *total* feed, no matter how little or how much is eaten.

Oystershell or limestone grits can be used separately in troughs, but to save labour the modern approach is to provide *all* the calcium in the diet, hence the formation of 'complete' for calcium layers rations.

It is very important to appreciate the functional difference between *soluble* (calcium/limestone/oystershell) grits which supply calcium for nutritional purposes and insoluble grit. The latter is for feed grinding purposes only, and as it does not dissolve in the gizzard juices it must be given in strictly limited quantities or it will overflow into the intestines to cause enteritis.

What Reliance can be placed on Feed Ingredients? The dozen or so ingredients commonly used in poultry rations—fish and meat-meals, soya, groundnut, sesame, sunflower, maize, wheat, barley, milo, grass-meal, yeast, etc.—can be expected to provide all the proteins and carbohydrates necessary, but sometimes there will be shortages of essential amino acids. Therefore these may have to be provided in synthetic form. There will normally be enough energy, except for high energy feeds when a concentrated source such as tallow may be necessary. There will also be enough fibre, except for specially formulated 'high fibre' rations, for which oat-feed may be needed; but what about the vitamins, minerals and trace elements?

In the case of vitamin A there will be a gross shortage, except that any rations rich in maize and grass-meals will contain relatively large amounts of carotene (pro-vitamin A) which can be expected to be converted in the intestinal wall into vitamin A. But how far can reliance be placed on the presence of this nutrient? How old is the maize-meal, and when was the grass-meal harvested and purchased? Have they undergone much oxidation during storage? Was the grass-meal protected with an anti-oxidant after drying took place, or alternatively was it cubed, thus exposing less of it to oxidative processes?

There is seldom any necessity to provide vitamin B_1 and enough nicotinic acid may be present, as well as folic acid, biotin, choline and vitamin B_{12} except for specialist rations. A supplement of riboflavin and vitamin D_3 is always necessary, whereas an addition of vitamin K may only be needed if the ration contains a sulpha drug or no grass-meal.

Vitamin E (alpha-tocopherol-acetate) is in a rather different category, since its presence may not be needed when there is ample vitamin A (in 'protected' form), and also an anti-oxidant such as ethoxyquin which 'protects' both vitamins A and E. Even so, for specialist 'starter' and 'breeder' diets a supplement of vitamin E is included. But how much? The literature on this subject shows that authorities differ by more than 100 per cent, and therefore, as with all the other examples quoted, feed manufacturers must take their own decisions, based on past experience or feeding trials.

Except for layers rations, most feeds contain enough natural calcium and in many cases sufficient phosphorus too, but owing to the fowls' inability to utilise phytin phosphorus from cereals and their by-products freely, an inorganic supplement is needed (see p. 233). Additional common salt may not be needed, nor iron, copper, cobalt, magnesium and potassium. But there is usually a shortage of manganese, and if the level of calcium is high then a supplement of zinc may be necessary too. Selenium salts have only been used experimentally, and even in the U.S.A. it is still illegal to incorporate selenium salts into compounded feeds.

Phased Feeding Laying Stock

Americans consider that the phased feeding of layers is a progressive step towards the use of more exact feeding programmes. It is an attempt to supply different feeds throughout the laying year on an economic basis—more precision feeding. Why not change the ration when peak egg production has been reached, and possibly make a further change when egg mass output is obviously declining? Similarly on a seasonal basis less energy is required in the summer months and more in the winter.

Scott and Nesheim (1966) divide the laying season into three periods, from 22 to 40 weeks; from 40 weeks to 65 per cent production and thereafter. They recommend (using rations containing 1300 M.E./lb.) the following:

	Crude protein (%)	*Feed/100 birds/day (lb.)*
Phase 1	17·5	21
2	15·0	25
3	14·5	24

From our trials we have not been able to confirm, however, that farmers will benefit financially, because if the cheaper feed formulation does not maintain production or egg size, income will fall. And if more food is eaten the end result may be no different at all.

Peak production does not place the greatest demand on the reproductive system for which egg mass is a more accurate criterion. Thus egg mass is less at 80 per cent × 1¾ oz. than at 70 per cent × 2⅛ oz. It also has to be remembered that physical maturity will not have been reached until after peak production, since the former takes 10–11 months, whereas peak production is generally reached after a pullet has been in lay for 6–8 weeks, i.e. at about 7 months of age.

Egg mass and physical maturity commonly coincide, but whilst egg mass may stay relatively constant until towards the end of the laying season, the bird will adjust its own appetite and take in less feed once it has stopped growing. In this way it phases its own feeding programme, linked in part to the fact that the laying season often ends during the warmer summer months in Britain.

Cost of Nutrients and Medicaments in Poultry Diets

Procedures for evaluating feeds on a combined economic and nutritional basis have been developed in the U.S.A. using the prices of corn and soya to establish costs per unit of protein and energy. The cost of 1000 kcal. metabolisable energy or 1 kg. of protein can be determined from the following equations:

$$\text{Energy} = \frac{4{\cdot}9\,a - b}{14{\cdot}4} \qquad \text{Protein} = \frac{1{\cdot}55\,b - a}{0{\cdot}59}$$

a = cost of energy and protein in 1 kg. of corn
b = cost of energy and protein in 1 kg. of soyabean-meal.

One can of course take each ingredient in turn and apportion the cost of its inclusion in terms of energy, protein, vitamins and minerals relative to their contribution to the diet as a whole. In practice since diets are usually formulated to a protein and energy standard and vitamins and minerals added separately, the exercise becomes simpler.

The following example taking a broiler starter formula aimed at 22·5 per cent protein and 900 P.E./lb. relates to soya included at a level of 18·25 per cent:

Cost/Ton	*Inclusion cost*	*Protein supplied*	*Energy (P.E.) supplied*
£48·1	£8·779	8·21%	138·88

% Total in diet		*Proportionate inclusion cost*	
Protein	*Energy*	*Protein*	*Energy*
36·5	15·36	£6·178	£2·599

Applying this method to each ingredient in the formula (including added methionine) gives the following result:

	Total cost (£)
Protein	16·7190
Energy	15·2180
Vitamins	0·3350
Minerals	0·4356
Medicaments (antibiotic + anti-coccidiosis)	0·8060
Total	£33·5136

Similar data on the comparative cost of nutrients has been published relating to Brazil (Bird and Lopez 1966) and Canada (Biely 1966), thus:

	Brazil (%)	*Canada* (%)	*United Kingdom* (%)
Energy	49·5	45	45·4
Protein	39·0	38	49·9
Vitamins	7·0	10·6	1·0
Minerals	4·5	1·8	1·3

These figures reflect the cheaper main source of protein (soya) across the Atlantic, and the surprisingly low cost of vitamins in this country, because our levels of inclusion are very similar to those in Canada.

It is probable that few producers realise that the cost of medicaments in broiler feeds is nearly 2½ times as great as that for all the vitamins, equal in fact to the total cost of both minerals and vitamins!

Mash, Crumbs or Pellets?

In the late 'twenties pelleted feeds for poultry came on to the market for the first time, and about 20 years later crumbs (crumbles or chips) appeared. The former are produced by special machinery to compress the mash (meal) into rolls, a guillotine cutting them into varying sized pellets—ranging from $\frac{3}{32}$ in. to $\frac{3}{8}$ in. Larger pellets (cubes) are available for cattle and pigs.

If a pellet is passed through suitable rolls it will break them down into smaller, irregular particles which can be sieved to particular sizes and sold as crumbs, crumbles or chips.

Advantages. The advantages of 'pelleted' feeds to farmers are that labour is saved (easier to feed: less dusty) and on many occasions there is also less wastage. In particular circumstances they will stimulate the bird's appetite leading to a greater feed intake. For example the feed intake of broilers on mash compared with crumbs/pellets is about ½ lb. less by 9 weeks of age resulting in a bodyweight of 3·92 lb. *versus* 4·23 lb. in a recent B.O.C.M. feeding trial employing similar formulae. From a veterinary standpoint pellets will contain a greatly reduced number of potential pathogens (e.g. Salmonellae) because of the friction (heat) to which they are subjected during manufacture.

Disadvantages. Pellets and crumbs cost more than mash, by about 7s. 6d. to 15s. per ton[1]. For stock which are closely confined, as in hen batteries, the use of pellets may lead to bullying, the stock consuming their daily ration in pellet form in about one-quarter the time it takes them to eat mash.

Crumbs tend to be intermediate between mashes and pellets, so that whilst they occupy birds longer than mash they do not have quite the same tendency to induce feather pecking, etc. as pellets.

[1] Such premiums differ according to feed manufacturers' subsidies.

Whilst a rapid feed intake (from crumbs) at the beginning of the laying season may stimulate egg size and peak production, some breeds tend to overeat and so lay down extra fat, which in some circumstances may favour the development of the fatty liver syndrome. In such instances there is often a place for mashes, since they appear less palatable and therefore feed intake falls by about 0·25–0·5 oz./bird/day once a change is made from crumbs or pellets to mash. This is related to two factors: (*a*) the consumption of mashes utilises more energy (peck for peck), and (*b*) the M.E. value of pellets is higher than that for mashes of the same composition, especially if the ingredients include wheat, offals, alfalfa-meals and other high fibre ingredients. Pelleting also enhances the availability of plant phosphorus (Slinger *et al.* 1966). Our own data show that egg size is nearly always greater with crumbs than mash, so that the economics of the matter relate primarily to egg prices, the premium to be paid for crumbs and feed intake.

The Role of Chelating Agents

Special interest has recently been created in the use of chelates (both in nutrition and veterinary medicine) by Foll (1966) who believes that the new turkey disease (T.S. 65; Turkey 'Y' Disease) can be cured or prevented by a chelate mixture. He also considers that some ruminants may benefit from a similar type of chelate mixture.

Early interest in chelates began after the German chemist Munz patented the compound E.D.T.A. (*e*thylene*d*iamine*t*etra*a*cetic acid) in 1935, and which was found in 1951 to be of great value for the treatment of lead poisoning. Later Peters and his associates discovered early in World War II that B.A.L. (*B*ritish *a*nti-*L*ewisite) was a satisfactory antidote to acute arsenical poisoning.

Foll's interest in chelates for ruminants concerns certain sterility problems believed to be associated with a manganese deficiency. From analyses of farm forages (grass, silage and hay) he showed that many samples were deficient in either calcium or phosphorus. Five out of fourteen samples were also deficient in manganese, which, linked with the fact that the average solubility of this element in the rumen fluid was only 43·8 per cent (lower still in the presence of molasses) suggested to Foll that such cases might benefit from the use of a chelating mineral mixture in the feed instead of straight minerals. For this reason he considers that many herbage samples are quite inadequate for the maintenance of health and production, thus throwing a greater onus on the use of adequate supplements. Here again he feels that minerals in straight form, or those normally included in compound feedingstuffs, are inadequate.

Chelation. Chelates form special complexes with metal ions, indeed any molecule or ion with an unshared electron pair may co-ordinate or complex with a metal ion. The arrangement of the ring structure is such that the metal ion is held in a claw-like fashion (*chele* = Greek, claw) by co-ordinating 'ligand' atoms, usually sulphur, oxygen or nitrogen. (Sodium is rarely if ever chelated, and iodine never, because it is not a metal.)

Common substances that can act as chelating agents include oxalic and citric acids, ammonia, certain amino acids, vitamin C, aspirin and various antibiotics. Examples of metal chelates in nature include chlorophyll (magnesium), haemoglobin (iron) and vitamin B_{12} (cobalt).

The best known synthetic chelating agent is E.D.T.A. which has been used experimentally in many agricultural spheres, more particularly in rations connected with zinc studies using soya products (Kratzer and Pran Vohra 1963); for preventing discolouration in shellfish, sliced beets and potatoes, and as fertiliser supplements or foliage sprays (combined with iron or zinc) for improving the physiological movement of these metals through the plant's root system, etc. The more recent use of iron salts for neutralising the gossypol content of cottonseed-meals is another example of a chelating effect.

Once a metal has been chelated its physiological, chemical or physical effects may differ quite considerably from normal. For example, the well known contractile effect of calcium on the frog's heart muscle is reduced a thousandfold if the calcium is chelated with citrate. Iron will normally precipitate as the hydroxide at a pH above 4, but in the presence of citrate this does not occur even in quite strongly alkaline solutions. The calcium in Ca E.D.T.A. chelate is so strongly bound that it cannot be detected by conventional analytical methods.

E.D.T.A. A good chelate has little tendency to dissociate, and in the case of E.D.T.A. the actual complexing agent is the completely dissociated anion; increasing dissociation will occur with increasing pH (alkalinity). As the pH decreases the concentration of dissociated cations increases.

Copper, iron and zinc E.D.T.A. chelates show relatively little dissociation in the acid range, but although glycine complexes copper almost to the same degree as E.D.T.A. in the alkaline range, in acid media glycine is of little value. It is important to note also that both hydrogen and hydroxyl ions frequently compete with the metal ion for the chelating agent. For E.D.T.A. the stability constant of the calcium is approximately 4×10^{10}; the solubility product of calcium oxalate is 2×10^{-9} and for calcium carbonate $0{\cdot}9 \times 10^{-8}$; either of these sparingly soluble compounds will dissolve in neutral E.D.T.A. solutions, but Ca fluoride will not dissolve unless a large excess of E.D.T.A. is present.

The facing table shows the reciprocal stability constants expressed as a logarithmic function.

Log stability constants for other E.D.T.A. complexes are sodium 1·66, magnesium 8·69, manganese 13·47, cobalt 16·1, lead 16·48, zinc 16·58 and nickel 18·45.

Metabolic studies show that only about 10 per cent of E.D.T.A. is absorbed from the gut and that this is excreted almost entirely unchanged in the urine. The compound is neither accumulated nor metabolised to any significance.

Log formation constants	*Calcium*	*Copper*	*Iron*
E.D.T.A.	10·5	18·4	25
Citric acid	4·8	14·2	11

Unfortunately in addition to specific metals, feedstuffs contain a variety of other competing substances—hydrogen and hydroxyl ions, adsorbents and even other chelating agents.

So far as is known there is no evidence to show that E.D.T.A. is of value in human nutrition either for aiding the absorption or utilisation of minerals; nor that chelated minerals would be of benefit to the turkey industry (Kratzer 1966).

Chelates in Medicine. Chelates already have a real place in medicine, for the treatment of cases of heavy metal poisoning (lead, zinc, nickel, gold, mercury), but they are best administered by injection and not *per os*. Care has to be exercised in case the release of the metal may result in acute symptoms as a replacement for the chronic state, the latter possibly being characterised by an almost complete lack of symptoms, e.g. acute versus chronic lead poisoning in cattle (Radeleff 1964).

In cases where excess iron requires to be removed biologically an injection with *desferrioxamine B* is one of the most effective chelating agents known, either alone or in combination with D.T.P.A.

The sulphur-containing amino acid penicillamine has a very high affinity for monovalent copper and can be taken by mouth. In addition to being effective against arsenic, B.A.L. can also be used for treating cases of acute poisoning by mercury or gold. Some metal salts of zirconium seem capable of chelating the *oleoresin*, present in poison ivy and oak.

Where radio-active poisons are involved it is important to appreciate that chelating agents should *not* be used early, as they will only render the substance more soluble and therefore more will be absorbed from the gut. First therefore render the substance insoluble so that it can be excreted in the faeces. Cesium 137 can be dealt with by iron-containing prussian blue, sodium alginate can be used to bind strontium 90 and E.D.T.A. or D.T.P.A. for plutonium and trivalent rare earths; B.A.E.T.A. or zirconium citrate for strontium 90. Use chelates only for dealing with any amounts which have already been absorbed and invaded the tissues.

Calcium ions compete with metal ions for chelates, and for this reason E.D.T.A. cannot be used against strontium, because of its stronger affinity for calcium. Radio-active metals are efficiently sequestered by the chelate D.T.P.A., whose 8 ligand atoms consist of 3 of nitrogen and 5 of oxygen. Certain sulphydryl compounds (e.g. M.A.A.) chelate copper, and these are also being considered for their protective value against radiation.

It is not easy for non-scientists to understand how chelates can be used (*a*) to seek out and so lead to the excretion of some metals, e.g. lead or calcium and certain radio-active substances; and yet also have (*b*) the ability to deliver essential trace minerals (like zinc) in greater amounts than usual for metabolic purposes. The two functions seem contradictory, but the different route of administration and the degree to which the dissociating anions remain biologically functional supply part of the answer. An excellent summary of the whole subject of chelation in medicine has been given by Schubert (1966).

Anti-bacterials. A third role for chelates relates to their inactivating effects on bacteria or viruses, by depriving them of essential metals. In this connection when the antiseptic *oxine* is chelated with iron it acts as an efficient bactericide, whereas when used in distilled water it is useless. But if it is chelated with copper instead of iron it then becomes effective against fungi as well as bacteria.

Many antibiotics including penicillin and the tetracyclines are chelating agents, and one (*Marboran*) has shown useful effects against the virus of smallpox, having been used successfully in the 1963 Indian outbreak. Of 1100 exposed persons given *Marboran* only three developed mild smallpox, whereas the control group suffered seventy-eight cases including twelve deaths. It has been suggested that salicylate drugs like aspirin owe some of their valuable properties to the fact that they chelate copper, and another drug with chelating properties P.A.T. (1-phenyl-5-amino-tetrazole) is proving of value in the treatment of rheumatoid arthritis.

Are we still to regard the chelates as a gimmick in animal nutrition, or is there a definite place for them? A few experts think that they have helped cattle to overcome certain infertility problems linked with mineral deficiencies, but little has been heard of their use on pigs or sheep. Except for their suggested use in TS. 65 in turkeys, and for ensuring that adequate supplies of zinc are available to poultry no other place has yet been found for them. However, as they are relatively cheap—about 6s. a pound—and as this is the usual amount suggested per ton of feed, no harm will follow further experimentation in any farm species.

We have used Foll's own chelate as well as commercially available manganese, copper and cobalt chelates but not with any great success. Our conclusions were: (*a*) that the chelate mixture recommended was not of value in the treatment of TS. 65; (*b*) that at some strengths it was toxic, probably due to the copper component; and (*c*) that poor feathering was not improved in turkey poults. The administration of the manganese chelate did raise the level of Mn in the feathers, but not significantly so in the liver. The amounts present varied considerably in both the treated and control groups.

We have also used chelated iron and copper, and checked the haemoglobin levels, but they were not increased in the treated groups of either the chicks or poults.

Nutrient Cycling

The modern broad concept of biology in which the world's living organisms form a single interacting unit with their physical and biological environments, including fields and forests, at the earth–atmosphere interface will be comparatively new to many readers. But of course not all of the air above the earth's surface or the rocks below are functional, and therefore one should really only consider those areas where atoms and molecules participate in the chemical cycling that occurs within this ecosystem.

Geological input involves the nutrients (including moisture) supplied from the soil to plants, while *meteorological* input (also including moisture) enters the ecosystem through the atmosphere in the form of gaseous products and particulate matter (dust and micro-organisms). *Biological* input relates to those activities of plants and animals which release end-products, including leaves and faeces, and the nitrogen cycle is the best-known example of one segment of this ecosystem.

Elements with a gaseous phase, e.g. CO_2, are removed by diffusion currents, but others involving organic or inorganic phases also participate in intrasystem cycling. Some components are now received from the air in larger amounts than ever before, such as from radio-active fall out (e.g. strontium).

Similarly the spread of viruses and allied micro-biological infectious agents is a comparatively new feature, associated with high concentrations of human or animal populations. This subject was not really appreciated until the use of underground hideouts for protection against bombing encouraged respiratory infections during the last war; and also more recently in relation to the spread of Newcastle disease virus (20 miles downwind) following outbreaks of 'fowl pest' amongst intensively housed poultry.

Nutrient input and output are closely geared to the hydrological cycle, i.e. to the amounts of water that move in and out of the system, and to the pattern of water availability so essential for weathering processes, ion exchange, hydrolysis, solution, diffusion, absorption, etc.

The nutrient budget for a single element can be considered in terms of meteorological and biological inputs less geological and biological outputs, the net result being a loss or a gain. At the Northeastern Forest U.S. Experimental Station, for example, it has been calculated that the input of calcium would be about 3 kilos per hectare, whilst output erosion accounts for more than twice this. Some 98 per cent is lost in the form of dissolved substances in stream water and only about 2 per cent incorporated into organic matter flushed out of the ecosystem. However, that which is lost (5 kilos per hectare) is replaced by calcium released by weathering action on soils.

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Chapter 18

DIAGNOSIS AND TREATMENT OF POULTRY DISEASES

B. S. HANSON

Diagnosis

The diagnosis of disease in an individual bird can be a relatively simple procedure requiring the ability to observe clinical signs and pathological changes, and to match them with the known characteristics of various diseases and conditions. The investigation of a flock problem is likely to be more difficult and lengthy. This is particularly true when a drop in egg production, inadequate food consumption or failure to achieve the progress anticipated may be attributed, perhaps prematurely, to disease.

The investigation of flock problems requires experience and knowledge of housing, management, nutrition and related subjects. The information obtained from a field investigation is necessary to narrow the field of enquiry at the outset and interpret the findings when a diagnosis has been made. The intermediate steps include the recognition of significant clinical signs and lesions, and the application of any necessary laboratory procedures. These are the subjects discussed in this chapter.

FIG. 44. The swelling of the left foot is the result of *My. synoviae* infection.

At the outset of an investigation the species, type and age of the birds affected should be verified. As certain diseases are commoner in certain species and age groups the wide range of possibilities can be reduced and some discarded altogether. Next it is advisable to ascertain what led to the suspicion of disease. Has there been an increase in mortality? Was it a sudden or gradual increase, and over what period has it occurred? Is the trouble confined to a single batch of birds or are several groups affected? Were they affected in a sequence which would suggest the spread of infection or did clinical signs appear simultaneously in all groups? In the latter instance the possibility of some nutritional or metabolic disorder associated with some change or accident in the environmental conditions must be considered.

Clinical signs

Observe the appearance of the flock as a whole before giving attention to the clinical signs shown by individual birds. Has there been a drop in food and water consumption? Has egg production or growth been impaired? What is the general appearance of the birds and what proportion of the batch appears sick? Abnormal quietness and dejection may indicate the onset of an infectious disease. Thirst may accompany febrile conditions, but can result from overheating. Similarly inappetence can follow a sudden change in the consistency or palatability of food, but may also occur during the early stages of a number of diseases. Pale combs and ruffled ragged plumage are more likely to be the result of chronic debility and unthriftiness, due to sub-acute coccidiosis, worms or ectoparasites. A sudden appearance of such signs may be associated with red mite infestation or the haemorrhagic syndrome.

Diarrhoea may be a very obvious clinical sign but the cause is often hard to define. Watery droppings may occur in worm infestations, whilst blood in the faeces of chickens is a common sign of caecal coccidiosis, although it may be seen in some intestinal infestations. Yellow or green faeces may indicate some septicaemia such as cholera, typhoid, colisepticaemia or Newcastle disease. In turkeys blackhead disease and erysipelas may be commoner causes, whilst blood-stained faeces in these birds is usually indicative of haemorrhagic enteritis. Pale, chalky or white diarrhoea indicates an excess of urates. It may be of little significance in individual birds, but as a flock sign is seen in outbreaks of pullet disease.

FIG. 45. The tell-tale symptoms involving the eye and infra-orbital sinus typical of Mycoplasma S-6 infection (infectious sinusitis).

Respiratory disorders can produce a variety of clinical signs depending upon the type, degree and complexity of infection. Only slight sneezing or 'snicking' may be seen in some outbreaks of mycoplasmosis, infectious bronchitis and colisepticaemia. But in advanced cases distinct dyspnoea may be apparent. Gasping in chicks can indicate aspergillosis, pullorum disease or infectious bronchitis, but the possibility of gapeworm infestation must not be forgotten. In older birds gasping and coughing are prominent signs of infectious laryngo tracheitis (I.L.T.). Conjunctivitis and nasal discharge can be seen in many respiratory diseases particularly when mixed infections have occurred. A purulent conjunctivitis accompanies vitamin A deficiencies, scabs around the eyelids occur in nutritional dermatitis and ulceration of the cornea indicates exposure to an excess of ammonia vapour. Swollen facial sinuses in turkeys are regarded as being characteristic of the infectious sinusitis resulting from infection with *Mycoplasma gallisepticum.*

When locomotor disturbances are observed it is necessary to decide in the first instance whether the signs are attributable to lameness or paralysis, or to a generalised nervous disorder. In the latter category must be included the trembling seen in epidemic tremor, the complete inco-ordination of crazy chick disease, and the torticollis which may

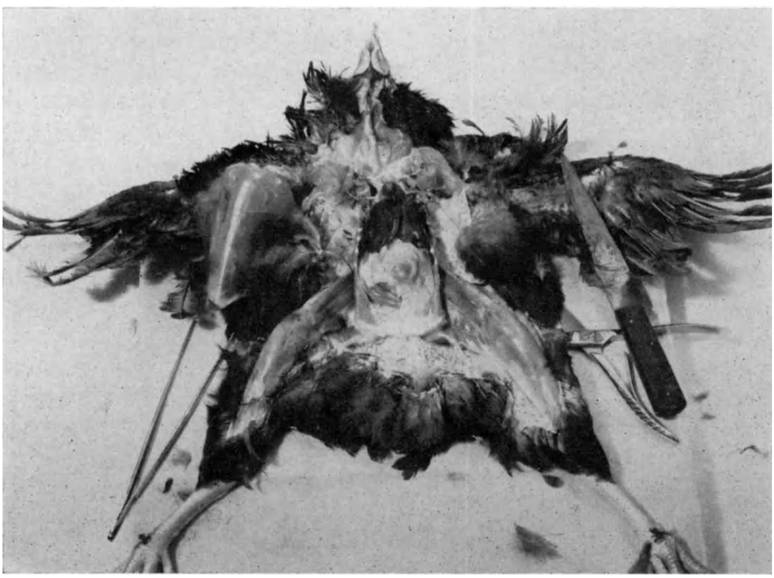

FIG. 46. Note the layout of the carcass. Removal of the breast bone reveals the liver, heart, intestines, etc.

be a sequel to Newcastle disease, or result from cerebral abscesses caused by bacteria and fungi. A general flaccidity of the muscles and an inability to raise the head is characteristic of pseudo-botulism or limberneck in chickens, but in turkey poults is a feature of folic acid deficiency.

Lameness and paralysis may be due to injuries or rupture of the gastrocnemius tendons, or spinal deformities such as 'kinky back' or the skeletal abnormalities resulting from perosis, rickets and cage layer paralysis. The most common causes of these signs, however, are likely to be Mareks disease or the inflammation of the joints and tendon sheaths resulting from bacterial infections or infectious synovitis.

Egg production may be adversely affected by Newcastle disease, infectious bronchitis, pullet disease and epidemic tremors as it affects a susceptible laying flock. But other non-specific factors such as shock and water deprivation must not be forgotten, and incorrect medication with preparations containing sulphonamides can interfere with production. Loss of colour and thin deformed shells are apparent in cases of Newcastle disease and infectious bronchitis. Watery whites and tremulous air cells may also be seen.

Having observed the clinical signs shown by the affected flock, attention may be turned to individual birds. Further valuable information can be obtained from the systematic description of clinical signs contained in the paper presented by Blount to the B.V.A. Congress in 1961.

The Post-mortem Examination

The amount of equipment required to carry out an effective post-mortem examination is small. It can be confined to a sharp-pointed chef's knife, a strong pair of scissors and a pair of rat-tooth forceps. But it is essential to carry out the examination in a systematic manner or important features may be missed.

At the outset examine the carcass for wounds, ruptured blood cysts, dermatitis, external parasites, or subcutaneous growths such as are found in acute Mareks disease. Examination of the head region may reveal scabs of fowl pox or the swollen wattles of sub-acute fowl cholera. A general swelling of the head results from infection following caponisation or the rupture of a blood vessel and subcutaneous haemorrhage. Swollen sinuses, necrotic ulcers in the mouth and accumulations of pus in the nasal cleft should be noted. In chicks the scabs of nutritional dermatitis around the eyelids and commissures of the mouth will be seen. Eye abnormalities can include corneal opacities, purulent conjunctivitis, the ulceration of ammonia blindness and the pale iris and ragged pupil of ocular lymphomatosis. As the skin is removed the presence of abscess formation in the sternal bursae, in the radio-humeral joints, hocks, feet and tendon sheaths might be noticed if infectious synovitis is present. In staphylococcal arthritis and similar bacterial infections the swellings are more likely to be confined to the hocks or feet.

If the hip joints are dislocated, the legs can be laid flat and the carcass will be sufficiently steady to permit further procedures. By cutting through the abdominal muscles, rib junctions and thoracic girdle the sternum can be removed. The visceral surface should be examined for petechiae or the accumulation of myelocytes and the consistency of the bones tested for any changes such as rickets, osteomalacea or osteoporosis. Before examining the viscera it is advisable to complete the examination of the head and neck. Open the oesophagus and crop, and inspect the contents and lining. The lesions of moniliasis may be present in the crop of turkeys whilst vitamin A deficiency produces characteristic necrotic flecks in the oesophagus of fowls. A plug of

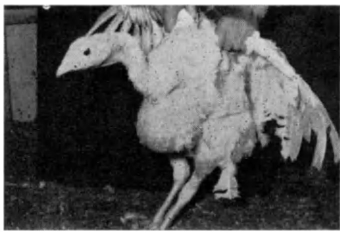

FIG. 47. Pendulous crop is considered to be linked with both genetic and environmental factors, particularly excessive drinking in hot weather. Multiplication of yeasts in the crop may also influence its development.

necrotic or caseous material occluding the entrance to the larynx is found in some respiratory diseases. It can occur in chronic pasteurellosis or I.L.T. and is fairly common in young chicks which have died of Newcastle disease. Varying amounts of tracheitis are present in most respiratory conditions. The lesions may be mild in mycoplasmosis and infectious bronchitis, more pronounced in Newcastle disease and most severe in I.L.T. In acute I.L.T. the lining of the trachea will be blood stained and clots of blood are found. In sub-acute cases the clots have changed into caseous casts and the lining membrane is destroyed. The presence of gape worms will be obvious. They are most likely to be seen in turkeys and pheasants.

The heart and liver can exhibit a variety of abnormalities of diagnostic value. The pericardial sac may be distended with fluid in cases of cirrhosis, salt poisoning or the toxic fat (chick oedema) syndrome. A fibrinous pericarditis occurs in colisepticaemia and in visceral gout the sac is full of urates. The heart is atrophied in debilitated birds, and distended, thin walled and flabby following cirrhosis of the liver or valvular myocarditis. Petechiation on the heart muscle and coronary fat occurs during the acute stage of septicaemic diseases such as Newcastle disease, typhoid, erysipelas and pasteurellosis. More extensive haemorrhages are found in cases of the haemorrhagic syndrome. The heart muscle is a common site for lymphoid infiltration in cases of Mareks disease whilst large areas of necrosis warrant the suspicion of listerellosis and a less severe myocarditis results from fowl typhoid and sub-acute pullorum disease.

The liver is covered by a fibrinous film in colisepticaemia and urates are deposited over the surface in visceral gout and sub-acute pullet disease. A pale liver results from internal haemorrhage, ruptured blood cysts or a heavy red mite infestation. A yellow greasy appearance indicates fatty degeneration and infiltration and may be associated with phosphorus poisoning. A bright red liver may suggest erythroleucosis or carbon monoxide poisoning, whilst a dark brown turning greenish bronze suggests typhoid. Gross liver enlargement occurs in leucosis, but a moderate enlargement with congestion and tendency to rupture easily is apparent in acute bacterial infections and in acute pullet disease. Small discrete necrotic foci are found in cases of typhoid, pasteurellosis, vibrionic hepatitis and acute pullet disease. Blackhead lesions are characteristic, as are the caseous nodules which tend to shell out from the friable parenchymatous tissue in cases of avian tuberculosis. Larger areas of liver necrosis may result from sub-acute staphylococcal and coliform infections.

FIG. 48. The second stage in carrying out a poultry post-mortem examination—removal of the gizzard, liver, etc., reveals the genital organs (testes) and kidneys.

If the liver and heart are removed, the proventriculus, gizzard and intestines are exposed. At this stage it is possible to identify lesions of traumatic peritonitis, egg peritonitis and blood clots from ruptured blood cysts or blood vessels, for example a ruptured aorta in turkeys. Accumulations of purulent material in the abdominal air sacs will be visible in cases of air sac infection or aspergillosis. As the alimentary tract is removed the spleen can be examined. The lesions which may be present in this organ resemble those described in the liver. The gizzard may be distended or impacted with fibrous material, or may be atrophied if the splanchnic nerve has been infiltrated in Mareks disease. The mesentery can be affected with various types of tumour. Some gross abnormalities of the intestines such as volvulus or intussusception will be obvious: excessive loss of tone occurs in debility and chronic worm or coccidial infestations; petechial haemorrhages are present in the serous membranes and intestinal walls in acute intestinal coccidiosis, Gumboro disease, the haemorrhagic syndrome and acute Newcastle disease. Abscesses with necrosis and caseation occur in coli-granulomatosis and tuberculosis, whilst swollen caecal tubes suggest blackhead disease or chronic caecal coccidiosis.

As the alimentary tract is opened up along its length the contents can be examined and the presence or absence of worms noted. Haemorrhages over the proventricular glands are seen in some cases of Newcastle disease but are more extensive in Gumboro disease. As the gizzard is opened fumes of phosphorus pentoxide may be seen and smelt in cases of phosphorus poisoning, whilst a smell of phosphine indicates poisoning with zinc phosphide. Varying degrees of enteritis may be exhibited by the intestinal mucosa, there are many possible causes but coccidiosis is still the commonest. The lesions will vary in degree with the severity of the infestation and in location with the species of coccidia. A flush in the duodenal mucosa and a catarrhal enteritis indicates an infestation with *E. acervulina*. Similar lesions in the lower part of the small intestine can be caused by *E. maxima*. Severe enteritis with haemorrhage, necrosis and extensive tissue damage in the small and large intestine is a sign of acute intestinal coccidiosis due to *E. necatrix*. Mixed infestations are common and when *E. brunetti* is present, necrotic enteritis may extend to the rectum. Caeca filled with blood and debris are characteristic of acute caecal coccidiosis due to *E. tenella*, but blood in the caeca can result from severe infestations of *E. necatrix* and the haemorrhagic syndrome. If a cross section of the caecal tubes shows concentric rings of necrotic tissue giving 'a furred water pipe' appearance blackhead disease is suspected, even though no liver lesions may have been noted.

If the carcass is that of a laying hen the ovary will now be a prominent feature, as would an impacted oviduct. An active ovary may show signs of rapid degeneration in Newcastle disease, pullet disease or any acute condition but a number of non-specific factors can also cause a cessation of ovarian activity. Chronic degeneration of the follicles is seen in carriers of pullorum disease and fowl typhoid and the ovary is the commonest visceral site of infiltration in Mareks disease.

A breakdown in the function of the kidneys is a common cause of death in poultry and may arise from a large number of causes. The kidneys are atrophied and pale with debility, swollen and congested in febrile disorders. The tubules are full of urates and a deposit of urates may cover the surface in cases of visceral gout or sub-acute pullet disease. Fatty infiltration or degeneration may be evident whilst lymphoid infiltration, tumour formation and cysts are quite common.

The lungs are usually bright pink and slightly moist but in birds which have died some congestion must be disregarded. Marked oedema and congestion can result from suffocation but if the lungs are brownish green and contain discoloured sanguinous fluid fowl typhoid may be suspected. Purulent pneumonia with abscess formation can be attributed to coli-septicaemia, staphylococcal septicaemia, pullorum disease, aspergillosis and pasteurellosis. The latter disease usually causes distinct hepatisation of the lungs.

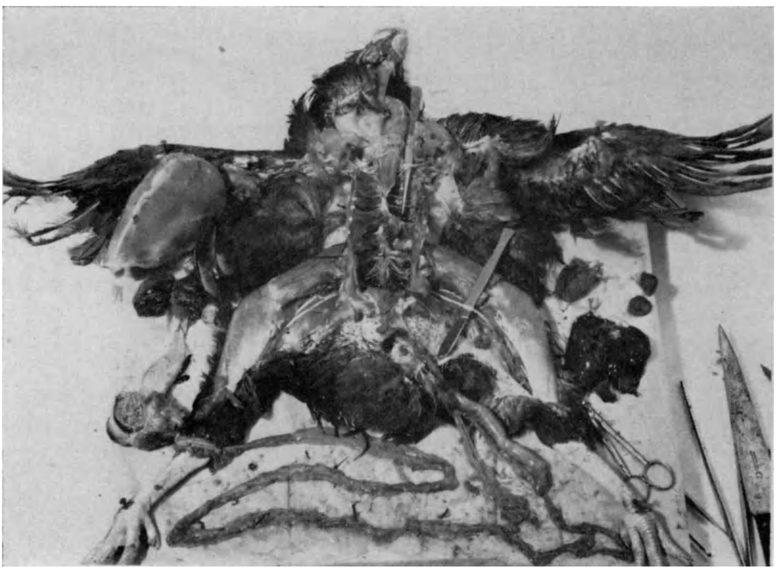

FIG. 49. After removal of the digestive tract, etc., various nerves should be examined for evidence of neuro-lymphomatosis (fowl paralysis—Marek's disease).

If the lungs and kidneys are removed the skeletal structure and major nerve trunks can be examined. Distorted ribs, enlarged costal joints and soft bones indicate rickets or osteomalacia, whilst accumulations of myelocytes along the ribs can be seen in discrete or nodular myeloid leukosis. Gross distortion of the spinal column and associated ribs, a non-specific type of scoliosis, is seen sporadically but a more specific type of spinal abnormality may be seen in the region of the fifth to seventh thoracic vertebrae. If these appear enlarged or prominent this region of the spinal column should be split down the mid-line. This may reveal a ventral displacement of the sixth thoracic vertebra with resultant pressure on the spinal cord (Spondylolisthesis). This is the condition which has become known as 'kinky back'. If a secondary bacterial infection, e.g. staphylococcal, has supervened there will be cancellous bone, a severe fibrous reaction and other changes indicative of a spondylitis.

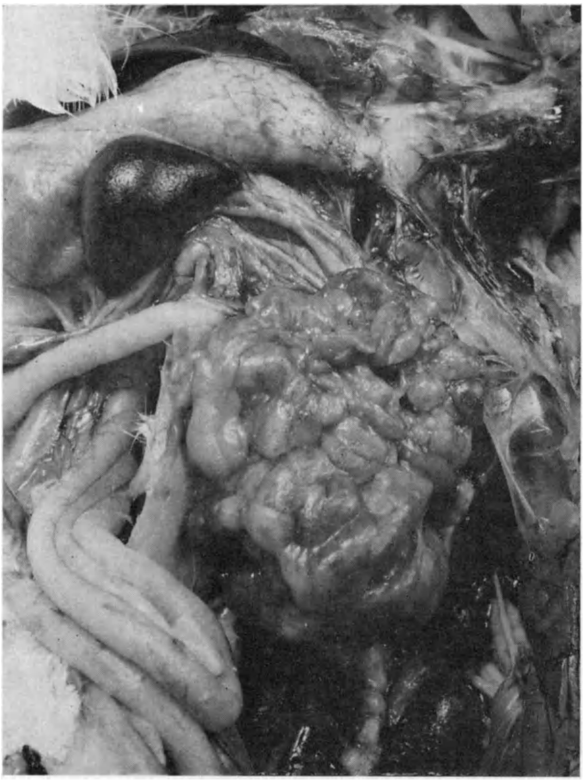

FIG. 50. Typical lymphomatous tumour of the ovary and enlargement of the nerves to the gizzard (passing below the spleen) seen in Mareks disease. U.K. and U.S.A. research workers have now established that a herpes virus is the causal agent of this infection.

All the major nerve trunks should be examined, the sciatic nerves being exposed for most of their length. In the classic form of Mareks disease the nerves are frequently grossly infiltrated. In less advanced cases it is advisable to compare the suspected nerve with its companion. Infiltration is usually distinctly apparent in the finer branches of the brachial plexus and in the intercostal nerves. In chicks 2–3 weeks old an even enlargement of the major nerves and a yellowish discoloration occurs in early toe paralysis (riboflavin deficiency).

An examination of the brain is frequently unrewarding in birds which have died or had their necks dislocated. If examination is contemplated a typically affected specimen should be killed by an injection of a barbiturate solution. In cases of crazy chick disease haemorrhages may be visible in the cerebellum whilst abscess formation may sometimes be seen. Often histological examination is the only means of obtaining information.

It is always advisable to make a full examination of several birds and to avoid the temptation of hasty conclusions. The various abnormalities should be noted as they are observed and a diagnosis based on their final correlation.

The principal characteristics of some of the common diseases of poultry are given in Tables 1 and 2.

Differential Diagnosis of Respiratory Infections

A study of the clinical signs, rate of spread, mortality and post-mortem findings may permit a tentative diagnosis to be made in an outbreak of respiratory disease. Such a diagnosis may justify immediate action, such as reporting the suspicion of Newcastle disease, where this is a notifiable disease; or commencing treatment of a batch of broilers when colisepticaemia is recognised.

An accurate assessment of the aetiological factors involved may be necessary, perhaps to decide on a suitable vaccination schedule, or plan hygienic measures for future purposes. In such cases the diagnosis of respiratory disease may be a lengthy procedure requiring special laboratory techniques. These will be necessary for the isolation of causal agents, the histopathological examination of selected tissues and the serological examination of blood samples.

Some of the main features of the common respiratory infections are shown below in Table 3. But it is emphasised that adequate laboratory facilities are an essential requirement for the precise diagnosis of respiratory diseases.

TREATMENTS

The efficacy of any form of treatment depends on the birds receiving the most suitable medicament in the correct amount as early as possible during the course of the disease. When an accurate diagnosis, rapidly obtained, indicates an uncomplicated disease for which a specific remedy exists, the problem is simple. Often, however, an investigation may indicate the presence of more than one type of infection, specific treatment may therefore be limited, symptomatic treatment may have to be adopted and less success must be expected.

In large groups of birds the cost of medication is important. If disease is well established any form of treatment can be little more than a salvage operation and further expenditure may be ill-advised. In some diseases, e.g. erysipelas in turkeys, a suitable medicament may be available but circumstances may make it more profitable to send the birds for slaughter. The treatment of a laying flock for any disease can only be advised if the flock is likely to return to a profitable level of production. The cost of the preparations and the cost of administration must be weighed against the results which may reasonably be anticipated.

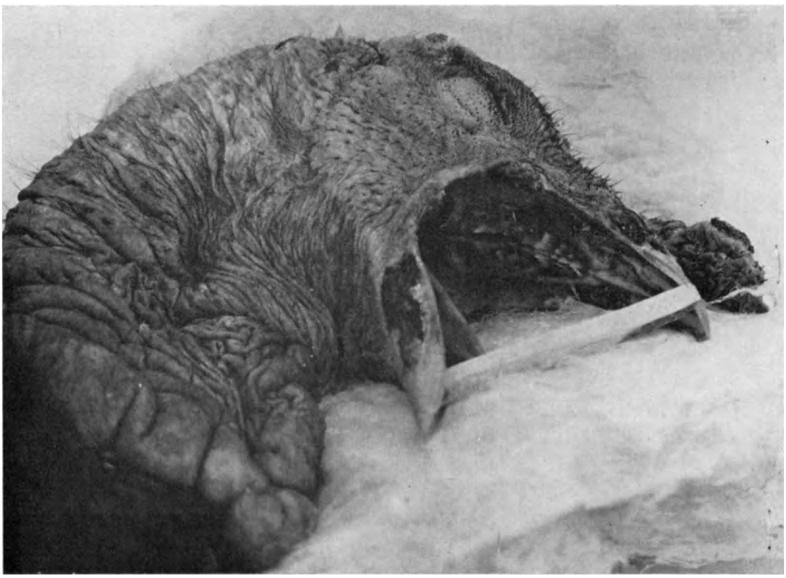

FIG. 51. Lesions of turkey pox involving the skin of the face, mouth and snood.

The method of administration may depend upon the type and severity of the disease and the visible effects it has produced. This in turn will affect the choice of medicament. If the birds have lost their appetite it is pointless to medicate the food and some water soluble preparation must be selected. When the food is medicated the mixing must be thorough and there must be adequate trough space or it will not be possible for all birds to consume an adequate quantity. The medication of water may present some difficulty; some forms of sulphonamide require the use of earthenware vessels and the presence of microbes in the water may reduce the efficacy of antibiotics. For treating larger groups of birds an automatic water proportioner is desirable: hand watering is expensive in labour costs and may result in deprivation or under-consumption. On the other hand treatment by parental injection although costly may be most effective and therefore justified in certain circumstances, for example in a breeding flock.

It is important to ensure that the birds get the correct dose and the manufacturers instructions must be followed precisely.

If the birds are already receiving some medication at a prophylactic level, the type and amount of the preparation should be taken into consideration before another preparation is administered at a therapeutic level. For example, if birds are receiving a coccidiostat containing a sulphonamide, some modification of the recommended dose may be necessary if another sulphonamide preparation is to be used for treatment. Similar remarks apply to the use of furazolidone, particularly if the birds to be treated are poults, ducklings or pheasants, as these species are susceptible to overdosing with this drug.

The accompanying table contains some forms of treatment in common use, it is by no means complete and no special recommendations are made. The active principles of the preparations are included so that the suitability of other products omitted can be recognised.

If large groups of poultry are to be kept under intensive methods of husbandry it is essential to reduce outbreaks of disease to the minimum. This can only be achieved by the practical application of sound principles of veterinary hygiene and preventive medicine. It necessitates obtaining expert advice from the planning stage onwards, for a rapid diagnosis and prompt treatment is no longer an adequate safeguard against the economic loss which can result from disease.

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TABLE 1

DISEASES OF CHICKS (from day old to approximately 4 weeks of age)

Disease	*Age incidence*	*History*	*Clinical signs*	*Prominent lesions*	*Diagnostic criteria*
Non-specific mortality, e.g. poor quality or badly hatched chicks. Faulty brooding. 'Starve outs' and similar adverse environmental factors	1–6 days	Increasing mortality usually reaching a peak by 5th or 6th day. Often drops sharply after this period	Chicks usually found dead, some appear weak but remainder usually thrive. They may be noisy, fail to eat or drink. Huddling indicates low temperatures. When overheating occurs, chicks avoid the source of heat	No characteristic lesions but frequently crops and gizzards are empty, gall bladders full and livers pale. Carcasses may appear dehydrated and an excess of urates is apparent in the kidneys. Lungs may be normal, but are sometimes oedematous or congested	Cultures eliminate bacterial infections. A diagnosis will often depend on the history available. A further investigation is recommended if mortality persists into the second week
Pullorum disease					
Acute form	Apparent from 1st day	Mortality increases, reaching a peak about 5th day, but continues without a sharp drop	Chicks appear miserable and do not feed. Diarrhoea and pasted vents may be apparent. Chicks are noisy and tend to huddle. Laboured breathing may be seen. Evidence that disease is spreading	In acute cases of Pullorum disease a general septicaemia may be apparent, but the more characteristic lesions may not have developed	The isolation of *S. pullorum*
Sub-acute form	1–10 days	Mortality higher than normal, persisting beyond the 1st week. A second peak of mortality may be apparent. High incidence of culls	Similar to above, but less acute. Evidence of spread may not be marked, but an increase in the number of culls may be apparent	Enlarged livers with areas of necrosis. Necrotic nodules in the heart muscle and lung tissue. Caecal casts	Post-mortem findings and isolation of *S. pullorum*.
Pullorum arthritis	7–14 days (or later)	Previous mortality may have been higher than normal and a varying number of unthrifty chicks will be seen	Affected chicks appear stunted and have fairly hard circumscribed swellings around the hock joints and on the feet	In addition to the lesions described above. Swellings around the joints consist mainly of fibrous tissue with a core of caseous orange-coloured pus	As above. Material from the hocks should be cultured on Mackonkey agar, and in selenite broth
Salmonellosis (*S. typhi-murium S. enteritidis S. thompson*, etc.)	1–14 days	Chicks fails to thrive. Inappetance, increasing mortality, signs of spread	Indigestion, diarrhoea, pasted vents	Carcasses have septicaemic appearance. Livers enlarged, congested, dark in colour, friable, focal necrosis. Heart muscle pale, some myocarditis. Caecal casts.	Isolation and identification of causal organism, using selective media.

TABLE 1—*cont.*

Disease	*Age incidence*	*History*	*Clinical signs*	*Prominent lesions*	*Diagnostic criteria*
Yolk sac infection (mushy chick disease)	1–7 days	In acute cases—dead and dying chicks on hatching trays. Foul smell in incubator. Heavy mortality during first 48 hours of brooding which tends to persist	Weak chicks, swollen abdomens with inflamed or scabby navels. Tendency to huddle, failure to feed, leg weakness	Yolk sacs unabsorbed, associated blood vessels congested. Carcass has fevered appearance. Yolk material becomes opaque flocculent, semi-solid and inspissated. An associated peritonitis may be present	Post-mortem findings and the isolation from the livers and yolk sacs of mixed growths of faecal bacteria, e.g. coliforms staphylococci, proteus, pseudomonas, anthracoids, paracolons
Sexing injuries	1–4 days	Sudden mortality during first few days unassociated with poor hatching results. Unsexed chicks from the same source show normal progress	Swollen abdomens, protruding or blood-stained vents. Sudden death, mortality tends to drop after 5 days	Similar to those seen in yolk sac infection, but yolk sacs are often ruptured, there is yolk material in the abdominal cavity and some peritonitis may be seen, whilst evidence of haemorrhage and injury is usually present	History and post-mortem findings. No specific bacterial isolates
Aspergillosis	1–4 days if incubator or hatching infection. Later if brooder infection	Abnormal mortality: with hatching infections, chicks may be dead on arrival and more die during first 24 hours in brooder. With brooder infections the increasing mortality gives the appearance of a spreading infection	Chicks fail to feed, huddle together, gasping may be a prominent sign. A number of chicks may show inco-ordination and apparent nervous signs, if the brain is infected	In acute cases lungs are consolidated and oedematous and have a pale pink translucent appearance. In sub-acute cases caseous nodules are found in the lungs, casts may be present in the bronchi, whilst, flakes of caseous material are found in the air sacs	History and post-mortem findings. Isolation of *A. fumigatus* on malt or Saboraud agar
Carbon monoxide poisoning	During brooding period	Sudden heavy mortality following possible exposure to gas or exhaust fumes	No characteristic signs in survivors	Blood bright in colour and unclotted. The whole carcass has a pinkish appearance	History and post-mortem findings
Epidemic tremors (infectious avian encephalomyelitis)	Clinically most apparent 10–14 days	May be a history of reduced hatchability and abnormally high mortality in first week of brooding period. Often no disease is suspected until about the 10th day after hatching	Typically affected chicks squat on their hocks and are reluctant to move. On doing so they move forward a few steps with varying degrees of inco-ordination and squat again. A fine trembling is visible in the head, neck and tail. This may be palpable when not visible	No gross pathological changes but there is usually evidence that the chicks have not been feeding or have consumed litter. Death usually results from starvation or crushing	The histological examination of sections from the brain and either pancreas, proventriculus or gizzard. Lesions of a non-purulent encephalitis in brain. Follicular lymphoid infiltration in viscera

TABLE 1—*cont.*

Disease	*Age incidence*	*History*	*Clinical signs*	*Prominent lesions*	*Diagnostic criteria*
Rickets	Commonly seen about end of 2nd week	Leg weakness and apparent paralysis in a considerable proportion of a batch—if due to a direct nutritional imbalance	The clinical signs closely resemble those described for I.A.E. Some trembling may be apparent but is not so persistent or rapid as in I.A.E.	Soft rubbery skeleton with enlarged, distorted and cartilaginous bones. Lesions most apparent in the ribs	History, signs and post-mortem findings
Perosis (slipped tendon)	Variable, but commonest about 3 weeks of age	Chicks, often well grown, lose the use of their legs. The number affected may vary depending on whether a direct or indirect deficiency is involved	Chicks are unable to stand and squat on their hocks. They flap their wings in attempt to move, but do not show nervous signs or inco-ordination	The shanks are short and may be distorted. The hock joints are enlarged and flattened, the gastrocnemius tendon of one or both legs slips from the condyles and is displaced laterally. Some secondary bruising and abscess formation may occur	Clinical signs and post-mortem findings
Curly toe paralysis (riboflavin deficiency)	Commonest about 2–3 weeks of age	Leg weakness, paralysis, fairly sudden appearance in a considerable proportion of the batch. Frequently a direct nutritional deficiency	The curled toes are most apparent when chicks are held or placed in an upright position, as they attempt to move, their legs may remain extended	A general and even swelling is visible in the major nerve trunks. The nerves appear oedematous and yellowish, striated appearance is lost. After death the curled toe appearance is lost	History, clinical signs and post-mortem findings. Histological examinations if considered necessary. Chicks fed normal diet or diet containing dried yeast recover rapidly
Crooked toe disorder	Not common before 4 weeks	Growth normal, no paralysis, but toes are crooked and bent, often medially	Apart from the obvious deformity of the feet no signs are apparent. In advanced cases leg weakness may occur	After death the toes remain crooked and it is apparent that this is a deformity not a dysfunction as in curly toe paralysis	Clinical and post-mortem findings
Crazy chick disease (nutritional encephalomalacia)	Rarely seen before 3 weeks of age. Commonest around 1 month	Fairly sudden appearance. After normal progress best grown birds often first affected	Chicks lose the use of their legs and show marked inco-ordination. They lie on their sides with heads twisted or drawn back. Rapid contraction and extension of the leg muscles results in characteristic 'bicycling' movements	No gross changes except in the brain tissue. Haemorrhages visible in the cerebellum. Gross degeneration of the cerebellum may be apparent. Lesions are emphasised if brains are left overnight in 10 per cent formol saline	Clinical signs and post-mortem findings. Histological examinations of brain tissue to confirm

TABLE 1—*cont.*

Disease	*Age incidence*	*History*	*Clinical signs*	*Prominent lesions*	*Diagnostic criteria*
Nutritional dermatitis (so-called 'Pantothenic acid deficiency', but other factors, e.g. biotin might be involved)	Commonest from 2–3 weeks	'Eye trouble' or 'inability to see' is often the first sign noticed by the rearer. High proportion of batch affected if a direct nutritional deficiency has occurred	Chicks show signs of irritation around the eyes. Later scab formation becomes apparent and the eyelids become stuck together. Examination reveals further scabbiness around the commissures of the beak and on the plantar surfaces of the feet	No characteristic changes in internal organs. In some cases dermatitis may be accompanied by poorly developed, ragged and broken feathering	Clinical signs and post-mortem findings
Ammonia blindness (ulcerative kerato-conjunctivitis)	Not applicable	An increasing appearance of chicks with swollen closed eyes. Old litter may have been used in brooder house	Affected chicks show intense photophobia. Eyes are swollen and there is a marked conjunctivitis with lachrymation	Examination will reveal ulcers on the corneal surface. These are more easily seen in dead birds	Clinical signs and post mortem findings
Caecal coccidiosis	Can occur within a week of hatching	Increase in mortality, varying numbers of sick chicks	Chicks huddle and appear dejected and weak. Blood can be seen in faeces	Caecal tubes are distended with blood, in typical acute cases. In sub-acute or chronic cases the blood clots in the caeca may resemble the caecal casts associated with salmonella infection	Post-mortem lesions and recognition of parasite. Schizonts in scrapings of caecal mucosa
Fatty liver and kidney syndrome (Pink Disease)	Commonest between 2 and 4 weeks of age	Sudden deaths of well-grown chicks with no evidence of disease in survivors	Chicks suddenly become obviously sick, with loss of activity, inappetance, and death in about 24 hours from the onset of symptoms. Chicks showing clinical signs usually die	Chicks are in good bodily condition, subcutaneous fat may be present. The liver is very enlarged, pale, yellowish and fatty. The kidneys are swollen, pale and fatty, and the subcapsular blood vessels may be prominent	History, clinical signs and post-mortem findings. Histological and chemical examinations if desired
Gumboro disease	Variable but frequently occurs between 3 and 4 weeks	A sudden increase in mortality which rises for 2 or 3 days. This wave of mortality is usually completed in about 5 days	Affected chicks cease feeding, become dull and reluctant to move. Feathers are ruffled and general appearance resembles that produced by caecal coccidiosis	Petechial haemorrhages in breast and leg muscles. Extensive haemorrhages in proventriculus. Bone marrow usually not very pale (cf. haem. syndrome). Congestion and haems. in bursa of Fabricius, followed by degeneration. Varying degrees of nephrosis	History, clinical signs and post-mortem findings

TABLE 1—*cont.*

Disease	*Age incidence*	*History*	*Clinical signs*	*Prominent lesions*	*Diagnostic criteria*
Infectious avian nephrosis	Variable	Similar to Gumboro disease but the course is not so well defined	Resemble Gumboro disease	Petechial haemorrhages not a feature. The most prominent lesion is a urate nephrosis. The kidneys are enlarged and the tubules, distended with urates, are prominent throughout. No visceral gout	History, clinical signs and post-mortem findings. The isolation of an infectious agent may take too long to be of diagnostic value
Haemorrhagic syndrome (so-called 'sulphonamide poisoning' or 'sulpha toxicity')	Not applicable	Whilst this condition is frequently associated with sulphonamide therapy, cases are seen where there is no history of the birds receiving this type of drug. A sudden increase in mortality, which may follow the diagnosis and treatment of coccidiosis	Marked increase in mortality, general appearance may resemble coccidiosis. Birds have pale combs and wattles	Pale musculature. Haemorrhages subcutaneously, in abdominal cavity, liver, spleen, kidneys and heart muscle. Bone marrow very pale, aplastic anaemia	History and post-mortem findings
Toxic fat syndrome (chick oedema disease)	Not applicable	A sudden sharp increase in mortality. Which may be linked with the introduction of a fresh batch of food. Whilst individual chicks may show lesions resembling those described, authenticated cases of this condition are rare	Affected chicks have distended abdomens, some difficulty in breathing may be apparent and will be increased by handling	Subcutaneous oedema, an accumulation of fluid in the abdominal cavity and pericardial sac. The liver is swollen, has rounded edges, pale capsule, giving a pale pinkish appearance. On cutting the presence of fibrous tissue is apparent. The heart is often distended, thin walled and collapsed. Whilst sporadic cases of cirrhosis produce similar findings, in the toxic fat syndrome, these lesions are found consistently	History, clinical signs and post-mortem findings
Salt poisoning	—	Chicks are thirsty, increased mortality, possibly associated with change of food, i.e. faulty compounding	Excessive thirst, distended crops, subcutaneous oedema. Muscular weakness and convulsions prior to death. 'Water-logged' carcasses	Carcass appears pinkish and has a brine-soaked appearance. Musculature and organs look wet and oedematous. Some fluid may be present in the abdominal cavity and pericardial sac. But gross changes are not seen in liver, e.g. toxic fat syndrome, enteritis and congested intestines	Post-mortem findings. Food analysis when practicable
Furazolidone or N.F.Z. toxicity	—	Sharp increase in mortality preceded by apparent nervous disorders. Usually the result of faulty compounding. In older chicks may, therefore, be associated with a specific batch of food or with N.F.Z. therapy	Hyper-aesthesia, chicks restless, easily scared, inco-ordination, torticollis, and similar evidence of nervous dysfunction	No gross changes visible. Pale livers with yellowish white markings forming a network may be seen. Kidneys pale with excess urates	Clinical signs. Quantitative estimation of drug in diet, Elimination of specific disease. e.g. I.A.E. and Newcastle disease

TABLE 2

MISCELLANEOUS DISEASES OF GROWERS AND ADULTS

Disease	*History*	*Clinical signs*	*Prominent lesions*	*Diagnostic criteria*
Caecal coccidiosis *E. tenella*	Although caecal coccidiosis occurs more commonly in young chicks, it can affect susceptible birds at any age	Dejection, possibly unexpected mortality, blood in faeces	Caecal tubes distended with blood and tissue from the caecal walls	Post-mortem lesions and recognition of parasite. Schizonts and oocysts in caecal contents and tissues
*Intestinal coccidiosis** *E. necatrix*	If a number of birds are affected there may be a distinct drop in food consumption and a sharp increase in mortality	Birds huddle, have ruffled feathers and are reluctant to move. Blood-stained faeces may be seen	*Acute form*. The upper and middle portions of S.I. are distended and discoloured with petecheal haemorrhages. Lumen of gut filled with blood and necrotic material from gut wall *Sub-acute form*. Thickened intestinal walls, necrotic mucous membranes, white specks indicating schizont colonies in gut wall	Post-mortem findings and microscopic examination of intestinal smears. Schizonts in S.I., oocysts in caeca
E. maxima	Acute infections rare. Some unthriftiness and an increase in culls	Loss of condition, pale combs, loose droppings	Flaccid and thickened intestines mucoid enteritis, blood tinged mucosa in severe cases. Greyish mottled areas visible in outer wall of duodenum	Recognition of characteristic oocysts in S.I.
E. brunetti	Acute infections result in increased mortality and a decrease in food consumption	Rapid loss of condition; general dejection and weakness	Blood stained mucosa lower part of S. intestines, including rectum in acute cases. Sub-acute cases—necrotic enteritis in lower part of gut	Post-mortem lesions. Oocysts in lower part of intestines only
E. acervulina	Loss of condition, increase in number of culls	General debility	Catarrhal enteritis of duodenum thickened wall, some flushing of mucosa, white spots indicating schizont colonies	Post-mortem lesions, numerous oocysts throughout gut

* Many clinical cases of intestinal coccidiosis are attributable to mixed infections.

TABLE 2—*cont.*

Disease	*History*	*Clinical signs*	*Prominent lesions*	*Diagnostic criteria*
Mareks disease Neural lymphomatosis Fowl paralysis	In the classic form the onset may be slow, sporadic cases of lameness and paralysis appearing with increasing frequency from around 10 weeks of age In the *acute* form the onset may be sudden, suggesting an acute condition; may appear when birds are a few weeks old	*Classic form.* Clinical signs will depend on which nerves are affected and will include spastic paralysis of legs and wings. Torticollis and irregular head movements if the C.N.S. is affected. Dyspnoea and impacted crop *Acute form.* A sudden increase in mortality may be the first sign. Daily mortality figures of around 1 per cent may persist for a period of several weeks	*Classic form.* Primarily enlargement of the main nerves and plexi with loss of striation. The nerves assume a greyish translucent appearance and the swelling varies, giving an irregular shape. All major nerves should be examined especially the brachial and sciatic plexi *Acute form.* Gross enlargement of the nerves may not be seen. Varying degrees of lymphoid infiltration and tumour formation may be found throughout the body. The gonads, liver, lungs, heart, kidneys, proventriculus, breast muscles, skin and subcutaneous tissue may all be involved. Occasionally tumour formation in the orbital fossae cause an obvious protrusion of eyes	Classical signs and post-mortem findings should enable a diagnosis to be made. In early outbreaks of the classic form it may be necessary to examine several birds History and post-mortem findings
Ocular lymphomatosis	Birds possess pale depigmented irises—'pearly eye'. Cases of neural lympho. are usually seen at the same time	Blindness may not be apparent. The iris is usually pale and may be almost white. Pupil varies in size and response to light stimulation	The iris is paralysed to a varying extent, resulting in the pupil having an irregular or ragged appearance. No opacities are visible in cornea or lens. Blindness from other causes may result in a contracted iris with no response to light, but the contraction results in an evenly distended pupil. Lesions in other nerves can often be found	Clinical signs and post-mortem findings
Avian leucosis Lymphoid leucosis Diffuse form	No flock symptoms are apparent, the leucoses result in a ragged mortality and an increased number of culls over a considerable period of time. Cases are rarely seen under the age of 8 weeks	Birds usually found dead or show loss of condition. The abdomen may be distended and the liver palpable	Gross lymphocytic infiltration, most commonly apparent in the liver and spleen which may be several times the normal size and have a uniformly greyish appearance. The kidneys, ovary and mesentery are also commonly affected	Post-mortem lesions

TABLE 2—*cont.*

Disease	*History*	*Clinical signs*	*Prominent lesions*	*Diagnostic criteria*
Discrete form (nodular)	As above	As above	Enlargement of the affected organs occurs but the lymphocytic infiltration accumulates to form nodular tumours, between which apparently normal tissue can be seen. The tumours are white with some translucency and have well-defined borders. The liver, spleen and kidneys often show the most typical lesions. Specimens showing a mixture of diffuse and discrete lesions commonly occur	Post-mortem lesions
Myeloid leucosis Diffuse form	As above Incidence much lower, rare in young birds	As above	Enlargement of the liver and spleen. Liver may have a granular or morocco leather-like appearance or the accumulation of myelocytes may be concentrated to give localised tumour-like areas. Lesions also seen in kidneys and lungs. The bone-marrow is pale and pinkish	Post-mortem lesions. Microscopically a proliferation of immature granulocytes is recogcognised
Discrete form (nodular)	As before	As before	Accumulations of myelocytes occur in the parenchymatous organs and on the surfaces of the ribs, sternum and pelvis forming nodules of a cheesy friable consistency. Myeloid tumours are not translucent but have a more consolidated texture than lymphoid tumours, and a cream rather than white appearance. Cases showing both types of lesions are common	Post-mortem lesions
Erythroleucosis	As above Rare in birds under six months of age and not a common disease	As above	Enlargement of liver and spleen but not so advanced as in other forms of leucosis. Enlargement uniform. No areas of nodular infiltration. A characteristic bright cherry-red colour. Bright red coloration of bone marrow	Post-mortem lesions

TABLE 2—*cont.*

Disease	*History*	*Clinical signs*	*Prominent lesions*	*Diagnostic criteria*
Osteopetrosis 'Marble bone disease'	Mainly occurs in older birds, usually sporadically	No general signs may be noticed, apart from thickened shanks. Palpation will reveal enlargement of other long bones	The characteristic gross enlargement is most apparent in the long bones, which are increased in size and density and have a flinty consistency. A cross-section reveals the increase in bone formation and reduction of the medullary cavity	Post-mortem lesions
Erysipelas	Rarely seen in chickens. In turkeys an outbreak of this disease usually commences with a number of sudden unexplained deaths. Birds appear sick for a short time only and flock symptoms may not be seen. The disease occurs most commonly when conditions such as overcrowding lead to fighting and multiple injuries, thus permitting wound infection. As these conditions are more likely to occur in the latter part of the year, the disease may appear to have a seasonal incidence. It is a perennial danger on some farms	Inappetance, dejection, sudden death. Congested and purplish areas may be seen on the head, neck and body. Swollen snoods may occur, but are not common	Congested carcass. Intense congestion of all blood vessels. Liver and spleen swollen and dark in colour. Blood tends to remain fluid. Petechial haemorrhages on heart, gizzard and serous membranes	Bacteriological examinations are necessary for confirmation. Blood smears stained with Grams stain may permit a tentative diagnosis
Pasteurellosis (Fowl cholera) In chickens	Acute cases of fowl cholera are no longer common, but when they occur birds show inappetance and an increased thirst. Mortality may rise sharply. The more common chronic form of the disease does not usually produce flock symptoms, but may be associated with some form of respiratory disease	Inappetance, thirst, dejection, ruffled feathers, whitish or yellow diarrhoea Swollen wattles or sinuses filled with caseous material. Necrotic areas around the larynx. Brain infections may cause nervous signs	A congested carcass. Swollen liver varying in colour from mahogany to dark brown. Spleen similarly affected. Necrotic foci in liver and spleen. Abscess formation in the wattles and sinuses; nasal clefts filled with purulent material. Occasionally an arthritic or tenosynovitis may be seen	Post-mortem lesions and history permit a tentative diagnosis but bact. exams. essential for confirmation As above
In turkeys	Often an acute disease with sudden onset and sharp increase in mortality	Cyanosis of the head parts. Difficulty in breathing. Marked dejection. Occasionally swollen snoods	Fevered carcasses. Swollen and congested livers and spleens with or without necrotic foci. Pneumonia with varying degrees of hepatisation and air sac infection.	As above

TABLE 2—*cont.*

Disease	*History*	*Clinical signs*	*Prominent lesions*	*Diagnostic criteria*
Fowl typhoid	This disease always tended to be localised in certain areas where it was endemic. It was primarily a disease associated with contaminated and 'fowl sick' ranges, and is therefore not common in intensively housed birds	Increased mortality. Marked dejection, cyanosed combs, yellowish-green diarrhoea inappetance, thirst	A congested dark brown liver, often with necrotic foci, which turns greenish-bronze on exposure to the air. The lungs are filled with a brownish fluid. Myocarditis may be present in subacute cases. Petechial haemorrhages on viscera	Clinical signs and lesions permit a tentative diagnosis. Confirm by bacteriological examinations
Pullet disease	This disease occurs in two forms, both of which were more common under range conditions. Etiology has never been defined and it seems possible that the two forms are the result of separate metabolic disorders. Pullets just in lay, most commonly affected			
Acute form	An increase in mortality with few flock symptoms	Poorly defined. A drop in food consumption and egg production may be observed. Prior to death cyanosis of the comb and wattle may be apparent	General picture suggests a septicaemic condition. Fevered carcass, petechial haemorrhages on viscera and on walls of thoracic and abdominal cavities. Liver pale mahogany in colour, friable in consistency, multiple necrotic foci, fatty degeneration	Post-mortem findings. Eliminate cholera and typhoid by bacteriological examinations
Sub-acute or chronic form	The onset of disease might be quite sudden and is frequently associated with some marked change in diet or environment. The appearance of symptoms in several batches of birds may present a pattern which suggests an infectious disease	Sharp drop in egg production. General inappetance, thirst, cyanosed combs and wattles, crops distended with food or fluid, whitish diarrhoea, variable mortality	Partially or completely impacted crops and gizzards. Pale streaks resembling fish flesh in breast muscles. Urates in pericardial sac and on viscera, urate nephrosis. Whilst visceral gout is a sporadic cause of death, in pullet disease it is a fairly constant finding	Clinical signs. Post-mortem lesions

TABLE 2—*cont.*

Disease	*History*	*Clinical signs*	*Prominent lesions*	*Diagnostic criteria*
Worm infestations	Worm infestations are likely to be associated with other causes of debility. They may occur concurrently with coccidiosis. Their presence is frequently associated with unsatisfactory conditions of the litter and poor hygiene			
Large round worms (ascarids)		Unthriftiness, impaired growth or production, loss of body weight, diarrhoea	A debilitated carcass. Flaccid gut with a catarrhal or muco enteritis. Lower bowel may be distended with fluid contents. In massive infestation the bowel may be impacted with worms	Recognition of the worms, 1–1½ in. long
Thread worms (capillaria spp.)		As above, but the signs may be more pronounced; the birds may appear anaemic	In addition to the above findings, the mucosa of the intestines may have a flushed appearance due to haemorrhages and enteritis	The worms can be found on close examination. They are only ½–⅜ in. long and are thread-like. The eggs with bi-polar plugs may be found on microscopic examination of faecal smears
Tape worms	Rarely a problem under modern methods of husbandry	Debility, diarrhoea, and increasing weakness	As above	Recognition of the parasite
Caecal worm (heterakis)	Little evidence of pathogenicity The principal significance of these worms is their role as an intermediate host to histomonas, the causal parasite of blackhead disease			

TABLE 3

DIFFERENTIAL DIAGNOSIS OF RESPIRATORY DISEASES

Disease	*Course*	*Clinical signs and lesions*	*Diagnostic criteria*
Newcastle disease			
In chicks	*Sudden* appearance with rapid spread and increased mortality, which may be heavy in susceptible chicks	Death may occur before respiratory signs develop. Nervous signs are common. Casts of caseous material in tracheas and laryngeal plugs. Petechiation of serous membranes. Dirty thickened air sacs	Post-mortem findings. Virus isolation
In adults and growers	*Rapid* spread, recovery in 2 or 3 weeks in uncomplicated cases	Signs and lesions will vary with susceptibility and vaccinal status 1. Coughing, sneezing, nasal discharge 2. Inappetance, dejection, greenish diarrhoea 3. Nervous signs—torticollis paralysis and leg weakness 4. Rapid drop in egg production soft shelled eggs 5. Fevered carcasses, petechiation serous membranes, thickened air sacs	Clinical and post-mortem findings warrant tentative diagnosis. Haemagglutination inhibition test. Histological examination of tracheal sections. Virus isolation
In turkeys	*Rapid* spread, recovery in 2 or 3 weeks in uncomplicated cases	Respiratory signs may be very slight, but nervous disorders are a fairly common sequel	
Infectious bronchitis			
In chicks	*Sudden onset*, rapid spread	Gasping, sneezing, huddling. Tracheitis and bronchopneumonia	Virus isolation, histopathology. Serological tests on recovered birds

TABLE 3—*cont.*

Disease	*Course*	*Clinical signs and lesions*	*Diagnostic criteria*
In adults and growers	*Rapid* spread	May be very slight 1. Some sneezing and coughing with mouth breathing 2. Rapid drop in egg production. Abnormal shells and watery whites persisting 3. No characteristic post-mortem lesions	Virus isolation. Histopathology. Serological tests
Infectious laryngo-tracheitis	Acute form may cause heavy mortality (over 25 per cent). Chronic form results in sporadic deaths only. *Spread usually slow*	In typical acute form: coughing, outstretched neck, blood expectorated. Extensive haemorrhagic tracheitis, blood clots, casts or caseous plugs in trachea and larynx. Few changes in other parts of the respiratory tract	Symptoms, post-mortem lesions, histopathology. Virus isolation
Mycoplasmosis In chickens: Chronic respiratory disease (C.R.D.). Air sac infection	In pure infections clinical signs may be absent until secondary infections occur. *Slow spread*	Slight catarrh, watery eyes, sneezing. Lowered egg production in layers. Slight tracheitis, flakes of pus in air sacs	Negative results from virological examination. Serological tests. Isolation of *Mycoplasma gallisepticum* on culture. Histopathology
In turkeys: Infectious sinusitis	Although the initial spread is insidious, the appearance of typical signs may be quite sudden	Facial sinuses, swollen and full of fluid which becomes thick and caseous. Purulent material in air sacs	Clinical signs, post-mortem lesions. Serological tests. Isolation of *M. gallisepticum*
Colisepticaemia Broiler septicaemia Chronic air sac infection	Usually associated with previous exposure to mycoplasma or virus infections. In broilers there may be a sharp but variable increase in mortality. Respiratory signs may not be prominent	Slight coughing, conjunctivitis and respiratory distress. Sudden deaths. Fevered carcasses, extensive fibrinous pericarditis, perihepatitis and air sacculitis. Congested livers and spleen, varying tracheitis	History and post-mortem lesions. Bacteriological examinations

TABLE 4
SOME FORMS OF TREATMENT IN COMMON USE

Disease	*Trade name*	*Manufacturer*	*Active principle*	*Dose*	*Remarks*
Coccidiosis	Bifuran	Smith, Kline & French Labs	Nitrofurazone (0·0055%) and furazolidone (0·0008%)	*Therapy* 2 lb./ton of food for 7 days *Prophylaxis* ½lb./ton of food continuously	
	Embazin	May & Baker	Sulphaquinoxaline	*Therapy* 2 fl. oz. to 3 gal. drinking water on 3 : 2 : 3 basis *Prophylaxis* 1 oz. premix to 1 cwt. food continuously for first 8 weeks	
	Nefco	Smith, Kline & French Labs	Nitrofurazone	*Therapy* 0·01% in food 0·005% in food	
	Paramez	I.C.I.	Sodium sulphadimidine and dimethyldipyridyl	1 fl. oz. to every 2 gal. drinking water	May be given continuously for 6 to 10 days depending on the type of infection
	Saquadil	May & Baker	Diaveridine (3·2%) Sulphaquinoxaline (2·8%)	1 fl. oz. to 4 gal. drinking water Interrupted schedule: 3 days treatment; 2 days off; 3 days treatment	
	Sulphamezathine	I.C.I.	Sulphadimidine	2 fl. oz. of 16% solution to 1 gal. drinking water Interrupted schedule 3 : 2 : 3: i.e. 3 days medicated water; 2 days plain water; 3 days medicated water	In intestinal coccidiosis it may be advisable to prolong treatment 3 : 2 : 3 : 2 : 3. The last two treatments being given at half strength
	Whitsyn S	Whitmoyer Reed Ltd.	A mixture of sulphaquinoxaline and pyrimethamine	1 fl. oz. to 4 gal. drinking water on interrupted schedule: 3 : 2 : 3 : 2 : 3	For the treatment of all types of coccidiosis
	Amprolmix	Merck, Sharp & Dohme	Amprolium	Incorporate in food at 0·0125% level continuously	Particularly effective against *E. tenella* and *E. necatrix*

TABLE 4—*cont.*

Disease	*Trade name*	*Manufacturer*	*Active principle*	*Dose*	*Remarks*
	Coyden 25	Dow	Metichlorpindol	Incorporate in food at 0·0125% level	No immunity follows the use of this drug intended primarily for broilers
	Darvisul	Burroughs Wellcome Ltd.	A potentiated sulphonamide	As above	Particularly effective against *E. brunetti* *E. acervulina* and *E. maxima*
Coccidiostatic preparations	Pancoxin	Merck, Sharp & Dohme	Amprolium and sulphaquinoxaline + ethopobate	Dosage varies with systems of management. Follow manufacturers instructions	Effective against all species
	Sulfacox (Premix)	Merck, Sharp & Dohme	Sulphaquinoxaline	Incorporate in food at 0·0125% level	
	Whitsyn 10	Whitmoyer Reed Ltd.	A mixture of pyrimethamine and sulphaquinoxaline	2½ lb. premix/ton of food fed until birds are 10 weeks old	For the prevention of coccidiosis
	Zoamix	Dow	Zoalene (25% premix)	Incorporated in food at 0·0125% level (18 oz. premix/ton)	
Blackhead disease	Entramin A (22·5% Premix)	May & Baker	Acetamido-nitrothiazole	*Prevention* 2 oz. premix/cwt. food fed continuously *Treatment* 4 oz. premix/cwt. food for 7–14 days	
	Entramin A Capsules	As above	As above	Birds 3–6 lb. weight 1 capsule Birds 7–10 lb. weight 2 capsules Over 10 lb. weight 3 capsules	Should not be used on birds less than 3 lb. body weight. Birds should not be dosed more than five times on alternate days
	Emtryl (Premix)	May & Baker	Dimetridazole	*Prevention—premix* Turkeys: 1 oz premix/cwt. food Chickens: 12 oz. premix/*ton* food *Treatment—premix* 4 oz./cwt. food fed for 7–14 days and then at preventive level	

TABLE 4—*cont.*

Disease	*Trade name*	*Manufacturer*	*Active principle*	*Dose*	*Remarks*
	Emtryl (Soluble)	As above	As above	*Prevention—soluble preparation* Turkeys: 1 oz./20 gal. water Chickens: ½ oz./15 gal. water *Treatment—soluble preparation* 1 oz. preparation per 10 gal. water for 12 days, then at preventive level	
	Histocarb S (Chickens) Histosep S (Turkeys)	Whitmoyer Reed & Co.	Organic arsenical compound	1 fl. oz./gal. water for 5 days followed by half-strength for a further 5 days	
	Carb-O-Sep	Whitmoyer Reed & Co.	Organic arsenical compound	*For prevention in turkeys* 2½ lb./ton of food fed continuously	Does not require a veterinary prescription
	Turk-E-San	Boots	Sodium acetarsal	1 tablet to 2½ gal. of drinking water continuously	Discontinue treatment 1 week prior to slaughter
Anthelmintics Large round worms	Coopane Pipricide Whitmoyer piperazine Safersan	Coopers Burroughs Wellcome Whitmoyer Reed Boots	Piperazine	Use in accordance with manufacturers instructions	It will be necessary to repeat treatment where heavy infestations exist every 3 weeks
Thread worms (capillaria spp.)	Mintic	I.C.I.	2-(3-methoxethyl) pyridine	One fl. oz./gal. drinking water for 24 hours	Discard eggs laid 3–4 days after commencing treatment
	Haloxon	Coopers	0,0-di-(2-chlorethyl)0-(3-chloro-4 methyl-coumarin-7 yl) phosphate	50–60 mg./kilo against adult worms	
Caecal worms	Phenovis	I.C.I.	Phenothiazine	2–4 oz./100 birds added to the food for 1 day. Repeat in 6–8 weeks	Used to control Blackhead disease by controlling the caecal worms
	Phenosan	Boots	Phenothiazine	2–4 oz./100 birds added to the food for 1 day. Repeat in 6–8 weeks	Should not be used on birds suffering from Blackhead disease, or on birds less than 5 weeks of age
Ascaridia and Capillaria	Hygromix	Elanco	Hygromycin (*S. hygroscopicus*)	9 million units/ton fed continuously	

TABLE 4—*cont.*

Disease	*Trade name*	*Manufacturer*	*Active principle*	*Dose*	*Remarks*
Tape worms	Dicestal	May & Baker	Dichlorophen (B. Vet. C)	One or two half gm. tablets by mouth	
Gape worms	Thibenzole	Merck, Sharp & Dohme	Thiabendazole	Incorporated in the food at a 0·2% level for 7 days (1 oz./34 lb. feed)	Heavier doses required for partridges
			Bacterial Diseases		
Anti-bacterials and *antibiotics*					
Pullorum disease	Animycetin Oral Solution	Stevenson, Turner & Boyce	Chloramphenicol	1 fl. oz. per 4 gal. drinking water	Requires a veterinary prescription
Salmonellosis Fowl typhoid	Animycetin Powder	Stevenson, Turner & Boyce	Chloramphenicol	1 oz./10 gal. drinking water 3 lb./ton of food	Provide medicated water for 3–5 days
	Furasol	Smith, Kline & French Labs	Furaltadone	A concentration of 0·04% in drinking water (1 lb. to 50 gal.)	
	Neftin	Smith, Kline & French Labs	Furazolidone	*Prevention* A level of 0·01% in food continuously	
				Treatment A level of 0·04% in food for 10 days (i.e. 1 lb. premix to 1 cwt. food)	
Coliform infections	Animycetin	As above			
Coli-septicaemia and respiratory diseases where	Aureomycin	Cyanamid of Gt. Britain	Chlortetracycline	Use at higher levels, e.g. 100–200 gm./ton	Also used for: infectious synovitis, pullet disease, pasteurellosis
a coliform infection has be-	Water soluble form	Cyanamid of Gt. Britain	Chlortetracycline	2–3 teaspoonsful/gal. water	
come superimposed	Chloromycetin	Parke, Davis & Co.	Chloramphenicol	By i.m. injection 1–2 mg./lb. body weight	Of value in the treatment of pasteurellosis in turkeys. Requires a veterinary prescription
	Framomycin	Crookes Labs. Ltd.	Framycetin	2 or 3 lb./ton of food	
	Soluble powder (25%)		Framycetin	Birds ½ lb. body weight: 5–10 gm./1000	Follow manufacturers instructions
	Furasol	See above			
	Neftin	See above			

TABLE 4—*cont.*

Disease	*Trade name*	*Manufacturer*	*Active principle*	*Dose*	*Remarks*
	Pro-Gen. Sodium	Abbott Laboratories	Sodium arsanilate	2 oz./40 gal. drinking water for 5–7 days	No treatment 7 days before slaughter
	Rondomycin	Pfizer Ltd.	Methacycline	Dosage varies with age of birds, follow manufacturers instructions	Efficacy against mycoplasma infections also claimed. Requires a veterinary prescription
	Terramycin Soluble form	Pfizer Ltd.	Oxytetracycline	100 gm/ton of food. 3–4 oz./10 gal. water	
Pasteurellosis	Animycetin	See above			Requires a veterinary prescription
	Aureomycin	See above			Requires a veterinary prescription
	Chloromycetin	See above			Requires a veterinary prescription
	Embazin	May & Baker	10·32% solution of sulphaquinoxaline	2 fl. oz./3 gal. drinking water	Avoid over-consumption of medicated solutions
	Streptomycin	C.I.B.A.	Streptomycin sulphate	*Turkeys* 25 mg./lb. i.m. or s.c.	Avoid overdosage. Requires a veterinary prescription
	Terramycin suspension in oil	Pfizer Ltd.	Oxytetracycline	*Poultry* 1–4 cc. *Turkeys* 2–6 cc. } by subcutaneous injection	
Staphylococcal infections and *Erysipelas*	Penicillin: Various injectable preparations	Various	Penicillin	Most cases of staphylococcosis and erysipelas will respond to treatment with penicillin. Where any doubt exists a sensitivity test on an isolate should be obtained. Long-acting injectable preparations are likely to be of most value. Requires a veterinary prescription	
	Terramycin suspension in oil	See above			

TABLE 4—*cont.*

Mycoplasma Infections

The following preparations are manufactured for the prevention and treatment of infections due to *Mycoplasma gallisepticum*. The methods of use and dosage vary considerably and the manufacturers have designed medication programmes for various types of stock, e.g. broilers, replacement pullets, layers. It is therefore advisable to obtain expert guidance so that the programme most suitable to a particular need may be employed.

Disease	*Trade name*	*Manufacturer*	*Active principle*	*Dose*	*Remarks*
Mycoplasmosis P.P.L.O. infection C.R.D. Infectious synovitis Infectious sinusitis	Erythrocin	Abbott Laboratories Ltd.	Erythromycin		
	Erythrocin Water Soluble	Abbott Laboratories Ltd.	Erythromycin		
	Aureomycin (improved)	Cyanamid (Great Britain) Ltd.	Chlortetracycline	200 gm/ton food	Heavier dosage may be given if combined with terephthalic acid
	Erythrocin Phosphate	Abbott Laboratories Ltd.	Erythromycin	For water proportioners 1 pack to 40 gal. water for 5 days	
	Erythrocin Premix	Abbott Laboratories Ltd.	Erythromycin	5 lb./ton food for 5 days	
	Poultry Erythrocin I.M.	Abbott Laboratories Ltd.	Erythromycin	1/10 ml. injection subcutaneously/lb. body weight Inf. sinusitis in turkeys: Drain sinuses and inject 1–2 ml. into each	No treatment 48 hours before slaughter Eggs should not be collected for human consumption for 48 hours during treatment Successful treatment of infectious synovitis is also claimed
	Rovamycin Soluble	May & Baker	Spiramycin	*Treatment* *Chickens*: 2 gm./gal. water for 40–72 hrs *Turkeys*: 2 gm/gal. water for 3 days or subcutaneous injection 100 mg./kg. live weight *Prevention* *Broilers* 3 days medication from day old. 1 day's medication when 3 or 4 weeks old (using 2 gm./gal. water) *Pullet replacements and capons* As above and in addition a further day's treatment at 9 weeks of age	Requires a veterinary prescription After injection turkeys may show depression for 24 hours

TABLE 4—*cont.*

Disease	*Trade name*	*Manufacturer*	*Active principle*	*Dose*	*Remarks*
				Turkeys 5 days medication from day old (2 gm./gal. water) or subcutaneous injection of 0·5 ml. of a 2% solution. Then a single day's medication at 4, 9 and 16 weeks of age	
	Tylan Tylan Soluble	Elanco	Tylosin tartrate	*Treatment* 2·5 gm./gal. drinking water for 24–72 hours according to severity of disease	
	Tylan Injectable			0·5 ml./lb. liveweight injected subcutaneously	
	Tylan	As above	As above	*Preventive programmes* *Broilers* Water medication (2·5 gm. soluble/gal.) for 72 hours at day old, and for 24 hours at weeks of age *Replacement pullets* Water medication for 72 hours from day old and for 24 hours at 4 weeks. Subcutaneous injection of Tylan injectable 0·5 ml./lb. liveweight at 9 to 12 weeks and again at 18–20 weeks	
	Tylan	As above	As above	*Breeders* Water medication for 120 hours from day old and for 48 hours at 4 weeks. Subcutaneous injection at 8–10 weeks, 16–18 weeks, 20–22 4 weeks and 24–26 weeks Alternatively: water medication for 120 hours from day old, then for 48 hours at 4 weeks, 8–10 weeks, 16–18 weeks, 20–23 weeks and 24–26 weeks	

Chapter 19

POULTRY DISEASES AND OTHER PROBLEMS OF DOUBTFUL AETIOLOGY WHICH HAVE BEEN LINKED WITH NUTRITION

W. P. BLOUNT

Fatty Liver Syndrome in Layers

Occasionally pullets die from rupture of the liver in association with fatty degeneration. More recently this has become widespread throughout the world and has been re-named the fatty liver syndrome whenever it has a flock basis.

Symptoms and Post-mortem Findings

Affected stock are generally pullets in full lay, in the first half of the laying season. They show few symptoms before their sudden death.

Post-mortem findings include advanced fatty degeneration of the liver, sometimes in association with old haemorrhages; death in many cases follows severe internal haemorrhage. Most cases are associated with large deposits of fat under the skin, around the heart, gizzard and proventriculus, lining the abdomen, etc., but few organs show naked-eye changes except the liver. In some cases the spleen may be larger than normal, and a cystic right oviduct may also be present, but these are not of pathological significance.

Causation and Treatment

Some authorities believe that the diet may be at fault, reference being made to low protein, high energy rations deficient in B vitamins, etc. However as many cases occur amongst pullets which are receiving a normal layers feed which is not lacking in balance, and which does contain the usual amounts of vitamins but no added fat, any direct relationship to feeding is less clear.

On some occasions the affected flock is known to have suffered from infectious bronchitis, and in these cases early egg peritonitis is commonplace. Pus is present amongst the intestines and the peritoneum shows clear-cut inflammatory lesions. Presumably toxins from this source account for the yellow, toxic, degenerate fatty liver seen in such cases; in others perhaps mycotoxins may have been acquired?

Couch, who first described the fatty liver syndrome in 1956, now believes that the condition may be precipitated by a low level of disease, hence his recommendation that treatments include N.F. 180 (furazolidone) (4 lb./ton for 4 weeks) with 12 mg. B_{12}, 1000 gm. choline chloride and 10,000 units vitamin E per ton additional to those amounts normally in the feed. (As a replacement for furazolidone 300 gm./ton of aureomycin can be used.)

Couch (1965) has also recorded that a decrease in egg size may precede the development of the fatty liver syndrome by about 1 week. In addition to the vitamins mentioned, Canadian workers at Guelph recommend the addition of 2 oz./ton of copper sulphate plus 1–2 per cent additional protein; the latter because they find that liver fat levels fall with increased protein:

Dietary protein (%)	*Average egg production* (%)	*Liver fat* (%)
13	76·4	49·3
15	77·0	40·2
17	78·0	38·2

FIG. 52. Enlargement of the liver with accompanying fatty degeneration (?infiltration) is typical of high-producing hybrids seen to be even more advanced when the stock are housed in laying batteries. Evidence of haemorrhage within the liver is also not unusual.

It is not clear however whether pullets get fat because they are not laying regularly, or whether it is their basal metabolism which is at fault, the birds failing to adjust their appetite to their energy needs. The condition is usually seen in pullets in laying cages where lack of exercise is an obvious feature. It is not a disease of layers housed on range or deep litter.

Some breeds appear to be affected more frequently than others, even though the latter are fed on the same rations and housed in the same type of batteries. The state of the feathering is possibly important, because when pullets get de-feathered from any cause (losing their natural insulation) they often eat excessively for heat maintenance purposes.

Fat Formation

Many veterinarians are not aware of the extent to which the liver automatically gets fatty when a healthy pullet is in full lay. Analyses for fat frequently show about 20 per cent to be present. This is a necessary physiological accompaniment of egg production, because it is the liver which is the centre of lipid metabolism for egg yolk (fat) synthesis.

In an effort to understand the liver's function in high producing layers the writer carried out a systematic examination of '404' and 'Nickchick' pullets prior to, at point-of-lay, and throughout a laying season. Two hundred normal pullets were sacrificed in this way, so that their internal anatomy could be inspected.

The change in the colour of the liver from mahogany (when a pullet is out-of-lay), to reddy-brown, brown and yellow-brown as laying progresses is very clear and has to be seen to be believed; as well as the reversal when a laying pullet is starved for 48 hours. A physiological degeneration (? infiltration) of the liver therefore appears to be *normal* in many high producing layers. The nature of any other factors superimposed on this condition is not yet clear, other than the fact that many pullets do not adjust their appetites to their energy needs, and if they are in laying batteries exercise is minimal.

SUMMARY

Pullets in full lay in battery cages may suffer from fatty degeneration (? infiltration) of the liver physiologically. When such birds over-eat and lay down excess fat they appear subject to further liver changes which culminate in a tearing of the liver parenchyma with internal haemorrhage and sudden death.

These cases may occur when the diet contains adequate amounts of choline (450 mg./lb.), vitamin B_{12} (4 mg./ton) and vitamin E (3500 I.U./lb.), but additional quantities are now being recommended for treatment purposes in conjunction with an anti-bacterial (nitrofuran or copper) agent.

In some instances the problem is accentuated in the presence of I.B. or other pathogen linked with egg peritonitis.

Liver and Kidney Syndrome (Pink Disease)

Although this condition is very well known to broiler producers in Britain it does not appear to have been recognised in the U.S.A. where many more millions of table birds are produced. It was first reported in Denmark by Marthedal, but its current incidence in that country is negligible, whereas nowadays it occurs in quite a high percentage of broiler crops over here (replacement pullets are rarely involved).

Affected broilers are generally about 10–28 days old, dying overnight without obvious symptoms. Morbidity is never high and mortality is low, usually about 1½–4 per cent.

Post-mortem findings are characteristic, including a pinkish tinge to the viscera seen when the carcass is first opened. The liver and kidneys are enlarged and fatty but the nature of the lipid has not yet been determined.

Our own laboratory examinations of the affected organs have shown the following percentages of fat to be present:

	Severely affected		*Mildly affected*		*Unaffected*	
	Liver	*Kidneys*	*Liver*	*Kidneys*	*Liver*	*Kidneys*
Mean %	19·03	21·42	11·4	12·9	8·39	10·98
Range	(7·24–41·4)	(2·58–45·4)			(4·85–14·3)	(6·67–16·8)
No. of analyses	10	10	1	1	7	7

Its causation has never been discovered and although the low incidence of the disease in an affected flock does not suggest a primary nutritional cause, recent evidence favours particular herring/fish-meals as being linked with the origin of a number of outbreaks. A reliable report from the field indicates that Pink disease does not occur when the chicks are brooded at temperatures 5° F lower than normal.

Nephritis

It is not surprising that some practitioners have believed that the relatively high incidence of nephritis in poultry is related to diet, because many years ago experiments indicated that high protein levels might cause degenerations of the kidneys. With this in view we fed chicks a 40 per cent protein baby chick mash for 3 weeks without causing nephritis, and indeed overall mortality remained normal but growth rate was lower than expected by 2·8 per cent.

As a fact there are quite marked familial differences in the incidence of nephritis amongst different breeds (Hicks 1958), and also amongst unrelated strains of White Leghorns (Biely and March 1957).

In some years nephritis occurs much more commonly than others, and an examination of many series of poultry post-mortem records shows that the incidence of nephritis often represents at least 16 per cent of all mortality in adult stock. This picture may be false in that a diagnosis is usually made by the naked eye, as it is very easy to see whether the fowl's kidneys are normal by their appearance, size, colour and texture. Some such cases should be labelled nephrosis rather than nephritis, because the pathological changes do not include inflammatory lesions.

The presence of the renal–portal system whereby blood from the legs, lower abdomen and tail region is diverted to the renal system before entering the general circulation may account in part for the high incidence of kidney disorders in birds. In many cases the disease involves *isolated* birds suffering from some septic lesions of the feet, hocks, legs, skin or posterior abdomen, including the reproductive system and associated air sacs.

In the case of chicks and poults when larger numbers of birds are involved, this is often linked with some management factor such as chilling or over-heating within 36 hours of hatching. Errors of management at the hatchery or during transportation appear probable and such losses may reach 7 per cent in the 10–14 days concerned. Specific virus diseases (infectious bronchitis and avian nephrosis) cause naked-eye changes in the kidneys which are also a feature of Gumboro disease.

Some years ago Spector (1951) studied the problem histologically, and came to the conclusion that a progressive chronic pyelonephritis, consisting essentially of an infiltration by inflammatory cells beginning in the apical portion of the pyramids, eventually leading to fibrosis, was commonplace. It appeared probable that solid urates in the collecting tubules predisposed to the condition, inducing stagnation of the urine which later became infected. Spector's investigation did not support the view that there was a congenital basis for the disease or that there was necessarily any relationship to 'messy vent'. He concluded that pyelonephritis in the fowl differed from case to case in its precipitating cause, that nephritis played little part in chick mortality, and he was not able to throw any light on the causative role, if any, of avitaminosis A.

Chick rations today contain ample vitamin A, and there is absolutely no evidence that any other nutritional deficiency is involved. Incidentally, in man chronic pyelonephritis is associated with hypertension, and in Spector's series of cases 11 per cent showed hypertrophy of the cardiac muscle.

Treatment

When numerous cases of 'nephritis' occur the administration of 2 per cent molasses in the drinking water often increases water intake by about 25 per cent, and this may aid the recovery of some cases, otherwise no specific treatment can be recommended, although potassium salts have been used successfully on occasions.

Cannibalism

The full aetiology of cannibalism in layers is not clear, although any factor causing the fowl to strain unduly (causing increased intra-abdominal tension) is one aspect of the problem. A list of such factors is complex, ranging from large cystic right oviducts to lymphomatous tumours of the abdomen, acute cloacitis, oviductitis, etc. The retention of shell membranes in the vagina, or the presence of insoluble grit in the cloaca can both cause straining, thus indicating the need for carefully differentiating intestinal causes from those involving the reproductive system. (Fig. 53)

FIG. 53. A typical example of prolapse. The fowl strains and exposes part of the cloaca but the cause may be of either intestinal or oviducal origin.

FIG. 54. The dark scabby lesion at the top of the neck (behind the head) is the result of continuous pecking by a dominant male. No other obvious ill effects usually follow this spontaneous short-lived vice.

From an aetiological standpoint it is not always clear whether the fowl strains first (so exposing parts of its cloaca) followed by pecking, or whether the attacker pecks first (causing a local injury) following which the fowl strains exposing even more of its internal anatomy. For some unknown reason the soft, moist, red appearance of these internal 'organs' provides a strong stimulus to repeated pecking. Fortunately the victim appears to suffer for only a comparatively short period, before severe haemorrhage and shock are followed by death.

Cases of cannibalism may occur under any system of management (except single bird batteries) including turkeys on free range, the victim generally making very little effort to escape from what appears to be its inevitable, fatal end. Animal behaviour studies should help to solve this problem. (Fig. 54)

Wet Droppings

The state of a bird's droppings is very important, and those which are normal must be memorised clearly. As a contrast scanty green droppings imply starvation rather than disease, whereas deep red (bloody) faeces indicate either caecal coccidiosis, intussusception or possibly haemorrhagic disease. Brick red, mucus, flecks are often normal. White residues relate to urinary excretions, the amorphous calcium sodium urates coming either directly from the ureters (via the cloaca), or from the lower intestines following an anti-peristaltic movement of the urine forwards into the rectum. That from the ureters is more watery in character, the latter drier and adherent to normal faecal matter, forming the 'white tip' to the droppings readily recognised by poultry men. Brown, tenacious, stinking faecal matter represent excreta from the caecal tubes, which if infected with *coliforms* becomes yellow and frothy, a feature seen characteristically in Blackhead in turkeys.

Watery droppings which mat or stain the feathers below the vent may be either pathological or physiological. Causal factors include such nutrients as molasses, sugars, common salt, potassium and magnesium salts, chlorides, sulphates and urea; also pituitary hormones (e.g. a deficiency of the anti-diuretic), oestrogens, etc. I.C.I. compound 33828 (used for force-moulting purposes) also gives rise to very wet droppings.

Genetic factors have been involved too, some breeds of broilers drinking 30 per cent more water than others. Physiologically pullets which are in lay drink very much more than those out of lay and water consumption is also much higher in hot weather, twice as much water will be drunk at 90° F compared with 70° F.

Our own records show that when room temperatures rise by 10° (e.g. from 69° F to 79° F) water intake increased by 18 per cent.

Wet droppings are also a serious problem with certain commercial egg producers in the U.S.A. and the only accepted remedy there is to reduce actual water intake, e.g. to 15 minutes four or five times a day; none being available to the birds during the night. This may sound drastic and liable to interfere with egg production, but such is not the case.

Wet droppings need have no harmful effects on health or egg production, but the poultryman objects to their presence because of the increased labour problems they create during their removal, especially from hen batteries. The importance of this subject is such that it is now being studied by a research team led by Hill and Anderson at the Unilever Research Station, Colworth, Beds.

Turkey X Disease (Aflatoxicosis)

The story of aflatoxin is now well known to many veterinarians in this country, but when Turkey X disease, which killed off over 100,000 birds (*ex gratia* payments totalled £250,000), occurred in 1960 the condition was not known here, in North America or on the Continent.

Thanks to the co-operative efforts of the British feedstuffs industry, veterinarians at Weybridge and scientists at the Tropical Products Institute, it was only a matter of months before the true cause was known. Furthermore after T.P.I. staff had visited countries where groundnuts are harvested, practical recommendations were able to be made for reducing the level of toxin production. In addition, following consultations with various Ministries, national feed compounders for the past 6 years have been 'vetting' imports of groundnuts or meals, using a rapid laboratory method developed by Lee. A more sensitive biological test has just been announced by T.P.I. Very small quantities of aflatoxin prevent cell development in fertilised invertebrate eggs. A marine borer is used (although any mollusc eggs will suffice) since the female produces over 1 million eggs, each 0·05 mm. in diameter. Cell division normally commences about ½ hour after fertilisation, but if aflatoxin is present (even in a minute amount in the fluid bathing the cells) no division of the cell walls occurs although the nuclei will commence cleaving. This effect is seen in under 4 hours even if the concentration of aflatoxin is as low as 0·05 μgm./c.c. If the reading of the test can be delayed for 24 hours, levels as low as 0·005 μgm./c.c. can then be detected. (Tropical Products Institute Report No. 66/77.)

After the initial large series of fatal outbreaks of aflatoxicosis had been reported in turkeys (associated with the use of groundnut-meals imported from Brazil), the effects of aflatoxin on other farm livestock were soon recognised. It was clear that whilst aflatoxin could attack most species, young calves and pigs were found to be affected far more severely than older stock, whilst adult sheep were almost immune. Ducklings, turkey poults, pheasant chicks and rainbow trout were amongst the most susceptible.

The following data from Barnes (1967) show the high resistance of the mouse and hamster compared with the susceptibility of the puppy and baby rabbit. Hence the necessity to pay great attention to any rations for these species likely to contain groundnut-meals:

SINGLE DOSE LD_{50} OF AFLATOXIN B_1
(Barnes, 1967)

	mg./kg.
Duckling	0·37–0·56
Rat (m) 1 day	1·0
21 days	5·5
100 gm.	7·2
Hamster (30 days)	10·2
Guinea pig (250 gm.)	1·3
Rabbit weanling	0·5
Adult dog	0·5
Mouse	9·0

In the dairy cow a secondary complication arose due to the excretion of an aflatoxin metabolite in milk, but due to the routine bulking of commercial supplies from several farms this has never been a hazard to man. As a fact it is still not clear whether man is affected by levels of aflatoxin likely to be encountered naturally, although the position may be different in various parts of Africa and elsewhere where groundnuts form part of the staple diet. The high incidence of cancer of the liver, for example, in Bantu natives and their high consumption of groundnuts has raised the question whether there may be some correlation between the two, since it is known that liver cancers can be produced in both rats and fish following the continuous intake of 'feeds' contaminated by low levels of aflatoxin. For this reason the Protein Advisory Group of F.A.O. now recommend that the level of aflatoxin in peanuts and other protein supplements should not exceed 0·03 mg. (30 mcg.) per kilo.

INCIDENCE OF LIVER CANCER
(Barnes, 1967)

	Liver cancer as % of all cancers
U.K.	3
U.S.A.	3
East Africa	34
West Africa	36
South Africa	52
Indonesia	42
India	17

Toxigenic strains of *A. flavus* are world-wide (India, Africa (Senegal, Nigeria, etc.), Burma, Brazil), etc. but high environmental temperatures and humidity are required for their propagation. For this reason the *A. flavus* strains indigenous to this country seldom appear important as they cannot flourish in our climate.

Research workers have now shown that there are four main components in aflatoxin, named B_1, B_2, G_1 and G_2, and many studies are now in progress at T.P.I., London, and Unilever Research Laboratory, Vlaardingen, Holland, to clarify the position regarding distribution, laboratory tests, pathology, etc.

Complementary work is in progress at Weybridge where Austwick and Allcroft have already achieved great success in their studies involving fungal infections of nuts, comparative pathology, etc.

Although groundnut protein appears to be a favourite substrate for these fungi (following physical damage to the kernels during harvesting), aflatoxin has also been shown to be present (on rare occasions) on a variety of other substrates, e.g. feed ingredients like wheat, maize, cottonseed, etc. The general distribution and presence of toxigenic Aspergilli in minute quantities in hot countries is an endemic feature, the significance of which must be recognised throughout the world.

Turkey Syndrome 1965 (Turkey Y Disease)

Early in 1965 a new disease syndrome affecting turkey poults was recorded. The affected stock were frequently between 3 and 6 weeks of age but careful observation showed that signs of the disease could be seen in poults as young as 7–10 days and, in a few instances, cases continued to occur in stock 14–16 weeks old. Symptoms were quite characteristic, being marked by lameness, there being obvious changes at, or below, the hock joints; but only in some cases was perosis present. When the disease hit young poults, their growth rate was very uneven and their feathering poor (broken).

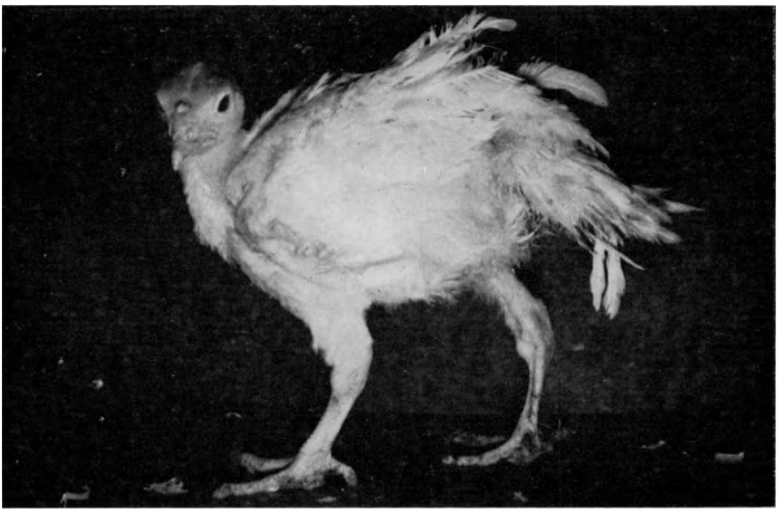

FIG. 55. Turkey syndrome 1965 (TS.65) demonstrating the leg deformity and poor feathering.

Since that time, many outbreaks have been reported involving most of the common breeds or strains of poults, and there has similarly been no specific link with particular feeds. On the other hand, it is fairly clear that more cases may occur when stock tend to be overcrowded, whereas, by reducing the number of poults per hover or pen, the incidence is greatly decreased or even absent.

Post-mortem findings failed to show any naked-eye changes in the internal organs, although, of course, the deformities of the hocks and metatarsi were very obvious. (It was assumed that air-sacculitis lesions were unrelated.) Perhaps one other feature should be mentioned, namely the fact that about 20 per cent of cases were characterised by a curvature of the spine. In some cases, too, an abnormality involved the joint between the last thoracic and lumbar vertebrae. These changes may, however, be no more linked with TS. 65 than the following. In a few cases, the shoulder joint appeared to be affected, but these were only discovered when the stock went to the packing station as a result of which 'dislocation' of the shoulder occurred. (This was, in fact, an epiphyseal separation affecting the proximal extremity of the humerus.) On rare occasions rickets has also been seen.

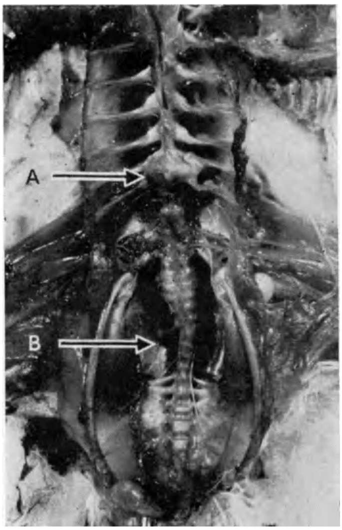

FIG. 56. TS. 65. Post-mortem examinations may demonstrate a 20 per cent incidence of spinal abnormalities, particularly in the thoraco-lumbar region (a), also scoliosis (b).

Cases of TS. 65 were found to occur both when poults were housed on wire floor tier brooders and also on deep litter, the source of heat coming either from gas or electricity.

Mortality varied greatly, occasionally being quite high, but this was probably quite unrelated to the syndrome and, in some instances, was linked with depraved appetites resulting in litter eating, etc. (the food appeared unpalatable).

Causation

In view of the enlargement and deformity of the hock joints (including cases of perosis) large numbers of feeding trials were carried out by feed companies incorporating additional manganese, zinc, folic acid, biotin, nicotinic acid, choline, vitamin B_{12}, pyridoxine, vitamins D_3, E, etc. But none were successful, nor were other feeding trials involving *arasan* (a seed corn dressing known to cause leg deformities); beta amino-proprio-nitrile; different dried yeasts, selenium, fluorine, mycotoxins, nitrosamines, etc. Checks for radio-active contaminants were negative.

The well-known 'Enlarged Hock' disorder reported by Scott in 1960 appeared not dissimilar, although only in relation to part of the TS. 65 syndrome. At that time Scott said 'There is no doubt that certain strains of turkeys are more susceptible to leg weaknesses than others. Some believe . . . that the turkey's skeletal structure is no longer capable of supporting the weight of its heavy muscle tissue, causing stress to the hock joints.' This conclusion may also apply to the stock involved in TS. 65. But factors other than genetics are clearly implicated including nutrition and, possibly, pathogens, too.

A condition comparable to TS. 65 has now been reported from both Canada and California, where some work has associated its occurrence with biotin and *Mycoplasma meleagridis*, furthermore some producers in this country believe that TS. 65 is less of a problem in flocks bred from P.P.L.O. (S6) free parent stock.

A histological study of the changes in the leg bones has been carried out by Grasso (1967) who has shown that the normal process of endochondral ossification is disturbed due to localised bone destruction. The lesion is suggestive of trauma or infection (rather than being metabolic or nutritional) but no pathogens have yet been isolated. Examinations of blood proteins at Houghton Poultry Research Station have shown changes not inconsistent with an infection.

In a recent summary of this condition, outlined in the *Veterinary Record* (Vol. 79, No. 25, p. 805) the conclusion of the Working Party was to the effect that 'no specific factor has yet been clearly or uniquely implicated'.

Haemorrhagic Enteritis

This disease is not uncommonly encountered in turkey poults and it is another example of a disease which requires animal behaviour studies before its aetiology is clear to the intelligent poultryman.

In most cases, the growing stock will have been moved to a new unit, after having been reared on wire floors (tier brooders or hay boxes). In their new house they will meet straw or wood shavings litter for the first time, which explains why they take a keen interest in eating some of it! If this doesn't result in semi-impacted gizzards and enteritis, the poults are lucky!

Whilst a specific anaerobe or vibrio may be linked with this complaint (as is believed to be the case in the U.S.A.), the real cause is the poultryman's inability to change the poults' environment without offering stress from litter. Special attention must also be paid to the type and quantity of insoluble grit supplement. Contrary to popular opinion this condition is not linked with 'high protein' rations, or the use of 'sulpha' drugs for the control of coccidiosis.

This condition is presumably unrelated to the necrotic enteritis found by Nairn and Bamford in broilers in Western Australia (1967). This complaint represented an entero-toxaemia, the lower two-thirds of the small intestines showing a thick, dry, yellowish-brown enteritis. Mortality seldom exceeded 5 per cent and some cases responded to zinc bacitracin or penicillin at 200 gm./ton. It could be reproduced experimentally using a *Cl. perfringens* suspension.

Taints

One of the complexing problems of intensive livestock farming is that of taints, either in milk, eggs or poultry. If 'fishiness' is involved the farmer's thoughts naturally turn to the question of fish-meals, but only in rare cases is it possible to pinpoint this ingredient as a cause for taint.

The level of unsaturated fats present in fish-meals might be thought to be critical, especially if rancidity had developed, but the recent experiment by Carpenter (1966) showed the fallacy of this argument. The Canadian Department of Agriculture recently (1966) reported details of an experiment carried out in Newfoundland in which wheat and whitefish-meal replaced corn and soya in a grain protein supplement. The wheat to fish ratio ranged from 95:5 to 75:25 but there were no differences in egg quality and no fishiness developed in any group. Earlier Biely had reported from Canada that he was able to induce fishy taints in eggs, but the ration contained 18 per cent fish-meal, five to six times the levels normally used in this country. At the 1966 Maryland Nutrition Conference, Ousterhaut reported that 'fishy' tastes could arise from the use of old grains, and that in one instance when a piece of equipment used for incorporating fats into poultry rations discarded brass valves and pumps, and when air entrapment was also eliminated a fishy flavour problem did not occur.

Bacterial infections of the oviduct have also been incriminated, as well as stale litter in nest boxes and also the use of rapeseed-meal. But in most cases the accusing finger cannot be pointed at any particular feature, and in a number of cases the problem disappears of its own accord almost as rapidly as it comes.

Betaine is considered to be responsible for one of the fishy taints associated with milk. It is present in sugar beet and in the animal body it may be transformed into trimethylamine which is really the responsible factor associated with the excess feeding of beet by-products. In other cases lecithin may be involved. As a contrast a volatile component in swedes and turnips can also taint milk. This however is absorbed by the milk from the air; it is not actually excreted into the milk (McDonald, Edwards and Greenhalgh 1966). However whether the supplements of choline chloride which are commonly included in layers rations today play any part in the tainting of eggs is not known. Our own experiments trying to induce taint by additions of rapeseed-meal, rapeseed oil and choline chloride have failed, but on one occasion a complaint appeared to be related to the use of a proprietary detergent (egg cleaner) in the presence of hair cracks.

Shell Quality

Perhaps the greatest problem of the egg producer today is shell quality, egg packing stations reporting from 5 to 10 per cent of cracked eggs! The situation has worsened over the past 3 or 4 years, and could be linked with the change in the Ministry's policy regarding fowl pest, because the compulsory slaughter of affected stock automatically meant that the level of virus infection, of both Newcastle disease and infectious bronchitis, was kept low. Now that a vaccination policy has been approved, these levels have changed and there is unquestionably far more I.B. live virus about today than was the case 5 years ago.

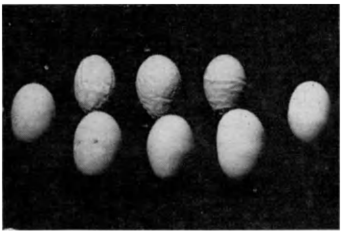

FIG. 57. Deformed eggs of this type often follow an outbreak of infectious bronchitis. Watery whites are also typical.

I.B. virus appears to favour the fowl's magnum and uterus as predilection sites and this has resulted in many cases of watery whites and soft or weak shells. What is not known is the relationship between this virus and the current high incidence of 'hair cracks'.

That nutrition is involved is undoubted because calcium in particular plays a vital part in eggshell production, hence the marketing of layers rations containing 3–3½ per cent calcium, i.e. 'complete feeds'. Vitamin D_3 also plays an important part, but mainly by assisting increased calcium utilisation; whilst other nutrients concerned are manganese, magnesium, zinc, phosphorus and possibly vanadium.

Several methods have been used to determine shell thickness in the hope that thicker shells mean stronger eggs (resistant to cracking), but that is not always true. As a breed the Kimber K137 probably lays the thickest shells, but the construction of cage floors, egg baskets, transportation and disease all play important parts in the cracked egg problem.

The lastest method of determining shell thickness is by means of a 'back scatter gauge', invented by American engineer, P. E. James, working in conjunction with the Atomic Energy Commission at Beltsville. Estimations of shell fragility are obtained by firing radioactive beta particles at eggs and counting those which are reflected back. Thin-shelled eggs reflect fewer than those with thicker shells. The beta energy radiation is obtained from ruthenium-rodium 106 isotope.

Previously of course one has used shell thickness (by direct measurement); specific gravity (using various solutions of common salt); and a variety of ingenious pieces of equipment such as Schoorl's Dutch (Marius) egg deformation apparatus; Dr. J. Brook's egg 'crushing' method, used at Cambridge; the 'falling ball' device first employed about 35 years ago by Swenson and James and by puncturing the shell. Tyler (1961) reviewed the subject, but has since carried out further researches at Reading University.

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Chapter 20

A SELECTED SERIES OF POULTRY PRODUCTION PROBLEMS INVOLVING MANAGEMENT FACTORS

PETER MATTHEWS

Many production problems are not concerned primarily with disease and therefore any investigator should have an intimate knowledge of the many management factors which might be involved. This is also useful when advice is sought about the expansion of units or the modification of farm buildings for poultry production purposes. An analysis of the last 56 farm visits paid during 1965/66 showed the following distribution:

Layers	30
Broilers	8
Growers	8
Turkeys	6
Breeding stock	4

The chief subjects upon which advice was sought were:

Layers

Conversions of piggeries or other farm buildings for hen battery production; similarly, conversion of deep litter units to hen batteries; conversion of conventional hen batteries to windowless controlled-environment units; expansion of existing poultry houses for increased stock accommodation; poor egg production; failure to reach peak production satisfactorily; small egg size; egg quality problems; unthriftiness under deep litter conditions; lighting and ventilation problems including air filtration; establishment of new laying projects; installation of flat deck cages; manure disposal.

Broilers/Growers

Plans for new broiler houses; decreasing profitability linked with poor bodyweights and feed conversions; ventilation problems; brooding techniques; capon production; growing stock; conversion of buildings; use of rearing cages; space heating and heat conversion; insulation and ventilation; controlled environments.

Turkeys

Conversion and expansion of existing brooder houses; siting of new houses; infertility problems; management and housing; poor finish in mini-turkeys; frozen water problems.

Breeding Stock

Conversion of buildings; ventilation problems; poor hatchability; construction of incubation rooms.

From this comprehensive list of subjects it will readily be appreciated that persons carrying out such investigations must have a good working knowledge of many angles to production as well as the ability to pass on information and advice to farmers who are always more practical than theoretical. A knowledge of building construction including ventilation, insulating and lighting standards is therefore essential, particularly when many farmers today are anxious to convert buildings or to change those with windows to windowless fully controlled environments.

Standards for floor space, feed and water trough allowances and similar subjects have recently been discussed by the Brambell Committee so that there are at least two 'standards' to be considered. Any recommendations, however, which involve loss of profit or unnecessary capital outlay are usually unpopular, but it is seldom that advice requires to be given which should not eventually improve the profitability of the unit.

On some occasions feeds are being used incorrectly or drugs unnecessarily, and therefore one has to be up to date both about modern feeding programmes, and the information disseminated by pharmaceutical companies concerning their various products such as antibiotics, 'bio-active' substances, growth stimulants, vaccines, disinfectants, etc. This automatically takes one close to the veterinary field, but this is really in a separate category from routine management problems.

Poultry equipment has changed drastically during the past 15–20 years so that here again a fairly intimate knowledge of the different types of feeders and drinkers, hen battery cages, fans and their outputs, etc. is an asset. Although on most occasions disease problems are secondary, it is generally worthwhile trying to convince the farmer that it is in his interests to send typical specimens away for post-mortem examination. As only a small percentage of producers belong to the Ministry's health scheme, many birds should now be going to those veterinary practitioners who have post-mortem facilities.

CASE I

Stock: 28,000 layers—Harcos and Thornber '404's
Housing: Californian hen battery cages
Complaint: Poor peak egg production

Stocking rate in the house was eight birds per 30-in. cage and only one nipple drinker was available for every two cages. All the birds had been reared on a 6-hour lighting pattern increased by 20 minutes per week from 18 weeks onwards.

A veterinary surgeon had periodically been called in to investigate the possibility of disease, but all infectious or contagious diseases were absent. S.N. tests for infectious bronchitis indicated that the birds had contracted this disease during the rearing period but no recent infection was present. Four post-mortem examinations showed: (1) advanced nephritis, (2 and 3) both birds were in-lay and had died following cannibalism: in one the ureters were semi-impacted, and (4) no abnormalities.

Examinations showed that the lighting intensity of the house was below 1 foot-candle in all parts, partly due to the fact that electric lights were hung at 20-ft. centres. The distribution of light was also irregular, the light bulbs hanging over the cage units themselves instead of being sited over the passageways.

Action. The distribution of light was rectified, 60 instead of 25 watt bulbs being re-arranged at 10-ft. centres to provide a minimum reading of $1\frac{1}{2}$ foot-candles at the level of the birds' heads. The number of nipple drinkers was increased to two per cage, and the value of an all-in/all-out policy stressed to the farmer. It was also recommended that in future the lighting pattern for the chicks during the rearing stage should be 8–10 hours up to 18 weeks, then increased by 2 hours followed by $\frac{1}{2}$-hourly weekly increases up to a total of 17 hours.

CASE II

Stock:	2500 Thornber '404's
Housing:	Hen battery cages
Request:	To re-organise the existing battery units to hold twice the stock; and to convert a 71 ft.×22 ft. piggery to accommodate 10,000 pullets in laying batteries

1. *Existing Battery House*

It was decided to remove all existing cages which were of an obsolete design giving rise to continuous breakdowns and labour problems. Four blocks of 16-in. cages were installed, four tiers high, two blocks to be cleaned out at alternate ends of the house. All the manure from these cages was able to be disposed of by main drainage.

The ventilation was changed completely, being ducted from the ends of the building through a false ceiling in order to obtain a more even ventilation throughout the units at the rate of 1 cu. ft./lb. liveweight/minute based on a maximum weight of $5\frac{1}{2}$ lb. birds. The lighting was also re-arranged to 10-ft. centres with shades for reflection purposes. This converted battery house was then capable of accommodating 5000 pullets.

2. *Piggery*

All internal walls and feeders were removed leaving a clear span to accommodate 600 cages. A conveyor belt was installed to remove the manure; also new lighting installations and a bulk feed hopper. Following these changes a regular Costings Service was employed.

However, having increased the stocking rate near to a built-up area, manure smells became a problem, but these were satisfactorily overcome by the use of '*Alamask*' (M.&B.).

All eggs from this unit were sold privately at the farm gate.

CASE III

Stock: 35,000 Cobb broilers
Housing: Converted brick buildings and wooden broiler houses
Complaint: Unsatisfactory bodyweights and poor feed conversions

It was first learned that there was no overall manager for the site.

A previous test of the tubular feeders used at this farm showed them to be efficient, there being only a 2 per cent wastage when operated correctly. But an examination of the feeders on the site showed that they were (*a*) overfilled, (*b*) incorrectly adjusted, and (*c*) hung at varying heights, many being only 1 in. from the floor when the broilers were 8 weeks old. Under these conditions food wastage was estimated to be about 10 per cent.

The ventilation in several of the houses was unsatisfactory, 15-in. fans being installed immediately alongside 18-in. or 24-in. fans. Some were fitted with shafts and baffles, whereas others were not. The free air inlet space had been reduced to less than 1 sq. ft. per 1000 cu. ft. air output (approximately one-third of the requirement). Some air inlets were directing the air upwards and others downwards. Grids installed to keep out wild birds had not been cleaned and the dust and dirt reduced the size of the air inlets still further.

The insulation in most of the houses was breaking away from the ceiling, rain having penetrated the fibreglass, materially reducing its efficiency. Because of the particular design of the house it was not feasible to completely clean it out properly between crops and infection was carried on to the next batch. Although thermostats had been installed in some of the houses, they were unable to operate correctly because of the dust. There was a shortage of drinkers throughout the whole unit, and as all the houses had earth floors this also made the disinfection programme difficult.

Following my visit an overall manager was appointed who concentrated on correcting the points mentioned, and there has since been a great improvement in the general position resulting in better bodyweights and feed conversions.

CASE IV

Stock: 3000 Thornber '404's, layers
Housing: Deep litter
Complaint: Poor egg production with high mortality through cannibalism

A veterinary surgeon had previously visited this establishment, and taken blood samples, later reporting that the birds had not been exposed to I.B. or N.D. but that P.P.L.O. tests were positive. The farmer had treated his birds with a 5-day course of antibiotics, giving a further dose when the pullets were 6 weeks old. All the stock had been vaccinated against I.B. and N.D. at both 6 and 16 weeks of age.

There were no obvious disease factors present to account for the low egg production. The birds were seen to be feather-pecking in the brightly-lit areas of the houses during the daytime, and although the birds had been debeaked this had been carried out very badly. The litter in all the houses was very wet caused by two main factors: (1) the air inlets were placed very high in the walls near the eaves and as a result the incoming air was automatically short circuited to the fans in the ridge. (Smoke candle tests showed no air movement at litter level or for the first 3 ft. above floor level) and (2) the fans were operated by a time switch which only came on for 2 minutes in every 10. Throughout the whole area stinging nettles and weeds had become overgrown, in some instances reaching 6 ft. in height, which interfered with the functioning of the air inlets.

It was not possible for the premises to be depopulated so that any low level of infection would presumably hold the birds back even though it did not give rise to any obvious mortality. As a result of the birds' poor egg production and high mortality the farmer was desperate because unless an improvement did occur he felt that he would quickly go out of business.

Immediate action was taken to clean up the premises, improve and amend the ventilation, and to have the birds correctly debeaked.

CASE V

Stock:	80,000 Chunky broilers
Housing:	Square and oblong wooden broiler houses
Complaint:	Poor weights and bad feed conversions (worse than previous batches in the same houses)

Five crops of broilers had been through the majority of houses, and profits gradually deteriorated.

The farmer had assumed that his birds were housed at 0·75 sq. ft. per bird but investigation showed that this was based on the *outside* measurements of buildings. These were constructed with a 9-in. thick brick wall base which reduced the inside measurements. In addition there were 9 in. upright supports, and the resulting square footage was also lowered by the presence of a large bulk feed container. After taking all these points into consideration it was found that the flock was in fact housed at 0·49 sq. ft. per bird. Only sixteen tubular feeders were allowed per 1000 birds, and in most of the houses the ventilation was less than that required, sometimes by as much as 10,000 cu. ft. per minute. Although the current batches of broilers were only 2 weeks old the air inlets were full of dust, showing that the house had not been thoroughly cleaned out.

The farmer was advised how to correct the many management factors mentioned including a reduction in the stocking rate, but the latter was the hardest pill to swallow.

CASE VI

Stock:	2750 laying pullets (Nickchick, A A-4 and Thornber 606)
Housing:	Hen batteries; modern fan ventilated laying house, with windows but otherwise well insulated
Complaint:	Sudden fall in egg production

The pullets were arranged in three parallel three-tier units (A, B and C) of twin-bird Dunblane cages, and production had been very good until a sudden fall in November 1965. Other laying units on the farm some distance away were not affected.

Although no egg quality defects were noted, the manageress of the unit felt that infectious bronchitis might be involved, presumably because no obvious disease symptoms were present. The flock had been properly vaccinated however against both N.D. and I.B. during the rearing period, but no further vaccinations had taken place.

The management of the unit was faultless, and there had been no fresh intake of feed which might have been associated with the fall in egg production. The ventilation system had been correctly installed in relation to the number and weight of birds housed and air distribution was very satisfactory, but the ducting arrangements laid emphasis on Unit B (see diagram).

Room temperatures had been normal until a few days before egg production was adversely affected, then fell in direct proportion to the much colder weather encountered; but if this alone had been the problem other units should have suffered similarly. It was noteworthy that the centre Unit B was affected much more than the other two, and the apparent explanation was as follows.

Although room temperatures were not unreasonable for the time of the year, the cold air entering the ducting system fell directly on to the pullets in the centre of the house, and it was obvious that this air would be almost at freezing point, although at the sides of the house (internally) thermometers registered a 12–16° F rise over outside temperatures. This appeared to explain the differential fall in the egg production of the three breeds, and although an I.B.S.N. test was later found to be positive, it appeared to me that the real fault lay in the cold air hitting the centre pullets (Unit B) during the very cold nights beginning November 13th.

Fortunately the solution to this case was simple. First to divert the air sideways instead of downwards, so that it did not strike directly on to the pullets in Unit B, and secondly to install a heater into the ventilation unit prior to air filtration so that the incoming air did not fall below 42° F.

PERCENTAGE AVERAGE EGG PRODUCTION AND TEMPERATURES

	10th–20th Nov.	*30th Nov.*	*15th Dec.*
Unit A	75%	57%	70%
Unit B	74%	26%	63%
Unit C	86%	66%	77%
Minimum inside temp.	52° F	38° F (23/11/65)	55° F
Minimum outside temp.	40° F	22° F (23/11/65)	42° F

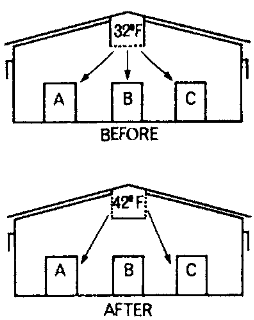

FIG. 58. As text (P. Matthews Case No. vi).

CASE VII

Stock: Laying pullets; equal numbers of the following breeds—Thornber 606, Hyline 934, Shaver 288, Nickchicks, Warren-Sex-Sal-Link and Kimber—totalling 1440 pullets

Housing: Old wooden laying battery house with windows and extractor cowls. Twin-bird cages. A feed store subdivided the house into two equal halves

Complaint: Sudden fall in egg production

Egg production had been satisfactory throughout the autumn until November when a sharp fall was noticed which only affected the pullets in the first half of the house. In the second half no similar problem arose, although the same system of ventilation was in use and also the same layers ration. No fall in egg production took place either in a smaller laying unit alongside. All stock had been reared together and received the same series of vaccinations against N.D. and I.B.

As soon as the fall was noted, a quick check was carried out for evidence of disease or mismanagement but none was found. Whilst the problem arose over a weekend, the staff concerned were trustworthy and reasonably experienced. No proof was obtained that the water supply might not have been at fault, but no evidence was obtained to support this theory. This was a case where nearly every line of enquiry came to a dead end, but one incident may have accounted for the trouble.

As was his custom the poultryman started to clean away cobwebs from the walls and roof and in so doing he disturbed the lighter breeds, many of which jumped up to hit their heads on the wire roof of their cages. It would appear reasonable to assume therefore that this was the stress factor involved, since all other enquiries failed to reveal any cause. (I.B.S.N. tests and those for N.D. were later shown to be negative, but an epidemic tremor test was positive so that this could have been the primary factor.)

	Egg Production (%)			
	5th Dec., 1966	*22nd Dec., 1966*	*29th Dec., 1966*	*Housing*
Thornber 606	90	63	76	First half
HyLine 934	88	68	83	
Shaver 288	86	67	86	
Nickchicks	80	84	80	Second half
Warren-Sex-Sal-Link	72	83	88	
Kimber	79	80	86	

CASE VIII

Stock: 30,000 layers, Honegger, Babcock, Shaver, White Link

Housing: Californian and conventional hen batteries

Request: To insulate and ventilate a brooder house adjacent to existing laying houses. First consideration had to be given to the fact that the pullet chicks were to be reared very close to the existing laying stock. They were to be brooded in cages in three stages, i.e. 0–3 weeks, 3–6 weeks and 6–16 weeks.

INSULATION

It was felt necessary to insulate the building using 2-in. expanded polystyrene throughout the house at the 0–3-week stage; 2-in. expanded polystyrene in the ceiling and $\frac{3}{4}$-in. in the walls at the 3–6 week stage; 1-in. in the ceiling and $\frac{1}{2}$-in. in the walls at the 6–16 week stage.

VENTILATON

In order to be able to ventilate this house adequately and at the same time reduce any risk of contamination from the adult stock housed close by, it was felt that the pressurised system (using aerofoil fans) should be adopted for two main reasons: (1) that filters could easily be applied; (2) that supplementary heat could be introduced at a reasonable cost. Two fans were used, the first for the 0–3 week stage only. Pegboard ducting was used, so that the second compartment could be shut off without interfering with the first.

A small room was provided at the entrance to the building to accommodate the heat and filter units. The former was gas-fired and had the additional value of preventing the filter from becoming clogged by frozen fog in the winter. (1 in. fibreglass was used for filtering the incoming air.)

It was felt that this insulation would be best to conform to the management's requirements namely that there should be no break in the cycle of chick rearing. The pressurised ventilation system enabled the chicks to have fresh air in each of the two compartments without serious risk of bacterial contamination. After the 3-week stage, the chicks were moved from Room A to Room B, and then a fresh batch of 5000 chicks were again brooded in Room A. Finally the chicks were moved to a separate rearing house at the beginning of the 7th week where a pressurised system of ventilation was again used with the object of helping to reduce infection from nearby adult stock.

RABBITS

Chapter 21

RABBIT PRODUCTION

W. P. Blount

Introduction

The farming of rabbits on intensive lines has been much less spectacular than that of poultry, although 'broiler rabbits' are now becoming quite popular. The three main reasons for the slowness of the development of a rabbit industry are that:

1. The myxomatosis scare of 10 years ago has not yet completely disappeared from the public's mind.
2. Whilst the demand for rabbit meat has recently increased, very few 'groups' have been successful in reducing their production costs significantly, thus the price to the housewife remains relatively high.
3. Few packing stations have specialised facilities for processing rabbits, which stifles developments on a nationwide basis.

Thus, we have no real rabbit industry as such, in spite of the valuable work of the British Rabbit Council and the Commercial Rabbit Association.

Broiler Rabbits

The production nowadays of 'broiler' rabbits weighing 4 lb. at 8–9 weeks of age, contrasts greatly with the older, less efficient rabbit of pre-war days.

This 4 lb. liveweight is important, because from it the processor can prepare two 1 lb. packs of eviscerated, oven-ready, rabbit meat. This sells readily in the shops at 4s. 6d. to 5s. per lb., although it is still more expensive than broiler chicken meat. Nevertheless it is much sought after in many areas, and to encourage greater production packers are currently offering 2s. per pound liveweight. A 3d. premium over that for 1966.

Breeds. Most rabbit broiler meat is produced from rapidly growing strains of New Zealand Whites, Californians or hybrids containing Danish Landrace, Lop-eared or Géant Blanc blood.

Housing. Both solid and wire-floored hutches are used, but sore hocks may develop in both systems with some strains of rabbit, and although wire-floored units give better control over coccidiosis they are not suitable for any does with poor maternal qualities since these may scatter their litters, resulting in deaths from chilling.

To reduce housing costs, use is now being made of straw bales, partly because of their cheapness on many farms and also because they are expendable. Not only do these provide excellent insulating qualities, but they also allow the rabbit to express its natural burrowing instincts

FIG. 59. After evisceration the rabbit's carcase is split into eight portions, half being arranged to form a 1 lb. pack.

to a high degree. Indeed no more naturally healthy, artificial housing system exists for rabbits, both for single does and colonies. Unfortunately the increased opportunities for exercise and play lead to a longer fattening period, and intestinal infections may also increase.

Management. Traditional methods are used except that the does may be re-mated at 4, 5 or 6 weeks after kindling, the litters being marketed at 8–8½ weeks. Although the technique for A.I. in rabbits is well known, no commercial use has yet been made of this feature.

As a contrast the determination of pregnancy (by palpation at the centre of the posterior abdomen) is practised by many experienced rabbit men, because in this way false pregnancies can be recognised by the 12th day, and re-matings carried out more quickly than would otherwise be the case.

Feeding. To speed up the growth rate and also to help to control digestive disorders (the 'Blows'; impactions of the stomach or caecum; typhlitis and scouring), fresh green-food or roots are no longer fed to commercial rabbits. Instead they should only be given a 'complete', compounded pelleted feed (in conjunction with hay) containing 10–14 per cent fibre and about 18 per cent protein.

Rabbit pellets are usually fed *ad lib.* through the latter half of the pregnancy and for the first 3 weeks of the suckling period, but at all other times hay is given freely. The quantities of pellets and hay given are on the following lines:

	Pellets	*Hay*
Dry does and bucks; growers 10–20 weeks	2–3 oz.	*Ad. lib.*
First 2 weeks of pregnancy	3–4 oz.	*Ad lib.*
Last 2 weeks of pregnancy	*Ad lib.*	Limited quantity only
First 3 weeks of suckling	*Ad lib.*	Very little or none
From 4–8 weeks of growing period	*Ad lib.*	*Ad lib.*

FIG. 60. A modern, cheap housing system for fattening rabbits. When depopulated the straw bales are burnt.

Meat Yields. One of the great advantages of the rabbit is its high meat yield, for example whereas with broiler chickens only about 20 per cent of the liveweight represents cooked edible meat, in the rabbit it is about 30 per cent. As a percentage of the cooked carcass broilermeat represents less than 50 per cent compared with over 70 per cent for the rabbit.

FIG. 61. After killing and skinning, the rabbit's carcass is slit open and the abdominal contents removed.

The results are the average for two rabbits in each age group:

	CALIFORNIAN Age in Weeks			GÉANT BLANC Age in Weeks		
	10	*12*	*14*	*10*	*12*	*14*
Average weights (lb.—oz.)						
Liveweight	4 0	4 12	5 8½	6 5	7 7	8 4½
Dressed weight*	2 3½	2 8½	3 1½	3 7	4 3	4 10½
Cooked weight	1 11½	1 15¼	2 6	2 10	3 3½	3 6¾
Weight of meat	1 4	1 7¼	1 12½	1 12¼	2 4	2 7
Weight of bone	4	4¼	5	7¼	8¾	8¾
Weight of viscera†	3½	3¾	4½	6½	6¾	7
% Weight losses						
Live to dressed weight	44·53	46·71	44·07	45·54	43·70	43·77
Live to cooked weight	57·03	58·88	57·06	58·42	56·72	58·68
Dressed to cooked weight	22·53	22·84	23·23	23·64	23·13	26·51
% of Cooked meat to						
Liveweight	31·25	30·59	32·20	27·97	30·25	29·43
Dressed weight	56·34	57·41	57·58	51·36	53·73	52·35
Cooked weight	72·73	74·40	75·00	67·26	69·90	71·23

† Liver, kidneys, heart, lungs.
* Dressed weight: abdominal contents removed except liver and kidneys. Heart and lungs not removed.

Economics of Table Rabbit Production

The main competing features are as follows:

(1) Good housing is usually expensive (e.g. metal battery units)

and can only be justified if results warrant the additional capital investment.

(2) Mechanised units (feeding, watering and cleaning out) save labour, but all-metal batteries with wire floors may not give as good results as wooden hutches with solid floors, in spite of the assumption that the former are associated with a lower incidence of disease.

(3) Small units can be maintained by family labour which is usually free, whereas large units require to be efficiently staffed which is inevitably an expensive operation. The former can generally make a profit (with no labour charges), whereas the latter must result in a more efficient operation to be justified economically.

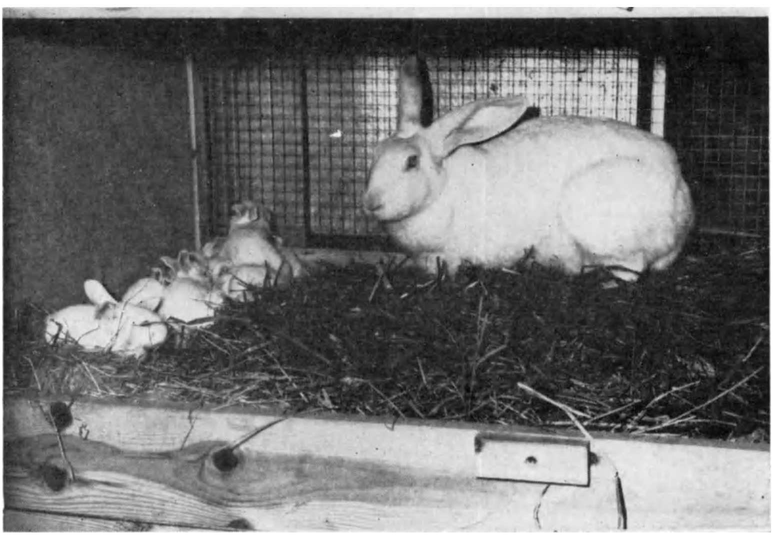

FIG. 62. Doe and litter housed on a solid-floored hutch indoors.

(4) Winter production is generally more efficient in indoor than outdoor units, but the former may involve additional costs through artificial ventilation, lighting and heating; the provision of nest boxes, etc.

(5) Whilst pellet feeding is the most efficient diet for suckling does, it tends to become uneconomic at other times unless used in conjunction with hay. Home mixed rations—oats, bran, fresh green-food, weeds, grass cuttings, carrots, etc. are cheaper but use more labour, and results may be inferior and mortality higher.

The main objective is to get as high a production rate as possible; so that instead of the conventional four, five or even six litters per year are possible. Thus, instead of obtaining 90–100 lb. rabbit meat per doe per year, the aim should be 120–160 lb. as follows:

Rearing method	*Meat/doe per year (lb.)*	*Litters/ year*	*Rabbits/ litter*	*Weaning weight (lb.)*	*Weaning age (weeks)*
Conventional	100–105	4	6–7	3¾	9
Improved	120–160	5–6	6–9	4	8–9

Assuming a £9 per doe housing investment charge with 10 per cent depreciation; 30s. per doe (40s. per buck) capital cost at 12 weeks, 5 per cent mortality per year and the use of does and bucks for 2 consecutive years—and if 4 lb. carcasses at 8 weeks bring in 2s. a pound the return on fixed capital is:

NO. YOUNG/DOE/YEAR

25	*30*	*35*
Loss	38%	58%

Manure Disposal. The large volume of urine and faecal droppings produced by rabbits is an encumbrance. Californian type units which allow the excreta to pass direct to the earth (sandy) save considerable labour, otherwise there may be the twice-weekly chore of removing the manure to a compost heap or other outdoor disposal unit. From an analytical point of view rabbit faeces contain twice as much nitrogen and phosphorus as farmyard manure, mainly because of its low water content—50 per cent.

Straw bale housing provides one alternative. If the housing unit consists of compressed straw bales, and if the floor has a good depth of loose straw, the rabbits will occupy much of their time burrowing naturally, and the straw will soak up the liquid manure without difficulty. Straw baled housing of this type can be used for individual breeding units or colony housing, but of course the straw must be a cheap, expendable product. After each crop of rabbits has been marketed the straw can be removed easily to a compost heap, or burned *in situ*.

Disease Control

'*Snuffles*' represents a local infection of the nares characterised by a watery, mucoid or purulent discharge. In cases where pasteurella organisms are recovered from the sticky nasal discharges, such stock should be eliminated from the colony as no cure is possible. Repeated bacteriological examinations of the nasal excrement may be necessary in order to exclude pasteurellosis. Whilst a great variety of drugs and antibiotics have been tried out, none has proved really successful, but on some farms '*Cuni-vaccin*' (Lissot Labs, Pacy-sur-Eure, France) has given very good results as a preventive.

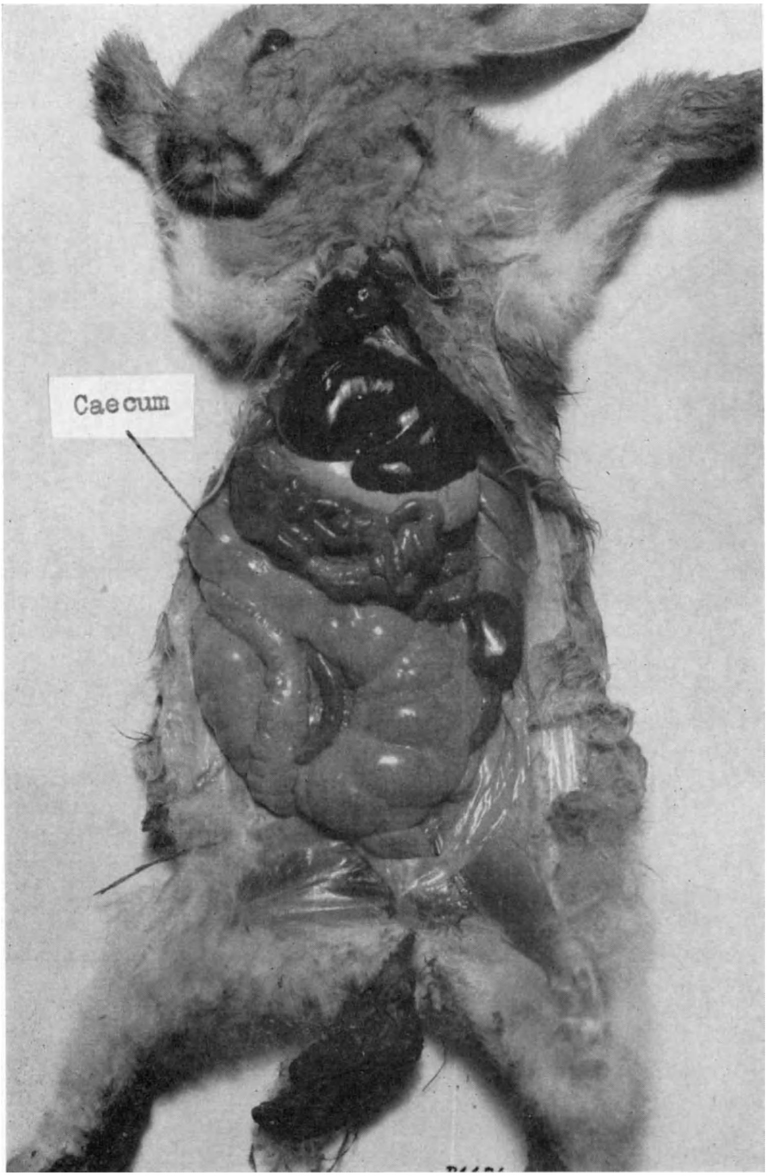

FIG. 63. The commonest form of scouring is characterised by a wet-matted tail. Internally the caecum shows the main post-mortem changes. It is thin walled and pale with very fluid contents. In most other cases the small intestines are flaccid and with haemorrhagic or mucoid contents.

A few cases of nasal discharge may be due to allergy (hay), and others are linked with non-pathogenic organisms, but a high proportion certainly represent carriers of pathogens. These may develop into frank cases of pasteurellosis, e.g. following parturition, possibly by direct spread from the nose to the vagina at kindling time.

Coccidiosis. Hepatic coccidiosis has almost disappeared following the use of wire floors and coccidiostats like sulphaquinoxaline, but the same is not true of intestinal coccidiosis. At least four varieties of coccidia reside in the intestines, and two (*E. irresidua* and *E. magna*) are considered to be the most pathogenic.

The continuous administration of sulphaquinoxaline (0·0125 per cent) '*Darvisul*' or '*Whitsyn 10*' in the feed as a preventive or sulphamezathine (0·2 per cent) in the drinking water are used for controlling coccidiosis, and there is little doubt that these methods would be even more successful if producers would use these drugs at the correct level. For example if large quantities of hay or green-food are included in the diet, then the level of any anti-coccidiosis drug incorporated into the pelleted ration must be increased proportionately.

Sore hocks usually arise when the stock have insufficient fur present to provide a natural cushion—this is probably of genetic origin. Local damage to the hocks may come from wire floors or sodden litter: this is often followed by a staphylococcal infection which may penetrate the tendon sheaths. Such cases seldom respond to antibiotic treatment and the infection may spread to the nose and feet particularly if any external parasites are present. Early lesions (non-septic) may respond to aerosol sprays, e.g. chloramphenicol, or '*Sintoderma*' (Maccagni).

Enteritis, Typhlitis and the 'Blows'. Many post-mortem reports refer to enteritis without specifying whether the inflammatory lesions are present in the small intestines, caecum or colon. They may also refer to scouring or diarrhoea, sometimes linking these with the presence of coccidial oocysts, but with no indication whether these are considered to be pathogenic. Many cases of diarrhoea are due to typhlitis, the caecum being pale, thin-walled and with very watery contents. The cause is unknown but probably not due to any pathogenic organisms: it may in fact represent a metabolic disorder involving possibly sodium and potassium.

The age incidence for scours in our experience is:

Age	%
Under 4 weeks	0
4–8 weeks	75
8–10 weeks	20
Over 10 weeks	5

Apart from typhlitis the major form of scouring is that which attacks 5–7-week-old growers, killing off one or more rabbits in a particular litter. This does not represent any infectious disease since it does not spread to in-contact stock or to neighbouring litters. This malady cannot be reproduced experimentally, but it sometimes follows obvious weekend changes of management, but the true cause is unknown and no particular treatment is of real value. Sulpha drugs, the nitrofurans and antibiotics have all been tried with varying success. Our best results recently have been from '*Orojet NS*' (Willows and Co.).

Digestive troubles like the 'Blows', formerly associated with the feeding of fresh or wilted green-food, are almost a thing of the past, partly because of the widespread use of compounded feeds.

Worms. Tapeworm infestations, both the variety involving the liver and peritoneal cavity (*T. pisiformis*) and that causing larger cysts elsewhere (*T. serialis*) are rare because intensive husbandry methods have prevented rabbits from consuming the tapeworm eggs present in dog faeces which contaminate fresh green-food. The redworm of the stomach (*Graphidium strigosum*) is also rarely seen today.

Cases of ear canker or *external parasites* in rabbits bred under modern intensive conditions are rare where hygiene is practised. However, unless rats, mice and wild birds are excluded from rabbitries, cases of *pseudo-tuberculosis* may still arise.

Pneumonia in isolated rabbits is well known but the causal agents are varied and in some cases pasteurellae are involved.

Rabbit Behaviour

Three ethological aspects of rabbit husbandry require emphasis:

Coprophagy. This is a normal practice carried out during the hours of darkness, e.g. midnight, being a peculiar habit characterised by the formation and swallowing of soft faecal pellets which are obtained direct from the anus. This phenomenon requires to be demonstrated to be believed!

The soft faecal pellets are rich in mucus and 'B' vitamins. They help to tide the rabbit over its long hours of darkness when feeding is normally impracticable, since the rabbit's stomach requires bulk to allow the muscles to compress its contents, passing these over into the small intestines. Coprophagy appears to be one of nature's methods for achieving this function as well as providing supplementary 'B' vitamins and muco-proteins.

Suckling. Unlike most mammals, does feed their young rabbits only once every 24 hours, and then for quite a short period. If during this time the doe is disturbed (by mice for example), her udder may become severely congested and mastitis may follow.

Kindling. Kindling usually takes place overnight in very secluded surroundings and therefore little has been written about its nature. My colleague, D. K. Glister, however, has recorded the subject in some detail. (See *Animal Behaviour*, chapter 36, p. 550.)

FISH

Chapter 22

MODERN FISH FARMING

W. E. PEARSON

The culture of fish can be traced back into antiquity. In the Far East, records show that fish were cultivated as far back as 475 B.C. according to the writings of one Fan Lai who describes carp culture in China. In India it is traced as far back as 300 B.C. The Chinese with their infinite care and patience have perfected fish culture and by their emigration have taken the art into Malaya, Indonesia, Formosa and Thailand. Originally carp were cultured but later other species followed. In Europe carp were first cultured then followed by others, notably the salmonids—trout, salmon and whitefish. Of recent years, interest has arisen in the farming of marine fish although oysters and mussels have been farmed for a long period of time.

There is no doubt about the value of fish as a human food and with the present world population explosion it is essential to explore all avenues of increasing the food supply. This must, of necessity, involve intensification and fish farming is an excellent example of this. It is stated that the yield per unit area is far greater with fish farming than any other form of agriculture. Yields of up to 8000 kilograms of fish per hectare have been obtained. Fish are very good food converters and conversion rates as low as 1·5 lb. feed per lb. of fish are obtained. The chicken by comparison is of the order of 2·25; other animals are higher.

As with all forms of intensive animal production, the utmost care must be paid to the type of stock, the environment, farm management, disease control and prevention and nutrition, all of which are of equal importance.

In conclusion a few figures relating to production of fish under intensive conditions will be of interest.

Given suitable water supplies, the potential for freshwater intensive fish production is enormous. With the research on marine types we should in the future really be able to 'farm the seas' and this will go a long way towards alleviating the chronic world shortage of good proteins for human consumption. It has been estimated that to cope with world populations in the year 2000, the food production must increase about thirty-fold from the present level. This in itself highlights the necessity for intensive animal production.

Country	*Approximate annual production (tons liveweight)*
Soviet Group	250,000
Germany	25,000
Denmark	12,000
France	8,000
Italy	6,000
Holland	3,000
Belgium	3,000

Fish Farming

Fish culture may be said to begin with the breeding female which is ready to spawn. The eggs are collected and hatched and then the young fry are reared to a suitable size for harvesting.

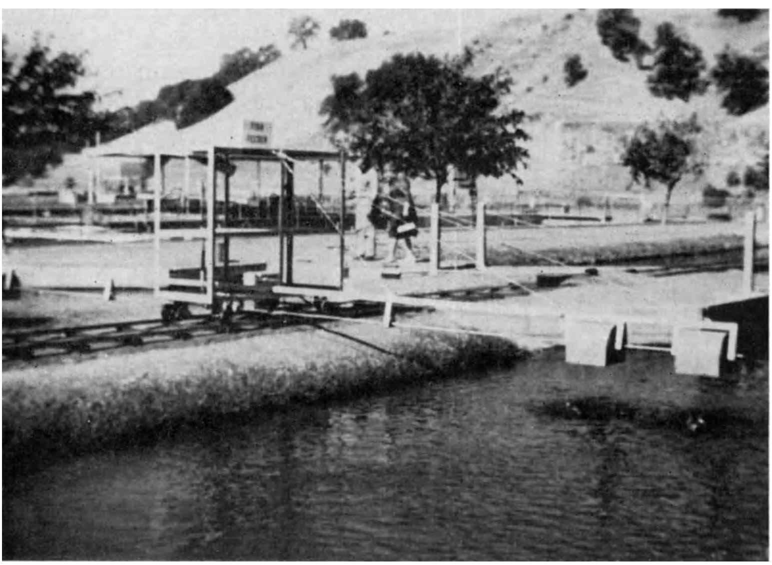

FIG. 64. Automatic feeding equipment on a fish farm.

Fish are poikilothermic animals and as such their metabolic rate depends on the temperature of their environment. This also reflects in the incubation time of the eggs which is temperature-dependent. Their growth rate is slower than that of the mammals and again depends on temperature and feeding.

Water

Basically fish culture is a question of water management and nutrition plus normal sanitary precautions. The first requisite for fish farming is a suitable, clean, plentiful water supply which is within the temperature range required by the species being cultured. Water supplies oxygen and removes the metabolic waste products of the fish, hence flow rates are important, to prevent an accumulation of waste products which would adversely affect the fish. The rate of water flow can be calculated from various easily obtainable data, e.g. its oxygen content and temperature, the altitude of the farm, weight of fish and the biological oxygen demand (B.O.D.) of the water. In the following example we assume the following data.

Temperature of water	15° C
Altitude	1000 ft.
B.O.D.	15·6 moles for 1000 lb. of fish

Research shows that trout require 5 p.p.m. oxygen in the water. From these data the requisite water flow may be calculated.

One p.p.m. oxygen in water is equivalent to $0{\cdot}625 \times 10^{-3}$ moles O_2 per litre so to provide 15·6 moles it will require:

$$\frac{15{\cdot}6}{0{\cdot}625 \times 10^{-3}}$$

= 250,000 litres/day
= 174 litres/minute
= 38·3 gallons/minute (Imperial gallons)

In the example of trout kept at 15° C at 1000 ft. the water contains 9·6 p.p.m. O_2 and they require 5 p.p.m. thus leaving a balance of 4·6 p.p.m. Hence to meet the B.O.D. requirement and to carry away the waste products the rate of flow must be:

$$\frac{38{\cdot}3}{4{\cdot}6}\text{ gallons/minute}$$

$$= \pm 8{\cdot}3 \text{ gallon/minute}$$

When there are changes in temperature, altitude or weight of fish then the water flow must alter to compensate.

Fish Ponds

Incubators and Hatcheries. The adult female fish are examined at regular intervals (twice weekly) and when they are ready to spawn i.e. they are 'ripe', the eggs are collected by a milking process known as 'stripping'. The female is subjected to a gentle pressure over the abdomen—and the expelled eggs up to 5000 per female, are collected in a suitable container. The male sperm, similarly collected, is added to the eggs and the fertilised eggs are allowed to harden in water for a while. The eggs are hatched in wire trays or baskets in vertical or horizontal incubators. The horizontal form consists of a trough of concrete, wood or aluminium about 16 ft. long, 16 in. wide and 7½ in. deep. The trays usually measure 13½ × 28 in. and hold 10,000–15,000 eggs (trout eggs are about ⅕ in. diameter). These are placed at a slight angle in the trough so that the water flows up through the trays in its passage along the trough. Some fish culturists use deeper troughs and stack up to eight trays one above the other in the series along the trough.

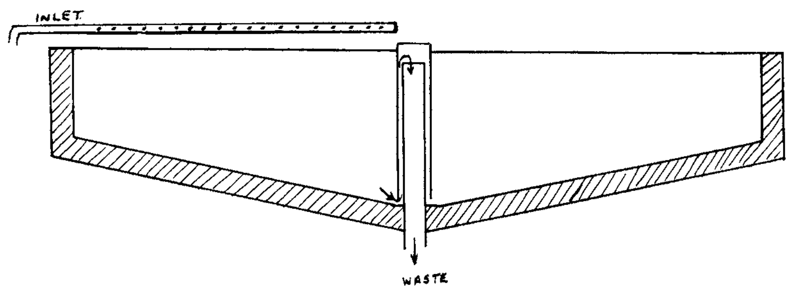

FIG. 65. Cross-section of a circular pond on a modern intensive fish farm.

In the vertical incubator, the wire trays are placed in plastic or fibreglass trays which are stacked one above the other. These latter trays are so constructed that the water entering the top passes through each tray in turn on its way down the incubator. This incubator has the advantage that it occupies less floor space and if the water is to be warmed in winter, it is less costly to warm than in another types of incubators.

During the first few days the eggs must be handled with care but after this they may be transported over long distances (e.g., from the U.S.A. to Britain) with safety.

The incubation period varies with temperature and figures of from 145 to 21 days over the temperature range of 2° C–15° C are given for trout. The preferred temperature is about 8–10° C (47–50° F).

When the fish hatch, the sac-fry are delicate and must be handled with care. They live on the yolk sac for about 2–3 weeks after which they then swim up to the surface in search of food. It is essential that at this stage they begin to feed as early as possible to prevent losses which can be large.

The standard hatchery troughs should not hold more than 20,000–25,000 fry. In the next couple of months, the fry become fingerlings—about 1 in. or so long and from this stage the rearing is fairly easy.

When the fish reach a length of 3–5 in. (7·5–12·5 cm.) they are transferred to the outdoor ponds.

Outdoor Ponds. Fish may be reared in lakes, ponds or streams. In intensive fish culture there are two main types of ponds, straight or circular.

Straight Ponds. Straight ponds are made either from a simple excavation in the ground or of concrete. These ponds are usually from 50–75 ft. long, 3–6 ft. wide and 2–3 ft. deep, but may vary from these measurements. In both these types the water is allowed to enter at a controlled rate and leaves either to an outflow channel or a second

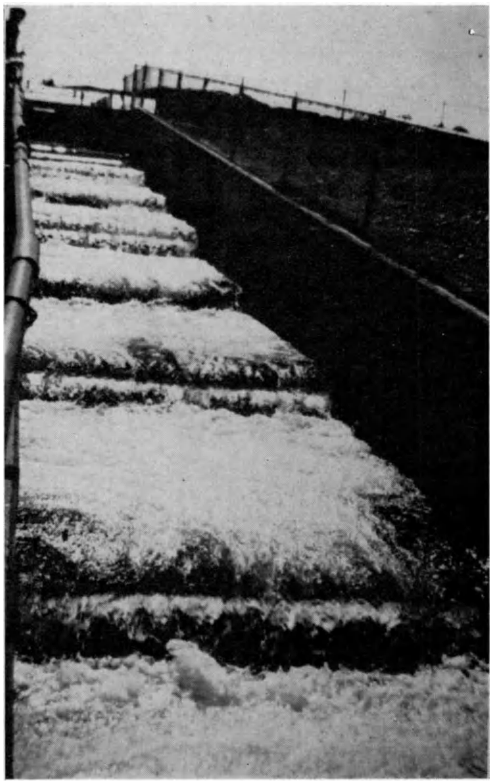

FIG. 66. A fish ladder to allow spawning salmon to go upstream past a dam.

pond in series. Concrete ponds are more expensive to construct but are much easier to clean or disinfect. Earth ponds are cheaper to construct but more difficult to manage and disinfect and there is often a problem of water-weed control.

It is not advisable to have more than two ponds in series because of disease risk and the possible accumulation of waste products proving harmful to the fish in the lower ponds. Where two ponds are in series, the lower pond is about 2 in. lower than the first.

The most usual arrangement is to have a series of parallel ponds either as singles or doubles fed from a transverse water supply channel.

The outflowing water is collected in a similar channel at the far ends of the ponds. In both types of ponds wire screens are placed at either end to prevent entry of unwanted fish or the escape of the cultured fish into the stream. Several such groups of ponds constitute a modern fish farm.

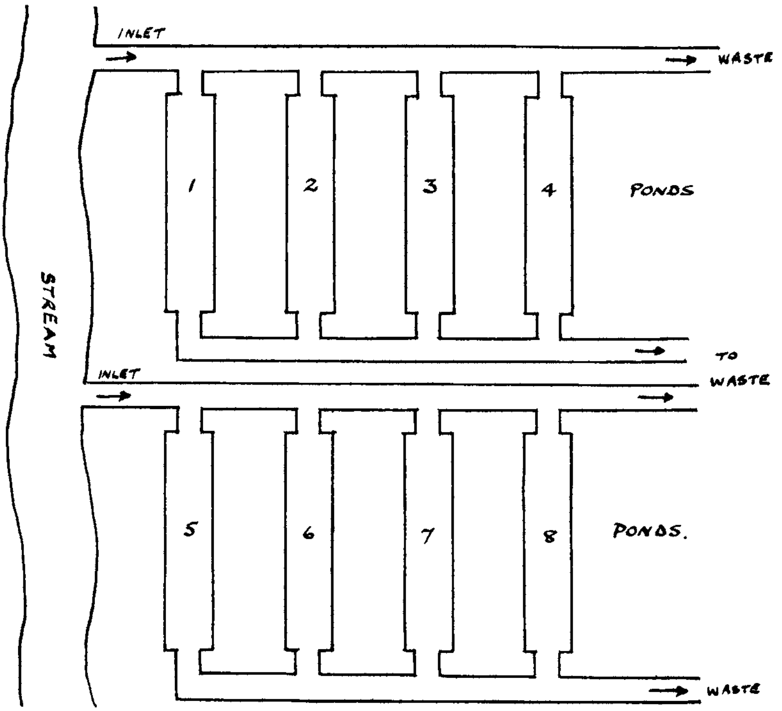

FIG. 67. Modern intensive fish farming—two rows of single ponds in an eight-pond unit.

Circular Ponds. The circular pond is a relatively shallow concrete structure with a floor which slopes down to the centre. They are usually 15–25 ft. diameter and 8–10 in. deep at the circumference and 18–20 in. at the centre. The water enters via a radially placed pipe provided with a series of holes or fan-shaped jets. The incoming water is arranged to strike the water surface of the pond almost tangentially so that it aerates the water and causes it to circulate round the pond. The outlet is by means of a vertical pipe set in the centre of the pond extending almost to the surface. Ponds are made to be self-cleaning by placing a larger sleeve over the outlet pipe. This sleeve has either slots in the bottom or an adjustable flange which clears the bottom of the pond. This has the effect of carrying the dirt up between the sleeve and the pipe thus cleaning the pond automatically.

The circular pond, by virtue of its better aeration and water flow, is capable of carrying a greater fish population than a straight pond of equal volume. Such ponds are very much used in the U.S.A. for rearing young fish.

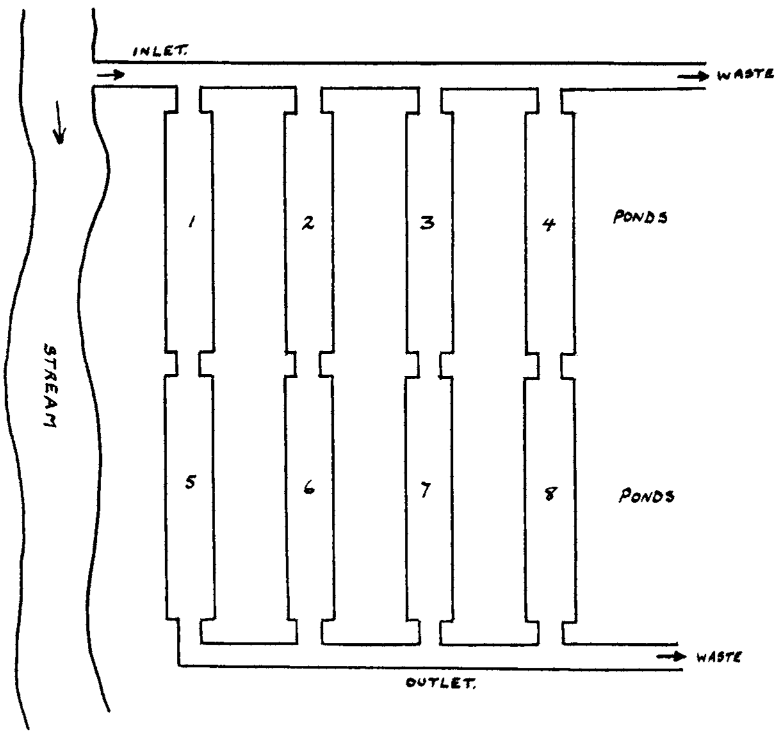

FIG. 68. Modern intensive fish farming—a single row of double ponds in an eight-pond unit.

Harvesting of the Crop. The fish in the ponds are sorted at regular intervals so that the growth is monitored fairly well. It is better to have all fish of the same size in any one pond. When this is being done or when the fish are being harvested, they are segregated at one end of the pond by a screen and the fish are removed by nets.

Fish Nutrition

The most commonly cultured fish in the world are the salmon, trout and carp and hence their nutritive requirements have been studied to some considerable extent. In early days of fish culture, particularly with the salmonids, their feeding consisted of giving a mixture of ground meat and fish offals with some cereal, but nowadays the majority of fish (trout) cultured are fed compounded diets as is the case with other domestic animals.

In the case of trout and salmon, requirements have been given for ten amino acids and ten vitamins and three minerals whereas with carp and other species there is not so much known. The carp is naturally omnivorous or possibly mostly herbivorous so it is much easier in practice to supplement a natural diet of pond vegetation than in the case of the carnivorous trout and salmon. In the recent development of fish culture—that of marine fish and crustacea, there is very little information available on which to base an artificial diet so it will be some time before a compounded feed is produced for these species. In the interim period, the waters may be fertilised to encourage a growth of natural foods and thereby improve the productivity of the waters.

TABLE 1
RECOMMENDED AMINO ACID REQUIREMENTS FOR SALMONIDS

	(As percentage of dry diet)
Arginine	2·5
Histidine	0·7
Lysine	2·1
Methionine	0·5
Tryptophan	0·2
Phenylalanine	2·0
Threonine	0·8
Leucine	1·5
Isoleucine	1·0
Valine	1·5

Fish show quite typical deficiency syndromes on diets low in vitamins such as riboflavin, pantothenic acid, folic acid, biotin, thiamine, etc. The recommended levels of vitamins for trout have been given as follows.

TABLE 2

Vitamin	*Tentative requirements (mg./kg. bodyweight/day)*
Thiamine	0·156 –0·186
Riboflavin	0·440 –0·680
Pyridoxine	0·225 –0·250
Pantothenic acid	0·970 –1·250
Nicotinic acid	3·0 –4·1
Biotin	0·0433–0·0796
Folic acid	0·00292
α-Tocopherol	1·50

With minerals, fish are able to obtain these directly from the water so the content of the food will depend on the composition of the water to some extent.

Fish Diseases

Fish are subject to a large number of diseases caused by bacteria, viruses, fungi, protozoa and also to parasitism by a whole host of parasites—protozoa, helminths, leeches and crustaceans. They are very subject to poisoning by metals and by many industrial and agricultural waste products, notably insecticides. Space does not permit a detailed discourse on fish pathology but the veterinarian who is interested in this subject will find some references to follow up in the list of suggested further reading at the end of this chapter. It is important for the veterinarian to realise that although he is dealing with a new animal in a new environment, the basic principles of hygiene, disease transmission, pathogenesis and epidemiology still apply.

Some of the common bacterial causal agents of diseases are listed below.

TABLE 3

Organism	*Disease*	*Susceptible*
Aeromonas salmonicida	Furunculosis	Trout, salmon
Corynebacterium sp.	Kidney disease	Salmonids
Haemophilus piscium	Ulcer disease	Most fish
Mycobacterium piscium and other species	Tuberculosis	All fish
Vibrio anguillarum	Salt water eel disease	Eels
Cytophaga columnaris	Columnaris disease	Most fish
Cytophaga psychrophila	Peduncle disease	Salmonids
Cytophaga sp.	Bacterial gill disease	Salmonids
Pasteurella sp.	—	Sea perch
Nocardia asteroides	—	Tropical fish

Viruses are responsible for such diseases as infectious pancreatic necrosis of salmonids, infectious carp dropsy, viral haemorrhagic septicaemia, lymphocystis disease, etc. (For fish pox, see Note at end of chapter, Ed.)

Protozoa may act as external parasites or as internal disease agents. The external protozoa which may cause mortality if sufficiently numerous are such as *Ichthophthirius multifilii* (white spot, ick) or *Costia necatrix*. The Myxosporidia are a large group of internal parasites that may have serious effects on their hosts. 'Whirling disease' caused by *Lentospora cerebralis* is a classic example of this.

Fungi too play their part in causing diseases of fish. *Ichthyosporidium* *hoferi* invades the tissues and causes mortality in both freshwater and marine species. *Saprolegnia* spp. on the other hand are secondary invaders of wounds and injuries, being ubiquitous in water, and contribute to the death of the host. The well-known fungus *Aspergillus flavus* produces the toxin Aflatoxin which in addition to affecting the usual domestic animals, causes hepatoma in trout and possibly other species of fish.

For the parasitologist, fish are a very good source of material. There are numerous nematodes, cestodes and trematodes to be found. Fish act both as final hosts and as intermediate hosts of cestodes and digenetic trematodes. Where they are intermediate hosts, the final host is either man or fish-eating birds or mammals. An interesting group of parasites are the monogenetic trematodes which are specific to fish and have a direct life cycle.

Crustacea parasitise fish. The families Ergasilidae, Caligidae, Sphyriidae, Lernaeidae, Lernaepodidae and Argulidae all contribute parasitic species which occur on the skin or gills of all types of fish.

Parasites are very often of local occurrence and as such have been employed as biological indicators of fish migrations.

Irish Salmon Disease

In Ireland and Britain a disease of salmon has been observed recently and the cause of this has not as yet been established. This disease also affects other fish. Bacteria such as *Aeromonas liquefaciens*, and *Cytophaga columnaris* have been isolated but transmission to healthy fish in the laboratory has not met with success. There is a suggestion that a virus may be involved. Work is progressing to determine the cause and its possible treatment.

Treatment of Fish Diseases. The modern intensive methods of fish culture lend themselves admirably to therapy of fish diseases. The medicament can be administered as an additive to the feed or be placed directly into the water. In the latter case, the water supply is shut off whilst the medicament is introduced and re-opened after 30–60 minutes to flush it away.

Bacterial diseases caused by *Aeromonas* and *Pseudomonas* spp., or *Cytophaga columnaris*, which are the most common diseases, may be treated with antibiotics e.g. chloramphenicol, tetracycline or oxytetracyclines at the rate of 50–100 mg./kg. fish/day in the feed. Sulphonamides such as sulphamerazine at 100–200 mg./kg./day or the nitrofurans at 50–100 mg./kg./day are very promising. Gill diseases due to bacteria are treated by exposing the fish to quaternary ammonium disinfectants at 2 p.p.m. in the water for 30–60 minutes. Mercurials such as pyridylmercuric acetate (P.M.A.) or ethyl mercuric acetate (Lignasan X) are useful too but are very toxic to rainbow trout.

Kidney disease due to a corynebacterium may be treated with 100 mg./kg./day of erythromycin given orally (in the feed).

The therapy for tuberculosis, viral diseases and neoplasia is as yet unknown so here hygiene and sanitation are by far the most important considerations, coupled with an early diagnosis.

Protozoal parasites and monogenetic trematodes can be eliminated by chemical baths using: (1) formalin 1:4000–1:5000 for 1 hour, (2) potassium permanganate at 10 p.p.m. for 15–30 minutes, (3) pyridylmercuric acetate at 2 p.p.m. for 60 minutes, (4) acriflavin at 2–5 p.p.m. for 1–4 hours or (5) acetic acid at 1:5000 for 1–2 minutes.

Intestinal protozoa such as *Hexamita* can be controlled by the oral administration (in feed) of 0·2 per cent carbarsone or calomel for 5 days. Other drugs such as 2-amino-5-nitro-thiazole and p-carbamido-phenyl are also very effective.

Digenetic trematodes and cestodes can be treated with 0·3 per cent di-N-butyl tin oxide in the feed. Kamala at 1·5–2 per cent in the feed will remove cestodes.

Copepods (crutacean parasites) and leeches may be removed by 0·02 p.p.m. of the active ingredient in a wettable powder of gamma benzene hexachloride used four times at 5-day intervals in the water.

For the prevention of fungal diseases such as saprolegniosis, malachite green is employed, especially in the treatment of eggs in incubators.

In all cases, the hygiene and sanitation of the ponds is of prime importance since prevention of disease is far better than treatment. Early diagnosis can save time in instituting treatment and prevention of the spread of the disease with its consequent losses.

From the above brief survey it will be seen that fish pathology can be a real challenge to the veterinarian and as the interest in fish farming grows, it will be necessary for the profession to take a real interest in the problems of fish diseases.

Note

Fish pox in the roach (*Rutilis rutilis* L.) has been described by Mawdesley-Thomas and Bucke (*Vet. Record* 8th July, 1967). It is characterised by conspicuous white skin lesions covering much of the head and body. Marked epithelial hyperplasia of the squamous cells was noted. It is considered to be not uncommon in European carp and cyprinids and was first described by Gessner in 1563. Believed to be due to a virus (? Herpes group), it is usually non-fatal and self-limiting [Editor].

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Chapter 23

STATISTICS—STOCK AND STOCKMEN

Agricultural Statistics Related to Intensive Livestock Farming

W. P. BLOUNT

Although there is no one official volume of appropriate statistics, *The State of British Agriculture*, by Hunt and Clark (1966) is invaluable since it gives most of the appropriate information with innumerable references.

Human and Animal Populations

Whilst the total U.K. population in 1958 was 54,624,000 it may well reach 74,660,000 by A.D. 2000, an increase of 36·7 per cent. These are the extra mouths which will have to be fed adequately, and which will be dependent to a considerable extent upon Britain's intensive livestock farming programmes.

The total number of agricultural workers in the U.K. has declined from 730,300 in 1958 to 551,000 in 1965, partly because their average total wage (1967 basic £10 16s. 0d. for a 44-hour week) is about £6 a week lower than that of workers in manufacturing industries. (In no sense is this offset by cheap milk, potatoes or a rented cottage.)

U.K. Livestock Population (1965)

Cattle and calves 11,945,000; sheep and lambs 29,911,000; pigs 7,979,000; fowls 112,100,000; ducks 1,350,000; turkeys 4,420,000 and geese 240,000. (The number of cattle calvings for 1965 is given as 741,000 (heifers), and 2,564,000 for all other cows.)

We have made great strides in agricultural output during the past 5–10 years, total livestock products (at constant prices) exceeding £669 millions in 1964–65 compared with £579 millions in 1958–59, mainly from eggs and milk. In nationally recorded herds milk production now averages almost 900 gallons per cow, an increase of 50 gallons during the period under review, whilst egg production per hen has gone up from 179 to 203.

The contribution from home agriculture to our own food supplies is as follows: chicken meat 98 per cent, pork 97 per cent, eggs 96 per cent, beef and veal 73 per cent, cheese 43 per cent, mutton and lamb 42 per cent, bacon and ham 37 per cent and butter 9 per cent. Whilst there would seem to be few opportunities for any marked expansion of the poultry industry, cattle and sheep producers are well placed.

Other countries presumably produce cheaper butter, bacon and cheese, but political considerations may also operate, e.g. the bacon quota (37 per cent home production).

Total amounts consumed per head per annum are in the region of 265 pints milk, 44 lb. beef and veal, 260 eggs (32½ lb.), 26 lb. pork, 26 lb. bacon and ham, 23 lb. mutton and lamb, 19 lb. butter and 13 lb. margarine. Lower paid workers (earning less than £10 a week) eat more margarine, potatoes, bread, flour, sugar and tea and less fresh fruit and green vegetables, milk, butter and eggs, contrasted with those earning over £26 a week.

The average weekly expenditure per person in 1963 was as follows: milk and cream 35·2d., beef and veal 30·5d., bread 24·6d., eggs 18·4d., mutton and veal 16·5d., bacon and ham 16·2d., butter 16·1d., sugar 10·5d., pork 7·6d., and poultry-meat 6·1d. This was equal to 4·87 pints milk, 17·2 oz. carcass meat, 39·5 oz. bread, 4·7 oz. eggs, 5·2 oz. bacon and ham, 6·3 oz. butter and 18·2 oz. sugar. In addition 2·6 oz. tea, nearly 1 lb. fresh green vegetables, 59 oz. potatoes, 23 oz. fresh fruit, 5·7 oz. fish, 3 oz. margarine and 3·3 oz. cheese.

Our imports of *beef* come chiefly from the following countries: Argentine 10 per cent, Australia 8 per cent, New Zealand 3 per cent, with home production 74 per cent of all supplies; *mutton and lamb*—New Zealand 50 per cent, Australia 4 per cent, home production 41 per cent; *pork*—all imports 3 per cent; *offals*—all imports 41 per cent; *bacon and ham*—Denmark 48 per cent, Poland 8 per cent, Eire 4 per cent, home production 37 per cent. We also export large numbers of cattle to Western Germany, Eire, Holland and Belgium: sheep and goats to Holland, Eire and Belgium and pigs to Eire, Western Germany and Belgium in that order of importance. All such exports (less those for breeding) total well over 300,000 animals.

Feed Compounds. The output of the feed compounder has steadily increased and now exceeds 9 million tons annually valued at nearly £350 millions. This was represented in 1966 by 3·26 million tons (35 per cent) for cattle and calves, 1·93 million tons (20 per cent) for pigs, 3·94 million tons (42 per cent) for poultry (including 810,000 tons for broilers and 240,000 for turkeys), and 180,000 tons (2 per cent) of compounds for other animals—sheep, rabbits, horses, etc.

As a contrast the following data (1965) apply to the Common Market countries and the U.S.A. (See Table on page 341).

About 31 per cent of total farm expenses go on feeds, the total expenditure now exceeding £470 millions. Farm products used as raw materials in feed compounds (wheat, barley, etc.) represent about 35 per cent of the total; the increased uptake of home grown cereals can be seen from the Table on page 341.

Of the imported cereals and proteins 30 per cent come from the Commonwealth countries, 29 per cent from the U.S.A. and 42 per cent from other foreign suppliers.

The efficiency of the feed industry can be seen from the fact that whilst prices are nearly all below those of 12 years ago, productivity is well up compared with pre-war: poultry-meat 354 per cent, pork 201 per cent, eggs 114 per cent, milk 66 per cent, bacon and ham 45 per cent, beef and veal 37 per cent, mutton and lamb 27 per cent (CAFMNA 1966).

COMMON MARKET COUNTRIES (MILLION TONS METRIC) 1965

	Germany	*Holland*	*France*	*Belgium*	*Italy*	*Total all E.E.C.**	*U.S.A.*
Cattle	1·52	1·00	0·62	0·63	0·23	4·02	18·8†
Calf	0·23	0·43	0·36	0·09	0·21	1·30	
Pig	1·86	2·20	1·40	0·94	0·50	6·93	10·0
Poultry	2·81	1·73	1·86	0·75	0·96	8·12	31·3
Any other	0·16	0·28	0·31	0·06	0·10	0·92	2·5
Total compounds	6·60	5·63	4·54	2·48	2·00	21·29	62·6

* Includes Luxemburg total production 48,500 tons.
† Dairy, beef and sheep.

	Wheat (tons)	*Barley (tons)*
1960–61	904,000	1,265,000
1964–65	1,370,000	2,090,000

Cattle

Dairy Farming

The increased efficiency of the dairy herd has resulted from better cattle giving higher yields (now between 800 and 900 gallons per cow) and a better use of labour so that one man may be responsible for about seventy milkers.

The high cost of land and labour has meant greater intensification—more cows per acre and per herdsman. Yard and parlour systems require heavier capital expenditure, hence the use of cheaper loose housing such as cow cubicles or kennels.

As less reliance is being placed on the use of grassland, new dairy units may be concentrated adjacent to cities where demand for milk is high; unless this is likely to be counterbalanced by such factors as the production of U.H.T. milk. (Here however the milk connoisseur will detect a flavour change which may restrict sales.)

A full account of the subject, including modern trends in calf rearing, is given by my colleagues, P. I. Bichan, J. P. Walsh and J. Wilson (Chapters 1–4).

Disease Risks to Man from Milk Supplies. Now that 95 per cent of all milk is pasteurised some of the medical scourges of the past have disappeared, but public health officials are still worried about the annual sale of 73 million gallons of raw milk, sold by 10,000 producer retailers (Parry 1966).

About $1\frac{1}{2}$ per cent of cases of brucellosis in humans prove fatal, and about one-quarter of these relate to people connected with farming, the male to female ratio being 2:1. Quite high proportions of farmers (and veterinary surgeons) are often brucella-infected so that every effort must be made to convince farmers in particular of the need to eradicate the infection from their cattle.

Since 1943 nearly 4000 cases of salmonellosis have been attributed to raw milk, of which 90 per cent might have been prevented if the milk had been pasteurised. All aspects of salmonellosis were thoroughly covered by the several papers given at the 1966 B.V.A. Congress, Brighton, and these should be made available to all veterinarians, farmers and agricultural advisers free on request.

So far as tuberculosis is concerned, the profession must ensure that there is no breakdown in their routine T.B. testing work, and also that more than one mixed sample should be subjected to biological test when a single cow in a herd of more than thirty is suspect, otherwise dilution may mask the infection. One cannot but agree with Parry's recommendations that there should be complete pasteurisation of all milk supplies together with improved techniques for the examination of samples.

Beef Production. As grass fed beef has never been very profitable (Jones, 1965) the nutritional developments associated with the use of high levels of barley provided the industry with a fresh stimulus to a new feeding system which has gone well in many areas. (See also Chapters 4 and 5.)

It is perhaps pertinent at this point to refer to the fact that Newcastle University Agricultural Marketing Department found after interviewing 2000 housewives that most people cannot judge the flavour of beef. Indeed beef steaks from cattle 1 year old appeared to them to be no better than those from 18–20 month old stock. Tenderness and a high proportion of fat (34 per cent) appeared to be more important factors than flavour! An earlier Newcastle report emphasised that most women (88–97 per cent) prefer to be served by a butcher because of his personal attention, rather than select their own joint at a supermarket. Only 14 per cent of housewives used Co-operatives and 3 per cent supermarkets or self-service stores for purchasing their meat supplies.

One of the pillars of modern livestock production is the way in which breeders have turned out new breeds with special economic qualities. One could say that this work began with U.S. geneticists producing hybrid corn, later applying the same principles for the development of hybrid poultry for egg or meat production. Indeed many large farming organisations in the U.S.A., Canada and Britain employ full or part-time geneticists solely for this purpose. Outstanding names in this connection are Arbor Acres, Babcock, Cobb, DeKalb, Hy-line, Kimber, Peterson and Pilch in the U.S.A.; Shaver in Canada; and Alexander & Angel, Sterlings (Ross), Thornbers, Bernard Matthews and British United Turkeys in Britain.

Whilst the emphasis with poultry has been on the production of *hybrids*, with cattle, pigs and sheep it has been more on *breeds* and crossbreds; one of the latest being the Jersian (Jersey × Friesian). Many beef breeders and producers received a shock when Charolais were introduced from France in 1961, because they believed that our own established beef breeds were unbeatable. The Milk Marketing Board instituted trials, involving nearly 4000 Charolais crossbred calves, in order to contrast the results from the use of French versus native breeds for crossing with dairy cows. It has since been estimated that these French bulls increased our beef output by an additional 28,900 tons, valued at £9,500,000. (*M.M.B. Charolais Report*, 1966, 7s. 6d.)

Rowson (1967) speaking at the British Cattle Breeders Club at Cambridge drew attention to the possible production of mosaic, man-made cattle compounded from several breeds (e.g. Jersey, Friesian, Hereford, Aberdeen Angus, etc.) by transplanting fertilised ova from one animal to another. Experiments in Australia had shown that a fertilised sheep egg could be grown temporarily in a rabbit's uterus, during which time the animal might be transported over long distances. The ovum could then be transferred to a ewe's oviduct where it would grow to maturity naturally. Similarly a purebred Hereford has been born elsewhere out of a Friesian cow.

Incidentally the main pure breeds involved in A.I. work in the U.K. are Friesians (49·6 per cent) for dairy cattle and Herefords (22·1 per cent) for beef. The 1965 breed distribution percentage for England and Wales is given as Friesian 64 per cent, Ayrshire 16 per cent, Guernsey 6 per cent, Jersey 4 per cent, others 10 per cent.

Food Preservation. The welcome news that U.H.T. milk could be made available quickly for export has unfortunately had to be tempered by the fact that not only would transport costs be high, but prejudices and local interests might delay its acceptance in many foreign countries. However, if the British housewife will accept its slightly different flavour (from that of fresh or pasteurised milk), one can foresee that it may not be long before there will be no U.K. milk deliveries on Sundays, and possibly only two or three during the week. In like vein we may soon see the use of cobalt^{60} for extending the shelf life of fresh poultry by 1–2 weeks, using a pasteurising dose of 250,000 rads. Cobalt ^{60} irradiators of British manufacture have already been sold to Holland for use at the Dutch Institute of Horticultural Produce

Research (Storage and Processing), Wageningen; and also to Turkey for the treatment of grain.

The irradiation of human foods for the control of pathogenic bacteria moulds or insect pests was first carried out in Britain a number of years ago, but the method has still to find a commercial application except possibly for rendering foods for laboratory animals or pets free from disease organisms. As a contrast in the U.S.A. the Food and Drug Administration has already approved the irradiation of bacon, pork, wheat and certain other foodstuffs, by a method which also destroys tapeworm larvae, oocysts, etc. This saves high transportation and refrigeration costs, and also extends the shelf life of many foods liable to rapid spoilage from mould growth, e.g. raspberries. (This latter function is being achieved by an electron beam, surface irradiation technique, which 'pasteurises' the fruit).

Pigs

The pig industry remained faithful for many years to three common breeds—Large White, Essex and Wessex—until it was shown that the Landrace (Swedish) gave a better performance, as was also the case occasionally with the Welsh breed. (The recent merger between the Wessex and Essex breeds to the 'British Saddleback' was well timed.)

Recently several pig breeding schemes have developed which may well result in a marked improvement on a national basis: Alexander & Angel provide 'synthetic' gilts, comprising at least four breeds and costing about £60, which are being recommended for mating to performance-tested boars. Thornber's too will market synthetic/hybrid stock after carrying out performance testing work.

The B.O.C.M. scheme, described in chapter 11 by R. W. Widdowson, relates to work, the records for which are computer analysed, and part of the total herd is fully recorded for 54 approved parameters. This breeding programme involves a 3-way cross and the establishment of multiplying breeders, together with weaner and fattener groups.

The P.I.D.A. national elite and accredited schemes are considered to be amongst the most beneficial to the U.K. pig industry, but progeny testing for detailed carcass assessment must presumably operate at a later phase in their breeding schemes. Data from 60,000 litters which have been sired by 914 P.I.D.A. premium boars show that the conception rate from A.I. now exceeds 78 per cent.

The Pig Improvement Company sells both virus-free and minimal disease Landrace and Large White gilts (£30) and boars (£60) of either breed for back crossing. Multiplying breeders are being established and pig groups are being formed.

Walls aim at producing a 3-way cross suitable for the manufacturing industry. Multiplying breeders have been established and their cross-bred female commercial pigs will be bred to suit Walls' heavy hog trade.

As a contrast the F.M.C.'s object is to produce pedigree, minimal disease, Large White boars; but their influence must of course depend greatly upon the genetic make-up of the gilts to which they are mated.

The prosperity of the pig farmer depends almost as much upon those who determine its price structure as it does upon management efficiency, and the recent chaotic situation is proof of this. Pigs bought under contract have been costing bacon curers more than they were able to realise for the carcasses, the net loss in some cases being between 40s. and 50s. a cwt. In the case of the Yorkshire Farmers Bacon Factory Company Ltd., for example, losses were running at about £6500 per week (30s. on every pig cured). A further example is that of the Fatstock Marketing Corporation (controlling 40 per cent of British bacon) whose bacon factories lost £250,000 between May and August 1966 compared with a profit of £500,000 in 1965. In some instances therefore curers prefer to purchase imported sides rather than to cure their own home-produced bacon.

This position has arisen because there is no distinction between the guaranteed prices for pork or bacon pigs, the subsidy being largely dependent upon the price of pork; and as pigs are in short supply, pork prices are high and there is virtually no subsidy. The distribution of pigs in England and Wales during 1965 was pork 60 per cent, heavy hogs 23 per cent and baconers 17 per cent.

Some economists have suggested that British farmers should concentrate on pork production, leaving Denmark for example to produce the Wiltshire bacon, realising that government loans totalling up to £1 million to bacon curers is only a makeshift remedy, particularly as the U.K. share of the total bacon market of about 650,000 tons is to remain at about 37 per cent (Northern Ireland supplying about 85,000 tons and Eire 28,000). One important aspect of this problem is of course a general shortage of home-produced pigs, the numbers of breeding sows having decreased by 103,000 during the past year.

In an attempt to bring greater stability to the U.K. bacon industry, the government has authorised new arrangements (to be reviewed annually) which are based essentially on a weekly comparison between the price of pigmeat for bacon and the price of bacon on the wholesale market. if the market becomes generally adverse to the curer, assistance will be given by the Exchequer, whereas when the reverse is the case the curers will pay the government a levy. It is intended that payments and levies will broadly balance one another, and that the scheme will help to encourage sensible planning and investment.

So far this new measure by the Minister, Mr. F. Peart, has proved very successful, the Chairman of the British Bacon Curers Federation stating that 'A big step had been taken in the right direction by the Government in establishing the new stabilisation scheme for the curing industry'.

Sheep

Years ago many agriculturalists would have laughed at the idea that sheep might be housed so intensively that there are reasonable prospects for obtaining 500 lb. lamb per forage acre (as recently forecast by Professor McG. Cooper), or of lowland sheep becoming indoor animals producing two litters a year. Present-day economic pressures are forcing some farmers to adopt more intensive methods, traditional methods of fat lamb production being completely uneconomic in relation to land values. But one of the real purposes of keeping sheep indoors is to protect their pastures from damage, rather than the animals. Newcastle University has kept flocks totalling over 1300 sheep indoors for over a 4-year period without any serious loss from disease or lack of exercise.

Such intensive methods place great importance on sheep nutrition, particularly during the last 6 weeks of pregnancy when it has a very definite effect on lactation performance. Unfortunately when using modern crossbred or hybrid sheep (e.g. involving Finnish Landrace, which are highly fecund) it is extremely difficult to determine when two or more lambs are to be born.

In the U.S.A. an ultrasonic analyser has been used, 2 months after conception, for the detection of pregnancy, since the sound waves bounce back after striking the placenta/foetal tissue, registering a total distance travelled of 36 cm. contrasted with 12 cm. for non-pregnant ewes. (Three trained personnel can examine 15 ewes an hour with an accuracy of 90 per cent.) Whether this device can detect multiparous animals is unknown, but a solution to this problem is important in order that specially concentrated rations may be formulated for those ewes which are liable to give birth to two to four lambs. Ultrasonics have been used for some time for measuring back fatness in pigs, and recently also for determining experimentally the breast-meat yield of broilers (Richter 1965).

The feeding and management of sheep is discussed in chapter 6 by my Scottish colleague A. B. Harker, and by E. F. Cantle outlines some aspects of Cobb's interest in modern sheep breeding in chapter 8. Those interested in a full account of obtaining meat from sheep should consult Bowman's (1966) review of the subject.

Poultry

Poultry show the greatest degree of intensivism of any farm species, since less than 10 per cent of layers are now housed on free range, and all broilers are kept fully intensively, nearly 100 per cent being reared on deep litter. Although some turkeys use range in the summer months, increasing numbers are kept in pole barns, yards or other buildings with at least semi-controlled environments. Light controlled buildings are of course essential for any breeding stock used for year-round production purposes.

Laying Stock

Housing. About 3½ per cent of all households in Great Britain keep poultry, two-thirds of which are not covered by the Ministry's data relating to holdings of over 1 acre. Between them these smallholders own an estimated 11½ million layers (contrasted with 44·3 million others which are recorded in the June census). About 5 million of the former relate to flocks of less than fifty-five birds (B.E.M.B. 1966).

FIG. 69. This is the degree of stock concentration which many critics of intensive livestock farming believe offers severe stress. If well managed, however, mortality remains low and growth rates normal, except in the presence of some specific pathogen or disease complex.

Although two-thirds of all producers have flocks of less than 200 birds, these only produce 9 per cent of all eggs, almost one-quarter of the pullets being housed in flocks of over 10,000 layers totalling in all over 12 million layers. The following table (B.E.M.B. 1967) shows the great influence of laying batteries:

	% of U.K. egg producers	*National laying flock (%)*	*Average flock size (Birds)*	*Average size of egg throughput (cases of thirty dozen/week)*
Laying batteries	14·8	66·9	2180	21·1
Deep litter	42·1	24·8	285	2·1
Free range	43·1	8·3	93	0·5

Laying batteries are most popular in Northern Ireland, whereas deep litter is the more popular in Wales and free range in Scotland. Average flock size is highest in England (568) and lowest in Wales (197).

The development of the poultry industry in England and Wales between 1945 and 1959 has been described in detail by Coles (1960) who has now brought the subject up to date—see Chapter 12.

Breeding. In addition to the great change in housing (from free range to intensive systems), perhaps the next most striking feature relates to breeding. The number of pedigree breeders entered in the Poultry Stock Improvement Plan reached its peak in 1948 with 450, whereas by 1965 it was estimated that there were only sixty-three active breeders (Hunton 1966). Instead there has been a massive breeding of hybrids, both home-produced and imported, chiefly from the U.S.A. and Canada. Some indication of the size of testing programmes involved in the breeding of hybrids can be seen from C. Thornber's

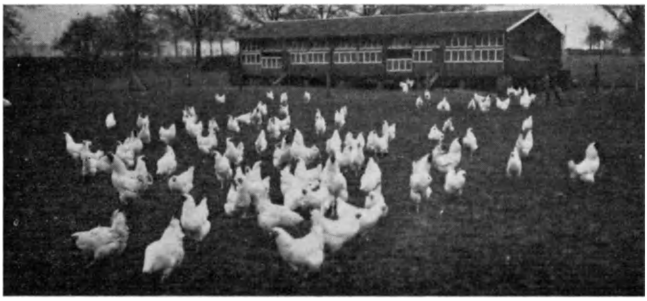

FIG. 70. Free range rearing is seldom practical today, and not applicable to commercial breeding or egg production.

statement at the Farmers' Club, October 13th, 1965 that 'A small breeding unit of 30 strains can provide 756,030 different 4-way crosses', an obviously impossible number to test under field conditions. Instead geneticists are experimenting with computers to breed a theoretical generation of chickens every 10 minutes. Thornber pointed out that normally pure-bred males are assessed by the performance of at least eighty daughters placed on four locations, eight different performance traits being measured, the results then being analysed by computer. Hybrids now probably form at least three-quarters of the total laying flock of the country, and it will not be long before crossbreds and purebreds represent only 10 per cent.

Breeds of Commercial Laying Stock

Pure breds

Light Sussex (tinted eggs, but rather high food intake);
Rhode Island Red (commonly used for supplying genes for brown shells);
White Leghorns (commonly used for the production of light/medium hybrids);
White Wyandotte (seldom used today, partly due to fertility problems).

The full list of poultry breeds is given in *British Poultry Standards*, Poultry World, Ltd. (1960), but of course the vast majority today play no part in the economic production of eggs.

Modern Hybrids

Brown Egg Breeds

Arbor Acres Sex Link
Babcock B390
Curnick Hunter C.H.40
DeKalb 507
Double-A3
Harco
Honegger Brownegger
Hy-Line 840
Shaver Starcross 555
Sterling Ranger 1 and Ranger 11 (In Northern Ireland also the 'Rocket')
Sykes Hybrid 7
Thornber '404-plus'
Warren-Sex-Sal-Link F.
Welp Line 650

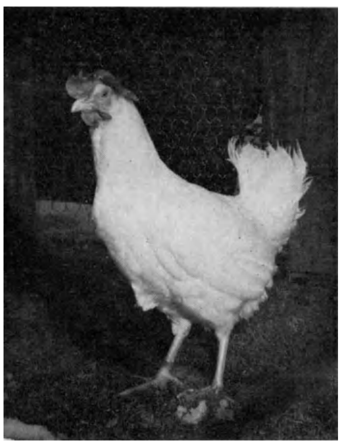

FIG. 71. A typical 'Mount Hope' White Leghorn pullet ('Ibreil', J734), the forerunner of many modern hybrids. This pullet laid 300 × 75 gramme eggs equal to 400 standard 2 oz. eggs in 1 year. The broken tail feathers tell the story of her repeated visits to the trap nests.

White and Tinted Egg Breeds

Babcock B.300 (white)
Curnick Hunter C.H.20 (tinted)
DeKalb 151 (white)
Double-A1 (tinted) and Double-A4 (white)
Hy-Line 934 (white)
Honegger (white)
Kimberchik K137 (white)

H.&N. Nickchick (white)
Shaver Starcross 288 (white)
Sterling White Link (white)
Sykes Hybrid 3 and 4 (tinted)
Thornber 606 and 808 (white)
Welp Line 937 (white)

For a consideration of the commercial qualities of these many egg-laying breeds the reader is referred to the available literature, plus the reports of official laying trials, both in the U.K. and the U.S.A./Canada. The latter gives the results of Random Sample tests and range group rankings (U.S.D.A. Report ARS 44-79-7, December 1966).

Broilers

A broiler is a mass-produced table chicken killed at about 55–70 days of age and weighing from 3 to 5 lb. The majority are only 8½–9½ weeks old, they are reared in large units (up to 20,000) on deep litter, and efficiency of production is such that feed conversions are falling each year and the 2:1 barrier is likely to be broken within the next 2 years. Broiler house mortality is usually very low, averaging about 3 per cent per crop, but mainly because veterinary advice is frequently sought concerning inter-flock disinfection programmes, vaccination and the use of specific drugs for controlling coccidiosis and other diseases.

Although the consumption of broiler meat in Britain now exceeds 16 lb./head/annum, this figure is rising steadily, and is unlikely to be affected should we enter the Common Market. For political and other considerations we import over 5000 tons of poultry meat annually as well as an equivalent amount canned, the latter coming mainly from the Netherlands and the U.S.A.

BROILER PRODUCTION
(in millions)

	1966	*Per cent alteration 1966:1965*
E.E.C. countries		
West Germany	77	+32·8
Belgium	102	+ 8·7
France	267	+ 8·1
Italy	247	+ 6·5
Netherlands	170	+21·4
United Kingdom	174	+ 9·2

Broilers represent the most intensive section of livestock production, but large numbers of producers still use earth floors due to the high cost of laying down concrete (£1 per sq. yard), although this latter is acknowledged to be far preferable for disease control purposes. Practically all current broiler houses are windowless and fan ventilated, and flock sizes average over 10,000 birds representing as-hatched chicks of such breeds as Arbor Acres, 'Chunky', Cobb, 'Hybro', Ledbrest × Pilch, Penobscot, Peterson, Starbro, etc.

BROILER PERFORMANCE

	1962	*1963*	*1964*	*1965*	*1966*
Total No. of birds recorded	2,758,580	3,472,535	3,490,018	3,877,033	4,391,120
Average age (days)	68	67	67½	66	65
Square feet/bird	0·74	0·73	0·72	0·73	0·69
Average liveweight (lb.)	3·80	3·82	4·01	4·09	4·11
Mortality (%)	3·15	3·04	3·12	3·22	3·74
Feed:					
Consumption/bird (lb.)	9·55	9·64	10·06	10·01	10·07
Conversion	2·52	2·52	2·51	2·45	2·45
Margin income at 1s. 6d. liveweight – feed cost (list)	2s. 4·10d.	2s. 4·19d.	2s. 4·68d.	2s. 4·71d.	2s. 4·49d.

The preceding table, based on B.O.C.M. costings data, shows the improvements which have taken place during the past 6 years, in terms of bodyweights, feed conversions and age at killing. Square footage and mortality remain more or less unchanged, although during the past year there has been a tendency for stock to be slightly more crowded to compensate for higher feed and labour costs, and this may have been reflected in the slight rise in mortality.

The following table shows the tremendous improvements in those economic factors affecting profits, which have taken place in table poultry production during the past 10 years at Stoke Mandeville:

BROILER PRODUCTION
(1958–66)

Year	*Age (days)*	*Liveweight (lb. oz.)*	*Feed conversion*	*Mortality (%)*	*Breed*
1958	70	2 15	2·83	4·74	Hall-Mark
1959	70	3 9	2·89	6·02	Hall-Mark
1959	70	3 10	2·55	2·69	Chunky
1961	63	3 12	2·41	1·77	Arbor Acres
1962	63	3 13	2·30	1·94	Arbor Acres
1963	68	4 1	2·37	4·05	Cobb
1963	63	4 2	2·27	2·85	Peterson
1964	63	4 7	2·29	2·36	Cobb
1965	54	3 4	2·10	1·80	Shannon River
1966	56	3 12	2·21	2·11	Ledbrest/Pilch

From these data it will be seen that great progress has been made in terms of liveweight gains at a younger age, as well as improvements in feed conversions. Both nutrition and genetics have played complementary roles in this example of improved livestock production under intensive systems of management.

It is perhaps noteworthy that mortality rates have not shown consistently the same degree of improvement, but this is partly due to a variety of environmental interactions.

Geneticists have characterised some broilers by the presence of yellow legs, a feature much favoured in the U.S.A. and also in some parts of France, but British housewives definitely prefer white shanked broilers, and so this has meant the use of so-called de-pigmenting broiler feeds to be used whenever broilers do not have a dominant white gene (W) in their final breed make-up (see Hutt 1949).

Broilers are killed at varying ages, partly according to market requirements, the following examples again being taken from our own costings data:

Killing age (days)	*No. of broilers*	*Liveweight (lb.)*	*Mortality (%)*	*Feed bird (lb.)*	*Feed conversion*
72	423,370	4·51	3·30	11·39	2·53
68	1,617,599	4·38	3·53	10·87	2·49
63	1,860,652	4·04	3·61	9·54	2·41

Comparable data from Maine (Berglund 1965) show that the market age for broilers has fallen from 80 days (1952) to 71 (1951) to 66 (1960) to 60 (1964) and 58 days in 1965 (bodyweight 3·75 lb.).

Some indication of the expansion which producers could anticipate during the next few years (with a rising population and increased standard of living) can be seen from the following 1965 estimate of poultrymeat consumption in the U.S.A. and elsewhere:

	Pounds/head
U.S.A.	40·7
Canada	36·0
France	19·8
Belgium	17·5
United Kingdom	16·5
Italy and Eire	16·1
Switzerland	12·6
Netherlands	9·9
Western Germany	13·9
Denmark	10·1

Slaughter yields are higher in males than females but differ with various breeds. The legs and thighs represent 24 per cent, breast muscles 14 per cent and edible offals 1 per cent. In practice the cooked meat only represents about 20–22 per cent of the liveweight, or 45–48 per cent of the cooked weight. This compares with a slightly lower yield in the case of the duckling (20 per cent) and with 35–45 per cent in the case of the turkey.

At the present time the statutory standards relating to the post-mortem meat inspection of cattle, etc., do not apply to poultry. This is undertaken by inspectors of the local authority acting under the provisions of the Food and Drugs Act, 1955, and the Food Hygiene (General) Regulations, 1960. The standards are those recommended in the code of hygiene practice for poultry packing and dressing published by the Ministers in 1961. Thus unlike the position in the U.S.A. (where all poultry undergoing inter-State shipment *must* be subjected to veterinary inspection), in Britain very few carcasses are examined, and then mainly by lay meat inspectors. In Canada there is now the trend for all poultry carcases to be inspected before sale.

Turkeys

The value of intensive husbandry methods for turkeys lies not only in their better initial growth rates and feed conversions, but also for controlling the egg production of breeding stock so that poults can be hatched at all times of the year, even though just over 50 per cent are hatched today during the 4-month period May–August ready for marketing at Christmas. In all 84 per cent are sold at that season, many of course having been in cold store for several weeks. In fact, the sales of freshly killed and quick frozen turkeys are about equal, in spite of the fact that many housewives believe that frozen poultry are inferior. This is quite untrue and taste panel tests show that the majority of people cannot distinguish between the two articles. *Per capita* consumption of turkey meat annually is now about 1·3 lb., with a total consumption of 70 million lb., compared with 0·5 lb. in 1958. This trend is expected to continue unless over-production occurs, when prices will fall and a setback is then inevitable.

Recently two distinct types of turkey have been bred, a smaller bird with an oven-ready weight of 5–12 lb. by 12–16 weeks of age and the much heavier bird (20 lb.+) for the restaurant trade. The former must be housed intensively and treated on similar lines to broilers, whereas the latter often spend many months out of doors or in pole barns.

There are now only about five main 'breeds' of turkey in Britain, excluding the Beltsville Small White which has almost disappeared partly because of its poor feed conversion factor. British United Turkeys (B.U.T.) and the Bernard Matthews company dominate the scene, but two recent imports from the U.S.A. (Wrolstad and River Rest) will offer competition in the small bird market. The Motley organisation also offer large numbers of poults, limited mainly to the south-western areas. For the names and addresses of other well-known breeders consult the B.T.F. list, published in *Turkeys Year Book*, 1967.

To achieve economic results turkey producers must use specialist rations designed nutritionally for particular purposes, e.g. 'Starter', 'Finisher', 'Pre-breeder', etc.

In addition the majority of strains of hens require to be artificially inseminated, since the male is too cumbersome for natural mating. A.I. techniques have been simplified and improved over the past 5 years, but no practical method is yet available for storing the semen, which must be used normally within an hour of its collection. Insemination is practised every 2 weeks, but if fertility is impaired or hatchability falls the hens may be inseminated once a week. Considerable care is necessary to avoid intra-vaginal infections, particularly as P.P.L.O. (Mycoplasma) are known to be egg-transmitted.

Mortality is sometimes as low as 5 per cent to killing age but it may be two to three times as high if Mycoplasmosis, blackhead or coccidiosis occur. For flocks which are not Mycoplasma-free a variety of antibiotics (Tylan, Rovamycin, Erythromycin and Rondomycin) are used; for blackhead control the chief drugs are *Carbosep*—Whitmoyer Reed (containing an organic arsenical) and *Emtryl* M. & B.; whilst for coccidiosis sulpha drugs or amprolium mixtures are generally effective. (See also Chapter 18 on Poultry Diseases (Diagnosis and Treatment) by B. S. Hanson.)

Ancillary Aspects

To support the poultry industry, whose sales are now worth over £300 million, are a large number of ancillary traders. Whilst breeders and feed manufacturers can be said to form the basis of the triangle, housing, equipment and drug manufacturers complete the picture.

Many poultry houses today are of the controlled environment type (accommodating from 2 to 20,000 layers or broilers) complete with appropriate equipment. These poultry excrete large amounts of manure and neither agriculture nor horticulture can cope with more than a small proportion of this. Machinery for drying the surplus is now being marketed, in addition to which some of the manure may possibly be processed in future for the production of methane gas, or alternatively compressed into fuel brickettes.

Whilst Calor or mains gas are often used for heating and brooding, electricity is also essential for many other operations—lighting, ventilation, automatic feeders, augers, manure conveyors, egg graders, time switches, etc. Indeed if power cuts take place chaos can be created at many poultry establishments today unless farmers have their own standby generators.

The pharmaceutical industry plays a vital part in helping to keep stock healthy by supplying antibiotics, anti-coccidiosis supplements and medicaments for controlling blackhead, intestinal or septicaemic infections (*E. coli*, Salmonellosis, Mycoplasmosis, etc.), whilst anthelmintics control large round-worms, hair-worms and Gapes. In many instances these are used under veterinary supervision, especially now that more practitioners are becoming keenly interested in all practical aspects of poultry pathology. At the same time it must be remembered that it is usually more economic for farmers to use preventives in the feed (when these are legally available to farmers and feed compounders) than to wait for a disease to develop and then to treat it under veterinary supervision.

These aspects of disease control are of course complementary to the use of vaccines, e.g. for Newcastle disease, I.B., I.L.T., I.A.E., F. cholera and pox.

Adequate disinfection programmes involve the use of steam generators, aerosol spraying equipment, vacuum cleaners, fumigants, germicides and parasiticides, and here too the chemical industry plays an essential part.

Instruments for debeaking, chemical caponisation and for the vaccination of poultry are required, as well as other equipment for egg-cleaning, washing, dipping, etc. For the transport of eggs and poultry, crates, flats and fillers are needed, whilst no large-scale breeding operations are possible without nest boxes, incubators, brooders and the like.

Whilst much of the heavy equipment relates to hen batteries and automatic feeding systems (including bulk delivery vehicles and storage bins), more is required at every egg-packing and poultry processing station. A visit to both of these, and to a modern compound feed mill, should form part of the education of every veterinarian and agriculturalist involved in intensive livestock farming.

Fish Farming

Whilst a 10-year fish farming programme has been set up by the White Fish Authority in conjunction with the Government (relating in part to the breeding of sole and plaice from spawn) it is the freshwater farming of fish which has received publicity recently. For example, in the U.S.S.R. it is believed that 13 million tons of fish from confined waters (ponds and reservoirs) will be available by 1970, whilst in the U.S.A. at the Kansas Tuttle Creek Fisheries, following a 7-year research programme, catfish have achieved a feed conversion of 1:1·1 for less than 5 cents a lb. on pelleted diets containing 25 per cent protein. Here again animal behaviour plays its part because it is known that the number of individuals an area will support is limited by interspecific competition for territory. And natural predators may serve a useful function by the removal of weak or deformed individuals.

Presumably, the controlled flooding of certain areas would be beneficial for this form of intensive livestock farming, once enough is known about fish nutrition, their efficiency of feed conversion, disease control, etc. Current interest in fish farming in Britain, as a supplementary source of first quality protein for human consumption, can be seen from Unilever's announcement in 1966 that they are investing £50,000 in the construction of an experimental fish farm at Lochailort, Inverness-shire.

The recent outbreaks of salmon disease amongst fish in Great Britain has emphasised the fact that systematic studies on piscian pathology are not usual in this country, no veterinary schools making any real effort to teach this subject, whereas fish diseases are taught at Colorado State University, and have also been studied for some time at veterinary schools in Munich, Hungary, Poland and Turkey. Allied aspects of the subject, we are told, are also taught in Iran and Japan.

During the past 6 years, Coarse Fish Conferences have been held at Liverpool University and as a direct result it was decided this year to form a British Fisheries Society to promote fish studies. Veterinary and other workers interested in this field of study, which clearly offers the profession a new challenge, should participate in such meetings; particularly as the B.V.A. has already had useful discussions with the White Fish Authority and believes that there are numerous members of the profession keenly interested in this subject.

W. E. Pearson is one of the very few veterinary surgeons in Britain who spends a considerable amount of time studying practical aspects of fish farming, and his article on this subject (Chapter 22) may stimulate others in the profession to concentrate on this most neglected topic.

Training Stockmen

In discussing the future pattern of British livestock production Professor T. K. Ewer last year emphasised the difficulties of obtaining stockmen with the right qualifications for managing modern stock, housed fully intensively. He pointed out the need for them to be able to recognise different behavioural patterns, to be generally observant and able to detect abnormalities which might indicate the beginnings of disease outbreaks. Allowance also has to be made for the differing effects of stock, climate, feed and disease.

At the same time emphasis was given to the fact that farm livestock are '*sentient beings, sharing deep emotional urges with ourselves*', and that stockmen must therefore really care for both the mental and physical well-being of their charges. The wish was also expressed that it would not be long before we would see '*an end to the attitude of pure exploitation with intensively kept animals*'.

That livestock can suffer physical pain is obvious to all, nevertheless Dr. S. A. Richard's chapter on this subject is very apt. At the same time one can draw upon the imagination far too freely in believing that hens, pigs or cattle, for example, share 'deep emotional' urges with their masters, whereas one would have no hesitation in believing that to be true of the domestic dog.

Just what are these urges and frustrations? Do they refer to the inability to scratch or root the soil; or to an inability to mate normally, either because no males are allowed or because of A.I.? Or are these frustrations linked with confinement, resulting in boredom?

Mental pain would certainly seem to be in evidence from the bellowing of the newly calved cow when suddenly separated from her calf, but fortunately this is very short-lived. Similarly with the physical pain which follows the castration of young pigs or lambs, or the debeaking of pullets. In the case of poultry their main needs are certainly very few and having satisfied these one assumes that their inner urges are of relatively little consequence, otherwise they would pine and become unproductive. That the mental suffering of the higher mammals is infinitely greater than that of cattle for example can be seen from the work of Kaufman and Rosenblum (1967) at the Department of Psychiatry, N.Y. Downside Medical Center. They showed that when infant monkeys were separated from their mothers (*Macaca nemastrina*) for 4 weeks, not only were they initially agitated, but they became severely depressed for about a week. (A reaction in fact comparable to the anaclitic depression of human infants who have lost their mothers.) After being re-united the monkeys showed a marked and prolonged intensification of the mother–infant relationship.

So that no matter what the species, we must train our stockmen to see that their essential needs are completely satisfied, and that they are then watched carefully for any other signs indicative of physical pain or discomfort. This undoubtedly means an insight into the ways in which animals communicate with one another, both vocal and postural.

With the coming tendency for a 5-day working week there is always the risk that methods of management will be developed which will supply the animal's needs for feed and water each weekend without the help of an animal attendant. But this form of automation must be resisted, because unless a daily inspection of a flock or herd is made, valuable signs indicative of mis-management or failing health may be missed.

Few would argue that the present minimum agricultural wage of 216s. for a 44-hour week is adequate for well trained stockmen, and much higher payments must be paid soon, both to them and to more experienced personnel who accept livestock responsibility on a flock/herd basis. Otherwise there will be an even more rapid drift away from agriculture to industry where wages are very much higher. The current average weekly earnings of men in a wide range of manufacturing and non-manufacturing industries (including overtime) is now £20 11s. 7d. for a 46·1-hour week.

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Chapter 24

THE ECONOMICS OF INTENSIVE LIVESTOCK PRODUCTION

W. P. ROBERTS

Introduction

Put in a nutshell, the principal aim in this chapter is to answer two simple questions. First, in general how much profit do farmers make out of intensive livestock production? Second, what are the main factors which dictate whether any individual is successful financially or not?

But, as everybody knows, no economist can ever put anything in a nutshell! If he did, there is always the danger that someone might understand what he was talking about, or so the cynic might remark.

Of course, this sort of comment is familiar to specialists in any field, and simply reflects the increasingly difficult communication problem which has resulted from the tremendous rate of technological progress which we have witnessed over the last 20 years or so. For example, geneticists now have to be mathematicians of high calibre, and their methods have become virtually incomprehensible to the general agriculturalist (and certainly to the economist).

Or take the statistician. He has invaded every field of agricultural activity, from production to marketing, and who on earth can understand him when he is in full flight.

It is not intended to dwell on this problem of communications but it has been introduced at the outset in order to explain how this chapter has been sub-divided, and why. The thinking behind this is as follows.

Given that the specialist has a communication problem to overcome, he is more likely to succeed in doing this if he is conscious of two things. First, he must make clear to his readers, exactly whom he is addressing. If he does this he is more likely to present the material which will most interest that body of people, and, furthermore, it should ensure that he uses the right 'language'. Second, he must reduce to a minimum the 'ifs' and 'buts' which, instinctively, he feels he needs to introduce as qualifications to his statements.

It is hoped that this chapter will interest the general agriculturalist and agricultural specialist in fields other than economics. It is not intended for the economist, who would find the lack of 'ifs and buts' little short of criminal. Nor is it intended for the general farmer who might well find the omission of practical husbandry implications frustrating if not infuriating. (This is not to say that the large-scale specialist producer of intensive livestock may not find it useful.)

Having established this, it was decided that the material most likely to be of interest would be that which answers the two basic questions set out right at the beginning—how profitable is intensive livestock production, and what are the main factors which affect this? But it was felt that, in addition, some comments on a broader issue might be considered of value. This constitutes a reminder of the economic importance of intensive livestock to the agricultural industry and the nation's food supplies.

For the sake of clarity, this issue is dealt with first, in Part 1 of the chapter, and the two basic questions referred to above are considered in Part 2.

Part 1. The Importance of Intensive Livestock Production to the Agricultural Industry and to the Nation's Food Supplies

(*a*) **The Importance of Intensive Livestock to the Industry.** Total output from the agricultural industry has risen steadily over the years and is now approaching £2000 million per annum. The proportion of output from crops on the one hand and livestock on the other has remained fairly constant. These simple facts are illustrated in Table 1.

TABLE 1

AGRICULTURAL OUTPUT 1956–66 (£ MILLION)

	1956	*1958*	*1960*	*1962*	*1964*	*1966*
Crops output	396·6	410·9	409·9	459·4	463·0	527·1
Crops output as percentage of total output	29	28	27	29	28	29
Livestock output	925·8	1026·6	1026·2	1113·0	1170·8	1265·5
Livestock output as percentage of total output	68	70	69	69	70	68
Total output	1352·8	1470·0	1496·4	1609·1	1661·7	1849·1

But within the livestock sector of the industry the contribution made by intensive livestock has risen very markedly. Exactly how much is not easy to measure. For a start it is necessary to define what is meant by the word 'intensive'. For example, do we consider all pig production to be intensive? Many farmers keep their sows outdoors, and on some large arable farms they range over considerable acreages as a means of using a grass break in the rotation.

Or, again, take beef production. We simply do not know what proportion of animals slaughtered are reared on the intensive 'barley beef' system. Because of difficulties like these it is necessary to be clear, for each livestock enterprise, how level of intensity is being regarded. Taking each one in turn, the position is as follows:

(1) *Dairy Cows and Sheep*. For all practical purposes these may be regarded as non-intensive in the sense that they are not housed during the whole of their productive life. Of course, it is true that some people are examining the possibility of keeping large numbers of cows under factory conditions, but the number of cattle involved is very small.

(2) *Pigs*. In spite of the incidence of outdoor breeding systems (and a very little outdoor fattening), for the purposes of this simple analysis all pig production may be regarded as intensive.

(3) *Poultry*. Before the war almost all egg and poultry meat production was extensive by present-day standards. It has been estimated that at the present time 80 per cent of our laying birds are intensively housed, and over 95 per cent of our poultry meat (including turkeys) is produced either through broiler-type production or as a by-product of intensive laying systems.

(4) *Beef and Veal*. Again it is necessary to rely on crude estimates but it seems likely that around 15 per cent of our home-produced beef cattle are reared under so-called 'factory' conditions. Output from intensive veal production is so small that it may be ignored in the context of the present discussion.

If we accept these criteria and estimates we are still left with certain difficulties in arriving at figures for the present-day value of the output from intensive stock. For example, if we take it that 80 per cent of our laying birds are housed intensively, it does not follow that they are producing 80 per cent of our output of eggs. Obviously, they must be producing much more than this (in fact, about 85 per cent), since egg production per hen is, on average, much higher under these conditions.

However, taking all these things into account as best one can, it seems likely that, at the present time, of all livestock and livestock products output, about 25 per cent comes from animals which have been kept intensively.

(*b*) **The Importance of Intensive Livestock in the National Diet.** The importance of meat as a whole in our national diet may be judged from an examination of statistics relating to our eating habits over a period of time. Like all other industrialised nations, we are tending to increase the proportion of our diet coming from animal protein, and of course much of this is produced under intensive conditions.

Once again, there are difficulties in assessing exactly how much. For example, economists might argue endlessly about how much of our imported beef is intensive beef; or how the amount of offal or canned meat coming from animals reared under such conditions may be allowed for, and so on.

The figures shown in Table 2 give an estimate of how important are intensive livestock in relation to our present-day diet (1963).

The Anti-'factory Farming' View

As we all know, this heavy reliance on intensively-reared animals for our protein needs has been bitterly attacked in some quarters over recent years and has led to a Government enquiry resulting in the Brambell Report. It is not the intention to enter into this controversy

TABLE 2

PROPORTION OF OUR ANIMAL PROTEIN COMING FROM INTENSIVELY-HOUSED LIVESTOCK 1963

Total *per capita* intake of animal protein/day (gm.)	52
From intensively-housed stock:	
Battery and deep litter eggs	3·7
Pigs	3·7
Beef and veal	1·1
Intensive poultry	1·5
Offals, etc. from intensive stock	3·9
	13·9
Percentage total animal protein coming from intensively-housed livestock	= 26·7

here. On the other hand, since we are considering the economic background to intensive livestock production, it would be unreasonable to ignore it completely. Therefore, perhaps it might be agreed that a reminder of just a few of the economic implications of the decision either to accept or reject intensive livestock production might not be out of place.

The antagonists to what they call 'factory farming' argue along one or both of two main lines. Some point out that since the world is short of protein, it is not sensible to process vegetable protein through animals since this is, biologically, an inefficient process and, therefore, meat production involves a great waste. In other words, it is desirable that man should turn completely vegetarian and use land to produce vegetable protein for direct human consumption and to reject meat-eating in order to help alleviate world hunger and malnutrition.

Others, who do not go this far, argue that intensive livestock production involves cruelty. They imply that those who produce food in this way are insensitive to the creatures they handle, and that legislation should be introduced to ban what they consider to be inhumane practices.

Meat—A Biological Waste? So far as the first argument is concerned, this revolves round not an economic problem, but a problem of individual conscience. The contention that production of vegetable protein is more efficient in terms of human food production than production of animal protein is irrefutable, of course. But whether or not it is reasonable to try and persuade whole nations to change their dietary habits is doubtful, some would argue ludicrous. If we accept that man is going to carry on being a meat-eater, then, on the grounds of making production of animal protein as biologically efficient as possible, there is everything to be said *for* intensive methods.

It is at this point that economics comes in. It is economic forces which have compelled livestock producers (and the ancillary industries which serve them) to find ways of reducing costs per unit of output. The biggest single cost item in meat production is the animal's food, and it is in this field in particular that great strides have been made. Reduction in food requirements per animal (surely a laudable goal to those who go so far with the 'anti-waste' protagonists but who cannot accept universal vegetarianism as feasible) has come about through a combination of four main advances in technology: one, better management skill on the part of the farmer; two, the breeding of more efficient animals by the geneticist; three, the development of more efficient feeds by the compounder; four, the adoption of intensive methods which provide an environment conducive to efficient food conversion.

So it is that, so far as the first anti-intensive livestock argument is concerned, two basic points may be made. First, if it is a person's view that we should all turn vegetarian in the interests of cutting out waste of vegetable protein through the production of meat, then that view can be respected and there is nothing more to be said. Second, if other people believe that we shall continue to be meat-eaters then surely they must accept that, in the interests of keeping waste of protein to a minimum, intensive livestock production is highly desirable.

Cruelty? So far as the anti-cruelty contention is concerned, economic issues are again pertinent. People who hold these views may attempt to put restrictions on intensity (or, for that matter, a ban on intensive systems altogether) through two principal channels.

First, through persuading the rest of the community that their view is the right one so that demand for meat or eggs coming from intensively-fed animals is reduced or even extinguished.

This process would be a normal economic one. Demand would fall; price would then fall; farmers producing intensive livestock would go out of production; demand for alternatives (eggs from free-range hens, poultry meat from free-range chickens, etc.) would rise; prices for these alternatives would rise; this would make production methods which are uneconomic at the moment become viable propositions; the nation would have voluntarily rejected eggs and meat from intensively-housed stock, and all would be well.

Certainly, no economist could argue that the process described above was anything but reasonable. The nature of demand would have changed and the normal economic chain of events would have taken place.

It is when one considers the other method of attack that danger signals arise. This method is, of course, the formation of pressure groups by the people who hold that intensive livestock production is cruel, with a view to forcing through legislation without it being clear to the majority of the population what effects this may have on them as consumers. This is not to argue that some legislation may not be necessary. From an economist's point of view, that is not the point. His concern is that legislation must, necessarily, have serious economic implications which the general public may not fully appreciate.

Again, it is convenient to look at a likely chain of events should legal restrictions be put on intensive livestock production. First of all, livestock farmers' costs would rise. Unless they are making big profit margins this means that they could no longer sell at the same price. If, as a result, prices rise, then they are no longer competitive with foreign intensive livestock producers and imports would rise considerably. At this point demand would have remained constant (or perhaps fallen very slightly since, in theory, due to transport costs, imported eggs and meat would be slightly higher in price than the equivalent home-produced article).

This all means that, as a nation, we would be eating as much intensively-produced eggs and meat as before, but the home producer would have been forced out of the market. Unfair? Of course. So what would have to be the next step? Possibly a ban on imported foods produced under the offending conditions. But how would we know how they had been produced? Certainly, statistically-based trials have shown that the average consumer is unable to distinguish between battery and free-range eggs, for example.

The only way round this difficulty would be to ban all such imports and guarantee the home producer the market for eggs and meat produced under specific minimum-standard environmental conditions. All well and good, but, as was mentioned at the beginning, these products are going to cost more. Hence we end up with a rise in the cost of living, forced on to the majority by a minority, possibly before the majority become aware of all the implications of the legislation being passed in their name.

We are now entering the field of politics, and it is time to stop. But before leaving this subject altogether, there are just two final points which must be made. First, while the 'anti' people should obviously be free to try and influence public opinion, it is ridiculous that they should hurl brickbats at the 'wicked farmer'. The intensive livestock producer has been forced into the production methods he uses because demand has given him a market and because competition dictates that he is efficient. Without this demand he would have no opportunity to produce at all. What is more, there is no evidence that opposition to so-called 'factory' methods has been reflected in falling demand.

The farmer may be criticised only if he is using methods which go against the dictates of his conscience and is, at the same time, exploiting his animals in order to make excessive profits. Clearly, the first does not apply. As to the money to be made out of intensive livestock production, that is exactly what Part 2 which follows is all about.

Part 2. Intensive Livestock as a Business Proposition

From the point of view of this discussion it is perhaps fortunate that considering efficiency and profitability of intensive livestock production is a relatively simple matter compared with dealing with the efficiency and profitability of general farming. The reason for this is as follows:

The general farmer, that is, one running a number of land-using (plus possibly one or two intensive) enterprises, has a fairly complex economic problem to face in his attempt to maximise 'profit'. He is using three basic resources, land, capital and labour, and he should be aiming to maximise return to his most scarce resource. So it is that comparing the 'efficiency' of farms is difficult. A very simple example will make the point clear.

Suppose two neighbouring tenant farmers, each farming 200 acres, had both invested £10,000 and were making profits of, say, £2000 per annum. Each would be making the same profit per acre and each would be earning a 20 per cent return on capital. So far, so good; they would be equally efficient in their use of land and capital.

Now, suppose one of them manages to get hold of a further £10,000, finds himself unable to rent more land, but expands his present business in such a way that his profit goes up by £1000 per annum. How do the two farms compare now?

The farmer who invested more capital has in fact reduced his percentage return from 20 per cent to 15 per cent. But can we say that he is now less efficient than his neighbour? Not at all. He has increased his return to his most scarce resource (assuming throughout that labour is in plentiful supply), *viz.* land. Can we then say that, since his profit per acre has gone up, he is *more* efficient than the man who was unable to get more capital? Certainly not. He is more prosperous but not necessarily more 'efficient' in the true sense of the word.

We could argue, knowing all the circumstances and with the knowledge that their efficiency was equal before one of them found more capital, that, as managers, they are still, in all probability, equal. But is this true? It could be said that the very fact that one of them strove to find more capital and increased his total profit shows that he is the more go-ahead, ambitious, and therefore more efficient. But, again, this would be unfair if obtaining the extra capital was fortuitous (money left by a relative, for example).

But if it is difficult to compare the efficiency of one farm with another, it is equally difficult to say how profitable is farming, taken as a whole. Once again, the problem is how to measure it. We cannot simply say that on the majority of farms land is the most scarce resource, therefore we can just look at profit per acre and use that as a measure.

Again, a very simple example will help. Suppose we were looking at farms of around the 100-acre mark, we might suggest that a profit (before capital charges) of £20 per acre would give a reasonable income, and that provided farmers make this sort of profit, farming is a reasonable business.

But would we then expect someone farming 2000 acres to make £20 per acre? Obviously not. We would point out that the sort of capital required per acre to give a profit of £20 simply would not be available to someone farming 2000 acres. Even if it were, his management ability would be unlikely to stand up to the sort of intensity which the 100 acres would be demanding to give its £20 profit per acre.

So we are back to the scarce resource once again. The man with a very large acreage is concerned more with return on capital than profit per acre. Then why not measure profitability of small farms in terms of pounds per acre and large farms in terms of return on capital? There are a variety of reasons. For example, where do you draw the line between a small and a large farm? Or again, what about the small farm which has become so intensive that capital and not land has become the limiting factor?

Thankfully, we can leave the topic of general farm profitability at this point. The discussion above has not even touched the fringe of the problem, but has gone far enough to give an inkling of how complex the whole subject is and to allow us to realise how, in contrast, the question of measuring efficiency and profitability of intensive livestock enterprises is simple.

The fundamental reason for this is, of course, that the vast majority of intensive livestock producers are concerned with maximising return on capital.[1] Farm land is not involved, and labour will not normally be a limiting factor. Therefore we can simply measure efficiency and profitability in terms of percentage return on the money invested. Life is simple again! All we must do is decide first how to measure profit, and second how to measure capital invested—then we have our answer. Each of these two will be considered in turn.

How to Measure Profit

To start with a truism, profit is output less costs. Therefore, our first task is to define output and state costs under convenient headings.

[1] It is true that if intensive livestock are kept on a general farm it is arguable that they must be considered as part of the over-all farm system. On the other hand, as units get larger it becomes more and more unrealistic to treat them as anything other than separate businesses.

For the purposes of discussing intensive livestock enterprises output may be defined as:

Sales (including subsidy, if any) *less*

- (*a*) Marketing charges and any levies;
- (*b*) cost of stock at start of fattening period (or depreciation of parent stock in the case of sow breeding units and egg production);
- (*c*) allowance for mortality.

Costs may be conveniently listed as follows:

- (*a*) food cost;
- (*b*) miscellaneous costs (e.g. veterinary and medicines, small tools, straw, fuel, etc.);
- (*c*) labour;
- (*d*) building and equipment depreciation and repairs.

If we express both output and costs on a per-animal basis we can arrive simply at profit per animal. But when we come to deal with our second problem we will find that it is more convenient to express capital invested in terms of 'per animal space' rather than 'per animal'. The reason for this is obvious. When a building is put up for, say, pigs, each pen will accommodate so many pigs at a time and so many batches of pigs in a year. In other words, a building provides 'animal spaces' and it is very simple to express capital invested per space.

But this need not present any difficulty. All we need do is multiply our 'profit per animal' by the number of batches produced in a year (or, if production is continuous, the average number going through any one space in a year) to get 'profit per animal space'.[1]

As a convenient example we may take pork production (see Table 6). Standard profit per pig works out at £0·55. Batches produced in a year = 4·33. Therefore, profit per pig space is £2·38.

How to Measure Capital Employed

The total capital invested in an intensive livestock enterprise is made up of two elements, viz. fixed capital and working capital, as follows:

Fixed capital	Buildings and equipment
	Animals
Working capital	Food
	Miscellaneous costs
	Labour

How these together make up a capital profile for the year may be put simply through considering pork production with output, costs

[1] Where production is on an annual basis, i.e., sows, 12-month beef, and laying hens, this complication does not arise, so that both profit and capital are calculated on a per-animal basis (or per 100 or 1000 birds in the case of poultry).

and capital requirements as shown in Table 6 but, for the sake of simplicity, a throughput of four batches per year.

Figure 72 illustrates, first of all, the investment per pig space at the start of production. Investment in buildings and equipment and in a weaner pig come to £18·62.

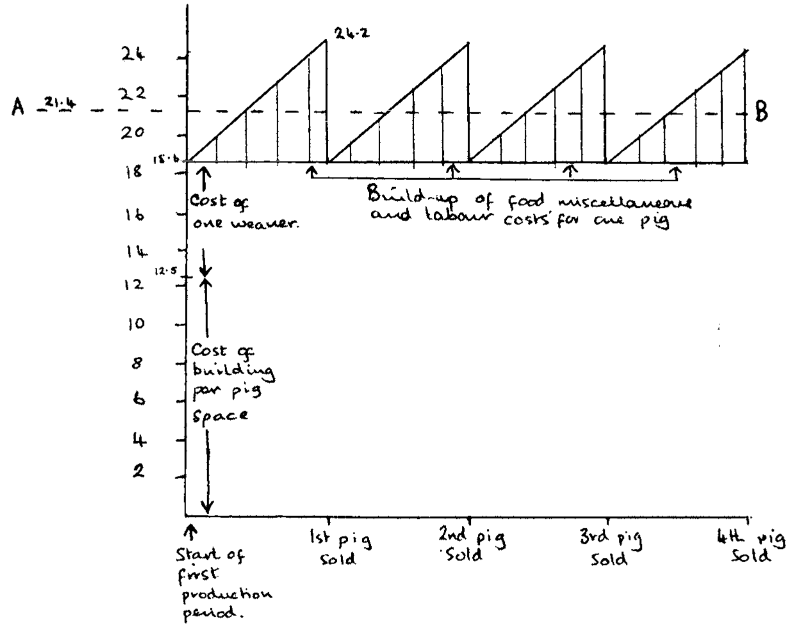

FIG. 72.

Then, as production proceeds, so food, miscellaneous and labour costs mount until they reach a peak at the time the first pig is sold. At that point the total invested is represented by the cost of the building (per pig space), the cost of one weaner plus the food, miscellaneous and labour costs required to produce one pig, viz. £24·21.[1] Then, when the first pig is sold, the proceeds pay off the investment in the weaner, food, miscellaneous costs and labour, and leave a surplus. But then there is an immediate re-investment in another weaner, followed by another build-up of food costs, etc., until the second pig is sold. If four pigs are put through the pig space in a year then this cycle will be repeated twice more.

A glance at Figure 72 shows two things quite clearly. First, there are four peaks in capital requirement per pig space made up of

(*a*) investment per pig space in buildings;
(*b*) the cost of one weaner;
(*c*) the cost, for one pig, of food, miscellaneous, and labour.

[1] This is slightly higher than the peak capital shown in Table 5, for a simple reason explained a little later.

Second, it is clear that the *average* investment over the year is illustrated by line A–B and is made up as follows:

(*a*) investment per pig space in building and equipment;
(*b*) the cost of one weaner;
(*c*) half the cost, for one pig, of food, miscellaneous, and labour.

Thus, we have two figures for capital invested. First we have *peak* capital, and second we have *average* capital. Before going on to discuss these there are just three points to mention.

Dealing with the build-up of food and miscellaneous costs, it was assumed that these gradually mounted until they reached their total per pig. But this is to ignore credit. For this reason the standard figure for peak capital invested in food (and in miscellaneous costs) in pork production (Table 6) shows not food cost per pig but eight-twelfths[1] of food cost per pig. Thus a normal month's credit has been assumed.

The second point to be made is that in Figure 72 the average capital invested includes the full cost of buildings for one pig space. This is correct in the first year. But over the years the buildings are depreciated from their new value to nil. Thus the *average* investment in buildings over their lifetime is *half* their new value. This is the figure used in Table 6.

The third supplementary point to be touched on concerns what happens to the 'surplus' released as each pig is sold. This money is not all profit, of course, since some of it must be reserved (at least in theory) to cover depreciation. Nevertheless, there is undoubtedly a sum of money released as each pig is sold. If this is used to help finance the next cycle, then, surely, the capital required for the next cycle is reduced.

But this is to misunderstand the concept of investment. Perhaps the point is best explained as follows. There are three things which could happen to the money released. First it may be spent on ordinary living expenses, in which case, obviously, more money will need to be found for the next cycle. Second, it might be invested in something other than the pigs, in which case, once again, more money will be required. Third, it might indeed be used to finance the next pig cycle, but, if so, the interest which could have been earned on it elsewhere will have been forgone. In other words, whether the capital used to finance an enterprise is borrowed or found by the businessman himself, in either case it is money invested.

Perhaps this will be made clearer if we go back to consider our two figures for capital, viz., average and peak. The average capital invested is that sum of money on which interest is either paid or forgone. It is the return on this sum which we would normally quote as our 'return on capital'. But the peak capital is also very important, since this tells us the maximum we will have to borrow (or find from our own resources) in order to get the enterprise through its first year.

[1] Assumes a month's credit on a 12-week production cycle.

To complete the picture for pork production (Table 6) we can see that the average capital required per pig space is £15·17 and the return we might expect on this is 15·69 per cent. The *peak* capital requirement per pig space is £22·49. Finally, since we have allowed for 500 pig spaces per man, the average and peak capital required for a 1-man unit are £7585 and £11,245 respectively. The profit which could be expected from a one-man unit is £1190.

A 'Recap'

Perhaps it would be helpful to summarise the position thus far.

1. Given our definition of output and list of cost items, we can readily calculate standard profit per animal and per animal space, given adequate costing data from a large number of farms.
2. From Figure 72 we can see how we can arrive at both average capital and peak capital requirements.
3. Knowing average capital required per animal space and profit per animal space we can calculate percentage return.
4. Knowing peak capital requirement per animal space we can estimate the maximum amount of capital necessary to start a unit of a given size.
5. Having assumed a certain number of animals (and therefore animal spaces) per man in the profit calculation, and knowing both the profit and the average and peak capital required per animal space, we can arrive at an estimate of each of these per one-man unit.

If we make all these calculations for each of the intensive livestock enterprises commonly found on farms, we can then get an over-all picture of profitability in the intensive livestock industry. These figures are shown in Tables 4 to 17. They are derived from data processed by B.O.C.M. Ltd. from records collected during 1965 (revised for current prices, 1967). Output and direct cost figures are either averages or, where extremes would have caused undue distortion, reasonable standards given sensible management. Peak capital costs of buildings and equipment have been charged on prices for new plant, i.e., the standards reflect what could be expected, under average management, were a new unit set up.

In Table 18 is shown a summary of standard and above-average returns on capital, together with capital requirements and profit expectations for one-man units. What conclusions can we draw?

First of all, it is clear that, on average, pig production and intensive beef production give reasonable, but certainly not excessive returns on capital, while the picture for poultry meat and egg production is less satisfactory.

But, as everyone knows, percentage return on capital means little unless we know the degree of risk involved. The biological risk is obvious. But we can get an idea of another aspect through considering the extent to which the standard percentage return on capital is affected by changes in output and costs, both those which are under the control of the farmer and those which are not.

In Table 19 is shown the effect of a 10 per cent change, up or down, in some of the principal factors involved in production. The most striking thing about these figures is the overpowering influence which is exercised by end-product price. For example, a 10 per cent rise in egg price takes the standard return on deep litter hens from only 15 per cent up to 31 per cent. A similar rise in turkey price takes the return from 20 per cent to 40 per cent. But end-product price is largely outside the control of the farmer. So, at least short term, is the cost of the animal at the start of the fattening process, and this also has a marked effect of profitability.

In the case of factors which the farmer can control to any extent, only food cost per animal has a very large effect on his success. In other words, we can say that not only is percentage return on capital no more than reasonable for pigs and beef, and less than this for poultry, but, in addition, the degree of business risk is high.

At this point it is pertinent to enquire why it is, if profits are but moderate and risk high, that farmers are prepared to go in for intensive livestock at all.

Falling Prices. In the first place, it must be realised that prices for most livestock products have been falling steadily over the last decade (see Table 3).

TABLE 3

INDEX OF FARMERS' PRICES FOR SELECTED LIVESTOCK PRODUCTS FOR CALENDAR YEARS 1955–65 INCLUSIVE

(Harvest years 1955–57 inclusive = 100

	1955	*1956*	*1957*	*1958*	*1959*	*1960*	*1961*	*1962*	*1963*	*1964*	*1965*
Bacon	101	102	94	90	88	86	83	88	81	84	81
Other clean pigs	101	100	95	88	88	92	88	92	85	89	86
Beef	101	97	107	107	107	105	111	113	114	119	122
Turkeys	119	74	87	103	91	87	80	87	77	84	78
Other fowls	102	99	99	98	90	89	75	75	75	75	71
Eggs	103	99	102	95	84	85	83	78	81	69	75

If we take eggs as an example we can see that, since end-product price has such an effect on profitability, egg production must have been pretty profitable per unit of output 10 years ago. Incidentally, we know that a 10 per cent rise in egg price probably raises return on capital invested in a battery hen unit by about 19 per cent to roughly 35 per cent. But it would be a mistake to assume that since egg prices were about 25 per cent higher 10 years ago producers' returns on capital were around the 63 per cent mark. Production efficiency (food used per bird, labour cost per bird, etc.) was nothing like as good then as now. However, prices have fallen much more rapidly than efficiency has risen, and it is true that in the 1950s, egg production (in fact, all intensive livestock production except beef) was much more profitable, at least on a per animal basis, than it is today.

This partly explains why people went into intensive production in the first place. They were combating falling profit per animal through increasing the size of their enterprises and securing economies of scale.

With regard to staying in production as prices fall, this may make a lot of sense if buildings (and possibly equipment) are still being used which have already been written off. The importance of this point may be seen by referring, once again, to the standard data for battery hens (Table 16).

If there is no depreciation of buildings or equipment standard profit per hundred laying birds kept in cages goes up from £23·4 to £36·15. Furthermore, average capital invested falls from £142·5 to £87·5. This gives a 41 per cent return on capital. Anybody in this situation may be happily carrying on for the time being but, of course, he cannot put off re-investment in buildings and equipment for ever. For one thing, apart from dilapidations, there is the question of obsolescence. Building and equipment designs improve as the years go by, and there is a limit to how long out-dated plant can be used profitably.

Of course the extent to which this is true varies with type of stock. For example, in the case of pig production, buildings are less critical, so that in very many instances buildings which have been written off for many years may be in use still. What is more, farmers go in and out of pig production to a greater extent than is the case with poultry. This is probably true of beef production, too.

On the other hand, unit size in pig production has grown less rapidly than has been the case for poultry. As more and more large pig fattening units come into being, it is likely that the 'in and out' tendency will fall off.

But, apart from the use of written-off buildings allowing farmers to earn a higher return than standard, there are other reasons why people stay in, and for that matter start, production.

'Make Do and Mend'. In the case of both beef and pig production it is common to adapt buildings originally built at great expense and in monumental proportions for quite some other purpose. A few pounds spent on an old covered yard built originally for dairy cows, or an old barn often produces quite reasonable accommodation.

Once again, the net effect is to increase the profit per animal (since building depreciation is very low) and, at the same time, to minimise capital invested.

Spare-time Job. During the time when the majority of intensive livestock units were still on a relatively small scale, they were often run as subsidiary enterprises on the general farm. Under these circumstances it was commonly found that, in effect, they bore no labour charge, since they were run by general farm staff who had to be paid whether or not the intensive unit was on the farm.

Many an agricultural economist has spent a happy hour arguing with an accountant about whether or not the new unit should be allocated a labour charge. But this is really irrelevant. If a charge is made, then the profitability of some other enterprise is raised because its labour cost has been reduced.

All that really matters is that total farm profit has risen and this extra profit in relation to the extra capital invested in the intensive unit is likely to show a higher return than standard.

This aspect of intensive livestock production, which was particularly common on the family farm, is tending to die out as units become larger, and in a very few years will probably be of no significance except, perhaps, in the case of pig production, particularly breeding.

'The Missing Egg'. The standard figures for egg production shown in Tables 16 and 17 include the average price paid for eggs sold to the Egg Marketing Board through packing stations (except in the case of deep litter hens). But, in fact, only about 60 per cent of all eggs produced in the country are sold this way. The remainder are sold at the 'farm gate', direct to the public and, since they are supposedly 'farm-fresh', they command a premium price.

After allowing for selling costs the net price per dozen has been well above packing station price for a number of years. So it is that very many eggs producers earn a much higher return on capital than is shown in the standard figures.

Integration. Yet another type of poultry producer who often is prepared to stay in production at low profit levels is the one who has 'integrated' production and marketing. The man who packs eggs or processes broiler meat may well decide that it is to his advantage to ensure a basic supply of eggs or birds to his own marketing organisation through being in production himself. Such a move has the added theoretical advantage of spreading his risk. But human nature being what it is, one branch of the business (usually the processing side) is likely to dominate, and one would expect that in practice many people who do this run the production side at below-average efficiency (although there are no data available to prove this one way or the other).

Conclusions. Returning to our two original questions, *viz.*, how important is intensive livestock production to British agriculture (and to our diet), and how profitable is this type of production to the farmer, we can crystallise the answer to the first in the one word 'very' and to the second in the two words 'not particularly'. Nobody would gainsay the first answer, however much they might regret or deplore the fact. Few farmers would disagree with the second answer, either. But other people may wish to discredit this view on the grounds that nobody forces farmers to produce intensive livestock and if profits are not high enough they are free to get out.

But things are not as simple as this. Once a man has committed capital to intensive livestock production he may more or less be forced to carry on, since even a low return at relatively high risk may be preferable to selling out specialist buildings and equipment at a heavy capital loss.

Another important point to remember is that the factor which most dramatically affects his level of profit is end-product price, and over this he has very little if any control.

This being the case, it is worth remembering that any legislation which might result from Brambell-type recommendations and which forces up his costs must surely be paid for by the community through higher prices to the housewife. Apart from any question of fairness, it is simply a fact that the intensive livestock business is not sufficiently profitable to absorb any artificial cost increases.

As mentioned at the outset, it was decided to restrict this consideration of 'The Economics of Intensive Livestock Production' mainly to considering how profitable it is. But many people interested in the subject will be concerned to look at the picture more broadly than this. In particular, they may be interested in the structure of the industry, e.g., the change in number and size of units over time, etc.

Yet others will want to delve deeper into the factors affecting profitability, i.e., they will want to know what husbandry techniques are, in turn, important as 'precursors' to profitability factors.

The answer to these, and many other questions which are inextricably linked with the economics of intensive livestock production will be found elsewhere in this book. This writer is determined to close this chapter at this point before the temptation to qualify and elaborate becomes overwhelming. A simple question was asked and, it is sincerely hoped, a simple answer given.

TABLE 4

PIGS. 8-WEEK WEANING

Basic details	*Standard*	*Above average based on B.O.C.M. sample*
Per sow	£	£
Sales 15 pigs at £6	90·00	98·18
Sow depreciation	5·25	5·25
Gross output	84·75	92·93
Less		
Total food cost including creep (30 cwt.)	54·00	56·17
Miscellaneous direct	5·00	5·00
Labour (£850) (70 sows)	12·14	12·14
Buildings etc. at 10% depreciation	6·16	6·16
Total costs	77·30	79·47
Profit per sow	7·45	13·46

TABLE 4—*cont.*

Basic details	*Standard*	*Above average based on B.O.C.M sample*
Average capital per sow	£	£
Sow (average value)	30·00	30·00
1/25 boar at £50	2·00	2·00
Buildings (half of net cost)	30·80	30·80
Food } half of cost for one litter	13·50	14·04
Miscellaneous } half of cost for one litter	1·25	1·25
Labour } half of cost for one litter	3·04	3·04
Total	80·59	81·13
% Return on average capital	9·24	16·59
Peak capital per sow (1st year)		
Sow	40·00	
Boar	2·00	
Housing	61·60	
Food } after allowing for 1 month's credit	22·50	
Miscellaneous } after allowing for 1 month's credit	2·08	
Labour	6·08	
Total	134·26	
One-man unit, 70 sows		
Average capital per one-man unit	5641	
Peak capital per one-man unit	9398	
Profit per one-man unit	£522	

TABLE 5

PIGS. EARLY WEANING

Basic details	*Standard*	*Above average based on B.O.C.M. sample*
Per sow	£	£
Sales 19 pigs at £6	114·00	128·21
Sow depreciation	5·25	5·25
Gross output	108·75	122·96
Less		
Food 24 cwt. at £35	42·00	73·90
5½ cwt. at £78	21·45	
Miscellaneous direct	6·00	7·22
Labour £850 to 60 sows	14·17	14·17
Housing and equipment at 10% depreciation	5·38	5·38
Total costs	89·00	100·67
Profit per sow	19·75	22·29

TABLE 5—*cont.*

Basic details	*Standard*	*Above average based on B.O.C.M. sample*
Average capital per sow	£	£
Sow (average value)	30·00	30·00
1/20 boar	2·50	2·50
Buildings (half of net cost)	26·87	26·87
Food } half of cost for one litter	12·69	14·78
Miscellaneous } half of cost for one litter	1·20	1·45
Labour } half of cost for one litter	2·83	2·83
Total	76·09	78·43
% Return on average capital	25·96	28·42
Peak capital per sow (1st year)		
Sow	40·00	
Boar	2·50	
Housing	53·75	
Food } after allowing for 1 month's credit	20·16	
Miscellaneous } after allowing for 1 month's credit	1·91	
Labour	5·66	
Total	123·98	
One-man unit, 60 sows		
Peak capital per one-man unit	4565	
Average capital per one-man unit	7439	
Profit per one-man unit	£1185	

TABLE 6

PORK PRODUCTION

Basic details	*Standard*	*Above-average based on B.O.C.M. sample*
Per pig	£	£
Sales 140 lb. l.w. 5 sc. d.w. at 51·5s.	12·87	
Less		
Marketing and P.I.D.A.	0·32	
Net receipts	12·55	12·00
Weaner 40 lb.	6·00	5·60
2% mortality	0·12	0·11
Gross output	£6·43	6·29

TABLE 6—*cont.*

Basic details	*Standard*	*Above average based on B.O.C.M. sample*
Less	£	£
Food 100 lb. l.w.g. at 12d.	5·00	4·48
Miscellaneous	0·20	0·20
Labour £850 per man, 2165 pigs per year (500 pig spaces)	0·39	0·35
Buildings etc., 10% of £12·5 per pig space	0·29	0·25
Total costs	5·88	5·28
Profit per pig	0·55	1·01
Weeks in fattening house = 12		
Batches a year = 4·33		
Profit per pig space	2·38	4·55
Average capital per pig space		
Buildings and equipment (half of net cost)	6·25	5·92
Weaner	6·12	5·71
Food (half of cost for one pig)	2·50	2·24
Miscellaneous (half of cost for one pig)	0·10	0·10
Labour (half of cost for one pig)	0·20	0·18
Total	15·17	14·15
% Return on average capital	15·69	32·16
Peak capital per pig space (1st year)		
Buildings and equipment	12·50	
Weaners	6·12	
Food (after allowing for 1 month's credit)	3·22	
Miscellaneous (after allowing for 1 month's credit)	0·25	
Labour	0·40	
Total	22·49	
One-man unit, 500 pig spaces		
Average capital per one-man unit	7,585	
Peak capital per one-man unit	11,245	
Profit per one-man unit	£1,190	

Table 7
CUTTER PRODUCTION

Basic details	*Standard*	*Above-average based on B.O.C.M. sample*
Per pig	£	£
Sales 170 lb. l.w. 6·25 sc. d.w. at 46s.	14·38	
Less		
Marketing and P.I.D.A.	0·35	
Net receipts	14·03	14·63
Weaner 40 lb.	6·00	6·00
2% mortality	0·12	0·12
Gross output	7·91	8·51
Less		
Food 130 lb. l.w.g. at 11½d.	6·23	6·46
Miscellaneous	0·20	0·20
Labour £850 per man 1855 pigs per year (500 pig spaces)	0·46	0·42
Buildings etc. 10% of £13·3 per pig space	0·36	0·30
Total costs	7·25	7·38
Profit per pig	0·66	1·13
Weeks in fattening house = 14		
Batches a year = 3·71		
Profit per pig space	2·45	4·52
Average capital per pig space		
Buildings and equipment (half of net cost)	6·65	6·00
Weaner	6·12	6·12
Food } half of cost for one pig	3·12	3·23
Miscellaneous } half of cost for one pig	0·10	0·10
Labour } half of cost for one pig	0·23	0·21
Total	16·22	15·66
% Return on average capital	15·10	28·86
Peak capital per pig space (1st year)		
Buildings and equipment	13·30	
Weaner	6·12	
Food } after allowance for 1 month's credit	4·45	
Miscellaneous } after allowance for 1 month's credit	0·14	
Labour	0·46	
Total	24·47	
One-man unit, 500 pig spaces		
Average capital per one-man unit	8,110	
Peak capital per one-man unit	12,235	
Profit per one-man unit	£1,225	

TABLE 8
BACON PRODUCTION

Basic details	*Standard*	*Above-average based on B.O.C.M. sample*
Per pig	£	£
Sales 200 lb. l.w. at 7½ sc. d.w. at 47s.	17·60	
Less		
Marketing and P.I.D.A.	0·39	
Net receipts	17·21	16·98
Weaner 40 lb.	6·00	6·00
2% mortality	0·12	0·12
Gross output per pig	11·09	10·86
Less		
Food 160 lb. l.w.g. at 12·5d.	8·33	7·80
Miscellaneous	0·25	0·25
Labour £850 per man, 1370 pigs per year (500 pig spaces)	0·62	0·55
Buildings etc. 10% on £15 per pig space	0·55	0·53
Total costs	9·77	9·13
Profit per pig	1·34	1·73
Weeks in fattening house = 19		
Batches a year = 2·74		
Profit per pig space	3·67	5·61
Average capital per pig space		
Buildings and equipment (half of net cost)	7·50	7·50
Weaner	6·12	6·12
Food } half of cost for one pig	4·17	3·90
Miscellaneous } half of cost for one pig	0·12	0·18
Labour } half of cost for one pig	0·31	0·28
Total	18·22	17·98
% Return on average capital	20·14	31·20
Peak capital per pig space (1st year)		
Buildings and equipment	15·00	
Weaner	6·12	
Food } after allowance for 1 month's credit	6·58	
Miscellaneous } after allowance for 1 month's credit	0·20	
Labour	0·62	
Total	28·52	
One-man unit, 500 pig spaces		
Average capital per one-man unit	9,110	
Peak capital per one-man unit	14,260	
Profit per one-man unit	£1,835	

TABLE 9

HEAVY HOG PRODUCTION

Basic details	*Standard*	*Above-average based on B.O.C.M. sample*
Per pig	£	£
Sales 260 lb. l.w.g. 10·25 sc. d.w. at 41s.	21·01	
Less		
Marketing and P.I.D.A.	0·48	
Net receipts	20·53	20·53
Weaner 40 lb.	5·65	5·10
2% mortality	0·12	0·12
Gross output per pig	14·76	14·91
Less		
Food 220 lb. l.w.g. at 12·8d.	11·73	11·11
Miscellaneous	0·23	0·23
Labour £850 per man, 1180 pigs per year (500 pig spaces)	0·72	0·64
Buildings etc. 10% on £15 per pig space	0·64	0·58
Total costs	13·32	12·56
Profit per pig	1·44	2·35
Weeks in fattening house = 22		
Batches a year = 2·36		
Profit per pig space	3·41	5·88
Average capital per pig space		
Buildings and equipment (half of net cost)	7·50	7·50
Weaner	5·77	5·42
Food } half of cost for one pig	5.87	5·55
Miscellaneous } half of cost for one pig	0·12	0·12
Labour } half of cost for one pig	0·36	0·32
Total	19·62	18·91
% Return on average capital	17·38	31·09
Peak capital per pig space (1st year)		
Buildings and equipment	15·00	
Weaner	5·77	
Food } after allowance for 1 month's credit	9·60	
Miscellaneous } after allowance for 1 month's credit	0·19	
Labour	0·72	
Total	31·28	
One-man unit, 500 pig spaces		
Average capital per one-man unit	9,810	
Peak capital per one-man unit	15,640	
Profit per one-man unit	£1,705	

TABLE 10
BEEF: 12-MONTH BEEF FROM 1-WEEK OLD CALVES (STEERS)

Basic details		*Standard*
Per head		£
Sales 896 lb. l.w. 512 lb. d.w. (57%)		
2s. 11d. lb.		74·50
Subsidy		10·25
Gross receipts		84·75
Less		
Marketing, say		1·75
Net receipts		83·00
Less		
Calf at 1 week:	18·00	
Losses at 6%	1·08	
		19·08
Gross output		63·92
Food		
to 3 months	7·2	
3 months to slaughter	40·9	
hay	0·8	
Total food		48·90
Miscellaneous		1·06
Labour £850 per man, 200 head		4·25
Buildings at £15 per head		1·50
Total costs		55·71
Profit per head		8·21
Average capital per beast		
Buildings and equipment (half of net cost)		7·50
Calf		19·08
Food	half of cost for one animal	24·45
Miscellaneous	half of cost for one animal	0·53
Labour	half of cost for one animal	2·13
Total		53·69
% Return on average capital		15·30
Peak capital per beast (1st year)		
Buildings and equipment		15·00
Calf		19·08
Food	after allowance for 1 month's credit	44·83
Miscellaneous	after allowance for 1 month's credit	0·59
Labour		4·25
Total		83·75
One-man unit, 200 head		
Average capital per one-man unit		10,738
Peak capital per one-man unit		16,750
Profit per one-man unit		£1,642

TABLE 11

BEEF: 12-MONTH BEEF FROM 3-MONTHS-OLD CALVES (STEERS)

Basic details	*Standard*
Per head	£
Sales 896 lb. l.w. 512 lb. d.w. (2s. 11d. per lb.)	74·50
Subsidy	10·25
Gross receipts	84·75
Marketing	1·75
Net receipts	83·00
Less	
Calf: 30·00	
Losses at 3%: 0·90	30·90
Gross output	52·10
Less	
Food	41·10
Miscellaneous	0·66
Labour one man £395 a year (344 spaces)	2·15
Buildings	1·02
Total costs	44·93
Profit per head	7·17
Calves per space per year: 1·15	
Profit per space	8·26
Average capital per space	
House (half of net cost)	6·65
Calf	30·90
Food (half of cost for one animal)	20·05
Miscellaneous (half of cost for one animal)	0·33
Labour (half of cost for one animal)	1·08
Total	59·01
% Return on average capital	14·00
Peak capital per space (1st year)	
House	13·30
Calf	30·90
Food (after allowance for 1 month's credit)	36·54
Miscellaneous (after allowance for 1 month's credit)	0·29
Labour	2·15
Total	83·18
One-man unit, 395 head per year, 344 spaces	
Average capital per one-man unit	20,299
Peak capital per one-man unit	28,614
Profit per one-man unit	£2,841

TABLE 12

BEEF: CALF REARING

Basic details		*Standard*
Per head		£
Weaned calf sold		28·00
Less		
Cost of calf:	15·00	
Casualties at 5%:	0·79	15·79
Gross output		12·21
Less		
Food concentrates:	7·20	
Hay:	0·60	
Total food		7·80
Miscellaneous		0·40
Labour £850 per man, 400 calves		2·13
Buildings		0·50
Total costs		10·83
Profit per head		1·38
Batches a year: 4·0		
Profit per space		5·52
Average capital per space		
Buildings and equipment (half of net cost)		10·00
Calf		15·79
Food	half of cost for one animal	3·90
Miscellaneous	half of cost for one animal	0·20
Labour	half of cost for one animal	1·07
Total		30·96
% Return on average capital		17·83
Peak capital per space (1st year)		
Buildings		20·00
Calf		15·79
Food	after allowance for 1 month's credit	5·20
Miscellaneous	after allowance for 1 month's credit	0·26
Labour		2·13
Total		43·38
One-man unit, 400 head per year, 100 spaces		
Average capital per one-man unit		3096
Peak capital per one-man unit		4338
Profit per one-man unit		£552

TABLE 13

TURKEYS

Basic details	*Standard*	*Above-average based on B.O.C.M. sample*
Per 100 birds sold	£	£
Sales 13·76 lb. l.w. at 2·13s. lb. l.w.	146·54	158·63
Poult cost	37·50	37·50
Mortality at 12%	4·50	4·50
Gross output per 100 birds	104·54	116·63
Less		
Food at £45·5 per ton (C.R. 2·83)	79·12	81·55
Miscellaneous	6·10	5·54
Labour £850 per man (6160 birds sold per batch of 7000 started)	4·76	4·71
Buildings, Equipment } £1·10 per bird space × 12·5% per year	4·74	5·15
Total costs	94·72	96·95
Profit per 100 birds	9·82	19·68
Days in house, 112+14 cleaning		
Batches per year, 2·897		
Profit per 100 bird spaces per year	28·45	57·01
Average capital per 100 bird spaces		
Buildings and equipment (half of net cost)	55·00	120·00
Poults	42·00	42·00
Food } half of cost for 100 birds	39·56	40·77
Miscellaneous } half of cost for 100 birds	3·05	2·77
Labour } half of cost for 100 birds	2·37	2·36
Total	141·98	207·90
% Return on average capital	20·04	27·42
Peak capital per 100 bird spaces (1st year)		
Buildings and equipment	110·00	
Poult	42·00	
Food } after allowance for 1 month's credit	51·50	
Miscellaneous } after allowance for 1 month's credit	3·96	
Labour	4·74	
Total	212·20	
One-man unit = 6160 birds sold (7000 started)		
Average capital per one-man unit	8,746	
Peak capital per one-man unit	13,072	
Profit per one-man unit	£1,753	

TABLE 14

BROILERS: SELLING AT MORE THAN 65 DAYS

Basic details	*Standard*	*Above-average based on B.O.C.M. sample*
Per 1000 birds started	£	£
Sales 4·31 lb. l.w. at 1s. 6d. lb. l.w.	323·57	327·01
Chick cost	63·00	63·00
Mortality at 3·5%	2·20	1·95
Gross output	258·37	262·06
Less		
Food (C.R. 2·45) £40·908 per ton, 10·29 lb.	187·90	183·64
Miscellaneous	27·70	26·50
Labour £850 per man (15,000 birds started, 14,475 finished) 68 days + 14 for cleaning out = 82-day cycle = 4·45 crops per year	13·20	13·14
Buildings 10s. per bird housed at 10% per year	11·60	11·56
Equipment 2s. 6d. per bird housed at 15% per year	4·36	4·34
Total costs	244·76	239·18
Profit per 1000 birds	13·61	22·98
Days in house 68 + 14 cleaning out		
Batches per year, 4·45		
Profit per 1000 bird spaces per year	60·56	101·83
Average capital per 1000 bird spaces		
Buildings and equipment (half of net cost)	312·50	312·50
Chicks	65·20	64·95
Food } half of cost for 1000 birds	93·95	91·82
Miscellaneous } half of cost for 1000 birds	13·85	13·25
Labour } half of cost for 1000 birds	6·60	6·57
Total	429·10	489·09
% Return on average capital	12·31	20·82
Peak capital per 1000 bird spaces (1st year)		
Buildings and equipment	625·00	
Chicks	65·20	
Food } after allowance for 1 month's credit	87·18	
Miscellaneous } after allowance for 1 month's credit	12·86	
Labour	13·20	
Total	803·44	
One-man unit, 15,000 birds		
Average capital per one-man unit	7,123	
Peak capital per one-man unit	12,052	
Profit per one-man unit	£877	

TABLE 15

BROILERS: SELLING AT 65 DAYS AND UNDER

Basic details	*Standard*	*Above-average based on B.O.C.M. sample*
Per 1000 birds started	£	£
Sales 4·11 lb. at 1s. 6d. lb. l.w.	308·34	310·73
Chick cost	73·00	62·00
Mortality 3·40%	2·14	1·27
Gross output	243·20	246·46
Less		
Food (C.R. 2·33) £41·221 per ton	173·65	172·24
Miscellaneous	25·30	24·71
Labour £850 per man per year (15,000 birds started, 14,490 finished) 63 days + 14 cleaning out = 77 days = 4·74 crops per year	12·37	12·31
Buildings 10s. at 10% per year	10·92	10·89
Equipment 2s. 6d. at 15% per year	4·10	4·09
Total costs	226·34	224·24
Profit per 1000 birds	16·86	22·22
4·74 crops per year *Profit per 1000 bird spaces per year*	79·94	105·33
Average capital per 1000 bird spaces		
Buildings and equipment (half of net cost)	312·50	312·50
Chicks	65·14	64·27
Feed } half of cost for 1000 birds	86·83	86·11
Miscellaneous } half of cost for 1000 birds	12·65	12·35
Labour } half of cost for 1000 birds	6·19	6·15
Total	483·31	481·38
% Return on average capital	16·54	21·88
Peak capital per 1000 birds (1st year)		
Buildings and equipment	625·00	
Chicks	65·14	
Feed } after allowance for 1 month's credit	74·40	
Miscellaneous } after allowance for 1 month's credit	10·84	
Labour	12·37	
Total	787·75	
One-man unit, 15,000 birds		
Average capital per one-man unit	7,003	
Peak capital per one-man unit	11,414	
Profit per one-man unit	£1,158	

TABLE 16

LAYERS—BATTERY CAGES

Basic details	*Standard*	*Above-average based on B.O.C.M. sample*
Per 100 birds housed	£	£
Sales 225 eggs at 2·93s. per doz. (18·75 doz.)	274·60	278·53
84 birds at 3s. per bird	12·60	12·60
	287·20	291·13
Less		
Point-of-lay pullet at 17s. 6d.	87·50	87·50
Gross output	199·70	203·63
Less		
Food 4·9 lb. per doz. at £34·875 per ton	143·04	140·01
Miscellaneous	9·88	10·12
Labour £850 per man 8000 birds	10·63	10·63
Buildings 11s. per bird at 10%	5·10	5·10
Equipment 11s. per bird at 15%	7·65	7·65
Total costs	176·30	168·51
Profit per 100 birds	23·40	30·12
Average capital per 100 birds		
Buildings } half of net cost	27·50	
Equipment } half of net cost	27·50	
Pullet	87·50	
Feed		
Miscellaneous		
Labour		
Total	142·50	142·50
% Return on average capital	16·42	21·14
Peak capital (as average capital)		
One-man unit, 8000 birds		
Average capital per one-man unit } Peak capital per one-man unit }	11,400	
Profit per one-man unit	£1,872	

TABLE 17

LAYERS—DEEP LITTER

Basic details	*Standard*	*Above-average based on B.O.C.M. sample*
Per 100 birds housed	£	£
Sales 202 eggs at 3s. 4d. per doz. (16·83 doz.)	270·08	280·20
85 birds at 3s.	12·75	13·14
	282·83	293·34
Less		
Point-of-lay pullet at 17s. 6d.	87·50	87·50
Gross output	195·33	205·84
Less		
Food 5·40 lb. per doz. at £31·432 per ton	127·48	123·08
Miscellaneous	8·87	8·92
Labour £850 per man per year 5000 birds	17·00	17·00
Buildings 24s. per bird at 10%	12·00	12·00
Equipment 6s. 6d. per bird at 15%	4·88	4·88
Total costs	170·23	165·88
Profit per 100 birds	25·11	39·96
Average capital per 100 birds		
Buildings } half of net cost	60·00	
Equipment } half of net cost	16·25	
Pullet	87·50	
Total	163·75	163·75
% Return on average capital	15·33	24·40
Peak capital (as average capital)		
One-man unit, 5000 birds		
Average capital per one-man unit } Peak capital per one-man unit }	8188	
Profit per one-man unit	£1255	

N.B. The majority of people using deep litter are selling in a retail or semi-retail market. Their price per dozen is therefore considerably in excess of packing station price.

TABLE 18

SUMMARY

	Table	*Standard % return*	*Average capital One-man unit*	*Profit One-man unit*	*Above average B.O.C.M. % return*
	Pigs		£	£	
4	8-week weaning	9·24	5,641	522	16·59
5	3-week weaning	25·96	4,565	1,185	28·42
6	Pork	15·69	7,585	1,190	32·16
7	Cutter	15·10	8,110	1,225	28·86
8	Bacon	20·14	9,110	1,835	31·20
9	Heavy hog	17·38	9,810	1,705	31·09
	Beef				
10	1 week—12 months	15·30	10,738	1,642	—
11	3—12 months	14·00	20,299	2,841	—
12	Calf rearing to 3 months	17·83	3,096	552	—
	Poultry				
13	Turkeys	20·04	8,746	1,753	27·42
14	Broilers more than 65 days	12·31	7,123	877	20·82
15	Broilers less than 65 days	16·54	7,003	1,158	21·88
16	Layers—cages	16·42	11,400	1,872	21·14
17	Layers—deep litter	15·33	8,188	1,255	24·40

TABLE 19

EFFECT ON STANDARD PERCENTAGE RETURN ON CAPITAL OF A 10 PER CENT RISE OR FALL IN CERTAIN OUTPUTS AND COSTS

±10 per cent in:	*End product price*	*Cost of animal start of fattening*	*Feed cost per animal*	*Building and equipment per animal*	*Labour cost per animal*	*Days to fattening*
Pigs						
8-week weaning	18	—	7	1	2	—
3-week weaning	15	—	8	2	2	—
Pork	37	19	14	2	1	2
Cutter	33	15	14	2	1	2
Bacon	26	10	12	2	1	2
Heavy Hog	25	7	14	2	1	2
Beef						
0–12 month beef	14	4	10	1	1	—
3–12 month beef	15	7	9	1	1	2
Calf rearing (to 3 months)	36	22	10	1	3	2
Poultry						
Turkeys	20	9	17	2	1	2
Broilers (more per 65 days)	29	6	18	2	1	3
Broilers (less per 65 days)	30	7	18	3	1	3
Layers (cages)	19	—	11	1	1	—
Layers (deep litter)	16	—	9	2	1	—

Chapter 25

THE COMMON MARKET—COMPUTERS—CONTRACTS—COSTINGS—COMPETITION

W. P. BLOUNT

The Common Market

Many economists believe that it will benefit Britain if we do enter the Common Market, although some agricultural economists have their doubts so far as livestock producers are concerned. They say that the average British family's food bill is likely to rise by about 7 per cent, although spread over a reasonable transitional period this would be little more than 1 per cent per annum which the housewife would not readily perceive.

Adapting U.K. farm prices to those prevailing in the community might increase producer prices by as much as 10 per cent; but if these in turn reflected higher prices for farm products, might this not induce those with lower wage packets to move towards cheaper starchy foods?

In the long run would we not lose the basis of stability which has been built so effectively into our support system? Might we not find the under-employed (including veterinary surgeons) in France, Italy and elsewhere tending to flood our labour market? Would we have to give up our existing animal health protection systems and start vaccinating pigs and cattle against foot and mouth disease, and use live virus poultry vaccines?

A careful study of many of these possibilities has been made by A. W. Ashby whose lucid contribution on the impact of Britain's entry into the E.E.C. provides most stimulating reading (Chapter 27).

Computers

One reads almost daily of a new use for computers, although many national organisations like the Milk or British Egg Marketing Boards, large business concerns (Ross, Unilever, etc.), geneticists and breeding organisations have used them for many years. But few farmers are able to understand their obvious complexity or realise their great potential, hence the special value of the account of this subject written by P. Roberts (Chapter 28). The Minister of Technology's recent grant of £195,000 to Edinburgh University's Department of Computer Science presumably brings the U.K. nearer to the time when a cheap, nation wide, computer grid will be available to specialist users.

Integration, and Marketing and Contracts

Food producers will only prosper if they satisfy consumer demands, so that there must be some form of integration or co-operation between the producer, processor and seller. Whilst this co-ordination is often *horizontal*, to ensure that the flow of livestock products is completely satisfactory *vertical* integration is taking over in some areas. This gives the smaller agricultural enterprise some of the advantages of large-scale management, rationalising marketing and spreading the risk.

Vertical integration (V.I.) was the subject of a study group initiated in January 1964 by the N.F.U. Council as there was then a fear that producers might lose their independence. The definition given was as follows: 'V.I. involves the linking together of different stages of the production and marketing complex under unified control'. Whilst this wording was not fully satisfactory, it presumably covered the production in quantity, of regular supplies of a uniform product at as low a cost as was consistent with the quality required.

This subject entails forward budgeting, cost control and large-scale intensive production methods based on standard costs; and the whole of the buying, production and marketing should be integrated under a *producer controlled* central direction. This usually leads to economies of scale, lower production costs and greater uniformity; but the small producer cannot compete effectively with this kind of set up, hence the modern emphasis on the Co-operative movement. This is one method by which many smaller producer members can remain viable, representing a good example of *horizontal* integration.

The N.F.U. Report stressed the improvements which had resulted since the war following research into genetics, animal nutrition, husbandry and veterinary matters; especially as regards beef, pigs and poultry production. It also pointed out that factory or concrete farming required less agricultural land but more capital, two facets which lent themselves to *non-agricultural* investment; hence the risk that many fully integrated units would not be producer controlled.

In one sense farmers' buying groups (which had increased rapidly) partly fulfilled the bill, but only if they were linked to farmers' Co-operative marketing groups whose main aim is to supply what the customer wants.

From the business point of view the question of finance for capital investment or working purposes was stressed, since this plays an important part in any integrated unit and means either large-scale borrowing or the provision of credit. In so far as credit is concerned many Co-operative and other societies are unable to provide long-term credit facilities, and in quite a number of cases farmers have turned to their feed merchants to solve this problem. For these reasons the N.F.U. wanted the Agricultural Corporation to be strengthened, and more trade to be diverted to the Agricultural Central Trading Ltd.

Under some circumstances contractual arrangements fit the picture (as seen in the U.S.A.), but in Britain these have usually been avoided, i.e. where a national feed manufacturer supplies broiler chicks, litter, feed, veterinary supplies and technical know-how, in return for which the 'farmer' supplies the buildings, water, electricity and labour. As regards such poultry *contracts*, it was felt that the choice of chick and feed should be determined by the producer-controlled organisation, and not imposed from outside.

Integration may also help to dispense with expensive sales promotion techniques, thus helping the group to compete more equally on terms with large-scale producers.

The 'Lamb Contract' was considered by the N.F.U. to be impressive. The master contract being signed by the central organisation, producers within this contract being organised into small local groups, with their own chairman.

The N.F.U. also rightly stressed the risks of over-producing commodities following 'integrations', but no large-scale operator today functions for long unless he has satisfactory and comparatively long-term marketing arrangements.

Farm Costings

Intensive husbandry systems should be geared so that they increase to the maximum, animal production per unit input of capital and labour; hence the value of farm costings for measuring these against the value of outputs. My colleague Bill Roberts describes the subject in considerable detail, supported by J. A. Miles who outlines the value of a costings service to the poultry industry (Chapters 24 and 13)

It is of course the *efficiency* of the livestock enterprise which counts most, and although this may entail the use of controlled environmental buildings, in some instances adequate returns can still be achieved from less sophisticated units. In general this means that less attention will be given to individual animals, but this does not mean that they will be subjected to either carelessness or cruelty.

Competition

The complexities of competitive interactions are seldom appreciated, even such a simple matter as the everyday relationship between butter and margarine.

Eggs are in direct competition with cereals like cornflakes, in fact with every commodity which can form a breakfast substitute. Only where eggs are essential can one rely on their use exclusively, and this is certainly not the case with the thousands of people who prefer half a grapefruit, toast and marmalade for their breakfast; or who want a quick evening T.V. snack. A chicken pie is much simpler to manage than many egg dishes.

If we are to increase consumption from 240 to 270 or even 300 eggs per person per year (as in the U.S.A. and Canada) we have got to extol their nutritional and other virtues, and show just how often they can be used economically day in, day out.

Sausages are similarly in competition with bacon, tomatoes, fish and chips, chops, cutlets, steak and kidney or chicken pies. *Red meats* compete with chicken and if the former rise in price or are in short supply, housewives quickly turn to *broilers*. Some are even prepared to use *rabbit* meat, the production of which is again booming to the advantage of many producers, particularly those who live near rabbit packing stations.

It is fortunate that sheer economics alone do not dominate the housewife's attitude towards her meat purchases, otherwise she would be demanding more facts from her butcher/poulterer about which joints provide the cheapest portions of edible meat. The yield is lower from the duck than it is from the chicken, but higher still from the broad-breasted turkey. One seldom gets more than four portions even from the biggest duck so that this alone puts it in the luxury class of poultry meat. The retailer of course knows these interactions better than anyone, and W. M. Justice describes the situation with accuracy and clarity (Chapter 26).

America has taught us that many housewives today are not prepared to spend much time preparing meals, they must preferably be purchased as ready to heat and serve as 'convenience' packs. Therefore to compete with 4–6 oz. lamb cutlets or 8–12 oz. steaks, cut-up chicken/turkey portions are available; as well as turkey steaks, boneless turkey rolls, chicken burgers (replacing hamburgers), chicken/turkey sausages (replacing beef or pork), quick frozen pies and other T.V. specialities. Here again, there is competition, this time between such self-service stores and the local butcher, poulterer, grocer and fruiterer.

Chapter 26

THE IMPACT OF INTENSIVE LIVESTOCK PRODUCTION ON FOOD CHAIN ORGANISATIONS

W. M. JUSTICE

Having spent the whole of one's working life so far in the employ of just one organisation, whose geographical boundaries in the retail sense are limited to an area of about 120 miles from London, must impose quite considerable limitations on the breadth of one's experience. Such comments as follow must quite clearly be read against this limiting background.

Another factor which should be borne in mind is that as compared with many, if not the great majority of other multiple traders, our own company's operation sells a high proportion of 'perishables' as against relatively non-perishable lines or hard goods such as cans, packets, etc.

Over the last 15 years two trends have made substantial impacts on the food industry here in Britain, one the adoption of self-service methods in food retailing, the other the spectacular growth of intensive livestock production. Whether either could have succeeded as much or in as short a space of time without the existence of the other is perhaps doubtful. Both are often thought of as essentially big-business methods, each has become dependent upon the other. One has provided a regular large volume supply, the other has added a sharper edge to retail competition and thus has had a substantial influence in assuring more efficient and much improved distribution.

It was not until mid-1954 that food rationing disappeared, when meat, the last of the rationed commodities became free again. Self-service retailing in Britain began to get into its stride at about the same time. The speed with which the movement has accelerated in the last 5 years makes it perhaps hard to realise now how shallow its history. It was in fact in 1950 that Sainsburys opened their first self-service store opposite West Croydon Station some ten miles to the south of London. Although we were not the first we were by no means laggards in experimenting with this development. There were good reasons why in the preceding years such development could not proceed freely. Quite apart from building restrictions, rationing of a number of food commodities was in force and self-service stores could not in practice be much more than about half self-service, for it was quite impractical to expect customers to serve themselves with the appropriate amount of rationed foods! It was bad enough to have to deal with the problems of commodities which although not officially rationed, were still inadequately supplied, such as sausages or cream biscuits. These headaches although only two-aspirin in size were nevertheless a regular part of a food retailer's life in those days. Self-service essentially requires adequate supplies.

There was much to learn. In our early ignorance the only effective way of preventing an excess of customers from completely clogging up traffic within the store was to shut the entrance door. Shut the door once a day, business was good, shut it twice, it was better. Somehow the logic fell down, we felt, if you shut it all day.

The tradition of breaking bulk, of weighing up and preparing perishable food stuffs on the counter in front of the customer, common until that time in traditional service shops, died hard. Initially doubt and scepticism were encountered regarding the success of the alternative method of pre-packaging behind the scenes. Until now the customer had liked to see her pound of butter cut from the lump and patted up in front of her or to have her biscuits weighed out of the tin or her bacon sliced on the machine on the counter. By dint of careful attention to quality control and to management in general the new self-service evolution (or was it revolution) slowly removed the majority of such operations from the shop itself to various preparation-rooms above, behind and below the selling area of the shop.

Gradually the consumer gained confidence in the trader of her choice and came to accept—and indeed appreciate—the reliability of *his* pre-packed perishable commodities. She liked the convenience and visible improvements in hygiene they provided. Instead of weighing and wrapping the various commodities in front of the customers (and whilst she waited) the self-service way was to pre-pack in a transparent cover and present the product to the purchaser marked with the weight and price. The only problem (or almost the only problem!) was how to get these perishable commodities packed and on display in sufficient quantities to cope with the enormous weekend peak demand from the public without employing an unnecessarily large labour force during the early part of the week.

Refrigeration began to play an increasingly important part; the possibilities of transferring much of this preparation work from the back premises of the retail store to a place where the high cost of urban rents would cease to be a factor rapidly became apparent. The difficulties in recruiting an adequate labour force for the distributive trades obviously hastened this trend. The larger retail units which came with the advent of self-service methods rapidly pointed the moral that centralised preparation—bringing in its train a more efficient labour utilisation—was a must, to be sought wherever technical product considerations made such a policy viable. It was against this almost open door that the first production of broiler chickens in Britain pushed, for it was in 1953, as I remember, that the first signs of an emergent broiler industry in the U.K. came to be noticed. About this time one of the best currently known figures of the poultry industry, now a giant in his field, started out in Sussex with half a cowshed converted for broiler production.

FIG. 73. The modern housewife helps herself to the goods she wants, but in passing down the long counters of the newly designed supermarkets often sees others which take her fancy. Tinned, frozen or other packaged goods are all clearly price displayed.

There is little doubt how much assistance this development of intensive chicken production gave to self-service retailing; equally without the development of self-service and the resultant quantities of chicken these larger units could sell, the broiler industry would have been hard put to it to find adequate outlets for the huge volume of production it so rapidly engineered.

Chicken in this country had for generations been roasted. Other methods of cookery were almost entirely unknown. In America fried chicken had a large following and it seemed to us some promotional work in this country was needed to launch a new method of chicken cookery. The very great majority of birds sold for roasting had been required for consumption at the weekend, generally on Sunday, and in consequence between 60 per cent and 80 per cent of the product was sold by retail on Friday or Saturday. If by promoting 'portion' sales and thereby reducing the unit cost of a purchase to, say, about 2s., it could be made available as an alternative to a chop or steak for a mid-week meal; there were almost boundless possibilities we believed. Although there were many doubting Thomases the project was launched and now represents some 20 per cent of the total national sales of chicken in this country. Some people argued the product cried out for the most attractive packaging, of necessity fairly costly. Others like ourselves believed the packaging must be kept strictly functional and moreover, of the lowest possible cost. This we still believe strongly—not that we have convinced, or for that matter would want to convince, all those who hold contrary views!

One of the major effects on self-service stores of the growing volume of the broiler industry was the need for better and more functional display equipment from which the product could be sold at retail level. An open-topped refrigerated display cabinet was rapidly developed. Looking at equipment of which one has been inordinately proud a few years earlier one is often abashed to realise how thoroughly outdated and old-fashioned it has become in the space of 4 or 5 years. Considerable progress has recently been made in this field, both in regard to the efficiency, the capacity and indeed the appearance of equipment of this nature. Whereas we started off in many shops with a single cabinet about 12 sq. ft. in size, the cabinets grew fairly rapidly to 50 per cent or more bigger and at the same time helped rather than hindered the consumer's view of the product on sale. Today three such cabinets for poultry alone is the normal minimum for one of our average self-service stores—each cabinet can sell several hundred chicken a week.

It so happened that back in 1953 two itinerant Britons were in America to study American methods of broiler production and processing. They were particularly interested in what we now call Poultry Packing Stations; one of them was the then Managing Director of a young emergent chicken company and the other myself. A bright and sunny afternoon stroll through Washington provided the background for a conversation which was to have a substantial effect upon the future. (I do hope this is not too presumptious!) Quite unable to keep our tongues and minds away from chickens we rambled on over the possibilities of how the chicken industry in Britain would develop. Would it be right, we argued, to replicate what was happening in America—an ice-packed chip-board carton operation providing a product sold in a relatively wet condition or should we plough an entirely new furrow and promote a 'fresh-frozen' chicken product which, as we saw it, would remove in one fell swoop the pressing problem of product perishability, the importance of which we knew only too well.

Even in pre-war days we had handled a fair trade in poultry, we even thought it a big trade then though in comparison with modern figures it now seems somewhat modest. At least we had learned (the hard way, be it admitted) the problems of handling 'fresh' poultry. We knew just how perishable this poultry was, although with increasing knowledge 'greening' had by then just become to be accepted as no longer an act of God but more logically as an act of carelessness. We knew how close a control on all stages of preparation, distribution and retail sale would be demanded if the consumer was to be given a reasonable larder life for the product she bought on, say, a Friday for consumption on Sunday. To us therefore it seemed preferable to quick freeze the product *for the purpose of efficient distribution.* Thereby, not only could the condition of the product be guaranteed to the housewife but in addition, the troublesome matching together of short-term fluctuations of supply and demand could be made more manageable. Of one thing we felt certain, freezing the product was not, and indeed never would be, a panacea for dealing with any period of significant over-production. Both believed it would be as easy, if not even easier, to freeze the industry into trouble as to get it out of it. Looking back, was this a prophetic note?

The frozen product enabled us to supply all our branches in readiness for the trade whenever and to whatever extent it developed during the week and thus permitted a large range of weights and unit costs to be kept before prospective buyers at all times. Without this it is doubtful if the increase in volume experienced by the industry could have been achieved anything like as rapidly.

During the formative stages of the industry the skin colour of broilers became a contentious point; some argued that because American strains of birds which were yellow-skinned were far better food converters, this was the bird the public must be persuaded to buy. Unhelpfully enough the British demand was for a white-skinned bird; Sainsburys took the view that it would be easier and cheaper to change the product than attempt to change public demand in this respect. Exhortation was—perhaps not surprisingly—not very successful but once we started to apply a discount to the yellow birds how rapidly the trend changed! Ultimately a compromise in favour of a straw-coloured bird resulting mainly from appropriate feeding achieved the best of both worlds—an acceptable colour at relatively low cost.

Next to broilers intensive turkey production has probably had the widest impact on retail food chains. Retailing at Christmas time before the war was often a nightmare; the huge weight of work involved in drawing and trussing Christmas turkeys often went on well into the night and even sometimes right through it. This was accepted then as part of a tradesman's life. Today the same conditions would be unthinkable for a variety of reasons.

The weather and its usual unpredictability were often a trial for in 7 years out of 10 it seemed to turn clammy and mild just when turkey time came round.

The development of ready to cook turkeys along the same general lines as the broiler industry brought a much more civilised approach to the problem. Although a quite substantial national demand for fresh birds sold to the retailer in the traditional manner with head, feet and entrails intact still exists, we have not found it to our disadvantage to have concentrated for some years past solely on our own brand ready to cook, quick frozen, individually pre-packaged turkeys. Even if one could conceive today an adequate staff to draw, truss and package at store level, it would be physically impossible to cater in the old-fashioned way for the increased quantities demanded nowadays at Christmas. Today we no longer find it necessary to take a single order, nor to deliver. In fact it would probably take longer to find a customer's bird put up as an order in advance than to serve several customers from stock. Moreover they can always see what they are buying, a considerable point when dealing with the most important menu of the year.

It would be more than surprising if all the results of such an evolution were advantageous. Of course, they are not. The game trade, for example, has suffered. No longer are poulterers available at the retail level capable of coping with the highly seasonal supplies of pheasants, partridges, grouse and the other game birds. As yet at any rate, centralised processing of this type of product has not proved to be entirely practical. Nor would it be easy to persuade the traditional buyers of this product that a quick-frozen product was 'right' for them.

Following upon the success of broilers and intensively produced turkeys some endeavour to apply the same general approach to other meat products was to be expected; these have met with varying degrees of success. Rabbit meat at one time reckoned to be a poor man's food is one example. Myxomatosis both in Australia and here altered all that. Although some importation of wild rabbits still existed there was at one time optimism about the production of white-fleshed, domestically reared rabbits. Some enthusiasts saw, they thought, the possibility of another broiler industry. The labour-intensive nature of the production and certain technical problems have largely prevented the success of many large-scale rabbit enterprises. There is certainly a demand for the product, as may be gauged from the fact that it has frequently been marketed at 50 per cent above the price of chicken meat. To what extent the prices would crumble in the presence of any significantly increased volume is, however, an important question.

There can be few people who are today unaware of the changing pattern of egg production. The trend towards large-scale intensive-production methods has inevitably been accompanied by the concentration of the industry into a very much smaller number of hands. By and large new entrants had a strictly cost conscious approach. Efficiency of production thereby increased at a smart pace. One side effect rapidly brought itself to our notice. In our self-service stores the public became increasingly interested in searching for eggs with some shell colour, perhaps because the proportion of brown eggs tended to get less. One might have expected this in view of their higher cost of production. We knew there was no difference in internal quality but ultimately had to cater for public demand and offer a premium to producers for coloured eggs, charging at retail level precisely the same premium to consumers. It is as yet too early to record the ultimate reaction on production patterns.

In the case of pig meat the trend towards an intensive form of production which began well before the war continued since meat decontrol in 1954. With this commodity, however, the pace might perhaps be described as steady rather than spectacular. Unlike most other livestock, pigs serve more than one major purpose.

Processing into bacon and manufactured products had become established as an industry in its own right before self-service retailing occurred. Fresh pork is frequently provided from carcasses, parts of which are used for other purposes. Whether we are likely to see in the near future new developments leading to more intensive production of light-weight pigs specifically for the fresh pork trade is a good question. Current indications are however rather against this view.

The most spectacular results in the field of production have predictably been attained where the reproductive cycle was short and the number of progeny large. Equally lamb, and to an even greater extent beef production could only follow relatively late in such a trend. As yet the impact of changes in production trends of these two commodities upon retailing has been minimal. We have, to a small degree, been concerned with certain experimental work in these fields but if anyone has achieved with them a significant effect upon modern retailing, we regret it is not us.

Chapter 27

THE IMPACT OF BRITAIN'S ENTRY INTO THE COMMON MARKET ON INTENSIVE LIVESTOCK PRODUCTION

ANDREW W. ASHBY

Differences in Support Systems

The European Economic Community, or Common Market as it is generally called, was set up by the Treaty of Rome in 1957, the signatories being France, Western Germany, Holland, Italy, Belgium and Luxemburg. Amongst the many provisions of the Treaty was one for a Common Agricultural Policy (C.A.P.). The aims of this policy, as laid down in Article 39 of the Treaty, were to provide Community farmers with a fair income and stable markets while ensuring regular supplies at reasonable and competitive prices to consumers, all within a single Community-wide market with a common price level. As such the aims of the C.A.P. are not very different from those of British agricultural policy as laid down in the Agriculture Acts of 1947 and 1957. What is different is the means by which these aims will be secured.

The British system is based on an annual review of the economic condition of the agricultural industry conducted by the Ministry of Agriculture, Fisheries and Food and the National Farmers' Unions. At this review the level and trend of farm incomes, changes in costs, and prospective supply, both imported and home produced, and demand for the major farm products are all taken into account. After the review the Government determine the prices, in some cases limited as to quantity, which farmers will receive for thirteen major products, accounting for about 85 per cent of the value of farm output. Where farmers fail to receive this price from the market the Government make up the difference in the form of a deficiency payment. Because of this system of support Britain operates a relatively liberal import policy, with low tariffs and few restrictions, since the burden of a low market price falls on the taxpayer and not the farmer.

The Common Market system is very different. There is no annual review in the British sense. Instead prices for the principal products—wheat, barley, maize, beef, milk and sugar beet—are determined by the European Commission in Brussels on the basis of prospective supply and demand for each commodity and on political considerations. The prices so determined are not guaranteed prices but target prices, i.e. prices farmers should receive. The Commission try to ensure that farmers are not prevented by cheap imports from receiving these target prices by imposing levies on imports. But if for a particular commodity Community production is in excess of demand at the level of the target price then the market price will fall below the target price and the difference will not be made up to the farmer by means of a subsidy, as in Britain. The only thing the Commission does is to fix an intervention price, at a level 5–10 per cent below the target price, at which price it will buy in all supplies offered. Such purchases are then either stored, exported with the aid of a subsidy, or debased and sold in a different market, e.g. denatured wheat is sold for animal feeding.

For other commodities, including pig and poultry meat and eggs, the Commission neither determines a target price nor an intervention price; it does, however, fix both a levy on imports and a minimum import price. With this exception prices of these products are left to find their own levels on the basis of supply and demand within the Common Market.

Implications for Livestock Producers

Entry into the Common Market would thus have several implications for intensive livestock producers in Britain.

Firstly, of the livestock products, only milk and beef have target prices and thus an indication of the probable market price. Producers of pig meat, eggs and lamb would lose their present guaranteed prices and gain nothing comparable in exchange, since prices of these products are left to find their own level in the Common Market. The only protection producers of these products would have would be against low-priced imports from non-member countries, assuming that there were such imports into the enlarged Community, including Britain. Thus there would be levies on all imports of pig and poultry meat and of eggs to equate production conditions—chiefly cereal prices and feed conversion ratios—in the exporting countries with those inside the Common Market. In addition minimum import prices (so-called sluice-gate prices) would prevent dumping. For mutton and lamb there would be no levies, but a tariff varying between 15 per cent and 20 per cent of the landed price.

Secondly, in the Common Market the price livestock producers pay for cereals is exactly the same as the price cereal producers receive, whereas in Britain livestock producers buy cereals at the market price and the difference between that and the guaranteed price is made up by the taxpayer. Within the Common Market, therefore, livestock producers contribute to the support cereal producers receive, although they presumably recover this in the price of their products. In Britain, on the other hand, livestock producers currently have the benefit of low cereal prices and do not contribute to the support of the cereal grower.

Thirdly, the cornerstone of the Common Agricultural Policy is a high price for cereals. This has been the case in the individual member countries for the last 100 years and continues under the C.A.P. Cereal prices are much higher within the Common Market than they have been in this country and, if we join, our prices will have to move up to the Common Market level. Not only will livestock producers have to pay for cereals the prices the growers receive, therefore, but these will be at a much higher level than cereal growers in Britain currently receive. The effect as far as livestock producers are concerned can be seen from the following figures:

£ per long ton

	*U.K. 1975 Probable market price**	*E.E.C. 1967–68 Target price†*	*U.K. 1965–66 Market price*	*U.K. 1965–66 Producer price*
Wheat	35·0	38·6	21·0	24·6
Barley	30·0	33·1	21·0	24·7
Oats‡	30·0	—	20·3	27·4
Maize	33·0	32·9	23·0	—

* Prices to growers will be slightly lower owing to the cost of transport from farm to market.

‡ At Duisburg, West Germany at the beginning of the season.

‡ There is no target price for oats, but it is assumed that the market price will rise with that of other cereals.

The probable market price has been calculated for about 1975 on the assumption that E.E.C. target prices remain unchanged in the meantime owing to the difficulty involved in lowering cereal prices because of their political significance. Since these prices will therefore have been in operation for several years there will have been sufficient time for their high level to stimulate cereal production in both U.K. and some of the present Common Market countries, thus causing market prices to fall below the target prices for wheat and barley. Even so, however, membership of the Common Market will bring to British livestock producers very considerable increases in the prices of the cereals they feed. These increases will be of the order of 45 per cent for maize and barley, 50 per cent for oats and 65 per cent for wheat over the market prices that prevailed in 1965–66. Moreover those farmers who feed their own grain will be faced with exactly the same increases in their costs, since the opportunity cost of cereals (i.e. the cost of the opportunity foregone of selling their cereals) will rise by the same order of magnitude.

Impact on Livestock Production

The impact of these tremendous increases in cereal prices on the level of livestock production depends on two things, namely on the extent to which farmers can change to other feeds which will show little or no change in price and on the extent to which livestock product prices change.

The prices of other feeding-stuffs should show little immediate change as a result of Britain's joining the Common Market, although they may tend to rise if demand for them increases as a result of the large increases in cereal prices. Thus oilcake and fish-meal prices should be unaffected by membership of the Common Market. Similarly the costs of growing grass and roots will not be directly affected by entry into the Common Market, but in so far as land used for these crops could be devoted to cereals, rents will ultimately rise and hence the cost of grass and roots to livestock producers. In none of these cases will prices (or costs) rise as much as for cereals, but this will not be of equal benefit to all kinds of livestock producers, since not all animals are equally flexible in their diets. Thus cattle producers, both those producing milk and those producing fat beasts, will have the greatest opportunity to substitute other feeds for cereals, while egg and broiler producers will probably have the least opportunity. Pig producers will be affected by high cereal prices almost as much as poultry producers, while sheep producers will be least affected.

The extent to which livestock product prices will change if Britain joins the Common Market is more problematical. As already mentioned, target prices have been determined only for milk and beef in the livestock sector. Both are above last season's U.K. price, that for beef significantly:

		E.E.C. 1968	*U.K. 1965–66*
		Target price	*Producer price*
Milk*	Pence per gallon	39·12	37·73
Beef	£ per live cwt.	12·0	8·9

* At the farm gate.

Since the U.K. milk market is predominantly a liquid market, with approximately only one-third of the milk manufactured compared with two-thirds in the existing Common Market countries, British producers should receive an average price slightly above the target price, say between 40 and 41 pence per gallon. Compared with the current British system the chief difference would be that summer milk prices could not fall below 38 pence per gallon and in fact would be very slightly above this figure while winter milk prices should not rise above 41 pence per gallon. There would, therefore, be much less seasonal variation in prices, with consequent encouragement to production of milk in summer and discouragement to winter production.

With regard to beef, there would be a considerable price incentive although the benefit of this would undoubtedly be reaped by the calf producer through a higher calf price. At the same time the calf producer would lose the calf subsidy, which would have to be abolished under the regulations determining the C.A.P., so that the high target price would not be all gain for him, although he would certainly benefit.

So far as other livestock products are concerned, e.g. pig and poultry meat and eggs, there are no provisions in the C.A.P. for determining target prices and no suggestion that provision will be made in the future. There are no firm guide-posts, therefore, to the likely level of prices in the U.K., as with the products so far discussed. Moreover, the price level that would prevail in the U.K. will not be determined by the prospective supply and demand within the U.K. alone. Since for each product there would be a Community-wide market with a common price level, the price that would prevail in the U.K. would be determined by the prospective supply and demand within the enlarged Community of which the U.K. would be a member. The only differences that could exist between prices in the U.K. and in other member countries would be for quality and transport. Thus if the U.K. needed to import supplies from other member countries the U.K. price would be above the Common Market average for identical quality produce by the cost of transport, and if we had supplies available for export to other member countries the U.K. price would be below the average by the cost of transport. These differences would be small.

Since the member countries of the existing Common Market do not harmonise their cereal prices until the 1967 harvest, it is difficult to estimate the probable effect of this on the supply and hence price of pig and poultry meat and of eggs. The possible addition of Britain, and of Denmark and Ireland, to the E.E.C. in the next few years will bring additional factors into play and it will probably take several years for the supply and demand for these products to reach equilibrium. The price at which equilibrium is attained will depend on the effect of changes in cereal prices on production of these livestock products, on the effect on the quantity demanded of changes in the prices of the products themselves and of competing products, and on the increase in technical efficiency for each product that will take place in the intervening period. Taking account of all these factors, the probable price of livestock products to producers in the U.K. in about 1975 if Britain joins the Common Market will be:

Product	*Unit*	*1975*		*1965–66*	
		s.	d.	s.	d.
Pigs	live score	37	3	33	6
Broilers	live lb.	1	6	1	6
Eggs	dozen	3	0	3	2½

If these forecasts are borne out, then pig producers can expect a price in 1975 about 10 per cent above the 1965–66 level, broiler producers an unchanged price and egg producers a price about 6·5 per cent lower, despite the considerable increase that will take place in cereal prices. In other words producers of all three products must expect a squeeze on profit margins since feed costs are certain to rise and only for pigs is any increase in product price expected, and even that is less than the increase in feed costs.

Conclusion

Both for milk and for the grain converted livestock products (pig and poultry meat and eggs), therefore, producers' profit margins will be squeezed in the U.K. The consequence of this must be that livestock numbers in 1975 will be smaller than they otherwise would be if Britain remained outside the E.E.C., although not necessarily below present levels. The exception to this is beef, where profit margins appear likely to be greater inside than outside the E.E.C., although not for cereal produced animals. It remains to quantify these changes.

The largest reduction in numbers is expected for laying hens, since egg prices will fall while feed costs rise. Proportionately almost as large a reduction is expected in the broiler flock, while pig numbers will be down only slightly compared with the likely situation outside the E.E.C. The beef herd will be larger if Britain joins the Common Market, as will the number of fattening animals. The increase in the latter, however, will be in 18 month beef, while barley beef will be ruled out by the high barley and calf prices. Lastly there will be a slight reduction in the dairy herd, owing to a relative decline in profitability of milk production compared with cereal growing. These changes are estimated as follows:

	June 1975		*June 1965*
	Inside E.E.C. '000 Head	*Outside E.E.C. '000 Head*	*'000 Head*
Dairy cows	2,900	3,050	3,187
Dairy replacements	580	590	621
Beef cows and heifers	1,400	1,350	1,162
Fattening stores	0	0	974
18 month beef	4,300	4,150	2,524
Barley beef	0	0	338
Cattle under 1 year	4,000	3,850	3,045
Total cattle	13,180	12,990	11,851
Pigs	8,775	9,175	7,979
Layers	68,000	80,000	80,073
Broilers	42,750	48,500	28,500

There is already a very strong tendency in virtually all forms of livestock production for output to be concentrated in fewer but larger enterprises. The number of registered milk producers in England and Wales declined from 123,137 in March 1960 to 100,450 in March 1965, while the number of holdings recorded as having pigs at the June census fell from 110,664 in 1960 to 94,635 in 1965, while in both cases livestock numbers rose. This tendency will continue in the future and will be even stronger if Britain enters the Common Market. Thus, with the exception of beef, the economics of livestock production will be adversely affected by entry into the Common Market, since feed prices will rise considerably while product prices are likely to change little. In these circumstances less efficient producers, who tend to be the smaller ones, will go out of business while some of the most efficient will expand their enterprises. The livestock economy that will emerge in Britain after membership of the Common Market has been obtained, therefore, will be one of considerably fewer but larger enterprises.

Finally, it must be mentioned that membership of the Common Market will lead to changes in legislation affecting livestock production. Thus the present legislation prohibiting poultry imports on health grounds from most countries, including all those already in the Common Market, would have to be removed, as would the prohibition on imports of fresh milk. Without the removal of this legislation there could not be a single Community-wide market with a common price level in poultry meat and milk. At the same time British livestock producers would have to conform to any enactments of the European Economic Commission in Brussels. In this connection it should be mentioned that the Commission has been asked by the German Government if it intends making any regulations about factory farming. So far no such regulations have been made but the possibility exists that they will be, especially if it is thought that too many small producers are being driven out of business. If such regulations were to be made they would probably prevent the formation of new large-scale units, while leaving existing large units untouched. They would therefore place a brake on the concentration of livestock production in fewer but larger enterprises.

Addendum

As a result of Britain's devaluation on 18th November, 1967 the sterling equivalent of each Common Market target price is automatically raised by 16·7%. The probable UK market prices quoted for 1975 also need to be raised. Examples of the new sterling equivalents are as follows:

		Post devaluation	*Pre-devaluation*
Wheat	£ per long ton	45·0	38·6
Milk	Pence per gallon	45.6	39·1
Beef	£ per live cwt.	14·0	12·0

Chapter 28

THE ROLE OF THE COMPUTER

P. ROBERTS

Descriptions of electronic computers nearly all contain superlatives, either on account of their speed or regarding the growth of numbers of machines in operation. Certainly their expansion in numbers has been very rapid, from nil to about 2000 in this country in 14 years, and they have solid achievements to their credit in agriculture. There are disadvantages in these extravagant descriptions or claims—potential users of computers may expect such miracles that they are disappointed by the actual achievements, or, even worse, they may be overawed and so prevented from ever trying to comprehend and use them.

The most elementary computer is the abacus, or counting-frame of beads; this has survived today as a teaching device or toy for children. It is easy to use and understand as the principle is simple and every part is visible. Numbers are represented by beads—four beads pulled to the bottom of the right-hand wire represent the number 4, but if two beads are then pulled down the second wire the number represented, utilising the decimal system, is 24. Modern calculating devices, particularly electronic ones, are the combined efforts of engineers, physicists, mathematicians and other technical experts and are somewhat complicated so that most users have to take the principles on trust; they cannot see the way it works so must regard a computer as a 'black box' which is fed with information at one end and gives out the answer at the other. Nevertheless computers do require some adjustment of mind, and an awareness of some of their features prevents over-dependence on computer experts who cannot be expected to know all the user's problems and are not always readily available for consultation.

Two types of electronic computer have applications in agriculture and it may be helpful to describe the main differences between them. The most important type is the digital computer—it is so-called because it represents numbers coded in terms of the *digits* 0 and 1 (numbers in this form are called binary numbers) just as letters and numbers are coded in dots and dashes in the Morse code, and has the ability to store numbers within it. The other type is known as an analogue computer, which represents the amount of physical quantity by the magnitude of an electric current. The rules governing the variation of the physical quantity are studied by an electronic engineer, who designs a circuit to vary the electric current in a similar way; thus the electronic variation is *analogous* to the physical variation. Each such circuit needs to be designed for a specific job, so a different job requires the circuit to be re-connected.

Programming

Coding numbers by strings of 0's and 1's as do digital computers seems at first sight to be cumbersome. However, it is also possible, by use of a branch of mathematical theory to represent *operations on the numbers* in the same way, including the basic operations in arithmetic of addition and multiplication. Hence it is possible to feed into the digital computer not only a set of numbers, but also the required operations on the numbers, so that the machine itself does not need modification between jobs. The list of operations, or instructions, is known as a program. The facility for a digital computer to receive data and program in the same form plus its incredible speed makes it a very powerful tool—although basically it performs simple operations on simple numbers, so many interlocking operations can be done so quickly that very complex calculations or logical processes can be carried out in a short time. Further, digital computers also have a store, or memory, which enables them to hold data and program until they are required.

Of course, once the sequence of instructions for a commonly used arithmetical operation is worked out, there is no need to repeat the thinking process the next time the same operation is needed. Writing out that sequence again can also be avoided if the computer can be referred back to it by using a code reference. As people do not think readily in terms of binary numbers much research has been done into ways of simplifying programming. A first step was to supply a list of sequences of instructions together with a corresponding list of code-references, so that when the programmer wishes to use a particular sequence he gives just the code-reference and the computer refers to the list to find the appropriate sequence of instructions. Each sequence is thus a miniature program, the full program being assembled by the computer. This is the first stage of a language for programming—the programmer uses references which can be called 'words', supplies the computer with a list or 'dictionary' and the means for the computer to look up words in the dictionary, and so to 'translate' the program.

The next stage is to make a programming language which firstly is phrased in familiar terms and secondly can be used on different types of digital computer. The best-known languages of this type are Algol and Fortran, which can readily be used by non-programmers especially if they are scientifically inclined. All recent computers will accept one or both of these programming languages, and the rudiments of them can be learned in 3 days. They give ample flexibility to the programmer, so many programs will appear very complicated. However, the following is a perfectly acceptable statement in Algol:

$$\text{interest} := \text{capital} \times \text{rate} \times \text{time}/100.$$

This means that the computer will calculate the interest by multiplying together the capital times the rate (of interest as a percentage, as usual) times time, and dividing by 100. A mathematician might prefer to write the equation differently:

$$I := c \times r \times t/100.$$

Information is fed into the computers in coded form, usually either on perforated paper tape or on punched cards. The results of the calculations, the 'out-put', can also be on tape or cards but will normally require to be translated by an electrical typewriter or printer. A line printer can be used directly for out-put but this may lead to inefficient computer use because even the fastest printer is slow in comparison with the calculating speed of the computer.

Computers therefore are useful when large amounts of data need to be handled even though only simple arithmetic is involved, or where long and complex calculations are needed. Commercial work often falls into the former category and scientific applications into the latter. At first different types of computer were developed for the two fields, but the most modern ones deal efficiently with both types of work.

Computer manufacturers

The largest and best-known manufacturers of computers are International Computers and Tabulators (I.C.T.) and the American firm I.B.M. They market ranges of machines which can cost about £20,000 for a small system, but a large and powerful configuration with sophisticated backing equipment could cost over £250,000. Other manufacturers include Elliott's with their 4100 series, and English Electric who have supplied many universities with machines. There are not so many manufacturers of analogue computers but Electronic Associated Ltd. (E.A.L.) have developed an analogue computer especially for feedstuff formulation which is described later in this article.

The Milk Marketing Board and the British Egg Marketing Board use computers to condense the large volume of data they receive; and the Ross Group are using the new I.C.T. 1902 computer at Guisley to help farmers carry out flock analysis and farm costing. There are a number of standard applications of computers—invoice calculation, stock control, pay rolls, producer payments, etc., which are used by the Boards as well as by firms in the compound feedstuffs, pharmaceutical and breeding industries.

Scientists in the concerns mentioned make good use of computers although perhaps not quite to the same extent as scientists in the universities and research stations working in agricultural research. Rothamsted Experimental Station was a pioneer in the field using computers for the analysis of experiments and for censuses and surveys.

Linear programming is an application of computers which is described in the following section.

Application of Computers to Linear Programming. This example of the use of computers is of both scientific and commercial interest. A prerequisite of its use is, of course, a clear and unambiguous definition. A definition is given in the appendix, using mathematical terms so that it is both precise and general.

The mere sight of such a set of algebraic expressions is enough to deter most non-mathematicians from further interest. This is unfortunate as linear programming is a most powerful tool for dealing with very

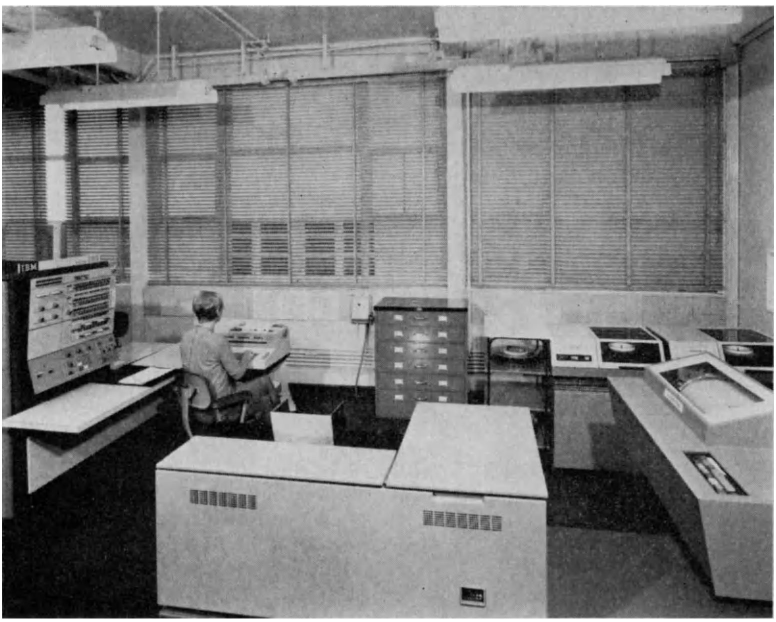

FIG. 74. An I.B.M. 360/40 computer installed at the Unilever Research Laboratory, Port Sunlight.

practical problems. Strangely enough linear programming was first used to solve theoretically a nutritional problem some 20 years ago, but the routine application in the feedstuffs industry is comparatively recent. The following problem is a simple example of feedstuffs formulation by linear programming.

Economic Feed Formulation

Suppose we wish to make an animal feedstuff from the following materials with analyses as shown, to reach a given standard of quality but as cheaply as possible.

The mixture is required to have at least 2·2 per cent oil, 16 per cent crude protein and 2 per cent fibre, but not more than 5 per cent fibre.

	Oil %	*Crude Protein %*	*Fibre %*	*Price, £/ton*
Barley	2	9	5	25
Milo	1	11	2	30
Groundnut	3	46	3	54
Soya	4	47	2	60
Wheatings	5	15	9	28

One such mixture which would satisfy these requirements is:

18% barley	*Analysis*
40% milo	2·7% oil
5% groundnut	16·1% crude protein
7% soya	4·7% fibre
30% wheatings	
	Cost: £30·86/ton

The question is what is the relation between this problem and the equations in the appendix?

Consider first the calculation of the oil contents of the mix. The contribution of barley is:

$$\text{amount of barley} \times \text{oil \% of barley}/100 = \frac{18 \times 2}{100}.$$

The amounts of oil in the other ingredients are treated in the same way so we get:

$$\text{Oil \%} = \frac{18 \times 2}{100} + \frac{40 \times 1}{100} + \frac{5 \times 3}{100} + \frac{7 \times 4}{100} + \frac{30 \times 5}{100} = 2{\cdot}69\%.$$

If the amount of barley in a mix is called X_1, the amount of milo X_2 and so on it is easy to see that the oil per cent is given by:

$$\frac{(X_1 \times 2)}{100} + \frac{(X_2 \times 1)}{100} + \frac{(X_3 \times 3)}{100} + \frac{(X_4 \times 4)}{100} + \frac{(X_5 \times 5)}{100}$$

$$= 0{\cdot}02\ X_1 + 0{\cdot}01\ X_2 + 0{\cdot}03\ X_3 + 0{\cdot}04\ X_4 + 0{\cdot}05\ X_5.$$

So if we want to stipulate that in a mix consisting of X_1 of barley, X_2 of milo, etc. that the oil must exceed 2·2 per cent we can write it thus:

$$0{\cdot}02\ X_1 + 0{\cdot}01\ X_2 + 0{\cdot}03\ X_3 + 0{\cdot}04\ X_4 + 0{\cdot}05\ X_5 \geqslant 2{\cdot}2.$$

(The symbol $\geqslant$ means is greater than or equal to.)

In a similar way we can write the other requirements:

Crude protein: $0{\cdot}09\ X_1+0{\cdot}11\ X_2+0{\cdot}46\ X_3+0{\cdot}47\ X_4+0{\cdot}15\ X_5 \geqslant 16$

Fibre: $0{\cdot}05\ X_1+0{\cdot}02\ X_2+0{\cdot}03\ X_3+0{\cdot}02\ X_4+0{\cdot}09\ X_5 \leqslant 5$

($\leqslant$ means is less than or equal to.)

These expressions are exactly the same form as those in the appendix, so we have written the familiar calculations for the analysis of a mix in the mathematical form required for linear programming. The oil and other requirements thus become the 'constraints' of the problem.

Now, a person tackling the mixing problem would realise that the mix must add to 100 per cent and would take account of this in his calculations. A computer does not 'realise' anything but has to be 'told' —in this case it must be supplied with a further equation:

$$X_1+X_2+X_3+X_4+X_5 = 100.$$

Lastly it is necessary to express the price of the mix, which it is required to minimise, in a similar mathematical form

$$\begin{aligned}\text{Price} &= (25\ X_1+30\ X_2+54\ X_3+60\ X_4+28\ X_5)/100\\ &= 0{\cdot}25\ X_1+0{\cdot}30\ X_2+0{\cdot}54\ X_3+0{\cdot}60\ X_4+0{\cdot}28\ X_5.\end{aligned}$$

This completes the expression of mixing problem in linear programming terms.

The above information can be used to solve the mixing problem by linear programming by hand or by feeding into a digital computer. In this latter case the information would have to be put into a form suitable for the computer being used, and this stage needs consultation between the investigator and a programmer.

The least cost diet is:

73·7% barley	*Analysis*
17·5% groundnut	2·4% oil
8·8% wheatings	16·0% crude protein
	5·0% fibre
	Cost: £30·34/ton

This problem is a very simple one and is not intended to portray a realistic diet. Hence the above solution could have been obtained by trial and error. In a practical situation there are many more raw materials to be considered. Furthermore the nutritional requirements of a high quality feedstuff are much more demanding and levels of various minerals, amino-acids, etc., will usually be specified as well as the properties used in the example. In these circumstances it will be virtually impossible to reach an economic solution by trial and error.

Electronic computers can and do readily deal with such practical problems and in many concerns are used to solve feedstuffs problems involving 30–50 raw materials and 15–20 nutritional restrictions, as well as restrictions on particular raw materials to cover considerations of palatability, etc. A great advantage is that one can be sure that the ultimate solution has been found, whereas trial and error always leaves some doubt that another trial may produce a better result. Linear programming routines are available for all modern computers, which enable not only the details of the optimum solution to be obtained but also the effects on cost of departures from the solution. For example, in the problem given above one question which might be relevant is the effect of requiring a minimum of 15 per cent milo. The cost of this requirement can be obtained very simply from the computer output without the necessity for calculating a new solution.

Other Applications

The mixing problem is not limited to the animal feedstuff field but is appropriate for any blending problem such as in the oil or metal industries. It should not be supposed that linear programming is restricted to mixing problems. Linear programming should be considered whenever a large number of 'activities' are competing for 'resources' which are limited in supply, and is regularly used for planning purposes in manufacturing industry, or indeed any situation which can be expressed in the terms given in the appendix.

It may be thought that undue emphasis has been placed here on the mathematics of linear programming. However, there are two great benefits to be obtained from understanding something of the underlying theory; firstly the technique will be more efficiently used in a familiar application, and secondly other potential applications in less familiar fields will be recognised.

In agriculture linear programming has been used for farm planning, including the most profitable combination of crops to grow on an arable farm. Here the activities to be considered are the various types of crop, and the resources are capital, land, labour, etc. These sources are obviously limited in supply and various cropping programmes make different demands on them, which may be particularly critical in particular seasons of the year.

An interesting account of this kind of work is given by Sturrock (1963). He shows not only how individual farm plans can be prepared but also how it may be possible to make generalisations about a whole class of farming. He emphasises that the definition of objectives should be given most careful thought. The computer will only answer the questions put to it, so the investigator must make sure that they are the right ones. The computer should not be asked for a farm plan to even out demands on labour, when it would be better to ask for a plan to maximise the farmer's profit *subject* to a limited labour supply.

The Analogue Computer

Returning to the feedstuff problem, it is unfortunately true that the coding and preparation of problems for a digital computer is difficult for many people to grasp and in any case is tedious for large problems. An alternative to the digital computer is the analogue computer. It is possible to obtain analogue computers specially designed for linear programming which have the virtue of being simple to set up and operate. The parts which a user needs to know about are a rectangular array of knobs, an illuminated register and some simple controls. Each row of knobs corresponds (in the case of the feed-mix problem) with the analysis of a raw material; thus if the first knob represents oil the user turns it until 2 per cent is registered, in the case of barley. The second knob is used to set 9 per cent for the crude protein of barley, and so on, until all the materials are set up. Raw material prices and the analysis required are set in a similar way. On the touch of a button the computer finds the least-cost mix automatically, and the solution is read from the illuminated display. The breaking down of the problem into a linear program has largely been done by the design of the machine, and all the coding, scaling, etc., which is necessary does not have to concern the user at all; being special purpose therefore, analogue computers are very attractive to nutritionists. However they are not cheap so are not likely to be economic outside the feedstuff industry; for example the E.A.L. analogue computer costs about £30,000–£40,000.

Future Developments

Defining the nutritional limits for a particular class of livestock sets a heavy responsibility on the nutritionist, when feed-mixes are prepared by automatic methods. It is salutary therefore to read the comments by the A.R.C. Working Party on Nutrient Requirements of Poultry. They were able to recommend minimum requirements of most nutrients for healthy growth but reported that published experiments dealt with only one nutrient at a time. They found no comprehensive experiments investigating whether the requirements for one nutrient depended on the level of another nutrient. Economic considerations were outside the Party's terms of reference but they reported that the amount of published work on most profitable levels of yield and substitution rates between feedstuffs was meagre. This type of investigation is admirably suited for computers as the calculations are readily defined but are long and complicated.

Dent (1964) has made an important contribution to the question of relating animal performance to rations obtained by linear programming. Using data published by Robinson (1962), he fitted mathematical equations which connected growth performance of bacon pigs to energy and protein in the rations fed. Linear programming was then used to find rations with the optimum protein-energy combination to give specific growth-rate at least cost. There are other criteria which can be explored by these techniques provided that the basic experimental data is available.

Filmer, elsewhere in this book, describes how modern nutrition needs to be related to economics with particular reference to the intensively managed pig, and shows with specific examples of the principles involved how nutrition is changing from a descriptive science to a measured one. There is, in fact, a fruitful field to explore in the interaction between animal research and linear programming.

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Appendix: The formal definition of linear programming

Choose values of variables $X_1, X_2, \ldots X_n$ that are positive or zero so as to minimise the following:

$$Y = p_1X_1 + p_2X_2 + p_3X_3 + \ldots p_nX_n \qquad (1)$$

Normally speaking the expression Y in equation (1) will represent some measurement of economic importance. In the feedstuff problem it will be the price of the mix, as obtained from the individual ingredients; we require the least-cost mix, so the price will be minimised. In appropriate circumstances the theory can maximise the expression Y; for example one could find the maximum protein in a mix costing a certain amount. Another case where maximising would be called for is the profitability of a farm plan.

Each variable X has associated with it the quantities a, b, c, etc. (which may measure, say, particular qualities of the variable). Then a_1, b_1, c_1, etc., are associated with X_1; a_2, b_2, c_2 with X_2 and so on. The variables are subject to limitations expressed as follows:

$$\left.\begin{array}{l} a_1X_1 + a_2X_2 + \ldots a_nX_n \geqslant A \\ b_1X_1 + b_2X_2 + \ldots b_nX_n \geqslant B \\ c_1X_1 + c_2X_2 + \ldots c_nX_n \geqslant C \end{array}\right\} \qquad (2)$$

etc.

These relationships are known technically as the 'constraints' of the problem. They are shown above as having lower limits (greater than or equal to A, etc.). If necessary the constraints may have upper limits or be exact equations and the theory can deal with these modifications.

Chapter 29

RESEARCH IN RELATION TO INTENSIVE LIVESTOCK FARMING

D. H. SHRIMPTON

'The mathematicians are well acquainted with the difference between pure science, which has to do only with ideas, and the application of its laws to the use of life, in which they are constrained to submit to the imperfections of matter and the influence of accident'. Dr. Johnson, in the fourteenth *Rambler*, May 5, 1750.

Introduction

In modern times the first livestock to be farmed intensively was the bee and it is to bee-keeping that the earliest reports of research in intensive livestock farming are directed. For 4 years (1874–77) Mendel studied the flying activity of bees and calculated that the daily harvest of nectar made by a strong colony was 6·30 kg. obtained by bees returning to the hive at the rate of 130 per minute. His further studies included a consideration of the implications of increasing the number of flights from the hive and hence of increasing the yield without increasing the size of the colony (*Mendel as a Beekeeper*; Orel, Rozman and Veselz, Brnö 1965).

These observations followed the publication of Mendel's major work on hybridisation ('Versuche über Pflanzenhybriden', *Verh d. Naturf. Ver. in Brünn* **4**, 1866, 1–47), a classic example of the application of the laws of pure science 'to the use of life', and one of the foundations of contemporary intensive farming. However, in spite of Mendel's broad interests as a biologist and his particular interest in bees he did not apply his theories on hybridisation to the animal kingdom and it was left to Bateson and his rediscovery of Mendel's work to do this at the turn of the century. Bateson chose the fowl and one of the earliest demonstrations of genotype segregation was made by him with his colleague Punnett during their studies on various types of combs in chickens (*Mendel's Principles of Heredity*, Bateson 1913). The major role of hybridisation in the present-day poultry industry was recently recognised in Mendel's own city of Brnö when, during the centenary celebrations in 1965 of Mendel's lectures on plant hybridisation, Warren was honoured by a presentation of the Mendel Medal.

Although it is difficult to characterise intensive farming by any one feature without distorting the value of the contribution of others, it is at least impossible to reject totally the importance of the use of the hybrid and its multiplication as one of the foundations of present-day intensive livestock farming. However, the facility with which new hybrids can be developed and the efficiency of their productivity open so many agricultural possibilities that a virtually new field of research has developed as a consequence. No longer is the agricultural scientist limited by the animal in the field. He may bring it indoors and select any climate and day-length he chooses; he may identify and then favour or suppress metabolic peculiarities; he may propagate widely the characteristics of a single sire by artificial insemination; he may change the proportions of a body and the components of a carcass; and above

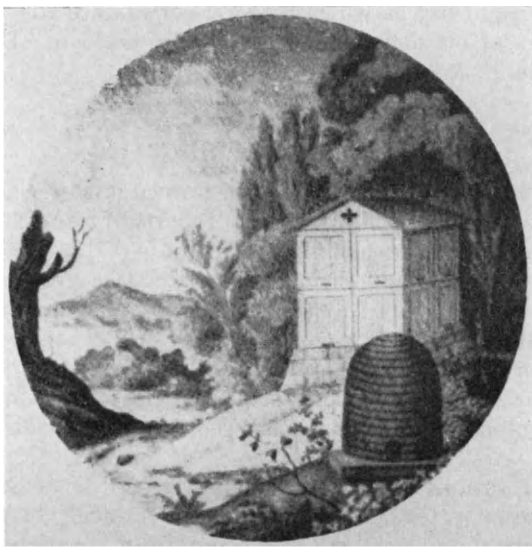


FIG. 75. 'Industry'. A symbol which Mendel, as abbot, caused to be placed on the ceiling of the Great Chapter Hall of the Augustinian Monastery in Brno.

all he now sees the possibility of overcoming 'the imperfections of matter' and eliminating 'the influence of accident'. Indeed the modern intensive livestock house has more affinity with laboratory housing for animals than with field conditions of even a quarter of a century ago. Hence the application in the field of the laws of pure science are now more straightforward and the pressure on the research worker is for the ideas of pure science itself. Currently, this is chiefly to explain new phenomena in intensively managed animals of high performance and to develop hypotheses into laws which may be used to guide the development of animals and their products into forms of more immediate appeal and convenience to the consumer.

During the past 2 or 3 decades, when the practice of intensive livestock farming has been developing, the basis of biological thinking has itself changed considerably. Argument by analogy with mechanics, which superseded the anthropomorphism of the nineteenth century, has itself been superseded by the philosophy of the dynamic equilibrium. Hence it is not only the tissue or the organ which is the focus of attention but also the mechanism which controls the equilibrium between synthesis and destruction to maintain a tissue. A consequence for agricultural research is the development of the research team and the fundamental position in it of the experimental scientist. This is, perhaps, surprising. It is well known and recognised that in agriculture today the control of disease is the dominant requirement and it is almost unthinkable to discuss present-day farming without thinking also of the need for research and the swift application of it to the control and ideally, eradication of disease. Indeed, one of the plenary papers to the 1965 Congress of the British Veterinary Association discussed this particular problem in detail ('Research and the Farmer', Field, H. I. (1965), *Veterinary Record*, **77**, 1128). Currently the loss in output from disease has been placed as high as 12 per cent in an industry with a gross output from livestock farming worth approximately £1140 million within a total value for gross output from all forms of agriculture of the order of £1600 million. However it is important to realise that Mr. Field was discussing research in relation to the farmer, the man who is here with a problem that is immediate.

In this chapter the purpose is to discuss research in relation to farming, the industry itself which has spanned countless generations and whose future can be projected without limit. In this context research is not dominated by the problems of the present but inspired by the future that their solution can reveal. Here is the opportunity for imagination and speculation and the development from it, by disciplined criticism and experimentation, of real advance. Here, the words of Thos. Spratt, a founder of the Royal Society, are as much a warning for today as they were a censure in the seventeenth century. 'It is stranger that we are not able to inculcate into the minds of many men, the necessity of that distinction of my Lord Bacon's, that there ought to be experiments of light, as well as of fruit. It is their usual word, what solid good will come from thence? They are indeed to be commended for being so severe exactors of goodness. And it were to be wished, that they would not only exercise this vigour, about experiments, but on their own lives, and actions: that they would still question with themselves in all that they do; what solid good will come from thence? But they are to know, that in so large, and so various an art as this of experiments, there are many degrees of usefulness: some may serve for real and plain benefit, without much delight: some for teaching without apparent profit: some for light now, and for use hereafter; some only for ornament, and curiosity. If they will persist in condemning all experiments, except those which bring with them immediate gain, and a present harvest: they may as well cavil at the Providence of God, that he has not made all the seasons of the year, to be times of mowing, reaping and vintage' (*The History of the Royal Society*, London, 3rd ed. 1722, p. 245).

Mendel's work in the monastery garden in Brnö has borne a rich harvest in this century. The hybrid chicken is now the norm in poultry farming; a similar situation is developing in pig farming and there are promising pilot developments in the production and intensive rearing of hybrids of sheep. However, the hybrids so formed are not the results of natural selection but are, instead, the consequence of deliberate selection and hybridisation for specialised production. In the case of birds, hybrids have been so successfully developed for the specialised purpose of egg production that their carcasses contain so little meat that it is seldom economic even to recover it at the end of the laying season. Conversely, birds for eating are now produced by hybrids specially selected for the purpose and which, as a consequence, are poor producers of eggs.

Selection and hybridisation is not always for the single-purpose animal. In the pig success has come to those in the United Kingdom who have recognised that integration between farm and abattoir is highly desirable and that under some circumstances it may be more efficient to allow the butcher to separate meats of different kinds rather than to grow pigs specifically for each type of meat. In this way the large 'all-purpose' pig has been developed, supplying in a single animal the needs of the pork and bacon industries. Clearly these two examples do not embrace all the facets of intensive livestock farming nor even represent the main classes of agricultural stock; but within the development of the intensive production of pigs and poultry there are displayed the major problems to which biological research must be applied for advance in the broad field of intensive livestock farming.

Whilst it is convenient to classify the problems of research into disciplinary fields it is nevertheless misleading because it can so readily be concluded that the divisions are real, whereas they are the artefacts of organisation which, through specialisation, can lead to still greater fragmentation. Study in depth is nevertheless an essential element in the process of research, for without it the objectivity of scholarship is impossible. The scholarly tradition is inseparable from research so long as it is confined to pure science, 'which has to do only with ideas', but in the application of ideas to a particular field of activity a problem arises which is greater now than formerly because of the mechanics of current biological research calling for great numbers of specialised technicians. Here each may lead to work of professional competence and occasionally to the aesthetic beauty of profound scholarship and yet the parts may collectively remain a mere aggregate never becoming organised so that each, whilst retaining its identity, contributes as in a mosaic to the design of the whole.

It is this synthesis of the ideas of the pure sciences or disciplines into a whole which can be applied to the solution of particular problems that is one of the major tasks of research in relation to industry and to intensive farming in particular. The many facets of scientific learning which are related to the intensive management of animals are themselves related to many other problems also. The study of protein nutrition may lead to greater feed conversion efficiency in the fowl and the pig; but it will also contribute to the relief of malnutrition in the developing areas of the world. The study of connective tissue will relate not only to clinical symptoms of vascular disorder, such as lathyrism, but also to meat quality and, in human medicine, to rheumatism. These parts, developed in depth and shaped with precision, can well be likened to the components of a mosaic so that the direction of their use, the application of the laws of science, to the particular problems of intensive livestock farming, is analogous with the artist creating mosaics. The components are the same, the combinations differ, but always the whole is an organised creation containing within itself the parts, each perfect in its way and yet subsidiary to the complete design.

In the following sections particular aspects of the problems raised by keeping animals intensively will be discussed. These are the pieces of the mosaic. At present it is not possible to identify all the parts and in this chapter it is not appropriate to consider in detail even all those that are at present under investigation. Instead, it is more suitable to select those in which advance is being made and within this to concentrate upon those which have attracted most the imagination of the author. An interpretation is not necessarily the poorer for being personal and indeed, the presentation of the facts may gain from it. In support of such a thesis, Lord Tedder, the present Chancellor of the University of Cambridge, has recently quoted Goethe: 'I can promise to be upright but not to be unprejudiced' (*With Prejudice*, London, Cassell & Co., 1966).

Allometric Considerations

For the experimental scientist the areas of research which offer most excitement are those which lie in the no-man's-lands between the well defined pathways of the classical disciplines. From study in these areas lies the promise of new theories raised from the synthesis of separate ideas developed from different activities and disciplines and only impinging upon one another at their margins. The term 'allometry' in its broadest sense describes such an area and it is one in which one may expect to see develop an integrated field of research to parallel the commercial liaison between breeder, farmer, miller and marketing organisation which has made possible the development of intensive livestock farming. Allometry designates the differences in proportions correlated with changes in absolute magnitude of the total organism or of the specific parts under consideration. The variates may be morphological, physiological or chemical; the differences in size may occur in ontogeny, phylogeny, or arise from the comparison of related forms at one growth stage; and the forms of mathematical expression used to abstract the general trend of variate correlation in one comparison may bear no relation to that used with a different set of variables (cf. Gould, S. J. (1966) *Biol. Rev.* **41,** 587–640). Here indeed is a no-man's-land within the biological territories which is at the very base of intensive livestock production.

The producer for the modern market is a specialist and the trend of present day affairs is towards even greater specialisation in the future. It is not the whole animal with which he is concerned so much as with the proportions of its parts. The beef animal is prized which has a large rump and the Charolais, with its 'double buttock' is specially prized. The pig which is most preferred is that which has the longest eye muscle and a uniform back fat. The turkey which is required has a cross-section which approximates to a square. Those particular preferences may well change but it is at least probable that if they change they will be replaced by others that are quite as specific. Moreover, the proportions have arisen from genetic history and from a pattern of nutrition which has permitted the inheritance to be displayed. Whilst these relations are important they are not the only ones. Economic success depends as much upon economic production as upon producing the article which the market requires. Fundamental, then, to the issue is the relation between the growth and conformation of the animal carcass or its products, and its nutrition. If the genetic make-up of the animal is accepted, the degree to which the potential is expressed is a function of the nutrition and management of the animal. Hence the variates are many; the form of growth, both by skeletal proportion and by composition, can differ widely; there are many disciplines of pure science which, by their interaction, give rise to the fields of nutrition; and so for management too, there are particularly the studies of ecology, stressing environmental studies, and those of animal behaviour. Clearly the numbers of possible correlations between so many variates where cause and effect are seldom known is almost limitless; but the pathways of most promise are those which provide at least a working hypothesis which can be tested experimentally for the proposed correlation. Without this there is a possibility of attractive but specious arguments gaining a prominence and influence out of all proportion to their origin. For example Baldwin (*An Introduction to Comparative Biochemistry*, 1940, Cambridge Univ. Press) has speculated, with some puckishness, on the correlation in time with the disappearance of the large reptiles and the dominance of flowering plants over ferns. The consequent change in the reptilian diet, involving the loss of fern oils and their purgative action, may be thought to have caused the death of the animals from constipation!

A series of experiments lead to an advance in knowledge when their results can be generalised into a form which permits the prediction of the consequence of certain actions. When applied to particular problems, such as the rearing of livestock, it is necessary for the generalised form of the results to take into account the variations of the environment to which the prediction is to apply. Because of this there have been, and are, continual attempts to expand and to modify the simple mathematical relations which can be shown to hold for controlled systems. D'Arcy Thompson in his classic studies (*On Growth and Form*, 1942, Cambridge Univ. Press) proposed the use of linear regressions whereas Needham (*Biochemistry and Morphogenesis*, 1950, Cambridge Univ. Press) has used successively higher polynomials. Between these extremes lies the earlier proposal of Huxley (*Problems of Relative Growth*, 1932, London) that the most generalised form for allometric studies was a simple power function of the form $y = bx^n$ and this enjoys almost exclusive use.

In the current application of the agricultural sciences to the problems of intensive livestock farming the emphasis is upon determining quantitative parameters of carcass conformation so that selection pressure can be applied in breeding programmes. However it is difficult to foresee how the full potential of these breeding programmes can be developed unless comparable parameters are also established for the biochemical–physiological mechanisms through which the genetic inheritance must be displayed and which are themselves limited by the nutrition of the animal. These parameters will be discussed later in the context of animal nutrition under the headings of energy, protein, mineral and vitamin nutrition. Immediately it is useful to develop further the discussion on the quantitative approach to body conformation.

Essentially the experimental technique depends upon the application of statistical methods to the study of populations, a field pioneered by Mendel and now described by the general term of biometrics. It is, of course, a fact of agricultural experience that the finest products of livestock management had been developed by the art of the breeder and the pure breed societies of today bear witness to their aesthetic success. Hence in part the present-day biometrician is attempting to quantify the characteristics selected by the classical breeders and accepted in agricultural experience as sound so that he may develop allometric relations on which sound predictions of future performance can be based.

One of the earliest attempts to quantify the conclusions of experienced judgement was made by Herbert Spencer (*Recent Discussions in Science*, 1871) soon after Mendel's introduction of statistical method into biological studies. In essence, Spencer wished to quantify the characteristic described by the stockman as 'going light' and the Ponderal Index was the result of his observations. Here liveweight (W) is related to a linear dimension (L) which may be the length or height of the animal so that the Ponderal Index (K) $= \frac{W}{L^3}$. Clearly this can be written in the form of Huxley's generalised allometric equation ($y = bx^n$) as $W = KL^3$. An early test of the Ponderal Index was with beasts of burden where the index was matched against the animal's reputation. For example, the following values were obtained for three Burmese elephants and compared with their reputations.

Ponderal Index W/H^3	*Reputation*
1·54	famous
1·36	good
1·15	weak

Where W is the liveweight and H the height of the animal. An important advance in thinking which the Ponderal Index summarised was the recognition that geometric considerations were only part of an animal's make-up and that dynamic criteria were of major importance. Hence some realism could be inculcated into speculations on the future development of livestock into super-animals. Whilst one may express surprise that distinguished zoologists in the nineteenth century may have let their imagination dominate their observation; as for example in the speculation of Kirby and Spence (*Introduction to Entomology*, II, 1826, p. 190) on the potential of the white ant where, they suggested, if it were as big as a man its tunnels would be 'magnificent cylinders of more than 300 ft in diameter', it is hard to understand why these errors are still occasionally repeated in present day speculation on growth and development in new environments.

The classification of animal populations by liveweight is not a sophisticated procedure and so, at the present time, it has a low ranking amongst the chosen experimental techniques in agricultural research. Nevertheless, it cannot be forgotten that profitability now is primarily a function of liveweight gain per unit of feed intake. Hence the direct observation which is required is the increase in liveweight and the field in which advance is expected is in increasing the economy with which the gain in liveweight can be achieved. It is here, in the study of the economy of production, that biometric methods may be expected to introduce new allometric expressions. In terms of livestock production increase in liveweight is a function first of water content, secondly of protein content and thirdly of fat content. The study of liveweight must therefore take account of these major fractions and relate them to the nutritive requirement of the human, between whom and the plant kingdom, the animal is merely an intermediate.

In the context of feeding the world population and with the ability in the foreseeable future to manipulate the proportions of an animal at will, it becomes a major challenge to develop in animals those tissues which cannot be supplied so economically by plants or micro-organisms. At present it is easy to consider that the special role of the animal is to produce protein which is rich in those amino acids that are essential to mammalian development. However, in conditions of starvation the first requirement is for energy, and protein, even though it may be rich in essential amino acids, is nevertheless an inefficient source of energy compared with carbohydrate and especially so compared with lipid. Where these requirements of energy are uppermost there is a case for selecting animals with a potential for forming fat, and those which can do so from dietary sources which are of low energy content to the human are especially valuable.

In this way one can think past the allometric relations of geometry and dynamics to those which are at the basis of nutrition: at present physiological parameters and, as the mechanisms become known, in the future of biochemical ones. Hence there has developed a field of study in animal energetics, aptly described by Kleiber as *The Fire of Life* (1961, John Wiley and Sons, Inc.). In the present context it is useful to consider this as an exercise in accounting; of the energy put into an animal and the energy obtained from it; of relative aspects as between animals of different species and of different phyla; and to describe these differences in quantitative terms where again the generalised allometric equation will be taken as the basis.

Animal Energetics

It is not the intention in this chapter to write comprehensively on each of the areas of biological research which relate to animal production. Rather it is to select from within them those parts which seem particularly pertinent to the present problems of intensive production and from which one might expect major developments in the future. Of no area is this more true than in animal energetics where the entire field develops from the biochemical and physiological processes of oxidation in multicellular organisms to the growth and development of whole animals. It is with parts of this last aspect, the whole animal, that this section will be concerned.

One of the most striking aspects of intensive livestock farming is the almost total removal of animals from pasture into houses where the environment may be completely controlled. As a consequence it is then possible to reconsider the surface-to-volume ratio in relation to climate and environment which hitherto has been a dominant feature of animal selection. From this point of view it is worth while reconsidering some of the evidence on which Bergmann's law is based. That is to say, the mammals of cold or temperate zones are large and that no small homiotherm can be expected to be found in the sea. The following values, used by Bergmann (*Verhältnisse der Warmeokonomie der Tiere zu ihrer Grösse*, Göttinger Studien, 1847, pp. 594–708) illustrate the point.

THE METABOLIC ACTIVITY OF SUNDRY MAMMALS PER 24 HR.

Animal	*Live weight (kg.)*	*Metabolic activity Kcal./kg.*
Guinea pig	0·7	223
Rabbit	2	58
Man	70	33
Horse	600	22
Elephant	4,000	13
Whale	150,000	1·7

In this table metabolic activity has been measured by the heat output of the animals, which is recorded as Kcal. The observation, that metabolic activity gives rise to body heat, is familiar to those who keep animals and is easy to demonstrate in a heat-insulated intensive animal house. For example, in a battery laying house the room temperature rises when the birds become active at 'dawn', that is, when the lights are

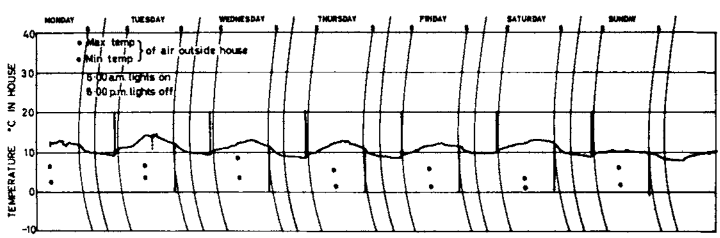


FIG. 76. A thermograph recording from a heat-insulated laying house showing the rise in room temperature associated with the switching-on of the lights (dawn) and the consequent increase in activity by the birds.

switched on. Conversely the room temperature falls when the lights are turned off and the birds cease to feed.

This experience in an intensive livestock house demonstrates that the heat output of an animal is related to its expenditure of energy and so also to the metabolic activities from which the energy was released. Furthermore, if these observations are placed in the context of the physical sciences, first, because of the fundamental law stated by Clausius, 'the energy of the world is constant', the production of heat necessarily requires the combustion of matter. Secondly, from the mathematical development of Clausius' statements of the laws of thermodynamics by Willard Gibbs and the introduction into the energy equations of mass it is possible to consider quantitative relationships between metabolic activity, necessarily related to the nutritional state of the animal, and heat output. It is inevitable, therefore, that the main instrument for reference in studying the energetic consequences of an animal's dietary should be a calorimeter. Equally, from Bergmann's Law, one is forced to consider the shape, and particularly the surface area of an animal as well as its weight.

One of the first to make comparative studies of heat production between species in terms of body surface area as well as live weight was Voit, and the following table is taken from a paper published in 1901 (*Z. biol.* **41,** 113) and in which he reported observations of the heat output from representatives of many different species under comparable resting conditions.

THE HEAT PRODUCTION OF RESTING ANIMALS OF VARIOUS SIZES IN A THERMONEUTRAL ENVIRONMENT

Animal	*Liveweight (kg.)*	*Heat production in 24 hr. in Kcal.* Total	*per kg. liveweight*	*per sq. m. of body surface*
Horse	441	4983	11·3	948
Pig	128	2445	19·1	1078
Man	64·3	2064	32·1	1042
Dog	15·2	783	51·5	1039
Goose	3·5	233	66·7	969
Rabbit	2·3	173	75·1	776
Fowl	2·0	142	71·0	943
Mouse	0·018	4	212·0	1188

It is immediately apparent that metabolic activity is more closely related to body surface area than to bodyweight and an extensive study by Benedict (*Ergebnisse d. Physiologie*, 1934, **36,** 300–346), from which the data below are quoted, has formalised the relationship in terms of a mean ratio $^{2}\sqrt{S}/^{3}\sqrt{W}$ where S (surface area) is considered as a square and W (weight and a function of volume) is considered as a cube. In this way the following values were obtained to test the concept of relation between body surface area and liveweight. (p. 428)

Although the surface area of an animal body is difficult to determine, the concept of the surface law has a simplicity which has attracted many in spite of theoretical objections which later work has raised. In this context the allometric relations, which summarise many and varied biological observations and are of value precisely because of this, have tended to develop into biological laws. Kleiber, as early as 1932

('American animals', *Hilgardia*, **6**) reported marked deviations from the surface law in experiments which were similar to those of Voit but in which the subjects were American rather than European animals. Since, the extensive development of biochemical knowledge has added

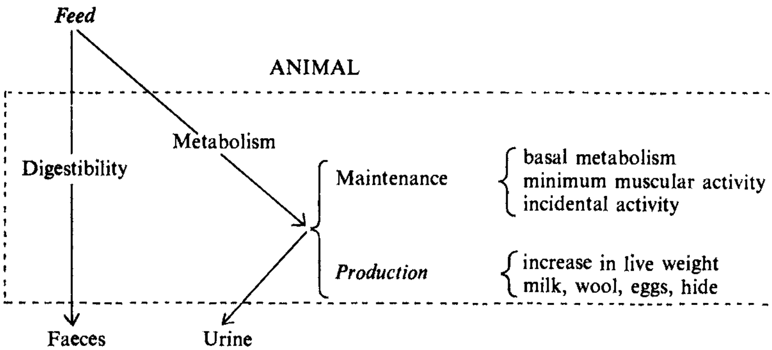
Animal	*Mean ratio* $\sqrt[2]{S}/\sqrt[3]{W}$ *in cm. g. units*
Snake	12·5
Ape	11·8
Man	11·0
Dog	10–11
Frog	10·6
Birds	10
Tortoise	10
Horse	10
Cat	10
Rabbit	9·75
Cow, Pig, Rat	9
Sheep (shorn)	8

to the evidence against a theory of 'surface law', even though there may be circumstances where the relation itself can be useful in a strictly allometric sense (e.g. Krebs, H. A. (1953) 'Some aspects of the energy transformations in living matter', *Brit. Med. Bull.* **9**, 97). A relation now almost universally used concerns only metabolic rate (R) and liveweight (W) in the form of Huxley's general allometric equation (Brody, S. (1945) *Bioenergetics and Growth*, N.Y., Reinhold Pub. Corp.)

$$Q = KW^n$$

where K is a proportionality constant and n may vary from species to species but for which a value of 0·75 is generally acceptable for farm animals and for which Kleiber has published tables (*The Fire of Life*, 1961, John Wiley and Sons, Inc.).

With these concepts, developed from the observation of whole animals, in mind, it is worthwhile considering the possibilities of present techniques of research, particularly those relating to intermediary metabolism, in relation to intensive livestock farming. Agriculturally, the environment can be totally controlled and so is no longer an unknown. More importantly selection in breeding programmes does not have to include resistance to extremes of climate and so greater pressure can be used on parameters concerned directly with production. The effectiveness is, of course, a function of the precision with which these parameters can be identified. For this reason it is necessary to consider what is means by basal metabolism and to evaluate the efficiency with which nutrients of different types can be converted by the farm animal under intensive conditions into saleable products (cf. Blaxter, K. L., 1964, *Energy Metabolism*, Academic Press, N.Y., London). The more obvious variables are summarised diagrammatically below.



The comparison of feed input with faecal output is the conventional measure of the digestibility of a feed. That portion of the feed which is digested is metabolised and three fractions result from this: urine, a proportion for maintenance and a proportion for production. Because the components of the urine are themselves the results of maintenance and/or productive activity in the animal it is reasonable to confine discussion to maintenance and production alone. Agriculturally the animal is fed for production, so it follows that if the same feed is to be used more efficiently the proportion of energy required for maintenance must be reduced. Secondly, the nature of the product itself produces special metabolic demands: a high protein requirement for meat and wool and a requirement for lipid in addition to protein for milk and eggs, where a further requirement for calcium is also present. From an understanding of the quantitative aspects of these metabolic systems will come the possibility of purpose-made diets whose performance can be predicted from the knowledge of the quantitative intermediary metabolism of the hybrid concerned and the content in the diet of significant metabolites.

There is, however, a possibility of quicker advance in the application of animal energetics to intensive livestock production. This concerns the field of economy and hence that portion of the energy intake required for maintenance. In contemporary farming conditions muscular activity is small and incidental activity as, for example, that associated with walking to feed and drink, can itself be held low. The most important fraction is basal metabolism, the minimum rate of expenditure of energy compatible with life, and this itself has three component parts: (i) expenditures of the individual tissues and organs of the body under conditions that will not stimulate their functioning, (ii) expenditures of the pulmonary, cardiovascular and renal systems in furnishing the tissues with oxygen and removing waste products of metabolism from them and (iii) 'heat increment' or 'specific dynamic action' (S.D.A.) of the body nutrients being oxidised in the fasting animal to provide energy for life processes.

Both (i) and (ii) are physiological consequences of the anatomy of the animal concerned. These cannot be influenced by nutritive means and at present it cannot be foreseen how a breeder could identify a parameter for selection pressure which would relate directly to either function. The third part, however, is an area where there is more promise of return for research effort. The study of S.D.A. is the study of the fundamental energy processes of the animal itself and by definition these biochemical studies cannot be made outside of the animal. Some degree of physiological preparation is consequently inevitable and so, too, is some means of identifying which of the known energetic systems of biochemistry is dominant. In essence one is wishing to study quantitatively the oxidation of organic, and therefore of carbon-containing compounds. Inevitably in higher animals carbon dioxide is the terminal product with a variety of associated nitrogenous compounds. Hence the study of respiratory exchange is itself a direct study of the metabolic, and so also energetic, processes of the animal. If to this technique of indirect calorimetry is added a system of marking individual metabolites so that the proportion of them which contributes to the terminal carbon dioxide can also be determined, one can then start to identify those metabolic pools which have the greatest energetic significance.

In the illustration a convenient instrument is shown for determining respiratory gas exchange and in this instance it is being used with the simultaneous infusion of radioactive glucose (labelled universally with ^{14}C) so that the contribution of this particular metabolite to the total energy requirement of the hen can be determined. It is important to stress that in such a technique the mass of the marker infused is so small that it can be neglected and that marking of the substrate is achieved by the rapid equilibration of the radioactive isotope with the inactive one. Hence a proportion of, in this case, all the glucose in the animal will contain, at equilibrium, radioactive carbon (cf. Comar, C. L. (1955) *Radioisotopes in Biology and Agriculture*, N.Y., McGraw Hill Book Co. Inc.).

By such means there is hope of progress in understanding the energy conversions which take place in animals and so of organising agricultural practice, both in husbandry and nutrition, to produce the product wanted with more economy. Nevertheless, it is clear that in this account more has been omitted than has been included and that in particular the entire problem of digestibility and its physiological implications has been neglected. However, other chapters have described in detail the physiology of digestion in ruminants and the microbiological interactions on intestinal function in both ruminant and non-ruminant animals.

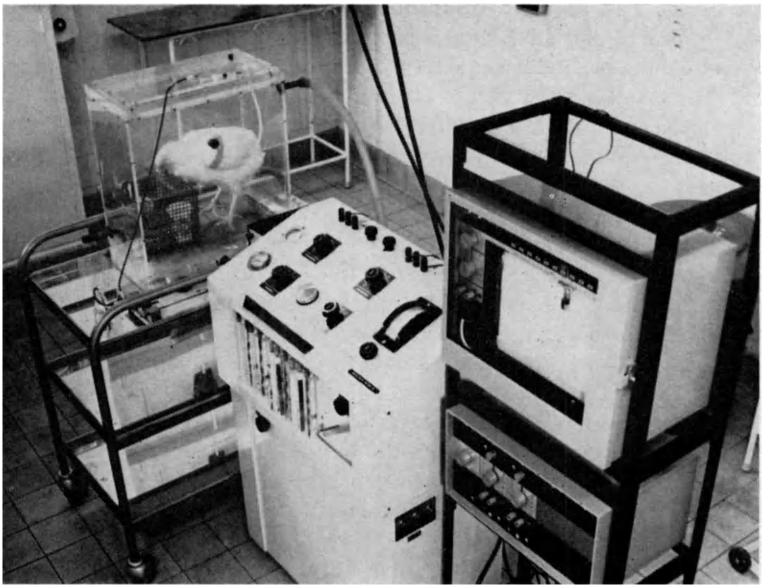


FIG. 77. A modern apparatus for determining metabolic rates. An indirect calorimeter based on the principle of Noyons (a diaferometer) which measures the consumption of oxygen and the output of carbon dioxide simultaneously.

Interactions between Growth and Product

The most spectacular result of intensive livestock farming is the increase in productivity. In developing economies the importance of this aspect outweighs all others, but in economically advanced areas large amounts of food are consumed for pleasure and the 'niceness' of the product is at least as important as its amount. 'Niceness', or what is liked, is not necessarily related to nutritional quality or to any other objectively appraised merit and neither does it necessarily have the same meaning in different places. Nevertheless where choice is possible purchase will be made on a basis of preference and whether this is capricious or not is irrelevant to the outcome. There is, then, some purpose in comparing the products of intensive farming with those of extensive systems and of applying research to determine how these products attain their characteristics. The field is difficult to study quantitatively because the final assessment is subjective but the extent of the interactions is so great that it is better to illustrate the general problems involved by reference to two specific examples than to attempt to outline a general account.

The numbers of eggs produced by hens in a laying year have increased by up to 100 per cent when the performance of the modern intensively housed hybrid is compared with that of the former extensively managed pure breed. This requires an output of approximately 2 gm. of calcium a day for up to 300 days, apart from the energetic and protein requirements of the egg. It also requires the secretion of an equivalent amount of carbonate. Skeletal calcium accounts for part of this total and there is a portion of the skeletal calcium which can be regarded as a metabolic pool in equilibrium with the plasma pool of calcium. Unfortunately for the bird, the mobilisation of skeletal calcium results in the concomitant release of other ions, particularly phosphate, and, because these are not included in the egg shell, they have to be excreted. To reduce renal damage a considerable amount of water is also excreted resulting in the field in 'wet droppings'. However, the movement of electrolytes is so complex in practice that this cannot be taken at present as even an adequate explanation of this particular syndrome and far less as an exclusive explanation of all symptoms of 'wet droppings'.

So far as the shell is concerned the mobilisation of both calcium and carbonate is only the initiation of the problem. Only part of the strength of the shell lies in its thickness; structural considerations, from which the organic matrix cannot be omitted are at least of equal importance in determining the strength of the shells from hybrid hens. Hence there is a problem of understanding how a structure is synthesised and what effect, if any, there is upon this if the parent organism, the hen, is under metabolic stress. The study is further complicated by the lack of any adequate rheological explanation of the mechanical properties of the egg.

The second example, taken also from intensive poultry keeping, concerns flavour. Again, as with the study of texture, there are at present inadequate means of objective assessment. It is widely stated that the meat of the intensively produced chicken has less flavour than that of its extensively produced counterpart. The active area of flavour and odour perception is so broad and so little developed (cf. Zotterman, Y., 1963, *Olfaction and Task*, London, Pergamon Press) that constructive discussion is difficult and made the more so because the subject is frequently raised in relation to intensive production. However, so far as chickens are concerned there is at least the speculative possibility that part of the profile of volatile compounds in the muscle may have its origin in the metabolic activities of the intestinal microflora (Shrimpton, D. H., 1966, *J. appl. Bact.* **29**, 222–230). Future research, building on the foundations described in the chapter on intestinal microorganisms, may well be able to determine how to adjust the microflora by nutritional means, thereby modifying its metabolism and influence upon the composition of the carcass.

Whilst neither example has been developed to the point of a complete account, each demonstrates the broadness of the interactions between scientists of different disciplines that can arise when a field condition is studied in detail.

In Conclusion

A conclusion is wholly inappropriate. The scientific study of intensive livestock farming is still developing and properly there is a dynamic state of ideas with little yet to be certain of except that most scientific disciplines can profitably be applied to the subject. In time a field of research will become established and with it a balance of research disciplines, which may consolidate the present, give emphasis to the prejudice and imbalance of this discussion, or give rise to yet another specialised discipline of applied activity.

Nevertheless it would be mistaken to conclude that there are no established precedents of intensive animal management on which to base a general pattern of research. Since the industrial revolution the human being has been housed as intensively as much of our livestock is today. It is clear through social studies of more than a century and a half that resilience and adaptation are two of the chief characteristics of the subjects of intensive management, and so, in a study of *The Physiology of Human Survival*, Edholm, O. G. and Bacharach, A. L., 1965, London and N.Y., Academic Press) McCance and Widdowson have concluded '. . . healthy, hungry men, women and children adapt to changes in their dietary pattern so rapidly that they can accept them without exhibiting any signs of discomfort'.

Chapter 30

THE PHYSIOLOGY OF RUMINANT DIGESTION

K. J. HILL

The presence of a large fermentation chamber strategically placed at the cranial end of the digestive tract has conferred many unique and advantageous features on the ruminant species. Exploitation of these has constituted one of the major avenues for the improved performance of our dairy and beef herds and there is little doubt that with further knowledge of the intimate mechanisms of the fermentation process the potentialities of the ruminant will be realised to an even greater extent.

The unusual arrangement of an extensive bacterial fermentation system operating within an animal species has attracted a great deal of attention during the past 30 years and much of the physiological and biochemical work on ruminant digestion has related to the effects of such a system on the digestive process. It is convenient therefore to attempt a synthesis of these observations in terms of the functioning and maintenance of rumen fermentation since it has become increasingly obvious that this process constitutes the key to the whole economy of the ruminant species.

All herbivorous animals require a compartment of the alimentary tract where bulky plant materials can undergo soaking and fermentation by cellulose-producing organisms. In the most successful group of herbivores, the ruminants, this requirement is met by the complex stomach where fermentation products are produced and absorbed and where large amounts of bacterial protein are formed for subsequent digestion in the lower part of the tract. Detailed accounts are available elsewhere of the gross and microscopic structure of the ruminant stomach (Sisson 1943; Habel 1956) but it is particularly worth noting the large capacity of the reticulum and rumen, which function as a single fermentation chamber, in relation to the rest of the tract (Table 1).

Because the reticulo-rumen is not simply a storage chamber but the site of intensive microbiological activity a constant supply of food material is necessary to permit a continuous fermentation process. This is achieved in the wild state and in domesticated ruminants at pasture by a more or less continuous grazing pattern. Observations on such animals have shown that they spend about one-third of each day grazing, one-third ruminating and one-third resting. Stall-fed animals, such as high yielding dairy cows, are frequently fed four times a day in an attempt to simulate grazing conditions and even more frequent feeding has been advocated within recent years. It is not irrational to expect any fermentation system to perform more efficiently with frequent small additions of substrate and this indeed appears to be so with the reticulo-rumen. Economic considerations may however preclude any large scale adoption of this system.

TABLE 1

AMOUNTS OF DIGESTA FOUND IN THE RETICULO-RUMEN OF SHORTHORN COWS RECEIVING VARIOUS DIETS

(From Balch and Line 1957.)

		Contents of reticulo-rumen		
Diet	*Cow*	*Total (lb.)*	*Dry matter (lb.)*	*Dry matter (%)*
Hay alone	W22	166	18	11
Hay + concentrates	D15	156	19	12
Hay + concentrates	L32	164	22	14
Hay + beet pulp	K	175	18	10
Grazing	W22	130	12	9
Grazing	D15	129	11	8
Grazing	L32	114	9	8
Grazing	K	125	13	10

The ruminant mouth is particularly well adapted to the rapid harvesting of growing plant material in that a relatively large cutting area is provided by the lower incisors and a firm base against which they can press by the dental pad. Several bites of herbage are usually accumulated at the back of the mouth, partially impregnated with saliva, and swallowed as a bolus which may weigh about 100 gm. in the bovine and 30 gm. in the sheep. Although not chewed to any great extent, there is considerable disruption of the plant cells and their contents are liberated into the rumen. Concentrates tend to be eaten more rapidly than hay, are mixed with less saliva and are masticated little if at all. One result of the relatively rapid ingestion of food is that stones, sand and other foreign bodies, particularly pieces of wire, are frequently swallowed.

Bolus formation is assisted by admixture with saliva but it has long been recognised that the major role of the well-developed ruminant salivary glands is that of providing a buffer system for the rumen contents. In the presence of a large population of micro-organisms capable of rapidly hydrolysing carbohydrates there is little need for a salivary amylase and this enzyme is indeed absent, although in the young monogastric ruminant this may be a disadvantage. The relatively high bicarbonate concentration and the large volume of saliva produced ensure that the continuous production of acids by the rumen microbes is able to take place without violent fluctuations in rumen pH.

The ruminant oesophagus is composed largely of striated muscle and hence the bolus when swallowed is transported rapidly and is forcibly ejected into the fluid digesta present in the anterior region of the rumen. Different foods tend to follow different courses once they reach the reticulo-rumen and the physical characteristics of particle size, specific gravity and moisture content have been related to the route followed. Hay and other roughage, for example, tend to be packed in the anterior region of the dorsal sac whilst concentrates and foods of small particle size, which tend to absorb water readily, accumulate in the ventral region of the rumen. The material in the reticulum and anterior ventral region of the rumen may have a dry matter content of only 5–7 per cent whilst that in the dorsal sac may be over 15 per cent.

Although, as will be seen below, a complicated series of muscular contractions takes place in the rumen and reticulum which ensures mixing of the digesta and rapid inoculation with micro-organisms, the physical form of the food is important in so far as the speed with which the fermentation reaction can develop and the rate at which food material passes along the tract. The physical form of roughage in particular is significant in this respect and a great deal of work has been carried out within the last 10 years on the effect of altering the particle size of roughage by grinding or by pelleting (Balch and Campling 1962). These procedures alter the rate of digestion of roughages and also the nature of the digestion products, both factors which influence food intake and utilisation. Thus if roughages are ground to a certain degree of fineness, food intake usually increases and passage through the digestive tract is accelerated whilst an increased rate of attack by the rumen organisms is also probable. Pelleting of ground roughage also results in an increase in its rate of passage through the digestive tract which may be the reason for the increased intakes noted with this type of feeding since intake is closely related to the amount of food in the reticulo-rumen. The control of food intake and appetite constitutes, in fact, one of the most intriguing areas relating to the digestive process and assumes particular importance under intensive feeding systems. In monogastric animals the tendency is now to regard the regulation of food intake as a multifactor phenomenon in which chemical and physical factors related to the presence or absence of food in the digestive tract affect higher centres and give rise to sensations of hunger or satiety and hence influence appetite. Among the physical factors involved is the degree of gastric distension and in this context the degree of rumen fill appears to be important (Balch and Campling 1962).

The complicated nature of the movements responsible for ensuring adequate mixing of the fermenting mass of material in the reticulo-rumen has already been referred to and these have been described in detail by many investigators (Schalk and Amadon 1928; Phillipson 1939). Basically, the cycle of movement commences with a double contraction of the reticulum followed by contraction of the anterior pillar of the rumen, the dorsal sac and then the ventral sac. The rate of contraction is about once per minute but it is rather faster during eating and slower when the animal is at rest. Each contraction cycle moves fluid digesta upwards, backwards and through the mass of digesta in the dorsal sac and so repeatedly exposes the digesta to inoculation with micro-organisms.

Rumination is a further process which assists in the reduction of the particle size of digesta and also facilitates bacterial attack. In general the coarser the fodder the greater the time spent ruminating.

During fermentation a mixture of gases, mainly carbon dioxide and methane, is produced in the reticulo-rumen and is continuously removed by eructation, although small amounts are absorbed through the rumen epithelium. Failure to remove this gas leads to bloat. Details of the eructation reflex have been carefully defined (Dougherty 1961) and one of the more fascinating observations is that a proportion of the eructated gas passes down the trachea into the lungs. One result of this occurrence is that volatile flavours rapidly enter the circulatory system and may be excreted in the milk and give rise to off-flavours.

Final consideration of the mechanical role of the reticulo-rumen relates to its function in the propulsion of digesta into and through the omasum. Although some reduction in reticulo-rumen content by fluid absorption through the reticulo-rumen mucosa occurs, the large food and water intakes of the ruminant, together with the copious volume of saliva which is secreted, render it necessary for there to be a more or less continuous discharge of digesta from the reticulo-rumen. Estimates of around 4 *l*/hr. (cow) and 7 *l*/24 hr. (sheep) have been made for the volume of material which leaves the rumen but further work has shown that in the sheep, the flow rate can vary from 5·8 to 18·0 *l*/24 hr. depending on the nature and amount of the diet (Hogan 1965). Flow from the rumen appears to be greater during feeding when there is also marked activity of the ventral sac of the rumen.

Examination of the abomasal content normally reveals only very fine particles and it is essentially the reticulo-ruminal fold and the reticulo-omasal orifice which are responsible for the retention of coarse particles in the rumen. The factors involved in the passage of digesta into and through the omasum are however, complex and it is not possible to make any generalisations to fit all conditions. It has been shown, for example, that the quantity and physical form of food eaten and the degree to which it is fermented influence the flow from the omasum of the sheep. Thus an intake of 400 gm. of long dried grass was accompanied by flow rates of 130–152 ml./hr. and when this was increased to 1100 gm. the flow rates were 250–346 ml./hr. Grinding and pelleting the grass resulted in a reduction in flow. Flow rates were reduced to a greater extent when ground pelleted barley was fed and it is possible that the much greater degree of fermentation of this high carbohydrate diet was responsible for the reduction in the amount of material which left the rumen and omasum. Reticular contractions, which are themselves influenced by many factors, and the volume of the abomasal contents also affect the flow of digesta through the omasum.

These results indicate the complexity of merely the mechanical factors responsible for regulating the fermentation system in the reticulo-rumen and serve to emphasise the need for further work in relation to novel feeding systems such as those based on ground roughage, pelleted roughage and high concentrate levels. Since the rate and extent of fermentation are primary factors in the degree of energy utilisation of many feeds it is important that the flow patterns through the stomach and their relationship to fermentation are fully understood.

Apart from its importance as a sieving mechanism there is evidence that absorption of volatile fatty acids and electrolytes occurs in the omasum and that a considerable amount of water is absorbed during this process so that the liquid content of the digesta which enter the abomasum is less than that in the reticulo-rumen.

The material leaving the omasum is immediately immersed in the acid abomasal content and is mixed by the slow regular abomasal contractions. Secretion of acid gastric juice is a continuous process (Fig. 78) largely attributable to the continuous flow of digesta through the abomasum and it is here where the ruminal micro-organisms are killed and where they start to be digested although proteolysis in the abomasum appears to be somewhat limited. Volatile fatty acids, which exert their effect directly on the abomasal mucosa and indirectly after their absorption from the reticulo-rumen are important stimulants of gastric secretion (Hill 1965), a fact which again emphasises the close functional interrelationship between the different chambers of the ruminant stomach.

Many studies have been made of the flow of digesta from the abomasum to the duodenum and rates of 10–12 *l*/24 hr. have been measured in sheep eating 1000 gm. of food daily. *Ad libitum* feeding results in increased flow rates and increasing the frequency of feeding also has this effect. Little has been done on the composition of the duodenal digesta under these conditions but it is possible that some of the diet may then escape rumen fermentation, particularly when large amounts of cereals are fed, and more efficient use may be made of dietary energy than by the somewhat wasteful process of fermentation.

The presence of a very large bacterial and protozoal population in the rumen confers several advantages on the host animal. Primarily, cellulose, which the host animal itself is unable to digest, is largely converted during fermentation into short chain fatty acids, which constitute an important energy source for the ruminant. Moreover during the fermentation process many of the bacteria are able to use non-protein nitrogen and low quality protein for their growth and multiplication and in so doing form bacterial protein of a higher biological value. This is subsequently digested and metabolised by the host animal. Vitamins are also synthesised by the rumen micro-organisms. The nature of fermentation relates to the types and numbers of organisms present and this balance is the product of many interacting factors (Fig. 79).

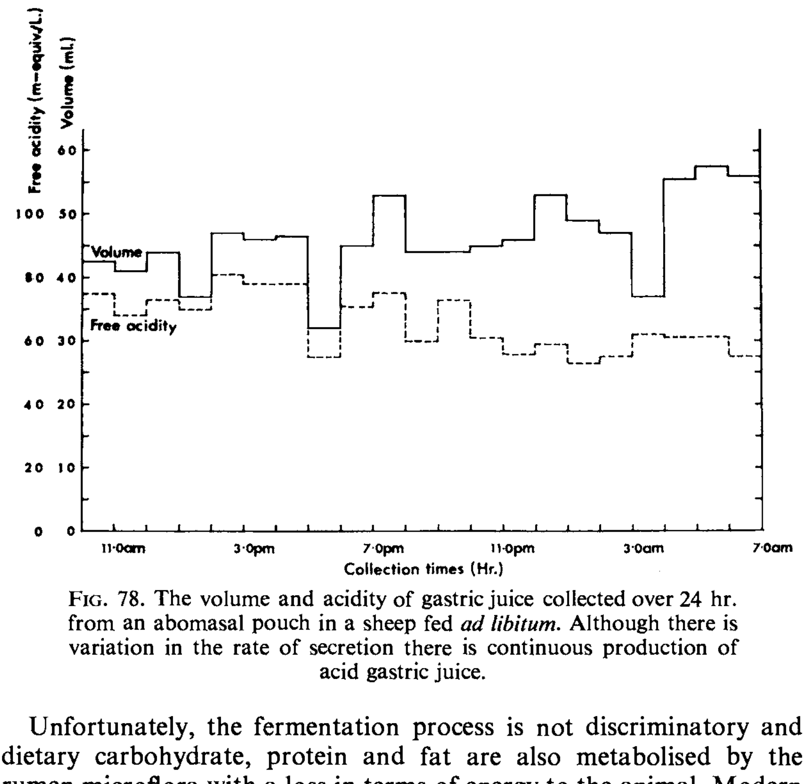


FIG. 78. The volume and acidity of gastric juice collected over 24 hr. from an abomasal pouch in a sheep fed *ad libitum*. Although there is variation in the rate of secretion there is continuous production of acid gastric juice.

Unfortunately, the fermentation process is not discriminatory and dietary carbohydrate, protein and fat are also metabolised by the rumen microflora with a loss in terms of energy to the animal. Modern concepts of ruminant feeding endeavour to exploit the desirable features of fermentation and although advances have been made in this direction little has been done so far to minimise or annul the less desirable aspects.

In summary, therefore, all the physiological activities of the anterior digestive tract are aimed at maintaining optimal conditions for the growth and multiplication of micro-organisms in the rumen. These are present in large numbers and are suspended in a liquid or semi-solid medium consisting of saliva, water and food material. A continuous intake of food and continuous salivary secretion permit a continuous fermentation system which is further maintained by the controlled discharge of residual cellulosic material and live and dead bacteria into the omasum. Adequate mixing and breakdown of the food material is ensured by the reticulo-ruminal movements including rumination. Removal of the gases produced during fermentation takes place by eructation.

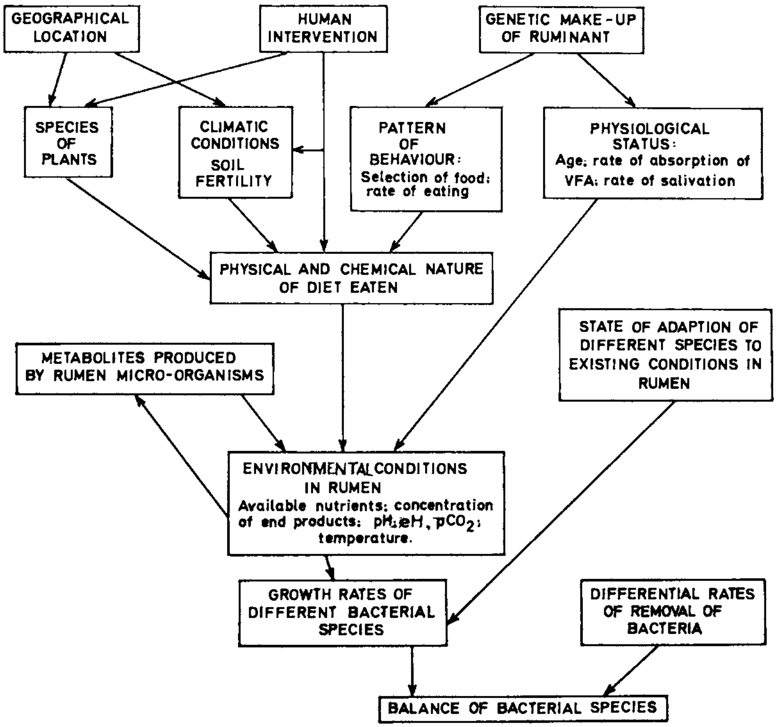


FIG. 79. Factors which influence the balance of bacterial species in the rumen. (From Kistner 1965.)

The rumen micro-organisms themselves have been investigated in considerable detail and the main classes of bacteria and protozoa adequately defined (Warner 1965). Their major nutrients are plant proteins, celluloses, starch and a small amount of urea derived from saliva and they are all broken down during fermentation to a variety of end products. Interest has however centred mainly on the volatile fatty acids (V.F.A.) which are products of cellulose and carbohydrate fermentation since it was shown that these are absorbed through the reticulo-rumen epithelium and constitute the major energy source for ruminants (Barcroft, McAnally and Phillipson 1944). Acetic, propionic and butyric acids make up over 90 per cent of the total acids produced, with acetic acid normally present in greatest proportion. Small amounts of the branched chain acids, iso-butyric, 2-methyl butyric and iso-valeric are also present.

The type and physical condition of the diet does, however, markedly influence the proportions in which the VFA's are produced. A hay diet usually results in about 70 per cent acetic, 18 per cent propionic and 10 per cent butyric, whilst the addition of carbohydrate produces an increase in propionic and a fall in acetic. Finely ground hay has a similar effect and an even greater one is produced by feeding a combination of finely ground alfalfa and steam-heated maize. This increase in the percentage of propionic acid is advantageous to the beef animal from an energy point of view but is a disadvantage to the dairy cow in that it leads to the production of milk of low butterfat content.

The interrelationship of the chemical and physical nature of the diet and the microflora is obviously complex and despite our present extensive knowledge there are many factors which still require investigation. Although these are essentially biochemical problems which relate to the fermentation process, the maintenance of this system within the animal is a physiological one which demands equal attention.

The Young Ruminant

Detailed studies on the embryology of the ruminant stomach have shown that the various chambers all arise from the primitive stomach spindle and that none of them are of oesophageal origin (Warner 1958). They differentiate early in foetal life (Fig. 80) and up to approximately

FIG. 80. Stomach of foetal lamb (90 days) showing approximately equal development of all the chambers at this stage of gestation

half-term grow at the same rate. After this time the abomasum develops more rapidly than the other compartments so that at birth it constitutes about 50 per cent of the total stomach weight. This is not surprising in view of the monogastric nature of digestion in the young ruminant although even the abomasum is not completely functional at birth.

Digestion and absorption of food material is essentially non-existent in the foetus although there is ingestion of amniotic fluid during foetal life and cellular debris, pigments and hairs are collected as meconium and slowly moved out of the tract. Immediately after birth the digestive tract is presented with large quantities of food and it is remarkable how efficiently the digestive processes handle this material. Under grazing conditions ewes suckle their lambs about once an hour so that there is essentially continuous digestive activity. After the first few days there is a gradual reduction in suckling time and a further greater reduction when the lambs are 14 days old. Lambs may be picking at grass when they are a few days old but only begin to eat appreciable amounts between 2 and 3 weeks of age. Calves suckle frequently during the first few days of life but are thereafter only allowed to suckle for three or four 15 minute periods each 24 hours.

The oesophageal groove mechanism by which colostrum and milk are diverted directly into the abomasum has been studied in detail and its reflex pathways delineated (Comline and Titchen 1961), whilst radiographic observations of milk containing barium sulphate have provided visual evidence of the route followed after sucking or pail feeding (Benzie and Phillipson 1957). In the lamb, kid and calf an accumulation of barium occurs at the level of the diaphragm which is indicative of a constriction at this point in the oesophagus and through which the food material passes in spurts. It enters the oesophageal groove in a liquid stream and is directed into the omasum. This organ, however, does not appear to fill with barium sulphate when the meal is suckled from a bottle; instead the fluid passes along the omasal sulcus and only traces of barium are seen adhering to the free edges of the omasal laminae. Small quantities of barium sulphate occasionally enter the reticulum and this appears to occur more often in the calf than in the lamb or kid.

The path followed by gruel meals containing barium sulphate has also been studied and whilst milk taken from a bottle invariably passes to the abomasum with occasional slight spillage into the reticulum, gruel meals drunk from a pail may not do so. Thus gruel feeds may pass into the reticulum and rumen or directly into the abomasum. The frequency of this latter occurrence has not been established nor has the basic reason been elucidated.

Irregular movements of the rumen and reticulum have been noted in the young suckling ruminant even though food was absent from these chambers. Regular co-ordinated movements of the reticulo-rumen do not appear to develop whilst milk feeding is continued and it is only with the introduction of roughage into the diet that the characteristic contractions occur. The basic nervous mechanisms are present from an early age and it would appear that the onset of contractile activity is related to the presence of solid food in the reticulo-rumen and to the increased muscular development which occurs with roughage feeding. The regular cycle of reticulo-rumen contractions which then occurs is comparable to that of the adult and has the same function of mixing and moving on the reticulo-rumen content.

The main organ concerned with the reception, mixing and onward propulsion of a milk meal is the abomasum and it is probable that this organ is never completely empty of food material. The frequency of suckling ensures a regular entry of milk, especially during early life, but in addition the milk-clotting mechanism helps to retard the emptying of a portion of the meal. The passing of whey from the abomasum to the duodenum is, however, a rapid process since barium sulphate given in a milk meal to calves up to a week old has been observed to enter the duodenum within 5 minutes of sucking. The rate of stomach emptying becomes slower after 1 week of age. Many factors affect stomach emptying and these have not been fully evaluated in the sucking ruminant. Boiled and autoclaved milk for example have been found to leave the stomach faster than raw milk and milk containing 6 per cent fat apparently leaves the stomach faster than skim milk. These differences have been attributed to variations in the type of curd produced in the stomach. Other evidence that curd formation is important in controlling the passage of a meal through the abomasum has been obtained from experiments in which the nature of the diet inhibited or excluded clot formation (Blaxter and Wood 1953). Thus a reduction in the casein content of liquid diets resulted in a decrease in the digestibility of fat and protein and in the onset of scours. Replacement of casein, which forms a clot with rennin, by gelatine, which does not, leads to profuse diarrhoea and lowering of the calcium content of an artificial diet which markedly increases clotting time, has the same effect. These observations indicate some of the factors which must be evaluated in the preparation of satisfactory early weaning diets.

The first milk obtained after parturition is colostrum and its composition differs markedly from that of later milk, the most striking difference being in the high concentration and distribution of proteins. The high content of immune globulins is important in the transmission of immunity to the young animal which is accomplished by absorption of the intact protein without prior digestion. The absorptive property of the intestinal epithelium ceases when the calf is 24 and the lamb 36 hours old and emphasises the importance of feeding colostrum immediately after birth.

An understanding of the enzymic changes which occur during the development and growth of the digestive tract is of considerable importance in the establishment of techniques of artificial feeding and it is unfortunate that so little meaningful information is available on the young ruminant. Enzyme estimations have been carried out on tissue extracts and have provided useful information on the nature of the enzymes present at particular ages. They do not provide however any information on the amounts actually secreted during the course of a meal and it is this quantitative aspect of digestion which is of particular interest in the evaluation of the digestive capabilities of an animal.

The importance of clot formation in the regulation of the flow of digesta along the tract has already been alluded to and it is the presence of milk coagulating proteolytic enzymes, rennin and pepsin, in the gastric juice which is primarily responsible for the rapid clotting of ingested milk. The relationship between the two enzymes has not so far been elucidated, although there are indications that rennin is the only enzyme present at birth and that provided the animal is maintained on a milk diet it is predominantly rennin which is secreted. With the introduction of solid food into the diet pepsin secretion is stimulated and rennin secretion diminished. Although the clotting and proteolysis of milk is satisfactory, other proteins, particularly vegetable proteins are not digested to the same extent; whether the ability of the gastric proteolytic enzymes to hydrolyse these proteins is deficient is not known.

The secretion of various enzymes concerned with carbohydrate digestion varies with age. Thus in the very young calf the lactase concentration is high in the intestinal mucosa and decreases with age. Maltase is low in early life but increases with age. Sucrase and pancreatic amylase are also present in low concentration in the very young calf and it is therefore apparent that apart from lactose the calf is poorly equipped to digest carbohydrates. These limitations impose a number of difficulties on the development of adequate milk replacers for the young calf and efforts are being made to overcome enzyme deficiencies by the addition of appropriate enzymes to calf diets. With the advent of more detailed information on the enzymes present and on the factors governing their secretion significant increases in the utilisation of many carbohydrates should be achieved.

Although there has been a great deal of work on the characteristics of a digestive system which commences as a monogastric process, passes through a mixed monogastric and polygastric phase and finally becomes completely polygastric, it is only comparatively recently that a detailed understanding of the mechanisms involved has been obtained. The recognition that the change from monogastric to polygastric is a variable process has led many workers to attempt to assess the relative capacities of the various chambers at different ages as a guide to the degree of development and a variety of parameters has been used, e.g. weight, volume, shape and position. The large capacity of the reticulo-rumen impressed many of the earlier workers and they measured this by filling the stomach with water and relating the volume of each chamber as a percentage of the total stomach volume. The major error in most of these determinations was over-distension of the stomach so that erroneously large capacities were obtained.

The need for an accurate method of measuring the relative capacities of the stomach chambers as an index of the extent of transition from monogastric to polygastric has however become increasingly important in relation to recent findings that the degree of development can be manipulated by various dietary treatments. Warner and Flatt (1965) have reviewed this problem and have proposed that the relative values of the weight of the wet content from the different stomach compartments and the relative weights of wet tissues from each compartment of the adult stomach should be used as numerical guides with which to compare the anatomical development of the stomach.

The abomasum constitutes about half the total volume of the stomach compartments at birth but gradually its relative size decreases (Table 2).

TABLE 2
THE PERCENTAGE OF TOTAL STOMACH TISSUE CONTRIBUTED BY EACH COMPARTMENT FOR CALVES AND LAMBS AT SEVERAL AGES
(From Warner and Flatt 1965.)

	Age in weeks						
Bovine	0	4	8	12	16	20–26	34–38
Rumino-reticulum	38	52	60	64	67	64	64
Omasum	13	12	13	14	18	22	25
Abomasum	49	36	27	22	15	14	11
Ovine							
Rumino-reticulum	38	63	75	72	75		73
Omasum	7	5	5	7	6		7
Abomasum	55	32	20	21	19		19

The most dramatic change is between 2 and 6 weeks and after 8 to 12 weeks the changes in the lamb stomach are small. Estimates vary as to the time the proportions of the stomach compartments of the calf reach those of the adult; 3, 6 and 9 months have been proposed but it would appear that after 3 to 4 months there is little further change in relative proportions.

The major factor which influences the growth of the reticulo-rumen is the consumption of solid food. Calves or lambs maintained on a milk diet for long periods show retarded development of the fore-stomach which has thin walls and little or no papillary development. The addition of roughage to the diet has long been known to promote an increase in growth of the reticulo-rumen and for many years it was considered that it was essentially the physical stimulus of roughage which was responsible. Brownlee (1956) and Warner, Flatt and Loosli (1956) suggested however that fermentation products were important for fore-stomach development, especially for papillary growth, and this view was confirmed when it was shown that papillary growth could be elicited by the introduction of the sodium salts of short chain fatty acids into the rumen of calves maintained on low fibre diets. Later work showed that the volatile fatty acids used were effective in the order butyrate, propionate, acetate and that the papillae produced were identical with those produced on normal diets.

Removal of hay and grain and reintroduction of a milk diet causes regression of the papillae, again indicating that fermentation products are necessary for papillary growth and maintenance. It seems probable therefore that the epithelial cells require V.F.A.s for their metabolism before they are able to grow and before they are metabolically active. The exploitation of these findings in terms of the promotion of rapid reticulo-rumen development by the addition of fatty acids to the diet has not so far been wholly successful although the practical advantage of an early introduction to roughage and concentrate is well established.

The early establishment of a ruminal flora is of course essential before any fermentation reaction can take place and direct contact with adult animals or with food materials contaminated with saliva is necessary. The nature of the diet and the time of weaning greatly influence the development of the flora and it appears that roughage diets allow the most rapid development of a wide variety of organisms.

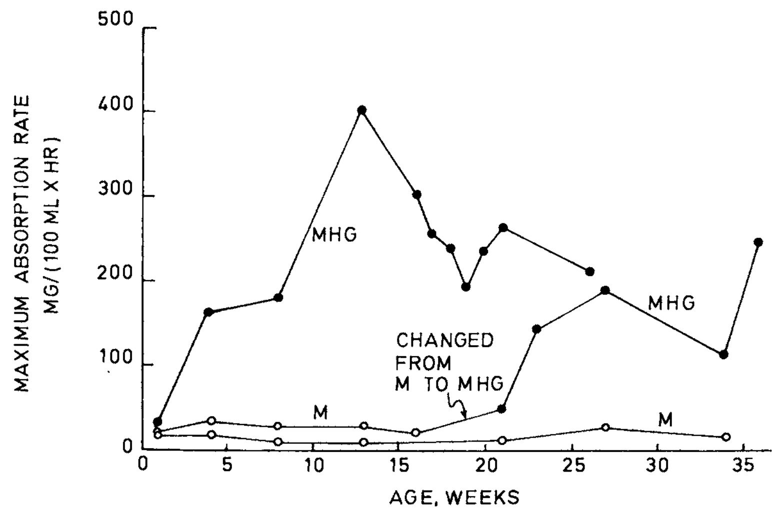


FIG. 81. Effect of age and diet on the maximum rate of absorption of acetic acid from a test solution introduced into the empty rumen of calves. M. = calf maintained on milk diet only. M.H.G. = calf maintained on milk, calf starter and alfalfa pellets. (From Sutton, McGilliard and Jacobson 1963.)

The explanation of the relatively poor response to feeding fatty acids may lie in the inability of the young ruminant to absorb these substances. This property is not inherent to the rumen and does not develop in calves maintained on a milk diet. Solid food is necessary before absorptive activity can develop and it is probable that butyric acid is the necessary substrate for stimulating the metabolic activity of the mucosa before its absorptive ability is apparent (Fig. 81). It is known that the adult rumen mucosa utilises butyrate at a high rate and that the mucosa of the young ruminant is unable to do so. It is apparent therefore that volatile fatty acids are important in stimulating the absorptive ability, the metabolic ability and the structural development of the reticulo-rumen. A fuller understanding of their precise role should provide a useful means of accelerating the progress of the monogastric animal to the ruminant state.

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Chapter 31

INFLUENCE OF BACTERIA ON ABSORPTION FROM THE SMALL INTESTINE

R. KENWORTHY

Effect of Environment on Nutrition and Disease

The development of intensive systems of management for farm livestock has introduced a number of problems, not the least of which are failures to perform well, and an increase in the incidence of disease, particularly respiratory and enteric. All manifestations of these phenomena are of great economic importance, and they are all difficult to investigate scientifically because they are insidious in onset and complex in aetiology. It is proper to point out at this stage that the observations and opinions expressed in this chapter are made in full awareness that only limited facets of the *intestinal* syndrome are being discussed. If these problems were to be given full investigational treatment the sciences of genetics and endocrinology would certainly have to be included.

Failures to perform in any particular respect (growth rate, conversion ratio, milk yield, egg yield) are commonplace in livestock management, and it is frequently found that the adverse situation can be corrected by introduction of a known bacteriocide or bacteriostat into the food or drinking water. A response of this nature immediately suggests that the reason for decline in performance is due to a living infectious agent which is propagated by the animals themselves. Further indirect evidence for the possible participation of a living agent comes from the observation that as the throughput of animals in any particular set of premises is increased, the initial failures to perform descend to problems of frank disease. When this happens the clinical disease is often a bacterially associated one, the micro-organisms involved usually being those which are endemic to the environment anyway.

The most common syndrome of this type is enteric disease associated with the proliferation of organisms of the *Escherichia* group, and depending upon the animal species involved, the disease might be called 'infantile gastro-enteritis', 'white scours', 'piglet enteritis', 'bowel oedema', or 'coli-septicaemia'. All these diseases are well documented and investigated, and an association between them and a limited number of serotypes of *E. coli* is indisputable. However, running throughout all enquiries into aetiology and epidemiology has come the theme that some underlying mechanism, as yet unidentified, is required for the clinical syndrome to precipitate. The reasons for this are the knowledge that the organisms can be found in healthy animals, apparently identical serologically and biochemically with those found in diseased animals, the difficulty in reproducing the field types of disease experimentally and with consistency, and the lack of response in some cases to antibiotic therapy when sensitivity of the organisms to the drug can be demonstrated *in vitro*.

Micro-organisms appear to be involved then both in the failure to perform adequately and in the clinical disease syndromes primarily associated with intensive systems of management. Hence, this chapter sets out to approach the problem from the viewpoint, not primarily of clinical disease, but of the effect which the intestinal microflora as a whole has upon the functional efficiency of the gut. It is hoped that in this way some understanding of the various components of the microflora might be acquired, together with the beginnings of an appreciation of their significance, collectively and individually. It is intended first therefore to give a brief outline of the major components of the intestinal flora as currently identified; this will be followed with a description of the morphology of the small intestine and the evidence which has already accrued indicating the participation of the microflora in the moulding of mucosal morphology. In conclusion the significance of the findings relative to their possible practical value and application is discussed.

Components of the Intestinal Microflora

Many studies of the intestinal microflora were undertaken in the decade following the end of World War II. The stimulus to this research was the availability of an increasing range of antibiotics, and the proven beneficial effects of these on growth rate and conversion ratios when they were added to livestock diets.

In the beginning qualitative and quantitative assessments of the flora by early workers tended to be contradictory. This was inevitable but useful; it was inevitable because the variety of micro-organisms composing the flora was not appreciated and therefore the selective media required for component separation had not been developed and exploited. It was useful because it spurred more detailed enquiries into suitable isolation techniques, so that more recent workers in the field are in general agreed upon the quantitative and qualitative distribution of bacterial groups currently identified within the microflora. Having said that, it is necessary to emphasize that there is also a general awareness that the *total* flora has almost certainly not been defined and a considerable amount of research remains to be done in this area alone. Hence the statements to be made relative to the quantitative and qualitative distribution of microbial groups cannot be regarded as unequivocal; they only stand in the light of bacterial isolation techniques currently in use, and are open to correction by subsequent work.

The major components of the intestinal microflora are members of the lactobacillus family (the lactic acid bacteria), in particular the lactobacilli and enterococci, the *Escherichia* group of the family Enterobacteriaceae, and the Gram-negative, non-sporing, anaerobic, highly pleomorphic rods designated *Bacteroides* spp. Other components are *Clostridia* and the Gram-negative coccoid forms usually classed as *Veillonella* (but see Fuller 1966). In the small intestine, which is our particular sphere of interest, lactobacilli, enterococci and the *Escherichia* group are quantitatively the most important, usually in the order stated; the distribution of *Veillonellae* is very irregular, whilst Bacteroides appear to have as their normal habitat the large intestine, but may also be found in the small intestine. The major genera only will now be considered in a little more detail.

Genus *Lactobacillus*. The lactobacilli are non-sporulating, aciduric rods of varying length, which divide in one plane only. They are Gram-positive, becoming Gram-negative with increasing age and acidity, and have been divided into three sub-genera by Orla-Jensen (1919) viz: *Thermobacterium*, *Streptobacterium* and *Betabacterium*. The first two subgroups are homofermentative i.e. carbohydrates are fermented to lactic acid, whilst the *Betabacteria* are heterofermentative and produce lactic acid + volatile acid + CO_2. They are said to have little or no proteolytic activity but according to Michel (1962) only the homofermentative lactobacilli lack the ability to deaminate arginine.

Genus *Streptococcus*. The streptococci are spherical or ovoid cells, mostly Gram-positive, and they ferment various carbohydrates with the production of acid. Streptococci of intestinal origin mostly belong to Lancefield's Group D and are frequently, but loosely grouped collectively as enterococci. This is not strictly correct taxonomically, but since the classification of Group D streptococci is both complex and controversial, it will suffice for the purpose of this discussion. These organisms are mainly homofermentative, and their proteolytic activities are variable. They can be broadly classed as predominantly saccharolytic, but some have a facultative capacity to decarboxylate amino acids.

Genus *Escherichia*. Members of this genus are Gram-negative, non-sporing rods, often motile. They ferment glucose, usually with the production of more acetic acid than lactic acid, and form in addition formic acid, CO_2 and H_2. They are also strongly proteolytic and form amines, indole derivatives and sulphur-containing compounds.

Of the remaining members of the flora referred to i.e. the *Clostridia*, *Bacteroides* and *Veillonella* spp., *Clostridia* are rather similar to the *Escherichia* group in their saccharolytic–proteolytic propensities, whilst *Bacteroides* and *Veillonellae* appear to give rise to few metabolic products of importance in this context.

It is pertinent now to consider the structure of the mucous membrane which lines the small intestine, relating morphology to function; then to follow this with a discussion of the experimental evidence implicating micro-organisms as one of the factors to be considered in epithelial cell dynamics and thereby also as one of the determinants in villous morphology. The substance of this next section is freely abstracted from a paper presented at the Nutrition Society's Symposium on Absorption of Nutrients from the Intestine (Kenworthy 1967).

Intestinal Morphology and the Dynamics of Epithelial Cell Renewal Relative to Gut Function

The main organ for absorption of dietary nutrients is the small intestine, the functional unit being the villus, and the epithelial cell clothing the villus. Since the influence of intestinal bacteria on absorption appears to be mediated through both of these components in the normal animal it is necessary to consider briefly the morphology of the intestinal mucosa, and also the dynamics of epithelial cell renewal.

The small intestine of mammals is especially adapted for absorption by its large surface area; it is very long, but its area is increased many times by the *plicae circulares*, and by the villi. These latter are small projections of the mucous membrane and have a length of 0·5 to 1·5 mm. (Bloom and Fawcett 1962). They cover the entire surface of the mucosa, and are clothed by a simple columnar epithelium. Verzár and McDougall (1936) state the length of the rat small intestine to be 600 mm. with a surface area of 6726 sq. mm. excluding villi; with villi the area becomes 45,486 sq. mm., an increase of some seven-fold. Between the bases of the villi, extending down into the *lamina propria*, are the crypts of Lieberkühn; the epithelial cells referred to arise from division of relatively undifferentiated cells in the crypt, but once division has taken place differentiation is complete relative to eventual function. In the normal animal the intestinal mucosa is in a constant state of renewal, with active proliferation of cells in the crypts followed by their progressive maturation and migration up the villi and eventual desquamation from the tips (Leblond and Steven 1948). The time taken for complete replacement of the epithelial lining of the gastrointestinal tract in man is estimated at 3–6 days (Lipkin 1965), a very short period when compared with the life span of the human red blood cell which survives for 120 days. It is generally thought that the epithelium moves as a sheet, and that the cells converge from all sides of the villus to the extrusion zones. Work reported by Friedman (1945) and Grad and Stevens (1950) indicates that the rate of cellular desquamation can proceed independently of the rate of cell production.

Morphological and histochemical evidence suggests that in the normal healthy gut as the cells migrate up the villus there is a progressive development of their internal structure. Immature, undeveloped cells in the crypts have a high concentration of free ribonucleoprotein (RNP) particles. When stained with one of the compound stains such as eosin/methylene blue under controlled conditions the cytoplasm of these cells is basophilic. The reaction can be eliminated by pretreatment of the tissue with ribonuclease and therefore can be regarded as specific. As the cells migrate up the villus they gradually acquire their characteristic columnar appearance and the reaction of the cytoplasm becomes progressively more acidophilic (Padykula, Strauss, Ladman and Gardner 1961). Thus as the cells mature the concentration of free RNP particles is decreased. Shorter and Creamer (1962) using tritiated uridine demonstrated that the site of ribonucleic acid (RNA) formation in mouse intestinal epithelium is in the crypts and lower third of the villus, and there is a steady loss of RNA as cells migrate.

Further evidence for a progressive development towards a functional compartment as migration proceeds is provided by the work of Hewitt (1954), Palay and Karlin (1959) and Ladman, Padykula and Strauss (1961) in studies on fat absorption. These authors showed that the cells nearest the apex of the villus, i.e. the oldest cells and those nearest the extrusion zones, accumulate lipid first and in the greatest amount; furthermore there is a descending gradient of absorption as the crypt is approached. Kinter (1961) studied the uptake of labelled sugars and amino acids by *in vitro* techniques and showed a gradient of absorption similar to that described for lipids.

A progressive development in the size and number of microvilli can also be demonstrated as progression up the villus occurs. The net result of all this is to increase the surface area available for absorption. McDougal, Little and Crane (1960) showed that the process of active transport of monosaccharides, which results in their accumulation in the cell against a concentration difference, is in the vicinity of the brush border. Miller and Crane (1964) further demonstrated that the liberation of monosaccharides by the digestive hydrolysis of disaccharides and sugar phosphate esters takes place within the brush border of the mucosal epithelium. Therefore if it is justifiable to combine morphological and biochemical evidence it would appear that the cells approaching the extrusion zones in a normal animal are possessed of better developed digestive and absorptive mechanisms than cells nearer the crypts.

However, it appears that the shape of the villus is also important relative to its functional efficiency. Finger-shaped villi are said to 'pump' actively (Verzár and McDougall 1936) whereas leaf-shaped villi never show any pumping movements; in these latter, circular contractions of the muscularis occur which have the effect of squeezing the villi together. Furthermore, striking features of certain malabsorptive states in the human are the absence or rudimentary character of the villi and the increased depth of the crypts (Shiner 1957; Shiner and Doniach 1960). It has also been shown in sprue-like conditions that the epithelial cells at the luminal surface are distinctly abnormal (Padykula *et al.*, 1961). Their cytoplasm is strongly basophilic, and they are deficient in succinic dehydrogenase, esterase, acid phosphatase and adenosine triphosphatase activities. Padykula *et al.* (1961) suggest that in sprue the epithelium is proliferating at a rate greater than normal, and the histological appearance of the mucosa is a result of the abnormally high rate of cell loss which is balanced by heightened mitotic activity.

The evidence that villus morphology and cellular differentiation play an important role in intestinal function thus appears conclusive. It is therefore reasonable to suppose that any factor which is likely to have a bearing upon rate of cell division in the crypt, cell migration up the villus, or desquamation from the extrusion zones will have an influence upon absorptive efficiency.

The possibility that an infectious agent might be one of these factors has been particularly apparent since animal management systems became more intensive. It is common experience that as the animal population and throughput of any particular project are increased, performance rates decline and disease incidence rates rise. Of particular interest in this connection is the work of Roy, Palmer, Shillam, Ingram and Wood (1955), and Young, Garrett and Griffith (1963). Roy *et al.* (1955) showed that in calves the growth rate decreased and the incidence of scours increased as the occupation time of the calf house increased. Young *et al.* (1963) showed that the absorbability of lard fatty acids in chickens was improved by fumigating the house accommodating the birds. There is much further evidence available from the literature that the use of antibiotics will arrest deteriorating performances, or even improve on those which have hitherto been accepted as normal. However practical experience has shown that such effects are often only temporary, and long term medication only succeeds in exacerbating the problem. Observations of this nature give further support to the concept of an infectious agent or agents participating in the nutritional status of the host animal, but the evidence has been throughout largely circumstantial. It is only with the advent of the germ-free animal as a research tool that the significance of the bacterial component has begun to be more specifically defined.

Since the use of germ-free animals for research purposes is relatively new to this country it is expedient at this point to define two terms which will be used in the ensuing text. The term 'germ-free' means that no micro-organisms are demonstrable within the limits of the screening media used to detect them, and in the recording of results from germ-free animal experimentation these media should be defined. The term gnotobiote ('known life', from the Greek roots *gnoto* and *biota*) is used in the sense suggested by Reyniers (1959) i.e. it refers to a state in which all forms of associated life are known. It thus includes the 'germ-free' and the specifically contaminated states.

Effects of the Bacterial Component in the Small Intestine. Conventional and Gnotobiotic Animals Compared.

The intraluminal substrate of the intestine is obviously in very close association with the epithelium, and may carry a heavy bacterial load. Table 1 shows the quantitative and qualitative distribution of microbes

TABLE 1

THE QUANTITATIVE AND QUALITATIVE DISTRIBUTION OF MICROBES IN THE SMALL INTESTINE OF YOUNG PIGS, MICROBIAL COUNTS × 10^6, EXPRESSED/G. WET CONTENT

(Adapted from Kenworthy and Crabb 1963)

Age of pig	*Intestinal site*	E. coli	Lactobacilli	Clostridia	*Gram-positive cocci*	*Yeasts*	*Total*
1 day	jejunum	0·05	0·50	0·40	0·25	0	1·20
	ileum	5·00	6·50	0·06	40·00	0	51·56
14 days	jejunum	0·85	400·00	0·15	10·60	0	411·60
	ileum	17·50	210·00	50·00	1650·00	0	1927·50
30 days	jejunum	6000·00	1000·00		0·03	0·005	7000·03
	ileum	3000·00	55·00		1·20	0·002	3056·20

in the jejuna and ilea of pigs 1 day old, 4 days old and 30 days old (1 week after weaning). It will be seen that the total bacterial loading can become extremely high in the small intestine (7×10^9/g. wet content) particularly after a change of diet. Therefore the composition of the substrate presented to the epithelial surface will be dependent, at least in part, on the metabolic activities of these micro-organisms. Michel (1962) has shown that the microbial flora of the pig intestine can produce from catabolism of amino acids, urea and choline, substances which have a direct pharmacodynamic action. Larson and Hill (1960) compared amine production in the ileal content of chlortetracycline-fed pigs with unsupplemented controls. They showed a greater amount and variety of amines in the latter. Spots with R_F values corresponding to putrescine, ethanolamine, tyramine and tryptamine were elicited from ileum contents of 22-day-old animals on basal diets. No spots were demonstrated from extract of ileum contents of chlortetracycline fed littermates. The authors conclude that a reduction in amine and an increased availability of nutrients resulting from the sparing of amino acids contributed to the favourable development of the supplemented group.

This, however, appears to be an over-simplification. We have to consider not only the sparing action, but also two other factors: (i) the effect of the immune response on villus morphology and (ii) the possible pharmacological influence of toxic amines, phenols, ammonia, etc. on the epithelial cell. This latter in turn has two implications; by toxic and irritative mechanisms the turnover rate of the epithelium is likely to be increased, leading again to distorted villus morphology and following on this the cells reaching the extrusion zones will be immature and thus not fully functional.

Relative to these considerations, the work of Gordon and Bruckner-Kardoss (1961) and Abrams, Bauer and Sprinz (1963) is of interest.

Gordon *et al.* (1961) showed that the presence of the flora augments the amount of *lamina propria* tissue, this effect being particularly clear-cut in the core of the villus. They concluded that the flora-induced increment of the lamina was partly caused by its greater content of reticulo-endothelial cells and possibly by increased hydration of the tissue. Abrams *et al.* (1963) studied the influence of the normal flora on mucosal morphology and cellular renewal in the ileum of germ-free and conventional mice. In the germ-free mouse the *lamina propria* consisted of only a sparse stroma, with few lymphocytes and mononuclear cells. In the conventional animal the lamina was expanded by the customary infiltration of lymphocytes, mononuclear cells and plasma cells. The epithelium of the germ-free animal was more regular, the brush border wider, the crypt shallower and the mitotic counts lower; thus there was an apparent shift in favour of the functional compartment with the germ-free status. Furthermore autoradiographic studies of the ileum after administration of tritiated thymidine showed that cellular renewal rates were influenced by the flora. The rate of turnover of the ileal epithelium in the germ-free state was found to be significantly lower than in the presence of the conventional flora.

Examination of the mucous membrane of gnotobiotic and multicontaminated pigs supports these findings (Kenworthy and Allen 1966). Experiments on initially germ-free pigs showed a step-wise degradation of villus morphology with increasing contamination (Figs. 82 to 86).

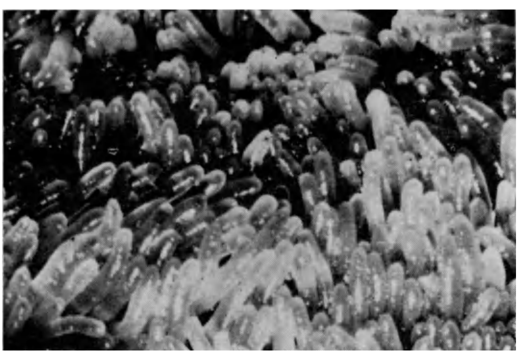

FIG. 82. Villi, small intestine, monocontaminated gnotobiote (*E. coli* 0141: K85a, c (B): H4). × 15 (Kenworthy and Allen 1966.)

In the monocontaminated pig, 5 weeks of age on artificial diet, villi were uniformly symmetrical and classically finger-shaped (Figs. 82 and 83); in the duocontaminant (Fig. 84) the beautiful uniformity was beginning to be lost; villi became broader at the base and showed evidence of branching. The multicontaminated animals were grossly different (Figs. 85 and 86); villi were considerably reduced in height particularly relative to crypt length, and there was much fusing and 'clubbing'.

Table 2 shows the various contaminations which were performed, and Table 3 the crypt/villus ratio and mitotic indices of the experimental animals when they were slaughtered 14 days after initial contamination. The diet was standard throughout. It will be seen that in the mono-

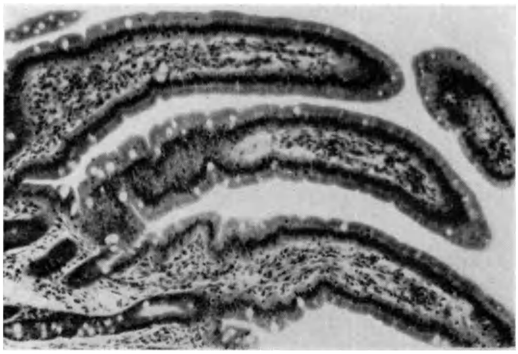

FIG. 83. Villi, small intestine, monocontaminated gnotobiote (*E. coli* 0141 : K85a, c (B): H4). H. and E. × 160 (Kenworthy and Allen 1966.)

FIG. 84. Villi, small intestine, duocontaminated gnotobiote (*E. coli* 0141: K85a, c (B): H4 and O8: H−). H. and E. × 160 (Kenworthy and Allen 1966.)

contaminant the villus was three to four times longer than the crypt, whereas in the multicontaminants the ratio was about 1:1.

A characteristic feature of limited contamination was the tall columnar nature and basally situated nucleus of the cells clothing the villi. The

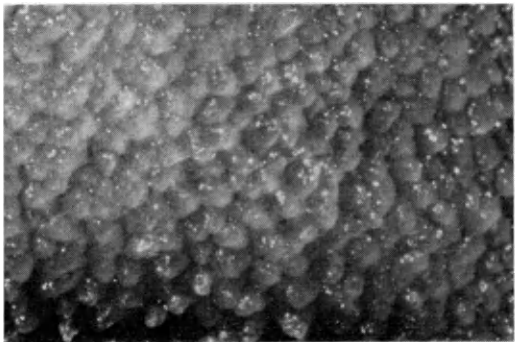

FIG. 85. Villi, small intestine, multicontaminated pig. ×20 (Kenworthy and Allen 1966.)

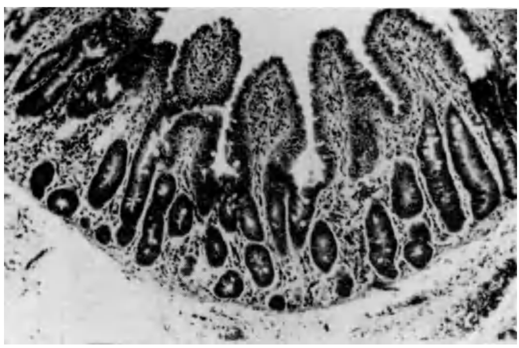

FIG. 86. Villi, small intestine, multicontaminated pig. H. and E. ×160 (Kenworthy and Allen 1966.)

TABLE 2

CONTAMINATION OF GERM-FREE PIGS WITH MICRO-ORGANISMS

(Kenworthy and Allen 1966)

Pig No.	*Contamination*
25	Multicontamination by housing in conventional piggery
26	Multicontamination by housing in conventional piggery
28	Non-haemolytic *E. coli* (08: H−). *E. coli* serotype /0141: K85a, c (B): H4/ added 10 days later
29	*E. coli* serotype /0141: K85a, c (B): H4/ only
30	Coagulase negative *Staphylococcus* only
31	*E. coli* serotype /0141: K85a, c (B): H4/ followed by *E. coli* /08: H−/ 8 days later

cytoplasm of these cells was uniformly acidophilic. The brush border was clearly defined in histological sections stained by haematoxylin and eosin, and the great length of the microvilli was demonstrated by electron microscopy (Fig. 87).

TABLE 3

CRYPT/VILLUS RATIO AND MITOTIC INDICES IN GNOTOBIOTIC AND MULTICONTAMINATED PIGS
(Kenworthy and Allen 1966)

Pig No.	*Crypt/villus cell ratio*	*Mitotic figures/100 crypt cells*
25	1:1·2	4·20
26	1:1·0	3·00
26 (mucous area)	1:1·2	5·50
28	1:3·0	2·10
29	1:3·5	1·50
30	1:4·0	1·20
31	1:3·8	1·60

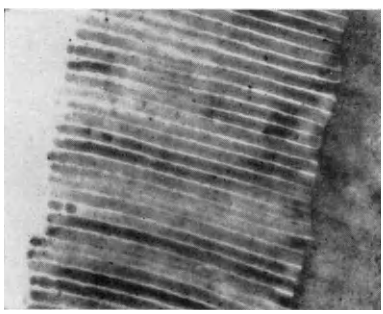

FIG. 87. Microvilli, monocontaminated gnotobiote (*Staph. albus*) × 30,000 (Kenworthy and Allen 1966.)

In the multicontaminated animals, the epithelial cells on the villi were cuboidal, with a centrally placed nucleus and a tendency to basophilic cytoplasm, even at the tips of the villi. The brush border could not be so clearly defined, and under the electron microscope the microvilli were about one-third the length of those in the gnotobiotic pigs (Fig. 88).

Direct physiological experimentation on intestinal function in germ-free animals compared with conventional controls has been carried out by Heneghan (1963). He showed that the absence of a microbial flora produced a two-fold increase in the absorption of d-xylose in germ-free mice as determined by the everted sac technique. The existence of a similar increase was confirmed in germ-free rats by using *in vitro* and *in vivo* techniques.

Coupling these observations with the detailed work of Padykula *et al.* (1961) already referred to, the evidence for a predominantly adverse effect of microbes on intestinal absorption is very convincing but the mediating mechanisms must be inordinately complex. The question that now arises is whether any particular group of micro-organisms is of particular importance.

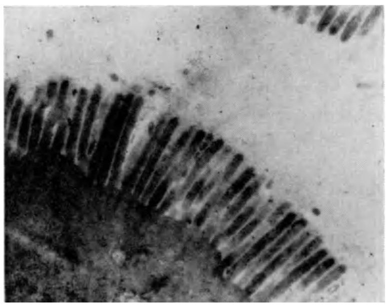

FIG. 88. Microvilli, multicontaminated pig. × 30,000 (Kenworthy and Allen 1966.)

Significance of Particular Bacterial Groups. Some attempts to specifically define those agents which are particularly obnoxious under a given set of conditions (species, type of management and age of affected animal) have already been made. Dubos and Schaedler (1960) found that mice delivered by Caesarian section and maintained in an environment protected from contact with common mouse pathogens grew more rapidly than conventional controls. Bacteriological studies showed that the 'protected' mice were lacking in Gram-negative lactose fermenters (*Escherichia coli*); when contaminated with this organism they acquired the characteristics of conventional animals with regard to weight gain on various diets. Eyssen and de Somer (1963) reported on a malabsorption syndrome in chickens which could be prevented by oral antibiotic medication. They were unable to reproduce the whole syndrome in germ-free chicks by various contamination experiments including a mixed flora of thirty-five strains of intestinal bacteria. A partial effect was, however, obtained by contamination with a Gram-positive coccus (Eyssen and de Somer 1965). Similar results have been reported by Huhtanen and Pensack (1964) using a strain of *Streptococcus faecalis*.

In conclusion it must be said that although the evidence for a bacterial influence on intestinal absorption appears to be conclusive, the mediating mechanisms are extraordinarily complex. It is clear that interactions between the various groups of bacteria in the intraluminal substrate are likely to have a bearing upon the biochemical activities of any single species; this is generally accepted. What does not appear to be so generally appreciated however, is the influence of the intraluminal substrate upon the micro-organisms. The effect that dietary change has upon one component (*E. coli*) of the intestinal flora of young pigs has already been referred to. Similar results are observed relative to dietary changes in sheep and their influence upon *Clostridium welchii*. In both these instances the implied alteration in metabolism shown by increased growth rate of the micro-organism is accompanied by an increase in its toxicity. The difficulty in experimental reproduction of enteric disease by accepted enteric pathogens is well known to workers in the field of gastro-enterology. Thus it is essential to remember that the absorptive organ, the small intestine is a dynamic physiological entity of which the microbial flora is an integral part. The mucous membrane of the small intestine, the intraluminal substrate and the intestinal microbes are inter-dependent; they are three components of a system which is in dynamic equilibrium and in the final analysis, one cannot be considered without reference to the other two.

Practical Application. It is reasonable to ask now, where does all this lead to from the practical aspect of everyday farming or veterinary practice? Well, it must be understood that work of this nature is very much in its infancy; in fact the participation of bacteria in intestinal physiology has been largely ignored, or examined and discounted, until very recently. Therefore the practical extension must be at this stage very much in the realm of speculation and hypothesis. But undoubtedly the most important facet of husbandry to need reconsideration will be the undramatic, low grade disease conditions already referred to, and which are commonly associated with organisms endemic to the environment.

It has already been pointed out that the fundamental aetiology of these conditions has not been determined, but most investigators consider that some underlying 'trigger' factor is required to precipitate them. The 'trigger' or 'stress' factor required is often a change in management, frequently a change in diet. If we now cast our minds back to the experimental work described in this chapter, particularly relative to the comparisons between conventional and germ-free animals, it becomes evident that morphological changes in the intestine depend in good measure upon interactions between intestinal bacteria and diet. In the production of distorted villus morphology, by the action of the so-called normal flora, we have a potential precipitating factor for proliferation of 'pathogenic' micro-organisms, in this particular instance certain serotypes of *E. coli*. But we also have more than this. We have a possible explanation for the failure of some animals to perform as well as they should, without necessarily showing clinical disease. Indeed we have a link here between the clinically healthy animal giving sub-normal performance, and the clinically diseased animal, either mildly diarrhoeic or dehydrated to the point of death.

We have a line of reasoning which suggests that in these low grade conditions there is no sharp demarcation between health and disease; it suggests that the failure to thrive, which is the traditional area of the nutritionist, is only one part of a graded series of changes culminating in the clinical state, which is traditionally the area of the veterinarian; but the basic, underlying mechanism is the same in all cases. The differences are only matters of degree.

As has been said already, a good deal of this thinking is unsupported as yet with experimental data, and it would be invidious to examine in relation to it any disease conditions which are given a specific pathological identity. It does, however, offer a possible explanation for numerous parasitological syndromes, be they bacterial, helminthic or protozoal, in which debility has preceded clinical infection.

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Chapter 32

HEALTH AND DISEASE PROBLEMS

W. P. BLOUNT

With the increasing concentrations of livestock which occur normally when intensive husbandry methods are adopted, disease problems are commonly encountered, sometimes in quite serious proportions.

A general view of the disease situation as it affects cattle, sheep and pigs has been prepared by J. F. Harbourne, whose broad picture gives a clear insight into the many problems which are constantly being tackled by practitioners and veterinary investigation officers. Whilst it does not indicate any specific detailed treatments (since these will be well-known to up-to-date practitioners) it does emphasise how important it is for the farmer always to seek sound professional advice.

The role of the veterinary surgeon in practice appears to be changing rapidly in many areas, because integrated concerns often require a common policy of action throughout their entire livestock activities. Indeed, instead of treating individual animals on several farms, preventive advice may require to be given for application to thousands of stock throughout the country. Thus a new relationship is being built up between farmer and practitioner. This is described vividly by Colin Gould whose far-reaching views on this important subject are attracting the attention of both veterinary surgeon and farmers alike.

As a contrast it has to be accepted that not many poultry problems are being tackled today by veterinary practitioners; indeed Dalton (1966) has stated that only about twenty specialists would be necessary to cover most of the poultry flocks throughout the whole of the U.K. That poultry husbandry and disease problems do lie in a special veterinary field is without question and many practitioners will therefore welcome B. S. Hanson's comprehensive article (Chapter 18) covering both the diagnosis and treatment of poultry diseases. As always it is a question of knowing the subject, keeping oneself up to date and getting the farmers' confidence.

In some respects the modern farm animal has been turned into a biological machine, churning out milk, eggs or meat at rates which appear quite fantastic. Clearly their environment, using this term in its widest sense, is of the greatest importance today, and as we know a great deal more about the intimacies of controlled environments for poultry (than we do for cattle, sheep or pigs) this subject has been described elsewhere in some detail.

'Scours', whether in rabbits, calves or turkey poults represents an ever recurring problem which may never be solved whilst stockmen are employed whose minds turn immediately to the use of drugs (antibiotics or nitrofurans) as the only method for controlling these 'infections'. Seldom do they seem to have been taught that management practices alone may be at fault—feeds improperly prepared or misused, overcrowding, the stress of journeying to and from farms to markets, chilling, etc.

A comparatively new angle to scouring relates to the interaction in the gut between different electrolytes (Watt 1965), in which metabolic factors are often more important than pathogens. Intravenous injections and the oral use of sodium/potassium/glucose solutions make an interesting contrast to the usual antibiotic medicaments. As scouring is common in rabbits and in view of the failure of most medicaments to cure such cases (plus an indefinite or negative bacteriological picture), perhaps the electrolytic approach offers new hope.

Antibiotics

The role of antibiotics in animal production has recently received a shock following the acceptance of Japan's 1956 researches showing that some bacteria can develop an 'infectious' form of drug resistance. Fortunately this cannot be of a permanent nature otherwise the antibiotics used in the feed industry since 1953 would have created havoc. As it is low, levels of several antibiotics can still be shown to stimulate the growth rate of poultry (other than water fowl), but whether their main effect is in the suppression of toxin producing anaerobes or not is still in doubt. For the antibiotic to reach the main body tissues levels above 50 p.p.m. appear necessary per os and the higher the level the quicker the effect. (Hence the value of 'potentiation' by terephthalic acid or the use of low calcium rations.)

Whether antibiotics should be used for controlling 'scours' in baby piglets or young calves, or for the control of 'bloat' in cattle is still being argued. In the meantime regulations allow the genuine farmer to obtain supplies of certain antibiotics from his pharmacist without a veterinary prescription; alternatively he can use a nitrofuran which also does not require a prescription. In one sense it is a pity that all important drugs allied to antibiotics have not been restricted to professional use; on the other hand it could be argued that agriculture has benefited more (and the profession less) under the present arrangements.

Two important points are (i) drug resistance with the nitrofurans is very much less in evidence than it is with antibiotics, and (ii) if traces of antibiotic do enter the animal's tissues, these are unlikely to do harm to consumers because they are destroyed by the normal cooking processes.

The complexities of the intestinal flora, relative to pathogenic bacteria and fungi are still far from being understood clearly, and R.

Kenworthy's account of intestinal function is therefore particularly apt (Chapter 31).

Growth promoting antibiotics (for use in contaminated premises) include procaine penicillin, aureomycin and terramycin, zinc bacitracin, virginiamycin, oleandomycin, etc. Whenever possible those which have specific effects, e.g. Tylan, Rovamycin, erythromycin and Rondomycin for P.P.L.O. infections; Albamycin for staphylococcal infections; soluble penicillin salts for erysipelas infection and the tetracyclines for pullet disease and F. cholera, etc., should be reserved for use clinically.

Imported Diseases

The ability of the Charolais to breed bigger and faster growing leaner calves has been amply confirmed, and therefore it appeared to some enthusiasts a great pity that the proposed importation of 260 more French cattle last November did not materialise because of health regulations. Veterinarians in this country will agree however that if a 'probang' test is required to prove that healthy cattle are not carriers of foot and mouth virus, then surely the Ministry of Agriculture must insist upon this procedure before imports are allowed from any country where this disease is endemic. (In the probang test material is removed from the oesophagus for laboratory examination for the presence of foot and mouth virus.)

The reaction of the French authorities to this ban is understandable since they do not believe that this test is sufficiently precise for international trade purposes. But the economic consequences of a break in our freedom from foot and mouth disease (as seen in the recent outbreaks in Northumberland and Hampshire) confirms how vital it is for farmers to be protected against *all* forms of virus invasion.

After we enter the Common Market there will presumably be regulations to help to keep at bay such epidemics as foot and mouth disease and swine fever. Currently there are a series of serious outbreaks of African 'plague' (cholera) in Italy, and the present epidemic of OI type foot and mouth in Holland has caused almost all countries in the E.E.C. to close their frontiers to exports from the Netherlands of ruminants, pigs, meat and offal. Belgium has also banned imports of hay, straw and manure.

During the winter there were 76 outbreaks in the Netherlands, whereas Belgium and Luxembourg remained free; France had 4 outbreaks and West Germany 436. In Italy, where imports from the Netherlands continued, there were 18 outbreaks in the latter half of December 1966.

Annual vaccination of cattle is compulsory in France and the Benelux countries, and the federal government of West Germany has recently advised its provincial governments to adopt a similar policy, whereas in Italy it is only compulsory in those parts of the country where there is a heavy livestock population (Agra Europe 1967).

Disease free Stock. How far is the veterinary profession correct in believing that agriculture would benefit if more producers would concentrate on producing specific pathogen free or minimal disease stock? If methods of husbandry were adopted like those in Maine where Shute has been popularising the development of disease-free poultry, would this give the farmer greater profits?

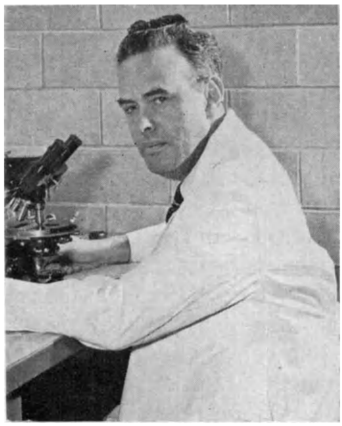

FIG. 89. Professor James A. Reyniers, founder and director of the LOBUND Institute (Laboratories of Bacteriology, University of Notre Dame, Indiana, U.S.A.). Lobund Report No. 2 (1949), dealing with the rearing of germ-free chickens and the need for a unified terminology in germ-free life studies, should be read by all students of this new technique in applied biology.

It is a far cry from the original researches of Professor James A. Reyniers at Notre Dame, who showed as early as 1948 that dental caries was absent in germ-free rats, and similar work has now confirmed that blackhead in turkeys is not caused by *Histomonas meleagridis* except in the presence of certain intestinal coliforms.

Whilst there are at least three institutes in Britain where germ-free animals are now being bred (mainly for experimental purposes), increasingly large numbers of pigs and poultry (broilers and turkeys) are being produced free from one or more specific pathogens.

In practice one finds that commercially produced poultry are commonly free from mycobacteria, salmonellae and pasteurellae; also epidemic tremors, F. pox, infectious laryngo-tracheitis, etc., whilst mycoplasma (S6) free broilers and turkeys are greatly on the increase.

Thus many of the real problems affecting poultry today (apart from the avian leukosis complex) are non-specific like infected yolk sacs, chilling, nephritis, the reproductive disorders, enteritis, etc. Others such as coccidiosis and worm infestations are seldom important because of the use of specific drugs. So that from the purely economic angle minimal disease (M.D.) or S.P.F. stock are less important than many imagine, but the subject is put into proper perspective by A. O. Betts, (Chapter 34) who as many will know, has been a pioneer in this field particularly where pigs are concerned.

FIG. 90. The diver prepares watering bottles for the germ-free colony.

The Chemical Age

Occasionally pioneers arise whose activities stir a nation's conscience. One such person was Rachel Carson who recently drew attention to the possible dangers from the use of persistent toxic insecticides. Unfortunately it is now commonly assumed if a minute trace of D.D.T., for example, is found in the liver of dead wild birds, that these animals will have *died* from D.D.T. poisoning.

Whilst it is quite true that they will have acquired the D.D.T. because of its use for agricultural or other pest control purposes, these traces do not cause wild birds to become ill and die; except in particular circumstances. They are living monitors, as are we ourselves, building up radio-active and other compounds in the liver, bones, etc., in minute amounts. It is for this same, cumulative, reason that one can demonstrate the presence of strontium in bones; but in the *extremely* small quantities which are present, no harm results. Theoretically these substances might be released from the liver or fat depots to pass into the general circulation (e.g. during starvation) and so give rise to an acute toxic condition but so far as is known this has never been demonstrated.

D.D.T. is of particular interest because a major route for its *excretion* is milk, just as egg shells dispose of unwanted strontium. The use by dairy cattle of hay containing 8 p.p.m. D.D.T. results in the excretion of 3 p.p.m. in milk; so that whilst this mechanism protects the cow herself, it might prove toxic to her offspring!

Fluorine can be said to fall into this same picture, but because of the ubiquitous nature of fluorine, normal bone may contain on a dry weight, fat-free basis 1200 p.p.m. fluorine. (*Normal* urine alone may even contain 5 p.p.m. fluorine.) Fifteen years ago selenium would have been placed in the same category, but because it is now known to play a specific part in the prevention of exudative diathesis in poultry it is sometimes classed as a nutrient, and the recommended level of inclusion is 0·02 p.p.m., an amount which is usually present in mixed diets in all parts of the world except where the soil is seleniferous.

Copper too is a nutrient as well as a growth stimulant (especially in pigs at a level of 125 p.p.m.), but the continuous intake of higher levels may lead to liver-copper concentrations which can prove toxic under certain circumstances; especially so in sheep which species is particularly susceptible to acute copper poisoning.

It is not unnatural for many persons to wonder and possibly to worry about the present-day use of chemicals such as pesticides, insecticides, feed additives, etc. Are they really harmless when used correctly, or conversely may they be carcinogenic, and if there is real doubt in the minds of the authorities should they not be banned?

In October 1965, however, the Minister of Agriculture stated: 'There is at present *no* positive evidence that any agricultural chemical now in use as a pesticide in this country has induced cancer in man.' That same month Hunter (1965) discussed the implications of the chemical age in relation to man and animals. Were we meddling with nature, and would the chemicals we use in agriculture act upon us deleteriously during our lifetime, he asked; and in his reply he stated emphatically that whilst excesses (from accidents) certainly were often harmful, the small amounts which we absorbed involuntarily did *not* have any adverse effects. One of the proofs is of course the fact that no adverse effects on growth have ever been reported, and in most European countries the human population is growing older so that chemicals cannot have done much real harm. Many will agree with Hunter that the choice of one's parents influences our own particular longevity far more than do any chemicals.

It is believed that the average concentration of D.D.T. in human fat is now about 10 p.p.m., and this of course frightens the 'Ruth Harrisons' of this world. But after such chemicals have reached the body fat depots they are inert, so that a mere accumulation *per se* is harmless. The position could be different in the case of any chemicals which the animal body has to metabolise before excretion can take place, because this extra 'work' might cause excess enzymatic activity. Few will deny Hunter's conclusion that inadequacies of water, calories, protein and vitamins are the real hazards to human health, *not* the presence of small amounts of man-made chemicals.

Further confirmation of the relative harmlessness of insecticides has been provided by Gouch (1965) who pointed out that amongst the 700 fatal accidents on farms between 1955 and 1960 not one was due to insecticides; furthermore out of nearly 100,000 non-fatal accidents only 25 illnesses were due to pesticides, insecticides, fungicides and weed killers. Up to that time there had been no authentic case of human illness due to insecticide residues on foods, where these sprays had been used in the normal manner.

Three government sponsored committees have recently been set up to enquire into the hazards from agricultural chemicals, in order to assess factual information. One result has been the initiation of the Pesticides Safety Precautions Scheme, and also the Ministry of Agriculture's Agricultural Chemicals Approval Scheme. In addition aldrin and dieldrin were subsequently banned, and farmers were also recommended to use persistent insecticides only when necessary.

If additional scientific evidence were required on the present position regarding pesticides, etc., then the papers given at the Royal Society of Medicine symposium on 'The Effect of Organochlorine Pesticides on Wildlife, Domestic Animals and Man' 1967 will be found by many to be convincing.

Moore (1967) pointed out that the vast majority of the 200 or so pesticides used today are non-toxic. The O.P. insecticides are not very persistent in soil or animal bodies whereas the organochlorines (O.C.) are fat soluble and very persistent. It is these insecticides which become dispersed outside the area of application and which may affect food chains via accumulations in animal bodies, and to which ecologists have drawn attention. To what extent is the environment contaminated with O.C. preparations? They are in fact almost everywhere except in Antarctic invertebrates, and predators contain much higher levels than other species. But data is not yet available to show whether these contaminations have led to declining populations. Moore concludes that it is highly dangerous to make sweeping generalisations about the harmfulness or harmlessness of O.C. insecticides.

Jolly (1967) recalled that sheep could be protected for months by the residual action of persistent insecticides; that gamma B.H.C. had eradicated the psoroptic mite from the British Isles, and that dieldrin protected sheep against maggots for practically the entire season. Also that 22·5 gm. of D.D.T. applied weekly to cattle for 3 years was without ill effect, and that sheep dipped in forty times the normal concentration of dieldrin was also without ill effect. But cattle dressed with D.D.T. and dieldrin eliminated the insecticides in their milk, hence the logical ban on the use of O.C. insecticides for dairy cattle. He also stated that there was no evidence that consumers of fat from sheep treated with dieldrin suffered in any way as a result of the minute amounts they ingested.

Goulding (1967) stated that certain doses of D.D.T. could be given to animals almost indefinitely without any significant effects; but O.C. compounds were capable (in sufficient dosage and after prolonged intake) of causing hepatic derangement. Yet some of the handlers and operators of these insecticides in agricultural practice had been watched for 10–20 years and careful scrutiny had failed to reveal any lasting damage. Monitoring elsewhere had also failed to disclose the slightest cause-effect associations. He concluded: 'I think if we are fair and scientifically minded we must say that, to date, there is not one iota of substantiated evidence that man has suffered any chronic toxicity at all from organochlorine residues in food.'

Indeed they are invaluable, (i) as aids in growing healthy food, (ii) in combating disease, and (iii) in making our lives and those of our farm livestock more comfortable.

Hunter (1967) emphasised that several hundred parts per million of D.D.T.-derived materials may be present in human adipose tissue, and yet these were compatible with good health. Furthermore his research findings confirm the view that the risk to health of the general population from intoxication with O.C. pesticides is almost non-existent.

Modern Treatments for Farm Livestock

Neither the farmer nor the veterinary surgeon has been served better, so far as specific therapy is concerned, than today. Modern developments in chemotherapy and in the biological control of infections have paved the way for healthier flocks and herds everywhere. There are few infections or infestations today for which there are no satisfactory remedies, although some diseases like brucellosis, Johne's disease and the avian leucosis complex will still need a few more years research before they too are mastered. The following admittedly very incomplete account of drugs used by the veterinary profession may stimulate someone to write up the subject in detail.

External Parasites. The modern control of external parasites in farm livestock was recently described by Wood (1966). For the maggot fly (now that dieldrin is no longer permitted) organophosphorus (O.P.) persistent larvicides are recommended; carbamates being less effective than several of the chlorinated hydrocarbons. In Britain, apparently, the only confirmed resistance to chlorinated hydrocarbons of other ectoparasites is the body louse of the sheep *D. ovis*.

Unless sheep lice are known to be resistant to B.H.C. this is the dip to use, otherwise O.P. insecticides are again recommended, and the same applies to the control of ticks in this country. Many O.P. preparations have also been approved for dealing with the warble-fly problem. B.H.C. still remains the favourite drug for controlling mange, but care must be taken as it is toxic for cats and cage birds and eggs quickly taint.

Red mites in some poultry areas appear to have become resistant to nicotine and B.H.C., but carbaryl (Sevin), malathion, Nuvan (Ciba), Nankor (Dow) or synergised pyrethrins are alternatives. Incidentally if poultry should ever be poisoned by organophosphorus insecticides they show pronounced salivation—a rare phenomenon.

Anthelmintics. Thiabendazole and bephenium hydroxymaphoate now offer good control over nematodirus infestations (Gibson 1965) which have hitherto proved intractable. In addition to other specific effects thiabendazole has the distinction of being the first drug to play an economic and practical part in controlling gape worm infestations in turkeys, pheasants, partridges, etc. Whilst phenothiazine remains extremely valuable, *Haloxon* (Coopers), *Helmox* (I.C.I.), *Mintic* (I.C.I.) and tetramisole appear to offer more specific control over a wider spectrum of pathogenic worms; in which field the oral vaccine 'Dictol' (A. and H.) now competes for controlling lung worms. This development of using irradiated larvae gave impetus to a new field of endeavour, and it was a great pity that the comparable work of Helen Hein in controlling certain coccidial infestations in poultry was not able to be given commercial application. Irradiation of a different character has been used for sterilising male flies, and in this way some unwanted species have been controlled over a wide area.

So that with a far better control today of the common stomach, hair, round and lung-worm infestations than at any other time in the history of agriculture, some farmers are now looking for more efficient taenicides. But these, as with improved fluke-worm remedies appear to be almost within our immediate grasp.

In the poultry field equally new developments have led to a more effective control of blackhead, i.e. by the use of dimetridazole 'Emtryl' (M. and B.) and organic arsenicals, e.g. 'Carbosep' (Whitmoyer) and 'Histostat-50' (Salisbury Labs.).

As for *coccidiosis*, after the initial use of various sulphas and nitro-drugs (nitrofurazone, nitrophenide, furazolidone and nicarbazin) came trithiadol, zoalene and amprolium. The latter soon needed ethopabate to deal with *E. acervulina*, and also S.Q. to cope with *E. brunetti*. Sulpha drugs were then potentiated (e.g. with pyrimethamine or diaveridine) and now a completely new series of drugs has appeared. These include metichlorpindol ('Coyden-25', Dow), buquinolate, aklomide and sulphanitran ('Novastat', Salisbury Labs.). It is known that others are under test by Ciba, M. and B., and I.C.I. so that before long feed compounders and veterinary surgeons will have to make important decisions as to which drug to use or recommend. (Unless farmers are allowed to use a coccidiosis vaccine, as is commonly practised in the U.S.A., e.g. 'Cocci-vac' (Sterwin).) Needless to say the chief factors to be considered will be, (*a*) effectiveness against all commonly encountered Eimeria, (*b*) whether or not immunity becomes established, and (*c*) cost.

Vaccines and Sera. The range of *vaccines* offered is enormous, since nearly fifty specific vaccines are now marketed for the control of: anthrax, botulism, brucellosis, clostridial infections (black disease, blackleg, braxy), contagious dermatitis (orf), *E. coli*, enzootic abortion (sheep), epidemic tremors, equine influenza, erysipelas, fowl pox, fowl typhoid, gas gangrene, haemolytic streptococci, infectious bronchitis, infectious laryngotracheitis, joint ill, lamb dysentery, leptospirosis, louping ill, lungworms (dictyocaulus), mastitis, Newcastle disease (fowl pest), orf, paratyphoid, pasteurellosis and snuffles, polyvalent infections, *S. dublin*, staphylococci, strangles, swine fever, tetanus, Welchii infection, etc.

The modern trend of manufacturers to offer combined vaccines is obviously labour saving, e.g. braxy with blackleg; distemper, hardpad and leptospira; Newcastle disease, infectious bronchitis and epidemic tremors. At the moment the ultimate is a seven-in-one sheep vaccine for the control of Welchii infections B, C and D (lamb dysentery; pulpy kidney), black disease, braxy, blackleg, struck and tetanus. Examples are 'Clostrin' (Glaxo), 'Covexin' (B. W.), 'Sevlam' (Agricare) and 'Seven-in-One' (I.C.I.).

FIG. 91. Paralysis associated with a case of pig oedema. A typical example of the result of an interaction between specific *E. coli*, and other gut contents (bacteria, nutrients, etc.) which result in the production of toxins (?) causing oedema of the stomach wall.

Although not quite so prolific there are also a multitude of *sera* (both straight and polyvalent) and also specific products consisting primarily of gammaglobulins to give passive immunity against *E. coli* infections in newborn calves and piglets, e.g. 'Gammaglobal' (Int. Serum) and "Gammabovine' (Hoechst).

Antibiotics. The antibiotic field is equally wide. It is important to distinguish between the use of procaine penicillin at low levels in the feed (since it does not then penetrate the bloodstream in worthwhile amounts), whereas by injection it can play a specific part, as well as being used in many long acting forms of penicillin therapy, e.g. 'Penidural' (Wyeth) where it is combined with benzathine penicillin. It also has to be appreciated that when organisms are shown by the routine sensitivity test to be resistant to penicillin, this does not usually apply to the newer synthetic penicillins, e.g. Ampicillin, 'Penbritin' (Beecham) which is bactericidal. Similarly when staphylococci or streptococci are resistant to routine penicillin tests sodium cloxacillin 'Orbenin' (Beecham) or novobiocin may provide an answer. Mixtures of antibiotics (chloramphenicol, penicillin or streptomycin) and vitamins have now become popular for the treatment of stress (e.g. A-V 25, Whitmoyer).

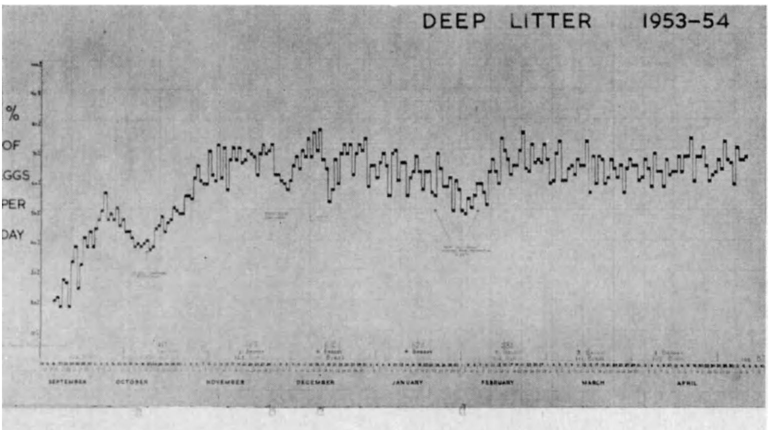

FIG. 92. The first drop in production (a) was due to the fall-off in daylight; the subsequent rise followed the introduction of artificial light.

At (b) and (c) the flock was dosed with piperazine for roundworms. Period (d) relates to a particularly cold spell when room temperatures fell to 26° F. These and other management factors meant that peak production was only 77 per cent after the birds had been housed for 4 months. Stress factors of this type are commonly, though sometimes erroneously, treated with high level antibiotics in the feed.

E. coli often show a marked resistance to procaine penicillin (believed to be due to the continuous use of this antibiotic in broiler feeds) and in this same context up to 20 per cent of both *E. coli* and salmonellae may be resistant to the tetracyclines (aureomycin and terramycin). As a contrast most strains of these two pathogens still remain susceptible to chloramphenicol (P. D. & Co.), and furazolidone in the feed, whilst framomycin and neomycin also appear to be effective in a number of cases. Streptomycin is not used as a feed additive, but given in the drinking water for specific infections, e.g. quail disease. Mycoplasma in poultry are now occasionally showing some degree of resistance to erythromycin, but this is not yet true of 'Rovamycin' (M. and B.) or 'Tylan' (Elanco). These three drugs are now officially termed macrolides.

Rondomycin (Pfizer) is also recommended against P.P.L.O. infections; whereas Oleandomycin can be used against erysipelas, listeria and haemophilus infections, as well as against rickettsia. It is also an excellent growth stimulant for broilers.

For the control of certain fungal infections (e.g. *Candida*) nystatin is used, but it is not satisfactory for cases of aspergillosis. Vibrio infections of the intestines are being treated with Tylan and streptomycin, whereas practically all combinations of antibiotics have been used for mastitis.

Alexander (1966) recently described certain aspects of antibiotic therapy, pointing out that the tetracyclines, chloramphenicol, streptomycin, neomycin and erythromycin all act by interfering with bacterial synthesis, whereas bacitracin and penicillin, for example, act directly on the cell wall.

Whilst the subject of acquired resistance to antibiotics is very important, the new phenomenon of transferable resistance is one which may prove less important than at present anticipated. There is one consolation about 'transferable resistance', namely the fact that the antibiotics which might be linked with this condition have been in use for 10 years or more, without any obvious ill effects. Whilst an antibiotic can lead to the proliferation of resistant bacteria, it does not *cause* them to arise (Brander 1966).

The two papers referred to should be consulted by all practitioners, because there appears to have been a tendency for some to use antibiotics against virus infections (against which they are normally ineffective), and also because it is not always appreciated that young animals are often lacking in those enzymes which conjugate antibiotics (prior to excretion) and therefore large doses may be toxic.

Anti-bacterials. Drugs which have marked anti-bacterial actions but which are not antibiotics include some of the nitrofurans, sulpha drugs, etc. Furazolidone has been the favourite because of its specific effects against *E. coli* and various salmonellae, but a water soluble form 'Furasol' (Smith, Kline and French) is also available.

Hormones. Hormonal drugs and others affecting metabolism are becoming more complex, and therefore Daykin's (1966) short account of the use and misuse of hormones is valuable. Corticosteroids and gonadotrophins appear in many forms, but their uses in veterinary practice are not always clear cut. Attempts are constantly being made to link the former with stress responses or ketosis, the latter for the relief of many sterility problems. Progesterone preparations are now being tried out for the force moulting of pullets! Oestrogens have long been employed for chemically caponising cockerels, whereas their use for fattening bullocks is of more recent origin (both in the feed and by implants). As a contrast for fattening lambs an oestrogen and progesterone pellet can be used. ('Synovex-L', Squibb).

Vitamins. Vitamins and trace minerals form another productive field. The following synthetic vitamins are available: A, B_1, B_2, B_6,

B_{12}, nicotinic and pantothenic acids, biotin, choline, D, E and K. In this connection Dutch research workers believe that milk fever can often be prevented by an injection of 10 m. units vitamin D_3 7 days before parturition is expected to take place. This has superseded the administration of 30 m.i.u. in the feed.

If a practitioner wants to prevent anaemia in baby piglets he has the choice of the following iron preparations: sulphate, ferrite, reduced iron, dextrin, dextran, colloidal iron oxide, iron protein complex, pyrophosphate, gluconate. Which is the better one to use, and should this be given by mouth, as a paint or by intramuscular injection? Is it advisable to use iron salts alone or in conjunction with copper and cobalt, vitamin B_{12} or liver extract?

For a full account of many of the drugs used in veterinary practice, the reader is referred to I.V.S., and *Index of Veterinary Specialities* (1966) 6, Veterinary Publications Ltd., London; and to the earlier work by Hamilton Kirk (1961) *Index of Proprietory Veterinary Preparations* Nivek Publications Ltd., London.

Stress and its Treatment

Since Heuser and Selye's publication on *Stress* (1956) great emphasis has been placed on the possibility that animals will perform sub-optimally after being subjected to a variety of stress factors. For some unknown reason it is often assumed that these stresses affect the bacterial flora of the intestines adversely, hence the advice to poultry producers to give rations medicated with a nitrofuran or broad spectrum antibiotic, when pullets for example are being transferred to their laying quarters.

The concept of stress as outlined by Selye (1955) implies that animals respond in a somewhat stereotype manner to a variety of widely different stress stimuli, e.g. infections, intoxications, trauma, heat, cold, muscular fatigue, etc. Stress response is considered to be characterised by an enlarged, hyperactive adrenal cortex together with an involution of the thymo-lymphatic system. Gastrointestinal ulcers may follow, accompanied by various manifestations of damage or shock. The adrenal response to stress represents an active alarm reaction, this being the first stage of a more prolonged general adaptation syndrome (G.A.S.).

Removal of the hypophysis effectively prevents the adrenal response during alarm reactions, and from this it is assumed that an 'agent' travels directly from the injured target area to the anterior pituitary which responds by an output of A.C.T.H. This in turn stimulates the adrenal cortex to discharge corticoids which increase the proliferative ability of the connective tissues to prevent further invasion by the stress factor. Consequently it is believed in the case of those diseases which have no primary cause (pathogen), that reactions to a non-specific stress will be followed fundamentally by a physiological response which helps to re-establish normal relations.

G.A.S. is characterised by tension, excitement, loss of appetite, subnormal libido (sexual desire; interest in life, etc.) depression of the nervous system, arterio-sclerosis of the brain, general breakdown and death. One cannot, however, recall seeing any animals kept under intensive conditions which have reacted in this way, although loss of appetite and general depression are not unknown on a few occasions. Indeed one must record that culls of this nature are very occasionally noted amongst newly housed layers which fail to adjust themselves to their new environment. These isolated birds lose their appetites and refuse to take any interest in their surroundings; they become depressed and might die if they were not culled from the flock. But in the past 20 years the writer can recall only very few such cases amongst many many thousands of pullets housed in batteries.

This experience is of course a far cry from those who try to imply that stresses are involved whenever poultry are being moved from one site to another, or when they are handled for vaccination or other purposes, or even if they are just being housed in laying battery cages. Even if such stresses were admitted there is no rationale for giving such birds an antibiotic in the food.

Some authorities recommend that extra vitamins are given presumably on the assumption that during stress the animal's requirements for these are increased. But as Selye has said: 'In perusing the world literature on stress we have been unable to find any reports of systematic investigations which would demonstrate the improvement in the response to stress that may be obtained with such remedies.'

It has to be remembered that nature provided the endocrine glands for functional purposes, and if conditions are such that a temporary rise in blood pressure follows or a degree of excitement occurs spontaneously for a short period, these are both natural reactions. Rarely should they require to be supported by medication, unless possibly when stresses operate over long periods.

It can be assumed that if the stockman looking after 'stressed' animals takes careful note of their behaviour and appetites, he will quickly learn whether they require to be vetted. It would seem completely wrong to jump to the conclusion that medicated diets should be used under all such routine circumstances, yet this is a common enough recommendation today by some agricultural advisers.

In the same way there will doubtless be others who believe that gastric ulceration in the pig is also a stress phenomenon, whereas there are many other causes of greater importance. On the other hand the obvious stress which follows the mismanagement of very young calves resulting in scouring is readily recognised and presumably quite unrelated to adrenal hyperactivity. It is indigestion!

Diseases Transmissible to Man

In Britain we are fortunate that the number of diseases transmissible to man is small, although the larger number shown in the table (pp. 483, 484) can spread from animals to man. Furthermore, on a world-wide basis W.H.O. reports that eighty-six diseases are capable of spreading to man from vertebrates.

FIG. 93. *Coenurus cerebralis* the larval phase of *Taenia multiceps*, the cause of 'Gid' in sheep and goats.

In this country the four most important are salmonella infections especially *S. typhimurium*; brucellosis (from cattle); tuberculosis and ornithosis. The occasional isolated case of anthrax, erysipeloid, Newcastle disease (ocular), ringworm and trichinosis may occur, as well as more rarely still foot and mouth disease, cow pox and hydatid disease.

The elimination of tuberculosis from cattle has greatly reduced the risk of spread to man, and one hopes that the same will also soon be said of brucellosis, but salmonella infections will continue for a long time. This subject was debated in great detail at the 1966 B.V.A. Congress, Brighton, and the important papers given by a variety of experts should be made freely available to all interested agriculturists.

So far as the feed compounder is concerned, as some animal proteins (mainly meat or fish meals) may show the presence of small numbers of salmonellae, these ingredients are purchased whenever possible subject to a salmonella-free certificate. Even so a few contaminated parcels may be received, but these of course are very greatly diluted with other feed ingredients. In addition, the processing involved in the manufacture of either pellets or crumbs reduces the number of such pathogens very considerably, and in consequence outbreaks of salmonellosis in animals rarely if ever occur from feed sources. One can of course never be certain that small numbers of salmonellae will not be ingested by a few animals, and the only real solution is to sterilise the suspect ingredients. Practical methods, however, have not yet been evolved for applying gamma-irradiation techniques to meat, fish, or feather meals either at the port of entry into the country or at the time of manufacture. (This can, however, be done at a moderately high cost for small quantities of feeds specially prepared for particular lots of laboratory animals.) Heat destruction alone in the form of pasteurisation may prove the best answer: in the meantime the pelleting of feeds does reduce considerably numbers of pathogens.

Fortunately many of the salmonellae imported via feeding stuffs are exotic varieties which seldom cause outbreaks of salmonellosis, but they may affect individuals under particular circumstances. For example, at a time when the person's vitality is specifically lowered; or, as suggested by Ashoff, at a critical time of the day in relation to diurnal rhythms.

Ornithosis is not uncommon in turkeys in the U.S.A. and may spread to personnel at poultry processing or packing stations, but it has not yet been reported in turkeys in Britain. The virus has been isolated from four different flocks of ducks, and 10 years ago at Weybridge it was isolated from seven psittacines and four pigeons out of more than 580 examined, most of the former being budgerigars. Keymer reported that active infections are relatively uncommon in all species, the highest incidence being in pigeons. Records of recovery of the virus relate to pigeons in Berkshire, Westminster and Liverpool.

In psittacines active disease may be present in recently imported birds, and the habit of householders kissing these pets is a simple source for transmission of the virus of psittacosis.

Public Health problems associated with intensive livestock farming have been studied by a working party of Public Health Officers and their report deserves careful study. It covers such problems as fly and cockroach control, manure disposal, rodent infestations, noise nuisances, river pollution and infectious diseases. The committee included four Medical Officers of Health and eight Chief Public Health Inspectors, but no veterinarians. They agreed that intensive farming methods had not introduced any new hazards to human health, but felt that existing disease risks had been increased, mainly through the greater possibilities which exist for cross infection to occur amongst livestock housed intensively.

Farm Accidents

Over 100 people were killed on farms in 1966, 20 more than in the previous year, and there were more than 9000 less serious accidents. Whilst tractors do not necessarily take a vital part in intensive farming, they are commonly used and are the chief cause of fatal accidents on farms, mainly due to overturning.

The following are examples of the many different types of farm accidents which have been recorded by our field staff to whom I am greatly indebted.

Tractors. When used for consolidating trench silos a tractor may be driven too close the the edge of the trench (the two parallel walls of which may exceed 12 ft. in height). The material gives way and the tractor falls over, ending upside down. This can also occur if the tractor man is trying to consolidate material close to the vertical end of the trench.

A 17-year-old youth died whilst cleaning out a broiler house. He was driving a small dumper truck, tipping the litter on to a heap outside the building, but the truck overturned, trapping the driver underneath. A man was killed when stones fell on to his head from the scoop-up bucket on the front of his tractor. The accident was due to overloading and excessive elevation. Another driver had his face crushed when his tractor turned over on steep ground, and in another case a child was run over after being bounced off the back of a trailer. A farmer was wearing wet rubber boots and riding on a trailer behind his tractor. Standing on the bar attachment, he slipped off unknown to the driver and was run over, dying before they could get him to hospital.

A young boy aged ten went into a shed, started up a tractor whilst nobody was about and took it out on to an icy farm road where it skidded and overturned into a farm pond, killing the boy who was pinned underneath.

After cleaning out a deep-litter house with a front-mounted hydraulic loader a tractor driver was taking a manure spreader down a country lane with the front loader raised to about radiator height. The loader had a bucket-type appliance fitted, the front edge of which struck an oncoming cyclist in the face, resulting in severe injuries.

Electricity. Although not usually considered a common cause of fatal accidents, electricity is potentially very dangerous.

A farmer decided to instal a bulk bin which was to be sited next to the entrance to a hen battery house. The electricity supply to the latter ran straight over a concrete apron where the bin was being erected. One of the men inside the bin decided that he would check the distance from the electric cable to the inspection hatch at the top. Owing to severe frost at the time the overhead electric wires conducted live current further than would be the case during fine weather, and the man was thrown down on to the concrete, dying from a fractured skull.

Many farmers try to do their own electricity repairs, and in some cases lines are overloaded by the addition of new plant, and fires may follow. When using fire extinguishers, it is important to choose those which do not short when played on to live electricity. In one poultry house an electric fire was moved whilst the mains current was switched off, and it was left in such a position that when the electricity was later reconnected it set fire to the wall of the building. A poultryman was examining the wiring of several electric infra-red brooders and at the same time checking the waterers. One such brooder had a loose wire and the man received a nasty burn and considerable shock. A farmer was in a broiler house inspecting his stock when his dog managed to get in as well. It sniffed at an automatic feeding trough, howled and promptly shot out through the door. The farmer came over and also touched the trough and received a sharp electric shock which shifted him several feet away. In some way electric current was arcing across from the electric brooders, making the whole of the automatic feeder alive. Investigation showed that the wiring system was in a very poor state and the fault must have developed after the main brooding stage. This accident incidentally gave an obvious reason why the birds were not eating their food satisfactorily. A farmer was electrocuted because a hay elevator came into contact with an overhead power cable due to the fact that he had not troubled to depress the elevation of the apparatus before moving it.

Sometimes it is the earth lead improperly connected or not even connected at all which is at fault, and even a debeaker can give a shock from this cause. In one instance when a farmer was using an electric aerosol sprayer the shock knocked him on to a set of tyne harrows which put him into hospital for several weeks. Even the handling of electric light bulbs and shades (when the current has not been switched off) may give a shock if they are old and leaking electricity.

Fires. Fires are a greater hazard to intensively housed livestock than they are to the farmer or his staff. This is obvious because of their confinement and comparative immobility should a fire break out. Even the simple procedure of overfilling a paraffin heater whilst the latter is still alight can result in a fire. One has to be careful also that sparks from bonfires do not set light to litter. In one instance this occurred whilst a farmer was feeding his bullocks. He shouted the alarm to his staff and then made a dash to the fire himself but in his hurry he stepped on to the prong of a pitch fork which ran into his foot, causing a nasty injury.

Wounds. It is surprising the number of injuries which involve rusty nails protruding through planks, etc. Sometimes these are hidden in long grass where they may readily puncture Wellington boots. With this type of injury it is obviously helpful if farming staff have previously received anti-tetanus injections. Lack of care whilst straining barb wire causing a whip-lash action is another common cause of local injury. In broiler houses when stock are being caught in a dull light, mechanical injuries from feeders may occur. This can sometimes be overcome by painting the top half of the feeder legs with a white fluorescent paint. In similar circumstances broilermen may severely injure their heads, e.g. if canopy brooders have been raised about five feet from the ground.

When using auto-scythes it is very important to switch off the motor before attempting to remove an obstruction, otherwise once this is removed the cutter comes into immediate action, and there have been several hand injuries from this cause. Hay forks are another cause of common injury, these being left propped up against loose hay. In one case a farmer was sliding down his rick and was seriously injured when such a fork pierced his stomach.

Ladders are an even greater cause of injury. A workman on a ladder was cleaning a ventilation shaft in his broiler house, an assistant standing with his foot on the bottom rung. When the farmer asked for a particular tool the assistant stepped away and the farmer suddenly found himself on his back on the concrete floor unable to move—the ladder had slipped. (The farmer was absent from work for over 3 months.) Sprained ankles can result from persons falling off step ladders due to faulty supports. When ladders are placed outdoors on icy patches (hidden partly by a thin layer of straw or hay) accidents can sometimes result, and in one case a poultryman was suspended upside down (held by his foot in a rung of the ladder) before finally falling heavily to the ground. Standing on a wooden box for egg collection purposes (from the top tier of a laying battery) can also lead to wounds and strains, if it gives way or the person slips.

Livestock. Perhaps the most common accident from livestock *per se* is that due to savaging by bulls which sometimes comes from familiarity with the animal, but a properly designed house and yard usually overcomes this problem. Many bulls have a habit of bellowing when given their hay which they toss about. In this way an inexperienced farm labourer was hit on the temple by a bull's horn, and when the animal turned its head to toss the hay the other horn penetrated the man's stomach as well as pulling out three ribs.

Pigs are sometimes particularly savage, and in one case when a boar went for a pigman the latter dived under an electric fence, but the pig seized hold of his thigh. Although the skin was not broken the leg was so badly mauled that there was a danger for several weeks of the man losing his leg. So that if one is going into a pig pen it is as well to be armed in any cases of doubt.

Cows which have just calved may be equally vicious particularly if they think their offspring are going to be hurt. An inexperienced farm pupil was crushed by such a cow in a corner of the calving box; fortunately the only adverse result was a dislocated shoulder.

Chemicals. A 4-year-old child was playing in a garden tool shed on a farm where a tin of nicotine sulphate Perch Paint was kept on a high shelf. The child could not reach this, except by standing on a wheelbarrow. The tin lid was not fixed tightly and the contents soon poured out on top of the child's head, face and chest. Death occurred shortly after admission to hospital.

Poisoning by carbon monoxide is also not unknown on farms. This gas is emitted from slow-running engines (cars or tractors) and may be blown by the wind into relatively confined spaces. In one such instance a poultryman realised that something was wrong when he found out that he could not lift $\frac{1}{2}$ cwt sacks, in conjunction with a severe headache. He was confined to bed for 5 days before he was able to throw off the ill effects, and for a year was unable to drive a tractor again comfortably.

Portable creosote sprayers can cause trouble if someone unscrews the filter cap without first releasing the pressure in the tank, and when creosoting buildings the eyes should always be protected against droplets. Serious burns to the face may occur on windy days unless great care is taken to be upwind.

The risks from formaldehyde are well known, particularly when the gas is generated by pouring formalin on top of potassium permanganate crystals. On one farm, having sealed the windows and fan outlets, the broilerman added the requisite amounts in the approved manner, but just as he was about to make his exit the door slammed to (from a gust of wind) and he was trapped. His frantic bangings were fortunately heard by another worker, but only just in time.

Perhaps ammonia is an even worse chemical to misuse, particularly if a container has been left out in the sun before it is opened. Artificial respiration may require to be carried out quickly because the gas generally affects both the eyes and lungs.

Other Injuries. Cut and bruised legs can occur should poultrymen fall through weldmesh floors which are supported by faulty timbers, or when walking on unfinished roofs.

The unloading of calor gas cylinders must be carried out with care, bearing in mind that a 100 lb. cylinder when full weighs 200 lb., and muscular strains or even ruptures may result from this cause; and if such a cylinder is accidentally dropped someone's foot may be severely crushed.

On some farms the steps leading to barns or lofts may be well worn, and severe bruising can occur from falls due to this cause. It is also an easy enough matter to slip on icy patches, smooth concrete, or greasy floors, the more so if the person is wearing newly repaired leather shoes, the soles of which have not been suitably scratched. Finally, there is the case of more haste less speed. One of my colleagues hurrying into a cattle barn to help with a calving case ran slap into a low iron frame which dislocated his neck in addition to causing temporary concussion.

The *Agriculture* (Safety, Health and Welfare Provisions) *Act* of 1959 does much to provide for the safety of farm workers and children, including the provision of regulations dealing with first aid equipment. It is amazing, however, how little attention is paid to this very important aspect of farm management. One person *must* be detailed to see that the cabinet is kept up to date with supplies of bandages, dressings, eye lotions, etc.

Where a farming enterprise employs a number of persons it is a good plan to appoint an accident prevention officer, who can then explain the risks which relate to particular jobs and the precautions to be taken, e.g. lifting feed bags, use of corrosive substances, hedging tools and mechanical equipment. 'Guards' in conjunction with moving belts, chain drives, etc., have a habit of being moved to the danger of all users, and such protective measures must be checked regularly.

SOME DISEASES OF FARM LIVESTOCK CAPABLE OF TRANSMISSION TO MAN

Disease	*Animals affected*	*Causal agent*	*Animal frequency*	*Symptoms in man*	*Probable occupation*
Viral					
Cow pox	Milk, Cattle	Poxvirus (D.N.A.)	Occasional	Vesicles, fever, lymphangitis	Farm workers, veterinary surgeons
Foot and mouth disease	Ruminants, pigs	Picornavirus (R.N.A.)	Occasional	Fever, localised vesicles	Farmers (V. rare)
Louping ill	Sheep	Group B arbo virus	Common	Meningitis/encephalitis	Veterinary surgeons
Newcastle disease	Poultry	*Myxovirus multiforme* Povrxius	Occasional	Acute conjunctivitis	Poultrymen, processing staff, veterinary surgeons
Orf (contagious pustular dermatitis)	Sheep		Occasional	Local skin lesion (face/hands)	Farmers, shepherds
Ornithosis	Duck, turkey, pigeon	Psittacosis-lympho-granuloma-trachoma group virus	Almost unknown in Britain. Occasional in U.S.A.	Atypical pneumonia	Slaughtermen at poultry processing stations, veterinary surgeons, meat inspectors
Paravaccinia (pseudo-cowpox: milkers nodes)	Milk cattle	Poxvirus	Occasional	Cherry red papules on the hands	Farm workers
Psittacosis	Cage birds	P-L-T group virus	Occasional	Atypical pneumonia	Householders
Bacterial					
Abortion	Cattle	*Vibrio foetus*	Uncommon	Fever, headache, broncho-pneumonia	Veterinary surgeons, farmers
Anthrax	Cattle, pigs	*B. anthracis*	Occasional	Malignant pustule, etc.	
Brucellosis	Cattle Goats Pigs	*Br. abortus* *Br. melitensis* *Br. suis*	Common Uncommon Uncommon	Undulant fever; headache, malaise, myalgia, erythematous rash	Farmers and veterinary surgeons; laboratory technicians
Erysipelas	Turkeys, pigs, fish	*E. rhuseopathiae* (*E. insidiosa*)	Occasional	Erysipeloid skin lesion; lymphangitis, septicaemia	Processing personnel at slaughter houses, packing stations; farmers, veterinary surgeons
Leptospirosis	Cattle, pigs, sheep	*Leptospira sp.*	Uncommon	High fever, headache, photophobia, myalgia, jaundice	All classes
Listeriosis	Cattle, sheep, poultry	*L. monocytogenes*	Uncommon	Abortion, C.N.S. symptoms	Farm workers, veterinary surgeons, slaughtermen
Pseudo-tuberculosis (Yersiniosis)	Ducks, rabbits and other rodents, etc.	*P. pseudotuberculosis*	Uncommon	Swelling of liver and spleen; jaundice	All classes
Salmonellosis	All species	*Salmonella typhimurium*, etc.	Common	Diarrhoea, food poisoning	All classes
Tuberculosis	Cattle	*M. tuberculosis* (bovine)	Occasional	Cervical adenitis, bone T.B., meningitis, skin lesions	Farmers, herdsmen, veterinary surgeons, slaughtermen, etc. Children

SOME DISEASES OF FARM LIVESTOCK CAPABLE OF TRANSMISSION TO MAN (*contd.*)

Disease	*Animals affected*	*Causal agent*	*Animal frequency*	*Symptoms in man*	*Probable occupation*
	Pigs	*M. tuberculosis* (bovine, human, avian)	Uncommon		
	Poultry	*M. tuberculosis* (avian)	Rare	Lymphadenitis, miliary T.B., etc.	Farmers; laboratory technicians
Rickettsial					
Q-fever	Cattle, sheep	*Coxiella burnetti*	Occasional	Broncho-pneumonia	Farmers, farm labourers slaughtermen, veterinary surgeons
Parasitic					
Helminthiasis	Cattle, pigs	*Ascaridia sp.*	Common	Dermatitis, erythema, vesicles	Butchers
Hydatid disease	Dogs, cattle, sheep, and pigs	*Echinococcus granulosus*	Occasional	Hydatid cysts in lungs, peritoneal cavity, bone, etc.	All classes in contact with dogs
Red mites	Poultry	*Dermanyssus gallinae* *Liponyssus sylviarum*	Common	Itching	All classes in contact with poultry; laboratory technicians, etc.
Trichinosis	Pigs	*Trichinella spiralis*	Uncommon	Eosinophilia, facial oedema, myalgia	Butchers, slaughtermen, householders
Protozoa					
Toxoplasmosis	All species	*T. gondii*	?	Clinical picture indistinct	All classes
Fungal					
Crop mycosis	Turkeys	*Candida albicans*	Occasional	? Thrush	? Children
Favus	Poultry	*Trichophyton gallinae*	V. rare	Scaly ringworm, alopecia	Poultry farm staff
Ringworm	Cattle	*Trichophyton sp.*	Common	Dermatophytosis (itching, scaly skin lesions, alopecia)	Farmers, farm labourers

Some other possible pathogens: Aspergillus fumigatus, E. coli, B. mallei, influenza type-A viruses, *Pasteurella tularensis*, other *Pasteurella* sp., staphylococci, streptococci *Trichuris sp.* (pigs). In overseas countries this list would be greatly expanded, for further details see Schwabe (1964).
Organisms transmitted from man to animals: Corynebacterium diphtheriae to cause ulceration of the skin of the udder, etc., *E. coli*; influenza virus type-A, various salmonellae, *Staphylococcus pyogenes* to cause infected yolk sacs in chicks, poults, mastitis; *Streptococcus pyogenes* (septic sore throat) to cause mastitis.

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Chapter 33

DISEASES OF INTENSIVELY HOUSED CATTLE, PIGS AND SHEEP

J. F. HARBOURNE

In the last decade there have been dramatic changes in the feeding and management of farm animals. Many animals are housed throughout their lives: others spend part of their time out of doors and a further group live entirely in the open. Whatever the method there has been a growing tendency towards a concentration of the stocking rate, so that today cattle and pigs are often housed in a third of the area they would have been allocated 10 years ago.

The reasons for this increased intensification are largely economic and are due to the shortage of land, the movement of population to the urban areas and the high cost of imported food. This has meant that a great deal of time and effort has been devoted to the scientific exploitation of all land resources, whether for animal production or crops. Thus the production of so-called 'barley beef' would have been impossible without a surplus of cheap grain grown in the drier eastern counties of Great Britain. Likewise, research in grassland management, by the production of quick-growing lush grasses on temporary leys has increased the stocking rate of both cattle and sheep on mainly arable farms.

It goes without saying that with every revolution there are bound to be some casualties and whilst most of the contents of this chapter will be devoted to a discussion of diseases associated with housed animals, it would be wrong not to draw attention to some of the potential hazards connected with intensive crop husbandry. These include the use of chemicals both as fertilisers and pesticides. Some of these agents are not in themselves toxic to animals, but may produce unfortunate side effects. Grass tetany or hypomagnesaemia is more likely to be induced in cattle or sheep if the magnesium levels in pasture have been allowed to sink too low through recent use either of nitrogenous fertiliser or of potash. Poisoning is not unknown in sheep which graze on ground recently dressed with basic slag, while certain 'hormone' weed killers may make poisonous plants—ragwort for example—more palatable to stock. Other chemicals, particularly certain organochlorine insecticides, are cumulative poisons and have been taken off the market and replaced by less persistent organophosphorus compounds. Similarly the dithiocarbamates are now employed as fungicides in place of the more dangerous organo-mercury compounds.

Worm infestation is mainly a hazard of the grazing animal but outbreaks of parasitic gastro-enteritis and even parasitic bronchitis do occur in housed stock, especially under semi-intensive systems, where animals are only inside for limited periods of the year or have access to straw yards. One species of stomach worm, *Ostertagia ostertagi*, is capable of surviving in the stomach of cattle in an immature form: this may lead to outbreaks of parasitic gastritis some months after the animals have been housed. Pigs which run out on an old paddock or orchard may become infested with lung worms and while this disease is generally mild it may help to increase the severity of other lung infections such as enzootic pneumonia and possibly swine influenza. Parasitic bronchitis in cattle is less of a problem than it used to be following the introduction of a husk vaccine and more efficient drugs to control outbreaks. Certain forms of Nematodirus infestation in lambs may be controlled by pasture management and the use of anthelmintics during the danger period in April and May. There is also a case to be made out in favour of treating sheep which are to be housed during the winter and sows before they go to the farrowing pen, but in spite of the fact that each new drug brought on to the market appears to have a wider range of activity, is less toxic and may have a better action against immature forms of parasitic worms, there is insufficient evidence to suggest that routine dosing for worms and pasture management are entirely satisfactory in preventing outbreaks of helminthiasis.

A recently published paper by Michel (1966) makes this point very clear when discussing the epidemiology of *Ostertagia ostertagi* and *Cooperia oncophera*, two worms responsible for certain forms of parasitic gastritis and enteritis in cattle. Owing to the slowness in development of the free-living infective larvae on the herbage, only two generations of the parasite will be made available to calves during the period when they are turned out in April and the start of an outbreak in August. Two other important points are (i) that the worm burden of the host does not continue to increase as more larvae are acquired, and (ii) that the output of worm eggs in the faeces does not bear any fixed relationship to the number of worms present. The translation time needed for a contaminated pasture to become infective is long in the spring and becomes shorter as the temperature rises, to reach a minimum in mid-July. This represents the danger period and so all that is required is to take the calves off the pasture in July, dose them with an effective anthelmintic and turn them back onto another pasture which has not been grazed by cattle since the winter.

Factory Farming

The housing of animals under intensive systems of management has caused a great deal of public concern. The term 'factory farming' is often used indiscriminately to cover a wide range of modern agricultural practices. How far this epithet is justified is a matter for each individual to decide, but it should be pointed out that under efficient management, where there is strict control of temperature and humidity and where each animal is under constant observation, the method works well. The most 'natural' ways of rearing stock are not necessarily the most humane. Hill sheep are able to survive for 80 per cent of the year, but live on a bare subsistence level for the remaining 20 per cent. Losses from malnutrition and disease are often accepted as inevitable in 'hardy' hill flocks.

As Sainsbury (1965) pointed out, however, most animals are probably healthier if they are kept out of doors on clean pasture. The greatest risks from disease occur when large numbers of stock are housed on one site. Enzootic pneumonias are all too common in fattening units where sudden changes of temperature, draughts and under-ventilation may lead to an epidemic of coughing and poor conversion rates. Similarly, there may be a build-up of enteritic disorders in pigs and calves where successive batches are run through the same house. Where possible it is better to keep stock in small groups, well separated from other groups, keeping animals of the same age together and working on an all-in–all-out system. This means that buildings can be rested between batches for a minimum period of 2–3 weeks and will allow time for thorough cleansing and disinfection.

It goes without saying that the health of an animal is intimately bound up with the type of food it receives. A great deal of attention has been paid to this subject in recent years, especially in relation to the diet of intensively housed stock. Animals which spend the majority or all of their lives indoors are of necessity unable to forage for food and so any deficiency either in the presentation or content of the ration will inevitably be reflected in their bodily condition. Unfortunately it is not always possible to know in advance whether any radical changes in feeding practice may lead to extra demands for one particular food factor. A case in point is that of the extra demand for vitamin A in calves maintained on the barley beef system. In the original diet, 4 million I.U. of vitamin A per ton were considered adequate, but this figure has now risen to something like 10 m.i.u. per ton. Energy is also a key factor in maintaining high levels of growth and this means that the energy values of diets have to be increased over and above the requirements for amino acids, vitamins and minerals. Fats have a high energy value and so they are increasingly incorporated in animal feeding-stuffs. At this point in time it is difficult to know how far fats will influence the disease picture, but it is conceivable that they may induce certain metabolic disorders.

Antibiotics. Another matter of supreme concern to the veterinarian is that of the addition of antibiotics to animal rations. The provisions of the Therapeutic Substances Act permit the addition of antibiotics at low levels to specified pig and poultry foods. Permission has been withheld for calf food, though a farmer may obtain antibiotic supplements from his chemist (B.V.A. 1965). The fact that such practices sometimes lead to resistant strains of bacteria is already well known.

Until recently it was assumed that such resistance was the result of chromosomal mutation, but in 1959 Japanese workers demonstrated another type of resistance that was transmissible from a resistant bacterial cell to a sensitive one simply by contact—hence the term 'infective drug resistance'. At present it seems that the phenomenon is restricted to such organisms as the *Salmonellae* and *E. coli*. Unlike mutation, the hereditary material of infective resistance is located in the cytoplasm of the cell and may result in resistance to a single antibiotic or to a number, including practically all the available antibacterial drugs.

Williams Smith *et al.* have shown that drug resistant strains of *E. coli* are frequently found in the faeces of human beings, calves, pigs and fowls and in one experiment the resistance of four non-pathogenic strains of these organisms was transferred to the principal Salmonella serotypes and to some of the *E. coli* serotypes that cause diseases in these animals (Williams Smith and Halls 1966).

Medical workers in this country have also drawn attention to the increase in the incidence of resistant strains of *S. typhimurium*. Most of the resistance was of the infective type and almost all the strains of one particular variety of *S. typhimurium* that commonly caused infection in calves and human beings were found to be drug resistant. It was felt that the increase in the incidence of these strains in the human populace was directly attributable to the rapid development of the intensive system of calf rearing (Anderson and Lewis 1965). Since this report was published there has been a reduction in the incidence of this variety of *S. typhimurium* infection in calves, probably as the result of a rigorous programme of disinfection at the primary sources of supply. It is also interesting to note that infective drug resistance of the multiple type was demonstrated by Williams Smith and his co-workers in two strains of *E. coli* isolated as long ago as 1956, indicating that the phenomenon must have arisen relatively early in the antibiotic era. This in turn suggests that infective drug resistance is inherently a problem associated with the indiscriminate use of a wide variety of antibacterial drugs. The sooner we can dispense with the need to employ these agents as a means of preventing outbreaks of disease the better. Such drugs should be used for the purposes originally intended—to cure sick animals.

Other chemicals, as well as antibiotic residues, are used as growth promoting stimulants in animal foods. Copper is often added to a pig ration to increase food conversion; levels of up to 250 p.p.m. of copper sulphate appear to have no untoward effect on the health of the animal or the consumer. Copper is also widely used to alleviate naturally occurring deficiencies in cattle and sheep and is sometimes employed as a worm medicine in sheep. Unforunately sheep are highly susceptible to copper poisoning and a number of cases have been attributed either to overdosing with an anthelmintic containing copper or to animals gaining access to concentrate food. Certain arsenical preparations have an action similar to that of copper in promoting the growth of pigs. While it is too early to draw definite conclusions, it is perhaps of some significance that after lead, arsenic[1] is the commonest cause of poisoning in domesticated animals.

Hormones. So far no mention has been made of hormones and related substances; since this is a wide subject and impinges on a whole range of topics, it will be discussed now rather than under separate headings of cattle, pigs or sheep. Until recently oestrogenic hormones were employed almost exclusively for treatment of reproductive disorders and as growth promoting agents. Suffice it to say that the British Veterinary Association in their evidence to the Brambell Committee suggested that these substances should not be added to the diet of animals since they were potentially dangerous not only to the recipients but to their attendants and to the ultimate consumer. If they were to be employed at all they should be strictly administered as implants.

[The Brambell Report states 'The feeding of synthetic oestrogens is no longer generally practised, though pellet implantations are used in some poultry and to a lesser extent in beef cattle and fattening sheep. We do not think the practice has adverse effects on the welfare of the animal' Editor.]

In this connection it is interesting to record that even implants may have disturbing side effects for male cattle and sheep. It appears that oestrogens increase the susceptibility of these animals to urethral blockage following the deposition of magnesium ammonium phosphate on an organic matrix.

One of the major problems which face the sheep breeder is lack of fecundity in ewes. It has been the practice for a long time now to increase the amount of food available at tupping time and again during the later stages of pregnancy in an effort on the one hand to raise the lambing percentage and, on the other, to reduce the incidence of pregnancy toxaemia. Later developments include the use of hormones to stimulate the production of twins and triplets, the early mating of ewe lambs, the employment of breeds with a long breeding season, and subjecting ewes to fixed periods of darkness so that they will produce lambs out of season. It has also been suggested that ewes with four teats would be in a better position to cope with two or more lambs, while early weaning would help to reduce the strain of lactation in highly productive animals. Up to now, the disadvantages of these methods have tended to outweigh the advantages and while some authorities are convinced that it is possible both to shorten the lambing

[1] Inorganic arsenic [Editor].

period and bring ewes into season 3–4 weeks early, by running them with vasectomised rams, others are equally convinced that the sight of a ram, whether entire or not, is just as effective. An even later development in inducing early breeding in sheep is that of intra-vaginal treatment with '*Synchro-Mate*' (G. D. Searle & Co.), progestin impregnated pessaries. Progestin stimulates the production of the corpora lutea in the ovary and after removal of the pessary the ewe comes on heat 4 days later. Ewes may be served at the induced heat or at the subsequent one. So far the results have been promising, but it is too early yet to assess the results in the field (Wishart 1966).

As with sheep, so with pigs, there has been an increasing tendency to try to telescope the breeding activities of the sow and boar. Breed as early as possible, make full use of artificial insemination, batch farrow and early wean, are the orders of the day. Unlike ewes, sows produce reasonably large litters, but by no means up to their full potential of eighteen or so. The trouble is that if such large litters were produced the sow would be unable to provide all the milk required to support her offspring. Feeding the sow during her pregnancy might also prove difficult. A similar problem already faces the lamb producer, since he has no way of knowing, other than by recourse to the X-ray or ultrasonic machines, how many lambs an individual ewe is carrying. At present a ewe with a single lamb is being fed at the same rate as one with twins.

Mastitis and loss of milk are responsible for a great deal of the neonatal deaths in both lambs and piglets. Animals which are born weakly or are undersized are also less likely to survive when in competition with their more active and heavier brothers and sisters. Slow farrowing, leading to lack of colostrum for the tail-enders, and overlaying are additional sources of trouble for the pig breeder.

Following the introduction of sow stalls and other innovations, great efforts have been made to control the breeding programme in large sow herds. Early weaning has increased the sows' potential to produce more litters in any one year and has been a useful means of bringing a group of sows on heat at the same time. Gilts have been more of a problem, but as with ewes, a new drug methallibure (I.C.I. 33828) has come on to the market to control oestrus and ovulation. This is given in the food in the form of a premix. Treatment lasts for 20 days, after which the gilts come on heat 6–8 days later (Groves 1966).

Batch farrowing, like concentrated lamb production, tends to increase the risk of cross-infection at any time between conception and birth. Enzootic abortion, vibriosis and toxoplasmosis are recognised causes of abortion in ewes. The position as far as pigs are concerned is less clear-cut since swine fever is now almost a thing of the past. Lack of vitamin A may lead to the production of eye-less or deformed piglets, insufficient iodine to mummified or goitrous ones, and a shortage of one of the members of the vitamin B group to malformed or trembling piglets.

But the likelihood of a gross shortage in the food of any one of these factors is remote. The chances are that a slight deficiency may lower the resistance of the sow to a variety of pathogenic agents, including viruses, salmonella and *E. coli* organisms, leptospira, staphylococci, pathogenic streptococci, pasteurella and toxoplasma.[1] There is no doubt that swine erysipelas is responsible for some cases of abortion but vaccination should help to control this infection.

The dairy herd is the breeding centre of the intensive beef trade. As such it has a dual role to provide milk for human consumption and calves suitable for the fattening trade. Fortunately the British Friesian is an ideal animal for this purpose, although much time and effort is being devoted to the improvement of the beef performance of the progeny by crossing with native beef breeds and imported breeds such as the Charolais. Unlike the old flying herds, which were so common in and around the industrial towns and cities between the wars, the majority of the present-day herds are self-contained and make ample use of A.I. services. Many of the farms are on the wetter, western side of the country and in consequence there is an increasing flow of traffic in calves to the drier eastern counties, where most of the grain is produced.

Mastitis and diseases of breeding are the major causes of loss to the dairy farmer and whilst intensification is not as complete as in certain other classes of stock, there has been a great move in the last few years away from the traditional byre with its individual cow stalls to some form of the yard and parlour system. The results so far have not always been an unqualified success: bullying and injury while animals await their turn to go into the parlour have increased the cows' susceptibility to infection with mastitis organisms. Misuse of antibiotics has not helped, by producing resistant strains of bacteria. Cow cubicles also have their disadvantages. Slurry may be a useful by-product but if it means that cows have to lie on cold concrete or wet boards without warm bedding, then it has rather a high price to pay in the form of chapped teats, eczema, stiff joints and pneumonia.

Other than mastitis, the three main bacterial scourges of dairy cattle are brucellosis, Johne's disease and salmonellosis. Vaccination with strain 19 has been a great help in reducing the incidence of contagious abortion: eradication, of course, is the next step. Johne's disease is a more intractable problem, but here again, vaccination is a useful means of control. Salmonellosis will be discussed later in greater detail, but it is worth remembering that in some areas of the country, one form of the disease is endemic. Eradication of the infection from adult cattle in the affected areas would greatly reduce the incidence of the disease in calves.

Correct Feeding. Correct feeding is all-important in maintaining the health of housed animals. Food may be bulky and coarse, fine and mealy, it may be presented in the form of cubes or pencils, as a wet or

[1] This is a very interesting surmise, but at present proof is lacking [Editor].

dry mash or as a liquid. Colostrum provides the newly born calf, pig or lamb with all the essential factors necessary to maintain health, and as well as its gentle laxative effect, it is rich in maternal antibodies. These are contained in the globulin fraction and since the molecules are relatively large, they must be fed as soon as possible after birth when the lining of the gut is still capable of absorbing them into the system. Lack of colostrum predisposes young animals to the septicaemic form of *E. coli* infection, and to invasion by Salmonellae and the various agents concerned in outbreaks of pneumonia.

Natural milk is an extremely valuable food for young animals, although feeding for prolonged periods may produce anaemia and symptoms of hypomagnesaemia in calves over 2 months of age. Vitamin A levels tend to vary with the season of the year and may be low towards the end of winter when there is a shortage of fresh green food. Anaemia is less likely to occur in veal calves fed on a concentrated milk substitute with added copper, iron and cobalt.

Occasionally one comes across a calf which is unable to drink satisfactorily from a bucket. This is a great nuisance and in the absence of a teat device, the animal often ends up with bloat. It has been suggested that the cause of the condition is the inability of the calf to close the oesophageal groove properly so that undigested milk is passed into the rumen.

One of the major problems associated with the feeding of high concentrate rations to beef animals is barley acidosis or the acute overeating syndrome. This condition is more likely to occur when animals are switched suddenly from a high roughage diet to one with a high concentration of barley. Precisely the same effect is produced when sheep are subjected to a similar type of feed or when they are turned out on to a field of stubble. When Preston and his collaborators introduced the system no hay was fed and at 12 weeks of age calves received a ration consisting of 85 per cent rolled barley and 15 per cent of a protein/mineral/vitamin supplement. The food was given *ad lib.* from self-feed hoppers and to ensure that there was sufficient roughage, the barley was rolled and not ground, at a moisture content of at least 16 per cent.

Since that time, beef feeding generally starts round about the 300–350 lb. mark and hay is fed at the rate of 1½–2 lb. per day. However in spite of these modifications outbreaks of barley acidosis are not infrequent, particularly when animals out on pasture are first brought indoors. Such animals may be hungry and gorge themselves. The intra-abdominal pressure increases, large quantities of lactic acid are produced in the rumen and there is a rise in the histamine level. Within 2 days of the change animals show signs of inco-ordination, dullness, diarrhoea and loss of appetite; later they may become recumbent and some may die. Intravenous injections of thiamine combined with oral doses of yeast may help to combat the worst effects, but now that the condition is better understood precautions can be taken to prevent outbreaks by gradually increasing the intake of cereals over a period of 2 or 3 weeks.

A condition known as cerebro-cortical necrosis (C.C.N.) is probably related to some forms of barley acidosis, in that the production of lactic acid in the rumen may interfere with the synthesis of thiamine—by the ruminal flora. Symptoms include excitability, loss of appetite, trembling, staggering and loss of vision. Both calves and lambs may be affected with irreversible changes in the brain, but it is possible to halt the progress of the disease by injections of thiamine (Davies *et al.* 1965).

Laminitis, a severe and painful foot condition, is another manifestation associated with barley feeding. The cause of the condition is obscure, but it is probably more common in yoked animals resting on a hard concrete floor. Treatment with anti-histamine drugs and corticosteroids has not always proved of much value, although exercise and a laxative diet may help.

In the early days of 'barley beef' production, up to 40 per cent of the livers of slaughtered animals were condemned as unfit for human consumption and a high proportion of the kidneys were rejected because of necrosis. One reason put forward was that the changes in these organs were due to invasion of the tissues by bacteria which had escaped from the damaged wall of the rumen into the bloodstream. Rumenitis with blackening and increased thickness of the mucous membrane is apparently a common finding in stirks fed on barley, but is much less common in animals which have received a more conventional diet. Liver and kidney damage can be alleviated to some extent if ½ lb. of hay is fed for every 5 lb. of concentrates. Outbreaks of tetanus are also occasionally encountered in animals maintained on high barley feeding and may again be related to intestinal damage, which allows the spores of the germs to penetrate more deeply into the tissues. Conditions are then ideal for the active vegetative forms to produce their potent toxins. Fortunately, cattle are more resistant to tetanus than man or horses and so treatment with antitoxin and antibiotics is well worth while.

Pigs, although omnivorous, seem to suffer from their fair share of dietary troubles. Anaemia is a perennial problem for the pig breeder, and injections of suitable iron preparations must be given as soon as possible after birth; but farmers must realise that unless the needles and syringes are sterilised before use, there is a great danger of abscess formation. Cases of acute liver necrosis have been recorded in pigs which have received two doses of an iron dextran preparation separated by a comparatively long interval of time. A recent method for controlling anaemia consisted of feeding ferrous fumarate to the sow, but the only way the piglets were adequately recompensed was by allowing them access to the sow's dung!

Sow's milk has a relatively high fat content especially when piglets are about 3 weeks old: this period tends to coincide with a drop in the maternal antibodies and hence the rise in incidence of dietetic scours in 3-week-old piglets. Nevertheless, piglets tend to thrive better when they are left on the sow and are not weaned too soon.

Feeding swill may lead to deficiencies of vitamins A and D; low levels of manganese, especially when combined with a calcium/phosphorus imbalance, may result in infertility in breeding herds, while tail biting and cannibalism are often a sign of boredom in animals without straw to play with and a too finely ground meal to eat. Dry, dusty, over-ventilated conditions also help to increase the spread of pneumonia in the fattening house, especially when floor feeding is practised. Certain skin diseases, such as exudative epidermitis, or greasy pig disease, may result from a shortage of one of the vitamin B complex, although where baby pigs are concerned, wood shavings or sawdust litter may increase the severity of the condition. One form of necrotic enteritis may be the result of a shortage of nicotinic acid or tryptophan in the diet, while lack of vitamin E may lead to outbreaks of haemorrhagic scours, damaged livers and mulberry heart disease, with sudden death in good-sized store pigs.

In a somewhat different category, but with possible psychological undertones, the incidence of gastric ulcers appears to be higher in pigs which are maintained on a diet of cheese whey than those fed on more solid foods. This method of fattening pigs is usually associated with the so-called 'sweat box' system where temperatures are held at 75° F (24° C) and humidity at 80 per cent. Advocates of the system consider that it cuts down respiratory troubles, but the atmosphere approaches that of a steam laundry and, without adequate ventilation, the possibility of heat stroke or suffocation cannot be discounted. Although a high percentage of sweat box pigs are able to live with their ulcers, others die from internal haemorrhage or from shock following complete penetration of the ulcer through the stomach wall.

Bowel oedema, although often associated with certain strains of *E. coli*, is particularly common in newly weaned pigs, which have been introduced too suddenly to a growers ration. One way of avoiding this problem is to leave the weaners in the farrowing house for 2 weeks after the sow has left and gradually introduce more and more of the growers ration and at the same time give less and less of the creep feed. Salt poisoning is another condition which is easily preventable. In my experience outbreaks usually occur at the weekend, when the regular pigman is having a day or two off. The cause of the condition is generally lack of easily available water. Symptoms resemble the acute form of swine fever, with fits predominating.

Dietetic disturbances in sheep, other than starvation, pregnancy toxaemia, barley acidosis and copper poisoning are relatively few in number. Vaginal prolapse and intestinal herniation occasionally occur in ewes carrying more than one foetus, if they are fed on bulky foods such as turnips and kale. Sheep fed exclusively on kale may develop a fatal anaemia or produce lambs with enlarged thyroids and there may be an increase in embryo mortality. Heavy silage feeding has been implicated in outbreaks of listeriosis—a brain infection—while a sudden increase in carbohydrates may result in outbreaks of pulpy kidney disease in lambs.

Muscular dystrophy may be a special hazard in housed lambs. Recently a colleague of mine (Wight 1966) drew attention to a mysterious condition in which 70 out of 800 lambs were affected with a stiff gait and muscular tremors. The lambs were the progeny of 560 Clun Forest × Suffolk ewes which were housed in December and started to lamb in January. Each ewe was fed 3 lb. of hay and 1–1½ lb. of barley per day: minerals were fed *ad lib.* Altogether twenty lambs died between the ages of 3 and 8 weeks and post-mortem examination of some of the worst affected revealed lesions typical of muscular dystrophy. Examination of blood samples helped to confirm the diagnosis. Daily injections of 60 i.u. of vitamin E produced a gradual but progressive recovery in the majority of treated animals.

Food may be the vehicle by which disease organisms gain entry to the farm. Imported feeding-stuffs or organic fertilisers may contain the spores of anthrax, which could result in sudden death, not only in cattle and pigs but in sheep as well. Groundnuts containing aflatoxin have produced typical liver lesions of cirrhosis and bile duct proliferation in calves and a severe drop in milk yield in dairy cows. Aflatoxins have been discovered in other foods such as cotton-seed cake, maize and soya bean meals.

Various strains of Salmonella, including *Salmonella typhimurium* have been isolated from different feeding-stuffs at one time or another. It must be made clear, however, that the possibility of any one of these agents being present in manufactured animal foods is most unlikely. It seems to be a universal habit to blame food for outbreaks of disease in farm livestock, especially when the husbandry is poor: better to look for the chronic carrier or the newly purchased animal.

One condition, however, may result from the mycotic spoilage of hay. In a recent survey it was found that 71 per cent of cattle suffering from fog fever and 45 per cent of cattle showing signs of a respiratory disease following contact with mouldy hay gave positive reactions when tested against farmers' lung hay antigens. Fog fever may be regarded as an extremely acute lung oedema and is occasionally associated with a lung worm infestation. In the farmers' lung type of infection, however, the likely cause of the disease is *Thermopolyspora polyspora* (Wilson 1966).

One problem which we may have to face in the future is urea poisoning. Urea is a useful source of non-protein nitrogen which is broken down in the rumen to produce ammonia; the latter is utilised by the micro-organisms in the rumen to produce bacterial protein, which in turn is made available to the host. It is obvious that urea is of no value to a single-stomached animal like a pig and that even in ruminants there is a limit to the amount of urea, as ammonia, which can be turned into protein. Any excess ammonia will be absorbed into the blood stream and excreted in the form of urea. Excess over needs may lead to poisoning with signs of increased excitability, staggering, frothing at the mouth and bloat. Later there may be signs of paralysis followed by coma and death. Treatment consists of glucose injections combined with oral doses of dilute acetic acid or sour milk.

Another development that should be mentioned is that concerned with the conservation or spot-grinding of the incisor teeth of sheep. Broken mouths are a widespread and significant cause of flock depreciation and a series of field trials were performed to see whether it was possible to preserve the cutting edge of ewes' teeth. The results of treatment were promising, but not entirely conclusive.

Housing

Although problems of housing are very much the concern of the modern veterinarian, they will be discussed in much greater detail in other chapters of the book and so my remarks will be restricted to a few general observations. Any stress may precipitate outbreaks of pneumonia or enteritis, likewise buildings may become 'animal sick' if no attempt is made to prevent a build-up of infection from one batch to another. This point is well illustrated in a recent experiment in which newly born calves were introduced at intervals of 1 or 2 days into a calf house maintained at a temperature of 55–60° F. Each successive calf gained less weight until eventually deaths occurred from a localised intestinal infection. This occurred in spite of the fact that all the calves had received colostrum and were on a diet of constant composition. After the cycle was broken by resting the house for 6 weeks, new entrants did well, but the position deteriorated as successive calves were introduced (Roy 1964).

The intensive housing of sheep is by no means a modern innovation; in-wintering of hoggs is still practised in a few places and is likely to gain popularity. The main change has occurred in breeding flocks and as Cooper (1966) has pointed out, the reason for bringing ewes indoors during winter is not so much to protect the sheep, but to prevent spoilage of the limited amount of available pasture.

Watt (1966) has recently published some useful information on how to tackle the problem of housed sheep, and one of his recommendations is that adequate ventilation is of prime importance if sheep are to avoid outbreaks of pneumonia. Changes of air must be frequent and the air should circulate above sheep level to avoid draughts, otherwise the animals will tend to bunch in corners where the air is stagnant.

To reduce the spread of infection at lambing time, ewes should be penned in groups of not more than fifteen to twenty-five, depending on breed and the duration of pregnancy. Two pens should be left empty so that if there is an outbreak of disease in a pen the unaffected in-lamb ewes can be removed to a clean enclosure. Gimmers should be kept together to prevent bullying from older ewes and due regard should be taken of lambing dates so that ewes in each pen will lamb at approximately the same time. This will lessen the risk of a build-up of infection, but if disease does strike a particular pen it should not be used again that season. Providing the bedding is dry there should be little trouble from foot rot, but it is essential to pare the feet and treat infected ones before the ewes go into their winter accommodation (Watt 1966).

Sheep in particular are extremely vulnerable to attack by ectoparasites. All sheep should be dipped and indeed wormed before going inside. Further dipping with one of the organophosphorus compounds may prove necessary in the early part of the year, especially in animals on bare maintenance rations. One type of louse (*Damalinia ovis*) is a particular nuisance since it has a small translucent body and is easily overlooked. It is especially active in December and January resulting in loss of condition and severe skin irritation, and prompt treatment using a hand spray often brings relief. Another nuisance disease associated with trough-fed ewes produces an eczema around the eyes and face. It is highly contagious and spreads rapidly just before lambing time. Control depends on keeping ewes in small groups.

Pigs, as well as sheep and cattle, have their foot troubles. Abscesses of the feet are by no means unknown, especially in heavy pigs, which stand on rough concrete floors. There is always the danger of spread of the infection leading to abscesses in other parts of the body including the lungs. An occasional animal may die from a generalised septicaemia. Outbreaks of foot-rot also tend to occur where the floor is uneven and abrasive. Foot baths and a soft bed are the real answer. Unlike foot abscesses, the condition may be seen in very young pigs and often starts with bruising of the heels.

Enteric conditions and outbreaks of pneumonia account for a very high proportion of the losses in housed stock. One problem which is of immediate concern to all stock owners is colisepticaemia, colienteritis, *E. coli* scours and dietary scours. Some of these terms do in fact have an exact meaning, but the division between the entities tends to be blurred when applied to actual outbreaks of disease on the farm. The precise role of the various strains of *E. coli* isolated from the different species of animal is not always clear-cut. Like so many problems, over-simplification often leads to distortion of the facts.

In a survey conducted a few years ago on the incidence and causes of mortality in thirty-seven herds of pigs, the results showed that during a 2-year period, the average death rate up to 8 weeks of age in 2581 litters was 25·9 per cent, and that of these losses the majority occurred in the first week of life. Physical and developmental conditions accounted for 67·5 per cent of the deaths in the first 3 days and by the 8th week bacterial infections, including oedema disease, were responsible for

25·8 per cent. From 2 to 4 months of age, respiratory, alimentary and bacterial infections were the major causes of loss and after 4 months bacterial and respiratory troubles were very common (Anon 1959).

Another more broadly based survey conducted over the same period referred to other diseases such as enterotoxaemia, transmissible gastroenteritis and ascaris infestations, to which should now be added the nodular and stomach worms. As in the previous survey the need to control losses during the first weeks of life was underlined, but the most striking factor to emerge was the important part played by *Escherichia coli* in pig pathology. The survey also confirmed the importance of streptococcal infections, which in the first weeks of life were almost invariably generalised; after this time arthritic or meningeal forms were more common. Swine erysipelas was seen most frequently after weaning, while acute paratyphoid caused by *Salmonella choleraesuis* was an important cause of mortality in the periods just before and just after weaning. Necrotic enteritis showed a peak incidence at the same time. Cases of acute haemorrhagic enteritis were confined to the post weaning period (Anon 1960).

Probably the most widely and easily recognised disease of the baby pig is piglet scours. Usually the animals are born healthy but within 12 to 48 hours of birth they develop a particularly obnoxious yellow diarrhoea. As a result the piglets become dehydrated and often die 24 hours after the first signs of the disease. Bacteriological examination of the faeces and of the intestinal contents invariably reveals a pure growth of one or other of the pathogenic pig strains of *Escherichia coli.* In this case there cannot be any dispute about the significance of these findings since the disease has been reproduced experimentally in naturally reared and in 'pathogen-free' pigs, while treatment with an antibiotic to which the *E. coli* are sensitive generally leads to a rapid cure.

The severity of an outbreak will depend on the virulence of the organism, the immunity of the mother, and the build-up of infection in the farrowing house. As might be expected the longer an animal has lived in a particular environment, the greater is its chance of acquiring a natural immunity against the germs surrounding it. Sows which are moved to another farm or gilts which are farrowing for the first time are less able to protect their offspring from incursions by pathogenic strains of *E. coli.*

As well as virulence, persistence is an important attribute in agents which cause outbreaks of disease. Some viruses are quickly destroyed once they have left the body of the host but unfortunately the same cannot be said of pathogenic strains of *E. coli* which may survive in the faeces for at least 6 months. This fact alone underlines the necessity for the thorough cleansing and disinfection of buildings and equipment between farrowings. Another type of piglet scour, which was touched upon earlier, occurs in piglets at about 3 weeks of age. It is less deadly than *E. coli* scour and is often referred to as 'milk scour'. It is probably a form of indigestion resulting from an excess of milk and the start of creep feeding.

Weaning is a difficult period for any animal and is particularly so for pigs especially when different litters are introduced to each other for the first time. There is a strong possibility of cross infection when large numbers of pigs are herded together: this in turn will lead to fresh outbreaks of enteritis in which pathogenic strains of *E. coli* may once again predominate. In one form of the disease the affected animals die after a very short illness from a severe haemorrhagic enteritis. On other occasions the condition is more chronic and animals die from necrotic enteritis after a prolonged illness in which portions of the bowel become grossly thickened. A third disease which may have certain affinities with the previous ones is bowel oedema. Death is comparatively sudden and the main signs are puffy eyelids and gelatinous infiltrations in the walls of the stomach and intestines. Correct feeding, as has already been mentioned, is often effective in controlling this disease.

One theory put forward to explain the sudden onset of both bowel oedema and haemorrhagic enteritis is that pigs become sensitized to certain strains of *E. coli* and so die of shock. Necrotic enteritis is considered to be a sequel to the same phenomenon, in which the damaged tissue of the bowel becomes invaded with secondary organisms such as *Salm. cholerae-suis* and *Vibrio coli* (Stevens 1963). Unfortunately despite this theory, it is not always possible to implicate one particular strain of *E. coli* in cases of haemorrhagic enteritis or in some outbreaks of necrotic enteritis, although there does appear to be a relationship between the latter condition and the proliferation of bacteroides in those portions of the small intestines affected with necrosis (Williams Smith and Jones 1963).

Another enteric condition of importance in pigs is transmissible gastro-enteritis, caused by a virus. The agent is quickly destroyed by heat and light and so perhaps it is no coincidence that most of the recorded outbreaks have occurred in the early part of the year. All ages of pigs are affected, but deaths are usually restricted to animals under 3 weeks of age. The incubation period is short, followed by signs of vomiting, excessive thirst and the production of a foetid grey to green diarrhoea. Temperatures are usually normal and in most outbreaks the disease runs a rapid course and may be over in 3 weeks, though individual cases may last as long as 10 weeks or more, especially when fresh pigs are introduced to the infected premises, or when a number of sows start to farrow during the height of the outbreak and so pass on infection to the newly born piglets. There is a certain amount of circumstantial evidence that the disease may be spread mechanically by flocks of starlings. At the time of writing, transmissible gastro-enteritis appears to be quiescent.

This statement hardly applies to the increase of parasitic gastro-enteritis in sows and store pigs. Two worms are involved, *Oesophago-*

stomum dentatum and *Hyostrongylus rubidus*: the former is found in the large intestine and the latter in the stomach. Both have a wide distribution in the pig population, though the nodular worm of the large bowel predominates in mixed infestations. Like similar worms found in sheep and cattle, there is a free-living larval stage and pigs pick up the parasites by grazing infected pasture or by living in close communities in straw yards. Until recently neither worm was regarded as being particularly pathogenic. *Hyostrongylus rubidus* was not supposed to affect the health of vigorous, well-fed pigs, although it was suggested that a poor diet and the strain of lactation might result in gastritis, with thickening of the mucous membrane of the stomach. Symptoms attributed to this condition included weakness, thirst, variable appetite and diarrhoea.

In the case of *Oesophagostomum dentatum*, infestation was held to have no effect on health although the latest information refers to intestinal lesions like paratyphoid leading to haemorrhagic diarrhoea, loss of appetite, slow growth and infertility. A number of workers are now convinced, however, that there is a strong link between parasitic gastro-enteritis and 'the thin sow syndrome' which is all too common in 'in-pig' sows on a restricted diet. Control of both types of worm rests on keeping floors dry and removing dung at least once a week from indoor accommodation. Pastures should be well drained, rested at frequent intervals, and where possible subjected to rotational grazing by other stock. Pelleted feeds containing both thiabendazole and piperazine (to control ascaris infestation) have proved their worth in reducing the worm burden in sows and fattening pigs although regular dosing may be required, since immunity against the stomach and intestinal worms is not high (Davidson and Sutherland 1966; Gitter *et al.* 1966; Taffs 1966).

One other enteric condition which is occasionally seen in pigs is caused by the organism *Vibrio coli*. This is associated with scouring and wasting, with blood and mucus in the faeces and usually affects pigs between 10 and 16 weeks of age.

E. coli infections in calves are possibly even more difficult to understand than those seen in pigs. Lack of colostrum may lead to a generalised septicaemia following the invasion of the tissues by certain pathogenic strains of *E. coli* and under circumstances already mentioned there may be a build-up of infection in a calf house. It appears, however, that the majority of cases of coli enteritis in animals over 2–3 weeks of age are the result of a disturbance in the balance of the intestinal flora which are already present in the gut and while it is conceivable that the *E. coli* population could produce an endotoxin or poison, it must be remembered that these germs are not the only organisms present in the bowel and that unlike the septicaemic form of the disease, different strains of *E. coli* may hold sway at different times over a period of a few weeks.

In other words 'indigestion' is the major factor concerned in calf scours. This may result from faulty feeding, especially over-feeding with indigestible liquid food or from travel weariness. The first thing that happens is that undigested food enters the small intestines and is broken down by bacterial action to produce smaller particles which irritate the wall of the gut. This in turn stimulates the muscular activity of the intestines and the food is pushed down the tract at an extremely rapid rate: fluid is withdrawn from the tissues and the animal quickly becomes dehydrated. This means that the best line of treatment for calf scours is to replace the lost tissue fluids; to do the job properly requires specialist attention using a fluid drip through which are passed plasma proteins and various essential electrolytes.

Richardson (1967) recommends that scouring calves should be given the following instead of milk, twice daily: salt, 1 teaspoon; sodium bicarbonate, ½ teaspoon; glucose, 4 oz.; water 4 pints. As soon as scouring ceases the milk is gradually re-introduced. At no time is the total fluid intake below 8 pints daily. [With this treatment antibiotics are frequently not needed. Editor].

Fortunately for the sheep breeder, *E. coli* infections in lambs seem to be relatively straightforward, although it is often difficult to separate the disease clinically from a condition referred to as 'watery mouth'. Lambs affected with 'watery mouth' often fail to suck and there is distension of the abdomen. Treatment with a mild laxative combined with antibiotics may help recovery by getting rid of the retained meconium. Colibacillosis usually affects lambs 12–36 hours after birth. Lambs rarely scour and die 6–12 hours after the onset of symptoms, which are restricted to general lassitude and collapse. Antibiotic therapy is usually successful, at least temporarily.

Coccidiosis is another enteric disease, which may prove troublesome in housed sheep, but the significance of the various strains and types recovered from apparently normal animals has still to be assessed.

The chances of the spread of navel infections are increased in housed lambs, so special efforts have to be made to dress the umbilical region with an appropriate antibiotic aerosol or disinfectant such as iodine as soon as possible after birth. Orf, or contagious pustular dermatitis, may be a great nuisance if it is encountered for the first time, leading not only to scabby areas on the mouth and face, but to infection of the udder of suckling ewes. This will certainly increase the chances of secondary infection with mastitis germs. Vaccination of susceptible stock will reduce the severity of an initial outbreak.

Organisms which cause abortion are another potential source of danger to housed sheep. Unless it is known that the flock is free from infection all ewes should be vaccinated for enzootic abortion or kebbing. Female sheep can pick up infection as lambs, hoggs, gimmers or ewes. If an outbreak does occur aborted ewes must be kept in isolation until all discharges have ceased: products of abortion should be burned.

Because of the carry-over of infection from one season to another, animals which have been in contact with aborted ewes should be placed in a special pen at the next lambing time.

Vibrio fetus infection is more likely to appear yearly in different pens, as sporadic outbreaks in the younger age groups of ewes. Injections of antibiotics may help in so far that affected animals are often sick. They may also limit the amount of infection in the discharges. What is required is a reliable vaccine.

Salmonella infections may occasionally cause outbreaks of abortion in ewes, and also spread to the live lambs. The three main species are *S. dublin*, *S. typhimurium* and *S. abortus ovis*: the latter has a restricted distribution and is responsible for outbreaks of abortion in the south-west of England.

'Toxoplasmosis' or white spot abortion is so called because of the typical appearance of the infected placenta. The disease is caused by a minute protozoan parasite *Toxoplasma gondii*, of which there are various strains, some of which are capable of causing disease in man. At present little is known about the method of spread, but whether outbreaks of abortion occur or not seems to depend on the time when ewes first become infected.

Two species of Salmonella are responsible for the majority of outbreaks of salmonellosis in calves. The first is *S. dublin* and in general this is the commoner of the two and unlike *S. typhimurium* is much less likely to cause disease in other animals. This means that the ultimate source of most outbreaks is the carrier cow at the breeding farm, although cross infection can occur anywhere along the line from collecting centres, through transport vehicles to markets and dealers' premises. Like *Escherichia coli*, Salmonella organisms can survive for a considerable period of time outside the body and in the case of *S. dublin* for as long as 6 months in faeces and 10 months on the walls of buildings.

In contrast to *S. dublin*, *S. typhimurium* is one of the most widespread of all bacterial pathogens, it can infect and be carried by most species, including man and many forms of wild life. On rare occasions *S. dublin* is the cause of disease in man and so it is absolutely imperative that every hygienic measure be taken to prevent the carriage of infection from the calf pen to the farm house. Young children should not, on any account, be allowed into a calf house when disease is suspected. Clinical salmonellosis is most frequently encountered in calves under 6 months of age, and as well as signs of dysentery, there may be evidence of pneumonia and swollen joints. Not all calves die, but a number develop chronic putty-coloured diarrhoea, often streaked with mucus or blood. Spread occurs from contamination of food and water with infected faeces which is sometimes present on the boots and clothing of attendants. Aerosols containing the organisms may infect via the conjunctiva. Fortunately the disease is practically self-limiting in calves since they either die from the acute condition or make a partial or complete recovery; very few become active carriers in adult life. This, of course, does not presuppose that animals in the acute stages of the disease are not a dangerous source of infection, and it would be very foolish to introduce young susceptible animals to an infected calf house, or not to take precautions to prevent cross-infection in adult stock.

Although treatment with one or more antibacterial drugs will often produce a satisfactory response in the sick animal, the possibility, for reasons already enumerated, of drug resistance must always be considered when treating cases of salmonellosis. For this reason alone, it is gratifying that a practical form of vaccination is now available. The vaccine consists of a live attenuated strain of *S. dublin* and for best results should be administered 2 weeks before calves are due to leave the breeding farm. This is not often a feasible proposition but even so, vaccination at the rearer's premises should not be discounted, since it may help to protect those animals which were not exposed to infection in transit. The vaccine also appears to have some protective effect against *S. typhimurium* infection. It is a live vaccine and therefore treatment with injectable forms of antibiotic should be avoided for at least 2 weeks after a calf has been vaccinated. Until more is known about its properties it should not be used on adult animals.

A similar kind of vaccine is available for *Salmonella cholerae-suis* infection in pigs. *S. cholerae-suis* is the cause of pig paratyphoid which may occur in acute and chronic forms. The acute condition is more often seen in store pigs, especially in animals which are subjected to a degree of stress, either as the result of overcrowding or the presence of some other infectious agent. Death usually occurs soon after the animal develops symptoms of a high fever. A characteristic sign is the purple discolouration of the tips of the ears and other extremities. The same organism may also be carried in the mesenteric lymph glands of apparently normal pigs and it may be responsible for some cases of necrotic enteritis and for some forms of swine dysentery.

As in cattle and sheep, *S. typhimurium* may be associated with outbreaks of salmonellosis in pigs. It has even been known to cause disease in a herd of hysterectomy-produced pigs and like *S. cholerae-suis* it has been isolated from the lymph glands of animals sent in for slaughter.

Respiratory infections are common in all classes of housed stock and this is especially so in calves reared for intensive beef production. In a survey conducted in Yorkshire (Harbourne 1966) it soon became obvious that while all ages of cattle could be affected, the worst outbreaks occurred in young growing animals. Eleven of the incidents concerned calves 1–8 months of age kept for beef production. The over-all morbidity rate was 58 per cent and the mortality rate 6 per cent. The clinical signs varied; there was usually a nasal discharge which was sometimes thin and watery and at other times profuse and full of pus cells. Rhinitis and tracheitis were not always observed in the living animal but a variable degree of conjunctivitis was present. Signs of pneumonia were common and in most outbreaks there was a dry cough which often persisted after the animals had otherwise recovered. In some cases calves were affected with diarrhoea. Elevated temperatures were recorded in animals where there were obvious signs of pneumonia.

Such a description probably covers a wide variety of different conditions and so it is not surprising that research into the problem has unearthed not one or two but several agents. These include a number of viruses some of which are closely allied to similar viruses found in man and other animals. Mycoplasma or P.P.L.O. have also been recovered from pneumonic lung tissue as well as different kinds of bacteria (Harbourne, Hunter and Leach 1965).

There is no doubt that some of these agents are picked up very early in life and are carried in the nose or at the back of the throat. Some may be present in other parts of the body including the intestinal tract. It is also possible that outbreaks may be delayed for weeks or even months, until the animals are under some kind of stress or have lost their colostral antibodies. This may help to explain why it is that so many outbreaks occur when calves are about 12 weeks of age (Dawson *et al.* 1966). If the position is anything at all like that seen in poultry, then one might postulate that the worst outbreaks are most likely to occur in animals which harbour more than one type of infection, namely a virus, a mycoplasma and a bacterium.

The position in pigs is rather similar, though there is a good deal more evidence to suggest that enzootic pneumonia or 'virus pneumonia' as it was once called is primarily due to a mycoplasma (Goodwin, Pomeroy and Whittlestone 1965; Goodwin and Whittlestone 1964). Another type of pneumonia is probably bacterial in origin and is caused by *Bordetella bronchiseptica* (Goodwin and Whittlestone 1965), while an upper respiratory condition which goes under the title of 'atrophic rhinitis' may be the result of a number of different physical, chemical or microbial agents and in that respect can be regarded as a non-specific entity. In Britain the most likely cause is a cytomegalovirus and a more apt description of the disease would be 'inclusion body rhinitis'. The virus is spread by contact and by short-range droplet infection. Affected piglets sneeze and snuffle and rub their snouts against fixed objects. Later the animals breathe through their mouths and there is a muco-purulent nasal discharge. The skin round the eyes becomes puffy and a dirty line appears down each side of the face where the tears run. Deformities of the snout are common, especially in long-nosed pigs with fine bones.

Put in its simplest terms enzootic pneumonia is a chronic disease of pigs that is transmitted from an infected mother to her offspring and from one litter to another. Gilts and young sows are the worst offenders, presumably because they have less chance in life to produce antibodies against the disease. In the initial stages of an outbreak a few pigs may die from the condition, but once it has become established in a herd, losses are infrequent The main effect is that of a debilitating disease in which signs of coughing and unthriftiness in store and fattening pigs predominate.

Nobody would deny that enzootic pneumonia is a severe drain on the over-all productivity of the pig industry and so it is not surprising that active associations have developed between pig breeders and veterinary research workers in an attempt to eradicate this particular disease from high quality breeding herds. One method, which has proved reasonably effective, has been to farrow sows in isolation and make a constant check on the progeny for signs of any respiratory disorder. All pigs exhibiting such signs have been discarded for breeding purposes. At the same time all lungs have been examined at slaughter for the characteristic lesions of pneumonia. In spite of all these precautions breakdowns have occurred and so further efforts have been devoted to the establishment of minimal disease herds in which the members are the lineal descendants of hysterectomised sows. Unfortunately the results so far have been somewhat disappointing.

Provided that sheep are maintained in well ventilated houses the problem of pneumonia is hardly likely to arise, unless the animals are subjected to an additional stress such as a sudden change in diet. The commonest cause of pneumonia in this species is *Pasteurella haemolytica*, although recent work indicates that other organisms including a virus and a mycoplasma may be responsible for some outbreaks in lambs and possibly in older sheep (Hore 1966; Hore and Stevenson 1967; Mackay and Nisbet 1966).

Control of respiratory diseases in cattle, sheep and pigs may eventually follow the 'blue-print' already prepared by the poultry industry. Suitable vaccines might help to protect animals against virus infections: timing would be all-important in view of the possible antagonistic effect of maternal antibodies in the blood stream of newly born animals. A judicious combination of blood testing, isolation and the employment of drugs might help to reduce the incidence of mycoplasma infections in breeding flocks and herds. Antibiotics would be used to combat bacterial infections and some of the larger viruses.

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Chapter 34

S.P.F. ANIMALS

A. O. BETTS

Enteric and respiratory infections that occur sporadically and in mild forms under traditional methods of management usually become more widespread and severe when animals are raised intensively. The precise aetiologies of most of these diseases are both complex and obscure. Not only is it probable that many of the infectious agents involved are still to be identified but relatively little is known about many of those that have been recognised. Moreover, many of the pathogenic organisms that have been isolated do not stimulate good immunity. It is unlikely, therefore, that the economically important infections associated with intensive methods of husbandry will be amenable to control by vaccination or by the use of antibiotics, and eradication of individual infection by traditional methods is not likely to solve the problem. More recently a different technique aimed at the eradication of several infectious diseases at once has been tried.

The technique depends upon the fact that, although under certain circumstances a few infections such as swine fever virus can cross the placenta, the vast majority of unborn animals *in utero* are free from micro-organisms. Thus, in most instances, if the unborn animal is removed from its dam in a completely aseptic manner and subsequently kept under sterile conditions it can be reared completely 'germ-free'. When it is only required to keep animals free from most pathogens, but not free from all bacteria, 'germ-free' techniques may be used to obtain the animals but less demanding precautions can be taken during rearing. Although there is no entirely satisfactory term to describe such animals, they and their progeny are usually known as 'specific pathogen-free' or S.P.F. animals. Amongst farm livestock most work has been done with pigs but S.P.F. calves and S.P.F. lambs have been produced. To date, only S.P.F. pigs have been used for the control of infections under farm conditions.

Production Techniques

1. Pigs

Germ-free and S.P.F. pigs may be obtained either by hysterectomy or hysterotomy.

(a) Hysterectomy. Hysterectomy techniques have been described by Young *et al.* (1955), Betts *et al.* (1960), and Meyer *et al.* (1964).

Hysterectomy is undertaken about the 112th day of pregnancy. The sow is anaesthetised, usually by lowering her head into a bag containing carbon dioxide gas, and the abdomen is disinfected. The whole uterus is removed aseptically and passed quickly through an antiseptic bath into the body of a sterilised operating hood. The sow is then exsanguinated.

Immediately the uterus has been pulled up into the operating hood the piglets are torn out by two operators working through rubber gloves attached to the side of the hood. The piglets are then dried and their umbilical cords ligated.

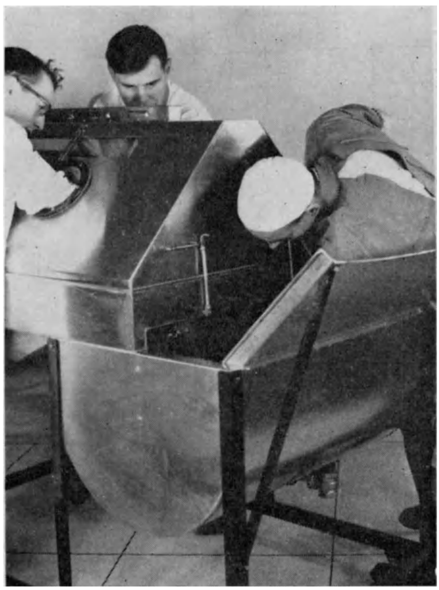

FIG. 94. Passing the uterus through an antiseptic lock into a sterilised operating hood.

(b) Hysterotomy. A hysterotomy procedure has been described by Meyer *et al.* (1963). The sow is anaesthetised either with halothane after sedation, by spinal anaesthesia, or by a combination of sedation and local anaesthesia. A plastic surgical isolator is attached to the flank of the sow and, working through rubber gloves inserted into the sides of the isolator, the operator incises through the floor of the isolator and the skin of the sow. The piglets are handled in the isolator as described in section 1a. An advantage of the hysterotomy procedure is that surgical repair of the sow is possible although the conception rate of recovered sows is sometimes disappointing.

Obviously, 'germ-free' pigs must be kept in sterile isolators throughout their lives. Greater latitude is permissible in the case of S.P.F.

pigs but, nevertheless, it is essential that adequate precautions be taken to prevent the entry of infection into the rearing pens. It is customary for S.P.F. piglets to be kept for the first 14 days of life in individual, sterilised incubators contained, in turn, within isolation rooms. After this time the piglets can be removed from the incubators and grouped together in some form of brooder (Underdahl and Young 1957) or on the floor of an isolation room.

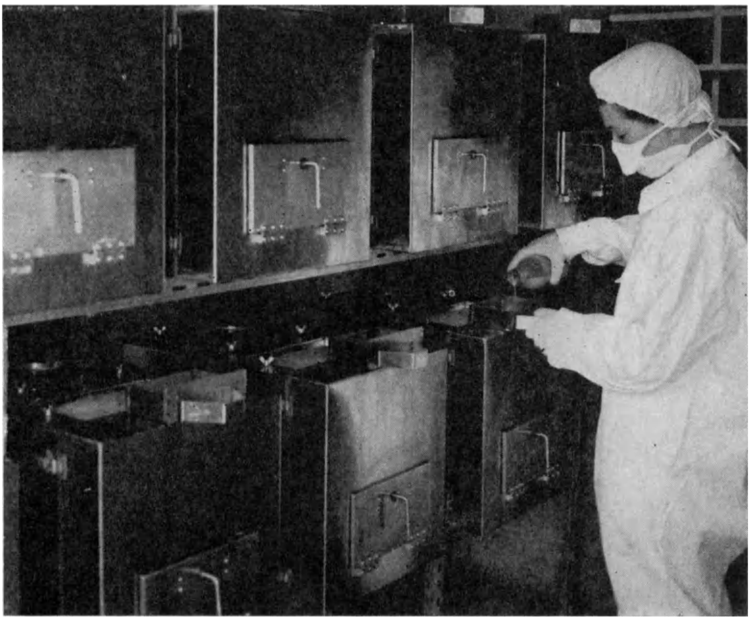

FIG. 95. Feeding piglets taken by hysterectomy a few days earlier.

For the first 2 weeks or so, the piglets are fed a sterilised diet. One composed of cows' milk, eggs and mineral mixture was used by Young and Underdahl (1953) but other workers have used commercially available human or sow milk replacers. The diet may be sterilised by heat or with beta-propiolactone (Amtower and Calhoon 1964). For the first 24 hours it is usual to feed vitamin K, and sterilised porcine serum can also be incorporated with advantage to compensate, in part, for lack of colostrum. From 14 days of age onwards dry food is fed with the milk. Subsequently, the pigs are given normal creep feed. By the time the pigs are 5–6 weeks of age they should be eating normal farm rations and the environmental temperature should have been lowered from 35° C (95° F) at day 0 to about 19° C (66° F).

It needs to be stressed that the production of S.P.F. pigs is far from easy. There are more practical difficulties than the literature would suggest and meticulous attention to detail is essential for success. In the first instance, it is vital that the service date of the sow be accurate and that her nutrition during pregnancy be adequate, particularly with reference to the levels of protein and vitamin A. Many difficulties arise directly and indirectly from the deprivation of colostrum which not only renders pigs more susceptible to organisms that are not normally pathogenic but can also cause oedema due to low protein levels in the plasma. Diarrhoea may also be troublesome.

2. Lambs

Hysterectomy techniques closely similar to those described for pigs were used by Grace *et al.* (1959) to produce S.P.F. lambs. Hysterectomy was performed 3–8 days before the calculated date of parturition. The diet fed comprised cows' milk, eggs and mineral mixture.

3. Calves

S.P.F. calves were produced by Betts *et al.* (1964) by hysterotomy performed within a week of full term. The calves were fed sterilised, homogenised milk and chloramphenicol was added for the first 2 days. Pasteurised 'calf nuts' were offered from 2 weeks of age onwards. The production of calves by hysterectomy has been described by Sweat and Dunn (1965).

The Control of Pig Diseases on Farms

The application of S.P.F. techniques to the practical control of pig diseases followed the observation that first generation pigs could be transferred from isolation quarters to ordinary farm conditions and would not only survive but also remain free from many important diseases for several generations providing precautions were taken to prevent the entry of infection. There were appreciable improvements in food conversion rates and growth rates. The practice began in the U.S.A. in 1957 but since then has been extended to several other countries, although it is still in the early stages of development and has undergone several setbacks and modifications.

In the original repopulation procedure (Betts 1961) first generation pigs were sent directly to the farm at 5–8 weeks of age. During the 8 weeks or so it took to produce and rear the S.P.F. pigs the farm was depopulated, the premises thoroughly cleaned and disinfected and left empty for 6 weeks or longer.

Once the pigs had been received from the production centre they were given special attention for the first week or so while they became adapted to conditions on the particular farm. Thereafter, normal rearing procedures were followed except, of course, that no pigs apart from those of the same health status were introduced and contact with conventional pigs was avoided. Precautions taken included keeping pigs in buildings or in double-fenced paddocks, reducing traffic to a minimum and insisting that people entering the area in which the pigs were kept donned disinfected gum boots and wore clothing that had not been in contact with ordinary pigs.

Although this procedure has worked successfully on some well-managed farms and remarkable levels of performance have been achieved with conversion rates as low as 2·6 to 200 lb. liveweight, the procedure has not proved to be practical on many farms. There have been cases of the introduction of infections that are spread by indirect means, such as transmissible gastroenteritis, swine fever and salmonellae infections, and even on the most successful farms enteric infections, albeit symptomless, with adenoviruses and enteroviruses have occurred (Derbyshire *et al.*, 1966).

Some nutritional problems have arisen and there is evidence that rations considered suitable for ordinary pigs may not be fully adequate to cope with the higher growth rates and better food conversion rates of S.P.F. pigs. It is apparent that more work is necessary on this subject. The problems of establishing and maintaining a large S.P.F. herd have been recorded by Heard and Jollans (1967).

Gradually, in several countries, a common pattern has developed in which small numbers of extremely well managed herds of S.P.F. pigs have been established. In these herds, high standards of hygiene are practised, elaborate precautions are taken to prevent the entry of infection and all pigs sent to slaughter are examined for the absence of respiratory and other lesions. In addition, comprehensive genetic improvement programmes are followed. The only entries to these herds are first generation S.P.F. pigs. From such elite herds breeding stock can be supplied either by sale or lease to other farms that have been depopulated, cleaned and disinfected.

For the control of pig diseases that are spread by close contact, such as some respiratory infections and infestations with external parasites, the potential of repopulation with S.P.F. pigs is apparent and, if American experience is any guide, is likely to extend in spite of the early difficulties. It is doubtful, however, whether similar techniques will have any practical application in the case of sheep and cattle.

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Chapter 35

THE FUTURE RELATIONSHIP BETWEEN THE VETERINARY SURGEON AND THE LIVESTOCK FARMER

C. M. GOULD

Introduction

Re-thinking the relationship between the veterinary surgeon and the livestock farmer from time to time is to be encouraged, though perhaps the results would be more fruitful if it did not coincide so often with an economic recession in agriculture, when the emphasis is more on reducing or cheapening veterinary services than on introducing changes to improve them. But when a 'free' comprehensive veterinary service under state control first became a real possibility for consideration, many farmers doubted whether the service provided would be as good.

Since neither farming nor veterinary medicine is standing still it is pertinent to change the usual order of discussion, to start with the requirements of the farmer for the 1970s, to consider how they can be matched by the veterinary surgeon in the field and what type of organisation could help the service, and finally to consider the main financial decisions to be taken which could affect this development.

The Requirements of the Farmer for the 1970s

Obviously farmers will endeavour to maintain their standard of living. The more successful have scaled up production year by year, generally by intensification and by experimenting as never before with new techniques. The less successful have either had to change their ways by reducing food wastage (especially by better grass utilisation), and unproductive land, labour and machinery, or have accepted a lower standard of living by going peasant farming. Some have opted out of farming altogether.

The accepted profit margin is likely to narrow still more, partly because the Government uses the annual price review to regulate production—and this narrowing is inherent in the nature of the method if production is increased—and partly because there is a growing belief that farming is undercapitalised and that there will have to be a greater influx of capital into farming. Now that farm costing techniques have highlighted the economic importance of certain disease problems on the farm—the most notable example, so far, being low fertility, the importance of which had been stressed again and again by the veterinary profession since 1940 without carrying conviction—avoidable losses due to disease will assume a far greater importance in the balance sheet. The risk of disease is increased whenever an enterprise is expanded, especially if stock are bought in and housed intensively.

Size of itself is not the main criterion of success, since the large scale operation of a livestock enterprise does not at present result in any spectacular economies. Furthermore, so far all the results of research can be applied equally well in small units and in larger ones provided the expertise is there. So, barring the development of some major innovation, efficient one, two or three man units should be able to compete with efficient large units—and inefficient small farms with inefficient large units. Indeed size poses some problems of its own which can be avoided only if management and stockmanship are good. The main criterion is the efficiency of the management and stockmanship.

The average standard of management and stockmanship will increase markedly—mainly by the removal of the less able from the farming scene—but also in increasing amounts by the improvement and better use of training. The livestock farmer will have a good understanding of basic costing techniques. He will be able to recognise and correct the common problems which require only costing to identify them. A greater number of farmers, generally among the most successful in the field, will realise that to increase efficiency further they require technical help in addition to the costing.

The standard of technical aid must also improve if it is to remain adequate. The importance of adequate technical advice in a rapidly changing situation must not be underestimated, especially by the manager of a small unit who finds it difficult to spend time away from the farm seeing new advances. The farmer needs the best veterinary and other technical advice possible, and it is up to him to demand it and to use it.

Ready access to such advice is even more important if new developments are being applied in the unit. Here the farmer and the adviser collaborate to solve a problem. A large unit has the advantage over the small unit in that the pattern of the problem will become obvious far more quickly—together with a fair indication of the full economic loss caused by it (provided adequate records are kept). Generally the records are identical with those required for costing. Ideally, the farmer should be able to consult a team which embraces the various aspects of a problem—veterinary, grassland, nutrition, accountancy, genetics, housing, engineering, etc.

The main veterinary problems will be:

1. Specific veterinary matters, e.g. calving troubles, etc.
2. The problems of greater size.

3. Problems following the adoption of new techniques.
4. Routine disease prevention by disease control and monitoring.

In the past the farmer has regarded veterinary medicine as almost entirely curative. Even today he does not often realise how much preventive medicine is being practised. Each time a veterinary surgeon sees a case, decides that other stock are affected or at risk, and advises the farmer on control measures (for instance to prevent hypomagnesaemia) he is practising preventive medicine. At the moment that advice is given when the farmer is most likely to act upon it, and this will continue until there is a realisation on the part of the farmer of the value of disease prevention and an early warning system (of the presence of disease) being built into the routine and fittings of the farm. This change of attitude cannot be forced upon the farmer against his will.

'Routine disease prevention' is now appearing in the larger units in this country and during the 1970s is likely to become the common picture over the whole country along with those units. Economically this pattern makes sense, since disease control measures which are barely economic or even uneconomic in small units are often well worthwhile in larger units because of the numbers involved—and early warning systems (systems devised to monitor production and spot the likelihood of disease as early as possible) require a sufficient number at risk for maximum efficiency.

In conjunction with other technical advice, veterinary advice should cover the following six subjects:

1. The system of husbandry in detail.
2. The prevention of the introduction and spread of certain diseases of economic importance.
3. What precautions, control measures and monitoring systems should be used to minimise the effects of disease.
4. The housing; facilities for handling and milking stock; access roads, etc.
5. The organisation of management—especially if the unit is to be run by a committee.
6. The implications of the most likely variants of the system of husbandry—in outline at least—and what modifications to the precautions would be advisable if change is envisaged.

The precise nature of this advice will vary according to:

1. The health status of the foundation herd or flock (if there is one).
2. The health status—in fact or assumed—of those stock which may be introduced subsequently.
3. The system of husbandry.
4. The standard of management and stockmanship.

How are these Requirements to be Met?

Over the past few years veterinary colleges have been forced to select their students more on academic record than ever in the past in an effort to prevent the present course from becoming any longer. The standard of the students and new graduates is far higher now than it has ever been before, and over the next 10–15 years they will certainly match the higher average standards of management and stockmanship. The colleges have recognised the importance of animal husbandry, housing and nutrition. The courses dealing with these subjects are now more detailed and longer than any of the corresponding courses in the agricultural colleges—they can still be improved.

The veterinary graduate is being educated to have a thorough basic understanding of both disease and health, an up-to-date knowledge of husbandry, the current disease pattern and the factors pertinent to it etc. and to use a laboratory service directly. If he wants to enter practice he will have the additional problem of gaining the confidence of the farmer. Since the farmer initially judges expertise by the efficiency with which a new veterinary surgeon does the simple routine jobs which are familiar to the farmer, such jobs must be used to facilitate the entry of new graduates into the field.

What Organisation will be Required?

The main problem is reconciling the demand for specialisation, greater knowledge in depth, at practice level with the onus on the veterinary profession to provide a local service for minority interests, e.g. dogs and cats in a rural area and farm animals in built-up areas. The trend is evident today. In many practices veterinary surgeons are tending to concentrate mainly, if not entirely, on large animal work or on small animal work—in some cases their interests are even more restricted. These men are not specialists in the medical sense—they have no post-graduate degrees. To a large extent the speed with which this type of specialisation is introduced at this level depends on the size of practice. How far it goes will depend on the concentration of enterprises and stock in the area, since mileage is a most important factor determining whether a local service to agriculture is economically viable or not. (This has been demonstrated already by the financial failure of at least one such service—the artificial insemination of pigs in Hampshire—whose technical efficiency was second to none.)

During a transition period such as this the problem can best be resolved by the encouragement of practices large enough to permit specialised interests and the development of a first class information service to the profession. No matter how the veterinary services are planned, in reality this evolutionary path must be followed either blindly or consciously if an adequate service to minority interests is to be maintained. The benefit of a specialised training, as we have seen in the past, is marginal if it is not followed by sufficient experience in the field.

Ideally, in order to avoid isolation and the lack of mental stimulation which often follows, there should be at least three field staff per centre. This also facilitates attendance at refresher courses and arrangements for holidays and illness. The radius of the area covered should be up to 20 miles so that one member of staff can reach a case within an hour in an emergency on practically every occasion. Where possible, the farmer should have the choice of at least two centres, so that the occasional personality difference has a chance of being accommodated.

Improved refresher courses and the information service should keep the whole profession well informed not only on disease prevention but also on new developments in agriculture generally and their veterinary implications. The information service must not be a one-way service. Information must be collected on health and disease in the field, especially on epidemiology, by veterinary surgeons and selected farmers. A clinical research unit responsible for this type of work will have to be developed and properly financed. A large practice aided by the information service would be able to provide a more efficient service whether the work be with major or minor interests. There would be more staff available to cope with any emergency work. Recent graduates could experience various aspects of the work before deciding where they wish to specialise. The cross-fertilisation of ideas from one field into another would proceed faster. The main danger would be too great a reduction in the work load, the local service being squeezed on one side by the farmer doing more work himself and on the other by regional specialists taking over more services. This risk can be minimised if each specialised service is examined in detail and run at local level if on balance it can be run equally well. In addition there will be closer personal contact and liaison with the other technical services to agriculture and with the medical service, in particular the public health service. This integration could proceed faster if certain anomalies in the statutory services provided by the Ministry of Agriculture were rectified.

The number of veterinary investigation service laboratories is being increased with the long-term aim that all veterinary practices are within a reasonable distance of one i.e. 20–30 miles. Practices are developing their own laboratories concentrating especially on tests where a rapid or preliminary answer is required. This trend will continue since the larger laboratories are unlikely to want a greater load of weekend work other than for specific short-term projects. One important deficiency in the laboratory services will be remedied if field staff have direct access to the laboratory, the poor feed-back of information relating the test result to the clinical findings in the field. Specialists based on these regional laboratories will investigate specific problems in the field. It will have to be impressed upon them that they are to develop diagnostic, prognostic or control measures as quickly as possible for general application in the field whilst they move on to a new problem.

Veterinary research and education must obviously have close links with all levels of this service. In addition veterinary education must be tailored to trends already evident. Alternative final year courses for those wishing to concentrate mainly on large or small animal practice could well be instituted. Specialist courses must be instituted during the next 5 years.

How will this be Financed?

Four main decisions have to be made:

1. How much outside support, i.e. Government aid, is to be given? And if a comprehensive service to agriculture is envisaged, what will be the position with regard to small animal practice?
2. How is the farmer to pay for the service—or which services is he to pay for?
3. How is the veterinary staff to be paid and by whom?
4. How are new developments to be financed?

Obviously the amount of support is a political decision, the range extending from nothing to a 'free' veterinary service to agriculture. Given full support, and Governments being what they are, the veterinary service is likely to suffer from financial stringency sooner or later, in addition to which the uncertainties due to annual budgeting will continue to hamper long-term schemes unless the procedure is modified to allow for such developments. Perhaps it would be better if the support was generous but not 'full', so that alternative sources of finance from the farmer, the M.M.B. or P.I.D.A. etc., could still be utilised regularly, or as and when necessary.

Special care must be taken to ensure that any veterinary advisory service is not only independent of Government but is seen to be so. The N.A.A.S. has suffered from inadequate provision for this—and farmers have related the inevitable fashions in advice they have experienced to the sinister machinations of government policy. Other bodies such as the Universities have been able to maintain their independence despite massive government support—generally by means of an independent Board of Governors or a Grants Committee. This type of top administration would be practicable and advisable. With benefit it could be adopted in other agricultural fields.

How is the Farmer to Pay?

If full support is given, he will not pay. Otherwise, the most flexible system is fees for services either direct to the practice or to a central or regional fund which is responsible for financing the practices. Details of the bill should be submitted even if the money is docked out of the price he receives for his produce. This would enable selected services to be cheapened or made free as the occasion arises. Contracts for certain routine work could be encouraged, but with such a wide variety of expenditure on veterinary services from farm to farm no standard contract for all farm work is likely to satisfy everyone. This disadvantage also applies to insurance schemes. Regional schemes could be initiated more easily. Extra work by veterinary staff investigating specific problems in co-operation with certain farmers would be facilitated.

The alternative—a flat rate on production or on headage—would minimise the size of the accounting department serving the farmer, but whether this would result in sufficient saving to offset the flexibility of the fee-paying system, would depend on the information required by the centres for record purposes and the method of payment of the veterinary staff.

How are the Veterinary Staff to be Paid?

There are two basic alternatives—fees for services, or salaries (almost certainly coupled with bonuses for certain services or skills). A promotion scheme with more emphasis on technical ability and less on administrative ability would probably prove more acceptable than 'merit' awards, despite the fine distinction. Those practising in certain areas, e.g. the Highlands and Islands, are already subsidised in order to maintain the veterinary emergency and statutory services. If a comprehensive service were introduced, it would be foolish to imagine that the method of payment is settled once and for all when once this decision is made. A salaried service could provide the best environment for the rapid development of specialisation. Later on, as with doctors, other factors may become more pressing and a change certainly desirable. The main essential is that the level of remuneration is acceptable to the profession as a whole.

What Provision is Made for New Developments?

The cost of any extra support cannot be justified unless certain material improvements to the service are made at the same time. The long-term value of the service to the farmer should be judged mainly by them.

To Summarise:

1. In reality the transition to specialisation is proceeding fast and is well advanced in certain areas.

2. The rate of transition is limited by economic factors mainly, in particular the available work load per 'specialist'.

3. To increase the work load of the services required, together with the ancillary information and laboratory services, financial support, e.g. the extension of the L.V.I. services, is indicated if minority interests are not to suffer.

4. Even if a specialist or comprehensive service to agriculture is set up during this transition period, the effectiveness of the specialists will still depend on their work load.

5. It is now time for veterinary education to pay more attention to

this trend. Alternative final year courses for those wishing to enter large and small animal practice should be instituted as soon as possible, and specialist courses initiated during the next 5 years.

6. Planning for the 1980s must begin in the early 1970s.

Chapter 36

FACTORY FARMING—ANIMAL MACHINES?

W. P. BLOUNT

A number of well meaning enthusiasts like Ruth Harrison have drawn the attention of the farming industry to one aspect of intensiveness seldom appreciated, namely cruelty. She maligns the farmer for failing to realise that some of his present-day husbandry methods may result in cruelty. Although most farmers know only too well that their animals will not remain productive unless they are contented, it could be said that a stage might be reached on some farms where production was falling because the farmer was unaware that he was maltreating his stock.

As a result of public pressure the Minister of Agriculture felt it advisable to have the whole subject studied carefully, hence the recently published Report of the Brambell Committee (1965). Unfortunately this Report has created further problems for the farmer, by making a number of recommendations which were either impracticable on economic grounds, or which were unsupported by sound evidence. More recently, however, the Minister has outlined sensible proposals which will allow the producer considerably more latitude than at one time appeared probable.

The Brambell Report

The Committee which was set up at the end of June 1964 under the chairmanship of Professor F. W. Rogers Brambell (Head of the Department of Zoology, University College, Bangor, North Wales), was appointed to examine the conditions under which modern livestock are kept under systems of intensive husbandry, and also to advise whether any standards ought to be set in the interests of their welfare. In addition to visiting over fifty establishments in this country the Committee went to Denmark, Holland and Northern Ireland. Its terms of reference did not include animal welfare in relation to transport, slaughter or breeding; nor was the question of nuisance value or sanitary problems involved.

Because the Brambell Committee was established in response to widespread concern for animal welfare, existing legislation was studied, particularly the Cruelty to Animals Act of 1835 and 1849, which formed the basis for the Protection of Animals Act, 1911. The main principle underlying these is that whilst man is free to subjugate his animals, it is wrong to cause them any unnecessary suffering. During transit animals are protected by the Disease of Animals Act 1950, but it should be appreciated that the 1911 Act specifically includes mental as well as physical suffering. The Committee rightly state that the evaluation of the feelings of animals must rest on an analogy with our own, being derived from observations on animal behaviour, including their cries, expressions, reactions, disease and health attributes.

An animal's nervous system is essentially similar to our own, and therefore they suffer presumably the same kinds of sensation that we do, but these obviously differ in degree. Imaginative anticipation, which plays such a large part in human suffering, is incomparably less well developed in most animals which appear to live more in the present.

FIG. 96. So-called 'loose housing' on wire or slatted floors has been totally condemned by the Brambell Committee.

Any suffering therefore is correspondingly more transitory. The Committee has accepted that pain, suffering and stress appear very substantially in animals, and that there is no scientific evidence that any single species is more sensitive than another. It considers that the emotional experiences of animals include rage, fear, apprehension, frustration and pleasure. The possible accumulative effect of the long continuance of conditions (which might be tolerable in the short term) was studied carefully.

Many of those who gave evidence to the Committee naturally believed that a satisfactory growth rate or egg production could be accepted as a reliable guide to animal welfare. The Committee pointed out that growth, whilst normally a mark of health, can be pathological. For example, an animal suffering from rickets would not develop this disease unless it were in the growing state. If however the condition of the animal's coat or plumage, its alertness, brightness of the eyes, and contentedness are all taken together, they may then form a better guide to the animal's welfare. The Committee did not state how they considered that egg production could be pathological; and most physiologists are agreed that no hen will continue to lay regularly and maintain her appetite and bodyweight, and remain free from disease and talk contentedly, unless it is healthy and free from obvious stress factors.

The Committee realised that one of the principal causes of suffering is disease, hence the necessity to recognise and treat a sick animal quickly. Good stockmanship plays an important part in the quick recognition of sickness, and it was pointed out that existing training facilities should be reviewed and all possible steps taken to encourage the education of stockmen together with training in intensive husbandry units.

One of the good features resulting from the use of intensively housed stock, is freedom from attacks by predators and exposure to such disease factors as worms and coccidia which are commonplace on poultry 'sick' land. Conversely, because livestock are always more crowded under intensive conditions than they are when kept extensively, this may lead to the development of vices. Fire risks also provide a particular hazard, and if there is any failure in electrical supplies these may seriously interfere with automatic feeders, ventilation and lighting systems, etc.

FIG. 97. When correctly debeaked a pullet loses one-third only of the upper beak.

Chickens. The Committee dislike all mutilation practices in principle, particularly those resulting in a permanent disability affecting normal animal behaviour, and they are prepared to tolerate mutilation only where the overall advantage is to the animal, its fellows or the safety of man. (Curiously enough, no mention was made of castration.) Many paragraphs were devoted to debeaking, although this is not a mutilation in the accepted sense, because it does not lead to a permanent disability if carried out correctly, as the mandible regrows within a comparatively short period.

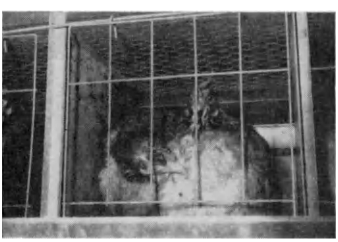

FIG. 98. Feather pulling is not usually painful but a vice associated with boredom. The result is unsightly but otherwise harmless.

Whilst it is true that some breeds of poultry are much better adapted to confinement than others, it is not true that the specific application of genetical principles has resulted in the production of strains specially adapted to large scale systems of husbandry. The Committee considers that the degree to which the behavioural urges of the animal are frustrated, must be a major consideration in determining the particular conditions of confinement. They like to see animals with sufficient freedom to be able to get up and down without difficulty, to turn round, groom themselves and spread their limbs. Furthermore, as many farm animals have a fairly high, organised social behaviour pattern they need companionship, and are therefore more likely to suffer from solitary confinement, particularly ruminants.

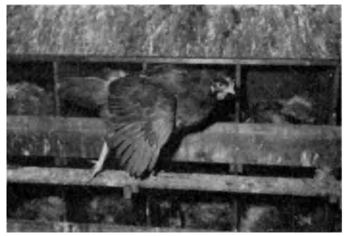

FIG. 99. This is the characteristic stretching of the wing and leg (on the same side of the body) which can be seen to take place daily amongst stock (fowls and turkeys) housed in cages, on wire or slatted floors and on deep litter.

In considering the use of drugs as feed additives it was concluded on balance that antibiotics were more likely to be beneficial than adverse; that synthetic oestrogens (implanted) do not have adverse effects on the welfare of animals, but that the feeding of arsenical compounds should be prohibited save on veterinary prescription.

The Committee paid special attention to the floors of buildings and cages, because these could induce strain on the legs or feet, or result in malformations. Wire floors should be 10 gauge and of a rectangular and not a hexagonal pattern. They also considered that animals should have a reasonable period of illumination each day, as well as one of darkness for rest purposes. The intensity of the illumination should be adequate to enable the animals to move about and feed in comfort as well as for a proper routine inspection of the animals by the stockman, preferably at least twice a day.

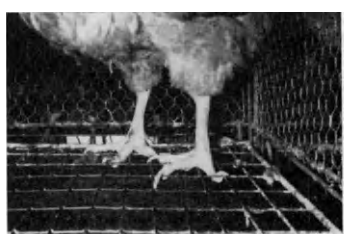

FIG. 100. Whether the cage floor mesh is of rectangular or hexagonal design appears to play no part in the birds' comfort when housed in a laying battery. No foot lesions follow either type of mesh if properly manufactured.

The Committee stated that debeaking 'is not a task normally undertaken by skilled operatives' . . . 'a farmhand is given the instrument and left to learn by trial and error how best to perform the operation', but this is far from true. Whilst a few poultrymen may learn by trial and error, the great majority are shown by successful poultrymen how to debeak stock. Nevertheless, it is agreed that any instruction in this and allied operations should be to the highest standards, and this is where the veterinary profession can obviously perform a very useful duty.

FIG. 101. Even with only two birds in a cage severe bullying can take place. Haemorrhagic lesions will be found on the part attacked (comb). Debeaking prevents this form of pain.

FIG. 102. These are the lesions on the comb of a layer following repeated pecking (bullying) which are prevented if the second bird is debeaked.

The evidence given to the Committee regarding the pain to be associated with debeaking was apparently conflicting, but this should not have been the case. Any veterinary surgeon who has carried out the operation knows that it *does* cause acute pain, but this should not last for longer than 5 minutes if the operation is performed correctly. On the other hand, if half the beak is removed instead of one-third, the pain will last for 2 hours or more, and this is clearly unnecessary.

The Committee appeared inconsistent in stating that debeaking may be allowed for birds kept under deep litter systems for a limited period (e.g. 2 years) and also for turkeys, whereas they condemn it outright for layers housed in battery cages. This peculiar attitude is not readily understood.

Another method commonly employed for preventing vent pecking, etc. is by the use of spectacles or visors ('blinkers'). These have proved particularly useful for replacement broiler pullets during the growing stage when they are loose housed on deep litter, but the Committee recommend that all such attachments obscuring vision should be prohibited.

The Committee did not object to the dubbing of day-old chicks as this causes neither suffering nor bleeding; but they might also have extended their recommendation to the desnooding of young turkey poults.

Turkeys. It seems hard to believe that the Committee assumed because so many turkey breeding stock have high individual values, that this 'makes it unlikely that they will suffer through poor or careless management'. Obviously everything depends upon the efficiency of the poultrymen concerned.

FIG. 103. Debeaking may be required under certain farming conditions. Instructions should be given (by veterinarians) to the staff carrying out this procedure so that pain is minimal.

FIG. 104. De-snooding baby turkey poults is another farm practice to be encouraged. It is almost painless and bloodless, but may save the adult stag considerable trouble in later life.

Ducks. The Committee consider that provided ducks are kept at a moderate stocking density (no standard is given) and the management is competent, they can see no welfare problem being raised by the commonly accepted methods of production. The flock behaviour of

FIG. 105. Haemorrhage from the flight feathers, due to feather pulling (sucking) may occur amongst overcrowded ducklings.

ducklings however is quite remarkable, and much damage can happen if such birds are not protected from fright and allied stresses. Apparently the Committee were informed that 10-day-old ducklings are sometimes debeaked to prevent down-pulling. They consider that it should be prohibited, but they 'have insufficient information to justify a positive recommendation'. Feather-pulling in young ducklings is nearly always associated with overcrowding and seldom occurs if stocking rates are correct, therefore debeaking should be quite unnecessary.

Rabbits. Rabbits were stated to be nervous and sensitive and to respond to sympathetic treatment. The Committee did not believe it necessary to recommend mandatory controls for rabbit production, but suggested that for single animals, a minimum of 1 sq. ft. per lb. liveweight should be provided. This is twice the normally accepted standard, and has already proved to be impracticable when applied to the housing of bucks used for mating purposes.

'ANIMAL MACHINES'

In a Foreword to Ruth Harrison's book *Animal Machines*, Rachel Carson states that the facts presented (dealing with the new methods of rearing animals destined to become human food) can no longer be ignored. Gone are the pastoral scenes in which animals wandered through green fields, or flocks of chickens scratched contentedly for their food. In their place are factory-like buildings in which animals live out their wretched existence without ever feeling the earth beneath their feet, without knowing sunlight, or experiencing the simple pleasures of grazing for natural food—indeed, so confined or so intolerably crowded that movement of any kind is scarcely possible.

In a Preface to this book Sydney Jennings, Past President of the British Veterinary Association, stated that the present increasing disregard for animal life under intensive farming is arising in large measure through commercial types who are entering farming as big business and who are, by example, at the same time turning the orthodox farmer away from his natural inclinations. Already farming is being financed increasingly by shareholders who know little of what goes on in factory farms. Ruth Harrison is doing her utmost to prevent ignorance in regard to animal life in Britain. She neither has, nor even professes to have, clear-cut evidence regarding such dangers but then neither have we scientists any clear-cut evidence that there is no danger.

When eminent persons write in this manner, those knowing nothing about intensive livestock farming readily accept the suggestion that factory farms exist solely to give their owners the maximum profit with no thought for the animals, unless it be for the administration of drugs and stimulants to make them work harder.

The following extracts from *Animal Machines* show the lengths to which the author goes in her determination to try to abolish 'intensive' farming methods, but rather than 'preventing ignorance in regard to animal life' Mrs. Harrison only paints a thoroughly distorted picture.

'Life is cheap to the factory farmer. The principle of exterminating less hardy animals starts right from the beginning. Thus a hatchery is advised to cull all (late hatched) chicks . . . because they are stragglers and therefore assumed to be weaklings.'

On the contrary life is not cheap, but if culls were not disposed of satisfactorily many would themselves suffer from cannibalism or injury from their livelier, healthier fellows; or become the victims of predatory animals. Others might die after a lingering illness. The farmer's method is therefore really humane, even if his prime motive is related to the profitability of his enterprise.

Lay people seldom realise that a percentage of most embryos die *in-utero* (or in-shell) naturally, no matter whether these are rabbits, pigs, blackbirds or chicks. Even pregnant women abort, and many healthy babies are born prematurely. All these are really examples of Nature's culls—completely unassociated with factory farming.

'But until recently they were individuals allowed their birthright of green fields, sunlight and fresh air; they were allowed to forage, to exercise, to watch the world go by, in fact to live.'

Unfortunately Nature's birthright consists of much more than sunlit fields. Gales disrupt nests in the hedgerows, foxes slaughter their victims, frost-bitten combs tell a sorry winter's tale and only a few weeks ago 60,000 valuable potential breeding turkeys were drowned in the recent floods in Italy. In Japan, every year numbers of people die because of volcanic eruptions and typhoons, and in India at the present time millions of peasants are on the verge of dying from famine. Nature is not so kind after all.

FIG. 106. Is this mating ('treading') of female with female an example of the type of frustration seen amongst layers housed on deep litter in the absence of male companions?

Indeed if it is to be claimed that an animal has a birthright, why not go back further still and claim a conception right!

'To-day the exploitation has been taken to a degree which involves not only the elimination of enjoyment, the frustration of most natural instincts, but its replacement with acute discomfort, boredom and the actual denial of health. It has been taken to a degree where the animal is not allowed to live before it dies.'

It is perfectly true that the life of intensively housed stock differs greatly from those kept out of doors, but this does not necessarily mean that they are deprived of all enjoyment. Baby chicks for example gamble and play when very young but their natural fighting instincts soon supervene in a few weeks' time. Furthermore never having known any different environment they cannot miss something they have never had. Hens in batteries 'talk' contentedly for long periods, and continue to show evidence of great curiosity throughout their lives. Discomfort, boredom and ill-health are not in evidence.

'*How far*', asks Ruth Harrison, '*has man a moral right to go in his domination of other life. Has he the right, as in these examples, to reduce life to a bare existence . . . to terminate these wretched lives by means that are wantonly cruel?*'

I took the liberty of discussing the moral aspect of farming livestock with the Diocesan industrial and social adviser to a well-known bishop and he agreed that there could be no quarrel with the profit motive. Having seen a modern intensive poultry farm (layers and broilers) he considered that things didn't look half as bad as they had been painted to him, but he wondered whether the confinement they experienced caused any mental suffering, although he could not pinpoint any particular behaviour pattern or incident which made him believe that suffering was created.

After experiencing an intimate picture of something you have never seen before and about which you may have been misled, is not of course conducive to clear thinking; therefore I was not surprised at the cleric's attitude to the problem. One can of course also think of several religious communities which frustrate many natural instincts, but presumably this is not objected to because it is undertaken willingly.

The factory farmer is not the only one to be castigated by Mrs. Harrison, because she also quotes from a statement by a veterinary surgeon in *The Observer*: '*The present scale of veterinary fees is so miserable that no vet can afford to antagonise his farm clients by accusing them of cruelty every time he visits.*' Is this really a true state of our professional affairs? I think not, but of course one cannot blame Mrs. Harrison for this mistaken view.

'*The conditions under which intensively kept animals are reared indoors cannot possibly lead to healthy animals, and animal health has deteriorated to a degree such as to cause acute anxiety to the veterinary world . . . farmers regard veterinary surgeons as the miracle men of their world, able to produce drugs to combat the effects of flouting every natural need of the animal. If the drugs happen to make serious physiological changes this type of farmer does not concern himself so long as the carcass remains saleable.*'

One might assume from all this that: (i) modern methods of housing

Factory farming is now described by Ruth Harrison (October 1967) as 'Methods of livestock production which keep animals immobilised permanently in buildings'. It also implies an attitude to the animal which regards it solely as a unit in a process for converting feeding stuffs into meat.

A distinction is made between the terms '*factory farming*' and '*intensive farming*' which may simply imply an increase in density of livestock kept, but no radical change of system or attitude. [Editor].

result in a higher incidence of disease, but the reverse is usually the case; and (ii) the provision of 'every natural need' would reduce disease to a minimum, whereas there is no evidence to show that such a utopian state of affairs exists anywhere, with any species of farm livestock; and (iii) drugs produce serious physiological changes, whereas most have absolutely no effect on the carcass at all. The only exception to this statement relates to the production of capons, but for all practical purposes a chemical capon has exactly the same type of carcass as a surgical capon.

'To keep animals alive in the conditions in which they are reared . . . heavier doses of drugs are given at the least sign of flagging, and growth stimulants, hormones and tranquilisers all have their part to play in the forcing of rapid conversion of animal feeding stuffs into flesh.'

So far as broilers are concerned, antibiotics are *not* used to keep them alive, but to overcome an adverse bacterial flora of the intestines, but it must be admitted that this could be classed as a growth stimulant. On the other hand, hormones and tranquillisers are *never* used.

'The feed also contains a small percentage of penicillin (10 mgs/ton) to promote growth. This is pushed up as soon as any disease is suspected.'

The level of penicillin is 5–10 gm. per ton; the level is never raised to combat disease, because procaine penicillin is a narrow-spectrum antibiotic, with effects confined mainly to the digestive tract.

'These animals are themselves unhealthy, and the drugs used so lavishly to keep them alive and make them put on weight speedily can have repercussions on man himself. Can these unhealthy animals possibly make healthy human food?'

It is completely untrue to suggest that when livestock are farmed intensively they are unhealthy and unsuitable as food.

'The height of some cages has been lowered so that the hen has to put her neck out of the cage front to stretch it.'

The hen's neck is normally held in a sigmoid position, and to stretch it forwards or downwards is just as good an exercise as to stretch it upwards. The actual requirement for the latter is only when the bird wants to see something not visible by any other means.

'Some calves have their heads caught permanently between upright bars.'

To imply that this occurs is as factual as to state that children get their heads stuck permanently between the banisters.

'Is there sufficient awareness for example of the final effect on man of all the antibiotics, hormones, tranquilisers, insecticides and growth stimulants used so lavishly in the industry?'

Why worry about 'final effects' when hormones, tranquillisers and insecticides are not even used in the production of broilers. Low levels of antibiotics as growth stimulants received official approval in 1953, since when if there had been any adverse effects the Ministry of Health would have banned them.

The Rev. J. Turnbull believes that many of our livestock troubles spread faster than ever before, in spite of modern wonder drugs. 'We go from grass staggers to fowl pest and swine fever, from mosaic of strawberries to deficiency diseases of the soil, from neurosis and coronary thrombosis to cancer in man'. . . . 'All this because of the hurry and frustration of modern life in the service of the great god Mammon'. . . . 'Natural theology (including agricultural and physical science) is almost totally disregarded.'

Statements like these in support of the campaign against all cruelty to animals are not easy to follow, because whilst one might conclude that grass staggers is occurring because of bad management practices, i.e. failing to provide magnesium in adequate amounts knowing the soil to be deficient in this element, how does this relate to outbreaks of fowl pest or swine fever which are of virus origin? If fowl pest is related to the hurry and bustle of life—seeking greater profits—why do we have the greatest number of severe outbreaks in the Far East where life does not bustle and where Mammon is not so much in evidence?

One of the finest examples of a natural misunderstanding relates to the element boron, without which leaves turn yellow. From this one might automatically assume that crops grown in boron-deficient soils would cause trouble when fed to poultry, but boron is not required by poultry. It is not an essential nutrient for them, whereas it is for crops. So one cannot extrapolate data from plants to animals, from one disease to another, or from one species to another.

The Humane Farming Campaign, launched in 1960, wishes to see the abolition of all forms of intensive livestock husbandry, although it realises that such a prospect is unlikely at present. Perhaps more sensibly they want to ensure, as do the vast majority of farmers, that intensivism does not involve cruelty, but one cannot expect that there will be no 'frustration of natural instincts'. It is, for example, not easy for the sex life of hens to be satisfied (no matter how they are housed) if they are deprived of suitable male companions. And are we then to allow these same birds to go broody, without ever attempting to break them of this instinct? Which is better, to house a bird in a laying battery cage, the environment of which prevents most laying pullets from going broody; or to house them on deep litter which tends to induce broodiness but from which habit the birds then have to be broken by putting them in a laying battery cage—out of doors! Alternatively the broody bird can be injected with oestrogens which is another but more expensive method for interrupting the broody cycle! Perhaps the humanists should decide a little more clearly what they mean by 'natural instincts'.

What is vitally clear is that farmers must *not* neglect these attacks—speeches in Hyde Park, pamphlets, books, letters to M.P.s. They all carry weight, and like a good advertising campaign, keep knocking the nail on the head.

The vast majority of farmers are never willingly cruel to their stock, and most take a considerable pride in their welfare. Millions of housewives accept that the eggs, milk and meat so produced are wholesome and well worth the money they pay for them. Nutritionists know that these products are as good and often better than their counterpart produced under more natural conditions. It is only the cranks who believe otherwise, and they must be fought at every opportunity!

Ruth Harrison's second line of attack on modern agricultural practice, emphasised her strong belief that the nutritional value of broilers, battery eggs, etc. was not to be compared with that of stock housed on free range. Here again most of her arguments lack scientific backing, and appear to be based more on prejudice than fact.

She fails to understand for example the difference between *inorganic* arsenical sprays (as used for horticultural purposes) and *organic* arsenicals used orally. The latter are approved in the U.S.A. and may be administered to within 5 days of killing. Mrs. Harrison writes, '*Anyone familiar with the notorious arsenic poison cases of past decades would raise their eyebrows at the regulation five-day period quoted above. These famous poisoners operated over a period of months, slowly building up a lethal dose. I have not heard of arsenical compounds being used as growth additives for pigs in this country, but they have certainly been used for poultry*'. . . . '*Next time you look along a row of patés in your delicatessen remember the arsenicals which may or may not still be there, and all other chemicals and toxic substances liable to be stored in the livers of broiler chickens.*'

Remember too that most broilers never see any arsenic. If they did it would be an organic preparation, administered such that the bird's tissues would not contain more than the Ministry of Health allow, 1 p.p.m. The public seldom realise that seafish contain from 1·5 to 4 p.p.m. arsenic and shellfish including oysters from 3 to 174 p.p.m. Calculated as As_2O_3 man can tolerate 3 mg. daily without hazard. Five mg. is a therapeutic dose, 50 mg. toxic and 500 mg. fatal.

Mrs. Harrison believes that '*it is natural to suppose that there must be some correlation between taste and quality in the nutritional sense, or how else could we have survived all these thousands of years when our natural guide to food has been its taste and palatability*'. She also quotes Dr. Milton who believes that 'if we are happy in eating our food I am quite sure that it is much more likely to produce good health'. A quotation from a French veterinary surgeon is also given to the effect that 'the taste of a food is proportionate to its digestibility and has a considerable influence on its nutritional value'. Mrs. Harrison also believes of course that all broilers are tasteless.

As a fact taste has nothing to do with digestibility, being related to olfactory, tactile and gustatory stimuli received at, or immediately after, food has been prehended. If most broilers were really tasteless why would 170 millions be sold annually, and at an increasing rate. Somebody must like them!

'The battery egg has appreciably less of the very important vitamin B_{12} than the eggs from hens reared in more normal conditions. By this is meant the fact that hens often obtain ample supplies of this vitamin (B_{12}) from animal matter or suitable micro-organisms in the soil or manure as in free range or deep litter production.'

Would housewives knowingly prefer the vitamin B_{12} content of their eggs to be derived from farmyard manure, or from hygienically manufactured fish meals, etc., because the B_{12} compound is identical (both chemically and nutritionally) from either source!

'Dr. Milton defines quality of food as the factor which will allow a condition of positive health to be maintained in the organism, and this may be the only means we have left of defining quality after the natural taste has been taken out of food and resubstituted by synthetics, and after its palatability and texture have been played upon by drugs and hormones.'

'Positive Health' is a meaningless utopian term, most people are healthy, a minority unhealthy. Both need good food to supply essential nutrients preferably including 'protective' foods like milk, eggs, chicken meat, etc. Try them and see! On the rare occasions when drugs or hormones are used in their production they have *never* been shown to have any adverse effect on either the palatability or texture of the resultant meat.

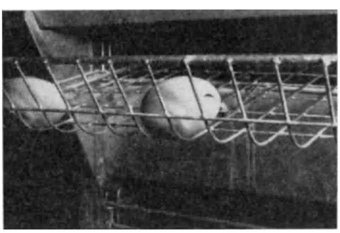

FIG. 107. This is the type of crack which follows the use of too rigid a cage floor, e.g. 10 gauge mesh. Resilience is essential if this type of cracked egg is to be avoided.

'Increased egg production brings headaches as far as egg quality is concerned: poor shells, thin shells, pale yolks, watery whites, all prove a problem.' Here Mrs. Harrison is confusing the picture relating to disease (such as infectious bronchitis), because increased egg production alone does not necessarily bring any egg quality problems.

To emphasise her dislike of batteries the author makes a special point of quoting statements which imply that battery eggs are likely to show a decline in yolk size. *'I am told by housewives that they now need three eggs to provide the same amount of yolk which two once supplied.'* Batteries have had the effect of *'flooding the market with more smaller cheaper, and inferior eggs.*

This was a surprising statement to make, and to test its fallibility we weighed a series of eggs taken from comparable groups of pullets housed differently. The results were as follows:

	No. of eggs	Average weight (oz.)	Yolk (oz.)	%	Albumen (oz.)	%	Shell and Membranes (oz.)	%
Free range	19	57·68	14·82	25·72	35·78	62·00	7·21	12·08
Deep litter	9	58·97	15·86	26·90	36·60	62·07	6·51	11·04
Hen batteries	10	59·01	15·74	26·50	36·61	61·53	7·06	11·96

The range of yolk weights were as follows:

Free range	13·8–16·6 gm.
Deep litter	13·9–16·7 gm.
Hen batteries	13·1–17·4 gm.

Therefore, contrary to the impression given by Mrs. Harrison, these facts show that the yolks of free range are not any different (in weight or percentage) from those of pullets housed fully intensively, nor is there any statistical difference between those of pullets housed on deep litter compared with hen batteries. One explanation for Mrs. Harrison's dilemma may however relate to the following fact. Whenever hens lay reduced numbers of eggs their size tends to increase, so that in the case of pullets on free range laying at a lower rate of production their eggs would be larger compared with other birds laying there or elsewhere at a faster rate.

Not everyone favours the consumption of poultry and other meats produced intensively. Fortunately the vast majority of housewives are not like Joan Judd (1965) who in a letter to the *Veterinary Record* stated that she can no longer poach an egg in the traditional manner because it immediately disintegrates, and who also believes that cold leg of chicken tastes like cotton wool. But if broiler chickens do require to be garnished with sauces and stuffing to bring out their flavour this is surely nothing unusual? Who has ever enjoyed roast beef without mustard or horse-radish sauce; pork without apple sauce or sage and onion stuffing; roast turkey without cranberry or chestnut stuffing? Many of these same pundits believe that lack of flavour is due to the use of chemicals, that 'chemicalised food is different; is *not* the same in nutritional value'. Such statements are totally without foundation.

Killing Poultry. As to whether birds 'know' they are in imminent danger when they arrive at poultry packing stations Konrad Lorenz has stated that in his experience chickens did not understand the situation when their fellows were being slaughtered or are lying dead; and therefore this would certainly not increase their suffering. Conversely a writer in *Poultry World* believes 'that there is no doubt that they know what is in store for them. This frightens them and a scared, tensed-up bird does not pluck well, in my opinion, because the grip on its feathers is increased.'

It must surely be fallacious to suggest such an effect since plucking takes place *after death*.

One can well understand that lay folk will wonder about the degree of pain which follows the severance of the main blood vessels in the upper part of the neck, yet this is the method of killing insisted upon when slaughtering takes place under Jewish ritual.

It is accepted that as soon as the brain becomes markedly anaemic pain is absent. Records from poultry packing stations show that the bleeding times tend to vary with the size of bird, larger birds taking longer. The normal time between venesection and the bird entering the scalding tank ranges from about 90 to 157 seconds (a killing line moving about 40 ft. per minute with the birds at 6 ft. centres allows 4800 birds to be processed hourly).

Richards and Sykes (1964) believe that birds may feel pain for as long as 177 seconds in certain circumstances, and that death may take up to 240 seconds. This subject requires further investigation to confirm the times mentioned, because from a poultry processor's point of view it is important that birds enter the dip tank within about 140–160 seconds, otherwise defeathering is affected adversely. What pain if any would be recognised by the bird 140 seconds after venesection, and how would this compare with pain from neck dislocation?

Mrs. Harrison asks why the birds can't have their necks dislocated in the old way, believing that this method is both painless and instantaneous. But here again the loss of sensation (pain) is linked with anaemia of the cerebrum and therefore the efficiency of the 'hanging' process will be all important. As to the practicability of dislocating the necks of poultry at the rate of 4000 an hour, one hesitates to think of the painful results which would occur once the operators suffered from fatigue.

Egg Quality. Any answer to the suggestion that eggs from battery hens are inferior in quality to those from hens on range is complicated by the fact that the nutrient make-up of either type of egg will be linked *almost solely* with the nutrient make-up of the feed given to the birds. If the ration fed to stock in hen batteries were to be deficient in carotene or vitamin A, then unquestionably the resultant eggs will also be deficient. Conversely if the layers ration is richly provided with either natural or synthetic vitamin A and/or carotene, then the resultant eggs will also contain rich amounts of this vitamin.

Unfortunately many laymen associate good yolk colour with high nutritional content, believing that the deeper the yolk the greater the chance that the egg will be rich in vitamin A. Whilst they may not know that vitamin A as such is practically colourless or that carotene is transformed into vitamin A in the fowl's gut, they usually know that carotene is yellow. What they also do not realise is that there are pigments other than carotene present in feed ingredients, these being coloured but non-nutritive. These pigments are classed as xanthophylls, and golden coloured though they are, few can be synthesised into vitamin A. That is the prerogative of carotene.

Thus, with vitamin A itself colourless and many natural pigments (xanthophylls) non-nutritious, the original premise falls to the ground. Therefore it is worth emphasising that yolk colour gives *no* indication of its vitamin A content, indeed if fowls are given rations which are devoid of xanthophylls but rich in vitamin A, the eggs produced by such hens will have pale yolks, but plenty of vitamin A.

An attempt to answer the original question was given by Cornford *et al.* (1960) who studied the baking qualities of eggs produced by hens housed on free range, contrasting these with eggs from battery hens. A series of tests lasting 5 months (covering the general quality and baking properties of these two classes of eggs) showed that there were only small differences between them, none being of commercial importance.

Functional tests were carried out on liquid whole egg (for the baking of sponges and Madeira cakes), and also on egg white for foaming properties, and for the baking of white cake and meringues. In addition the eggs were examined for the presence of off-odours, blood spots, volume of liquid egg, egg and shell weight, Haugh units, total egg solids, viscosity, etc.

Only minute differences were observed in the fruit-slip recipe cakes baked in month 3, and also in the adjusted recipe cakes in months 1, 4 and 3; and these were in favour of the battery hen eggs. Similarly only very small and apparently irregular differences were observed in foam volume and drainage.

In fact the only striking difference between the two types of egg was in their colour, although the eggs from the battery hens were slightly heavier, due to extra egg white and shell but not yolk. No difference could be detected in the quality of the egg whites in any of the tests carried out, or in the flavour or aroma in sponges or cakes.

The reason why the yolks from the hens on free range were much deeper yellow was due to the fact that the mash fed to these birds contained 1·5 per cent more yellow maize, 6·7 per cent less fishmeal, and 0·4 per cent more dried grassmeal. In addition of course the birds were housed on free range, and therefore they were able to help themselves to grass. (The breeding folds housing the stock were moved over moderate quality sward three times a week.)

Mrs. Harrison is correct in believing that we could revert to extensive farming if we had to, but land and labour shortages alone kill this idea. The following data show the futility of such an attempt.

In 1965 a trial began at Stoke Mandeville comparing birds on free range with comparable groups housed on deep litter and in hen batteries, totalling 600 pullets in all (Thornber '404'). The test began in August and ended the following January after the birds had been in lay for 5 months.

Temperatures. As was to have been expected outside temperatures fell to below freezing on numerous occasions, reaching as low as 16° F.

Lighting. Daylight was decreasing throughout much of the period, with only 8 hours per day in December. Artificial light was provided to half the pullets on range, and to all those housed intensively.

FIG. 108. Free range conditions in the summer.

FIG. 109. Free range conditions in the winter.

Labour. Using a milometer the manageress kept a strict record of the times spent on her daily chores, with the result shown in Table A, from which it will be seen that much more time was required on range for feeding and watering (including thawing water), egg collecting, washing dirty eggs, grass cutting, raking and burning, etc. These of course are amongst the reasons why farmers today have chosen to house their layers intensively.

TABLE A

LABOUR DISTRIBUTION (26TH AUG., 1965 TO 12TH JAN., 1966)
(Man-hours)

	Batteries	*Deep litter*	*Free range*
Feeding and watering	35·00	11·65	46·65
Unfreezing water supply	—	—	15·50
Egg collecting	22·97	35·00	82·83
Cleaning out	40·00	—	1·00
Littering nest boxes	—	9·50	—
Debeaking	—	3·00	—
Vaccinating pullets	3·00	2·00	3·00
Moving houses and delivering feed	—	—	18·50
Fencing-in free range	—	—	4·25
Raking and burning grass	—	—	11·00
Washing dirty eggs	3·33	2·05	8·39
Cutting grass	—	—	2·50

Sexual Maturity. First eggs were laid earlier in the intensively housed pullets by 8 days.

Egg Production. As anticipated egg production in the range unit which did not receive artificial light was very poor, but surprisingly high when the birds were given electric lighting. (Table B.)

Cracked Eggs. By far the lowest number of cracked eggs was laid by the pullets on free range.

Dirty Eggs. Some 24 per cent of the eggs laid by the pullets on range were dirty, requiring to be washed, contrasted with 4 per cent on deep litter and 6 per cent on hen batteries.

Food Intake. Food intake of the birds on range was comparatively low until the colder weather set in, but even by the end of the trial it was lower than that of the pullets on deep litter. These had the highest food intake, and their egg size was the smallest.

Body Weights. There was no difference between the average weights of the pullets in any of the three different groups at the end of the trial. Starting at about 3·7 lb. they ended up at 5·0 lb.

Mortality. Mortality was highest on deep litter and lowest in hen batteries.

Hunting. On 14th December as the local hunt was passing the farm, hounds picked up scent in a nearby ditch and then ran in full cry towards the area of free range where the pullets were housed, one or two actually getting through the nylon netting. Many of the pullets were considerably disturbed, running to and fro, but others in the nearer

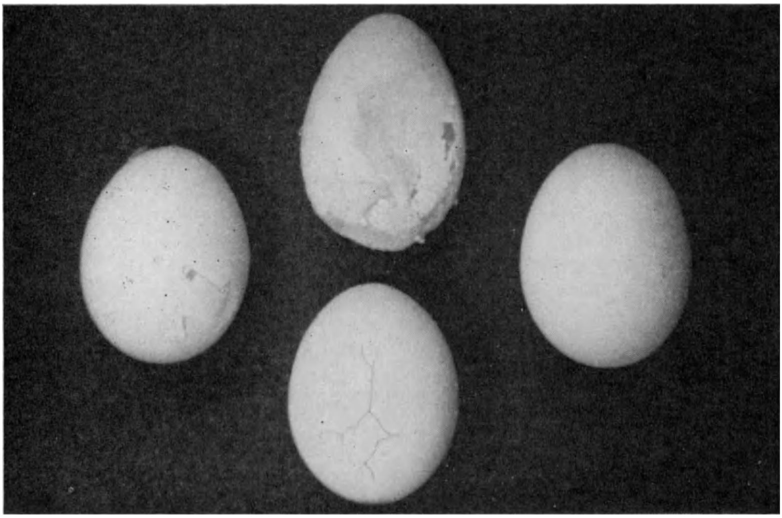

FIG. 110. Varieties of eggshells encountered on modern farms: (top) *Soft-shelled* (with very limited deposition of calcium); (bottom) *hair-crack*; (right) *normal shell*; (left) *cracked.*

TABLE B

	Free range	*Free range Lighted*	*D.L.*	*H. batteries*
No. of pullets	99	93	199	200
Mortality	5	7	13	4
Egg production (eggs/bird)	53	85	98	96 (102 single cage, 78 large cage)
% egg production	38	60	70	69
Feed/bird/day (oz.)	3·6	3·9	4·6	4·1
Total feed (lb.)	32	34	41	36
Feed conversion/12 eggs	7·0	4·8	5·0	4·5
Egg size (oz.)	1·97	2·01	1·93	1·97
Large and standard	69·8	80·2	65·2	73·3
Cracked eggs (nos.)	1	2	34	57
% dirty	24	24	4	6
Total eggs	4980	7310	18228	18816

field continued pecking about. In all the hunt passed by the farm on three occasions between 11.30 a.m. and 1 p.m.*

* Previously 23 pullets were killed by a fox overnight during the rearing period.

Small and Large Cages. Most of the pullets were housed as twins which accounted for their high labour cost, but sixteen were put into single bird cages and a small group of four were housed in very large single bird cages, allowing sixteen times the normal floor area. This latter was mainly with the object of seeing whether the pullets would attempt to fly, having been given a cage large enough to do so if they wished.

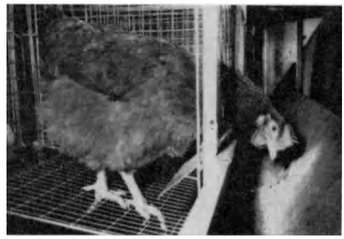

FIG. 111. Most modern laying batteries have an egg guard projecting inwards (from the food trough). It will stop the bird from egg eating by preventing it from reaching the egg once it has rolled forwards down the cage floor.

The pullets housed singly (normal sized cages) laid the greatest number of eggs, whilst those in the large units were less productive. This may have been due to their genetic make-up rather than their environment. Two points about their behaviour were noteworthy. First, they did not attempt to fly, nor even to stretch their wings in any way different from that normally recorded. But when they were about to lay their eggs these birds became most unhappy. They walked around trying to escape, and pawed at the side of the cage trying to get out temporarily. This desire stopped however immediately the egg was laid, and it was clear that it was their natural maternal behaviour pattern trying to assert itself in the particular circumstances concerned. This type of behaviour pattern was *not* seen in normal sized cages.

Comments. This little exercise may help to explain to the layman why farmers prefer to house their birds intensively. They are easier to manage and this means much less labour. Their egg production is higher and many fewer eggs require to be washed or dry cleaned. There are no problems with frozen water, foxes or losses from impaction of the digestive tract.

It was also shown that there are no advantages to be gained by giving the birds extra large cages, indeed *more* frustration is caused than when smaller (normal) cages are in use. Given the freedom of a very large cage pullets did not attempt to fly nor to flap their wings differently from usual.

My thanks are due to Miss Kate Herron, S.D.P., S.D.D.H., N.D.D., for undertaking the organisation and running of this trial.

Free Range Rearing

Advocates of free range often have little or no knowledge of the type or extent of loss which can occur with this system of management. The following balance sheet relates to a fairly large group of pullets which were reared for B.O.C.M. by a very experienced pedigree poultry breeder who has always employed and advocated the use of small brooding units in conjunction with range rearing.

The group consisted of eleven modern hybrids comprising 5864 chicks which were received at the rearer's farm between May 3rd and 19th, 1966. Losses to 16 weeks of age were as follows:

	Chicks	%
Died (from natural causes)	271	4·7
Unaccounted for	195	3·3
Sexing errors (cockerels)	39	0·7
Killed by crows, magpies, hawks	32	0·51
Killed by strange dog	24	0·41
Accidents	10	0·17
Killed by foxes	9	0·15
Rejected at time of despatch (culls)	130	2·2
	710	12·14

Apart from the culls which were rejected when the remainder of the pullets were despatched to Stoke Mandeville, overall mortality totalled 9·29 per cent, out of which 3·3 per cent related to stock unaccounted for (this is a common experience with range rearing). Losses from attacks by crows, etc. took place throughout the whole of the rearing period from the third week onwards, whereas those due to the fox occurred during and after the 9th week. The losses from the strange dog took place when the pullets were 8 weeks old, eight chicks from each of three breeds being killed.

ANIMAL BEHAVIOUR

Studies on animal behaviour can be of the greatest value to those who advise on intensive husbandry practices. *The Behaviour of Domestic Animals* (Hafez) gives an excellent textbook account of the subject but much additional information is still required. It is therefore up to the professfonal agriculturist to study his animals in detail (under particular circumstances) and then to report the facts in readily accessible journals.

Although the journal *Animal Behaviour* deals solely with behavioural studies, the majority relate to laboratory or other exotic species. For example, during the period 1962–65 less than 10 per cent of the 240 original papers published in this journal concerned cattle, sheep, pigs, goats, dogs or rabbits.

Brownlee *et al.* (1966) outlined the role of animal behaviour in veterinary science, pointing out that every good stockman, experimentalist and veterinary clinician is to some extent dependent upon an understanding of the principles underlying behaviour. They pointed out that surprisingly few husbandrymen or veterinary surgeons take an interest in this subject as a scientific discipline. Behaviour patterns may be indicative of pain, discomfort or stress, a subject strongly emphasised by the Brambell Committee (1965). This may also involve psychotic problems, some of which may relate to deprivations, boredom and the development of vices.

FIG. 112. Two-week old poults imprinted at Stoke Mandeville. This practice leads to greater docility and ease of management, but must be carried out before the poults are 48 hours old.

Brownlee *et al.* (1966) also drew attention to the part which animal behaviour should play in a modern veterinary curriculum. Learning behaviour and animal training; animal restraint, so that the handler does not suffer injury from feet, teeth or claws (aggressive behaviour); signs and symptoms of disease like emesis, pica, pawing, licking; grazing behaviour, defaecation and the ingestion of internal parasites; reproductive behaviour in relation to sex, parturition and egg laying are typical examples. They concluded that formal instruction in ethology (covering a period of 10–20 hours' teaching) should properly be included in any modern syllabus dealing with animal husbandry.

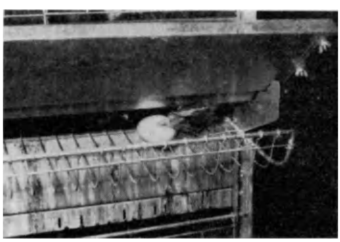

FIG. 113. The instinct to retrieve its egg can be seen even in pullets housed in laying batteries. But this form of frustration does not appear to cause any mental or physical harm that can be detected by a veterinarian.

Whilst some studies in ethology may involve quite complex equipment (including cinematography), the observant stockman can do much with his own eyes and ears. Good powers of observation and concentration, together with suitable opportunities for watching intimate movements or functions are all that are required, as well as satisfactory records. If these are combined with a knowledge of the animal's husbandry, physiology and possibly psychology the results can often be used very intelligently.

Discussing the subject briefly with an eminent veterinary professor recently in London, the writer was informed that there would be little teaching in this subject until the profession knew more exactly what information was wanted. But it is surely cogent to know what signs indicate health, discomfort or disease, and these cannot always be distinguished satisfactorily until enough observations have been recorded and evaluated.

What did we know for example of coprophagy in rabbits until the subject was studied in detail? What is the meaning of tail-biting in pigs, or toe pecking in hens? Are we right to assume that pigs or sheep housed on carefully prepared slatted floors are under either mental or physical stress; and in view of their satisfactory growth rates and freedom from disease can we not assume that these species have adjusted themselves to their new environment without undue stress?

If economic conditions show that town byres should be considered again for milk production (as they were in the 'twenties) by what criteria shall we judge whether the behaviour of the cattle is 'normal'? By their milk supply, appetites, bodyweight gains, freedom from mastitis and foot troubles, or what? Is the system 'cruel' because of the absence of exercise, or little different in practice from the housing of layers in single bird hen batteries? What do the behaviourists think of the psychological stresses of artificial insemination *versus* natural mating; and has the former in fact ever been considered? Rabbits commonly chew the ledges of their wooden hutches; is this due to boredom, lack of fibre in their diet, or just an attempt to sharpen their incisors? When two dogs go for a walk together and attempt to fight another dog across the road (but cannot do so because they are held back on a leash) they may in fact set about each other. A real fight may develop between them unless the handler knows about the danger and takes preventive action. Is this due to lack of self control, a bad temper, or what might be expected of any fully grown male in the circumstances. Or is it perhaps that the main attack-releasing stimulus is that of physical contact—dog with dog—and therefore the moment the one dog feels the *fur* of another (even though it be that of his companion) he immediately starts to fight and bite vigorously? This is the writer's belief.

Under modern housing conditions (pole barns) many growing turkeys seem to develop a craving for eating caecal droppings. Is this a form of pica, indicative perhaps of a shortage of vitamin B_{12} (or other bacterial nutrient), or is it merely an effort to overcome boredom? Is it a peculiar response to some nasal attractant (e.g. a volatile fatty acid component) or to the colour of the caecal excreta? Does it mean that the flock will grow badly or that mortality from enteritis can soon be expected? When a fowl lays its egg *pointed* end first, is this an example of a breech presentation, or has the bird had its laying cycle interrupted so that the normal 180 degree turnabout was unable to take place?

And so one could go on asking question after question, many of which can only be answered if someone will take the trouble to watch and record the behaviour of their stock.

This I think is the answer to the professor's question. Quite often ethology conjures up complex apparatus and a specialist knowledge of animal psychology, but the veterinary student or the farm worker can carry out many valuable studies without either. The following accounts of widely different studies on animal behaviour will emphasise this point. Here first is a description of the night-time activities of the slug, as a result of which recommendations were able to be made about the control of this pest by chemicals.

The Nocturnal Behaviour of Slugs

(Agriolimax reticulatus)

The common slug, closely related to the snail but having no shell, has a moist skin which functions as part of its respiratory system. As an agricultural pest it damages crops such as winter wheat or potatoes, also lettuce, carrots, brassicas and legumes.

P. F. Newell (1955) has recently recorded by means of a high speed flash, time-lapse cinematography (operating discontinuously at pre-set intervals) the noctural behaviour of slugs. This unique study permitted the identification of their activities during darkness and showed that they have four main functions:

1. Crawling (to find other slugs, food, fresh feeding or laying sites, etc.);
2. Copulating (snails are hermaphrodites);
3. Feeding; and
4. Resting.

In this pictorial study the slugs emerged from their holes during the night, carried out the functions mentioned over a period lasting about 3–13 hours, and then in many instances they returned down the same hole in the soil from which they first emerged. This 'homing' instinct, though a well known feature with certain snails, had not previously been recorded for slugs. It may have a survival value, there being less chance of such snails being eaten by hunting predators (birds), than with snails which undertake long complicated journeys after daybreak, eventually going underground at a different site.

Observations by Newell on one snail showed that it used the same hole to rest in (after three successive nightly excursions), on the 4th occasion it found a new hole, but on the next night it returned again to the same hole from which it emerged. It copulated on both the 1st and 5th nights and had ten separate feeding sessions of varying duration, as well as almost as many rests.

The majority of slugs appear to remain in relatively small areas so that pest control measures need only be applied locally. The following diagram and activity flow chart tells the story of a typical 'homing' slug:

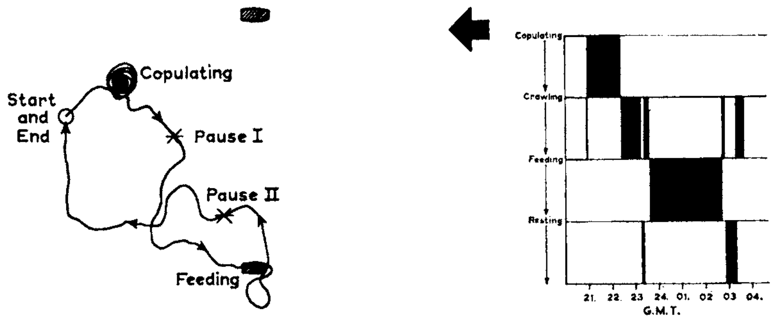

FIG. 114.

Pigs

The pig is an excellent animal for behavioural studies, either by direct study or cinematography, and the recent observations by Jones (1966) on parturition (in the pre-partum, parturient and post-parturient phases) are a model of clarity. This work was carried out to establish whether there were any possible correlations between these events and puerperal diseases, or with mortality amongst the piglets.

Other studies such as those on baby piglets have been put to good use by national compounders who market special creep feeds. For example Niwa *et al.* (1951) showed that piglets took their mothers' milk at about hourly intervals up to the end of the 2nd week, but Rasmussen *et al.* (1962) found by means of a camera with a timing device (exposed a single frame every 10 seconds) that piglets suckled twenty times during the first 12 hours compared with fourteen times by the end of the 6th day. By the time weaning has taken place each piglet may consume 37 kg. of milk containing 10 per cent of butter fat, whereas colostrum only contains just over 6 per cent fat. Birth-weight and teat position account for 40 per cent of the variation between the 3-week weights within litters; the larger piglets being more successful in getting to and keeping the use of the anterior teats, although one in five may suckle more than one teat. Runt piglets (in the bottom 5 per cent of the weight range) are below average weight at birth and they are also low in the social order (McBride 1964).

As a contrast the sow herself may spend only about 1 hour in 12 eating and drinking and in 60 days may secrete 254 kg. of milk, during which time, however, she may lose as much as 100 lb. in weight. Whenever there is aggressive behaviour amongst pregnant *gilts* a check on trough space should be carried out since Rasmussen *et al.* (1962) found this to be linked with a shortage of feeder space and in such cases a definite dominance order developed. That gilts do not adjust themselves to farrowing pens as readily as sows and are also more fearful of their attendants, is a behavioural feature of significance which all good stockmen should act upon.

Pregnant sows do not appear to make any signs of importance until about 24 hours before parturition, and then only a restlessness which might easily be confused with other causes. Jones (1967) described their subsequent behaviour in considerable detail and it is remarkable how closely this picture approximates to that of the pregnant rabbit (see later). An associated feature readily recognised in the sow but not in the doe, is the development of the mammae which may not become turgid until 2–3 hours before birth takes place, although farrowing frequently takes place within 24–48 hours of milk secretion first appearing. Indeed when milk flow is abundant farrowing often takes place within 6 hours, a clinical sign of the greatest importance to the pigman. Conversely Jones found vulval swelling to be of no value in assessing the actual time of parturition, and so his recommendation to practitioners that vaginal exploration should not be delayed beyond 24 hours after the first obvious onset of milk secretion (in combination with 'bed-making', restlessness, etc.) is of the greatest value whenever obstetrical procedures are likely to be involved.

Farmers are not always aware that concrete has a poor heat capacity for which reason it is far from ideal as a flooring for the rearing of piglets unless ample bedding is present. Whereas if it is insulated with 'Styrofoam' (incorporated as near to the upper surface as possible) ti is not only warmer (there may be seven times as little heat lost compared with bare concrete), but it actually feels warmer to the hand. The total heat loss from the use of a concrete floor may be 15 per cent, whereas this falls to 6 per cent with a wooden floor (Mount 1967). Here again there are important practical implications to be appreciated since as many as 25 per cent of baby piglets may die from starvation and gastroenteritis (Leedham 1966), and many such cases will be linked with 'chilling' in the first place.

The blood supply to the pig's belly is such that the skin temperature there is higher than elsewhere, hence the ease with which 'chilling' may take place when piglets lie down in the relaxed prone position. When standing, heat losses (by convection to the air) are far lower than those from conduction (to the floor), but of course baby piglets cannot be expected to stand for long, and so to conserve body heat (like many other animals) they often huddle together (Jones 1967).

Eliminative Behaviour in the Dog

In man the increased peristalsis following a meal frequently results in early defaecation, but as adult dogs often take only one meal a day (in the evening) this can never directly result in reflex defaecation since this often does not occur for about 12 hours. Thus a different stimulus would appear to be necessary.

Whilst some ethologists believe that both defaecation and micturition serve as sources of communication between Canidae (involving the use of scent posts in the locality), the writer considers that in the male it is urine which is primarily important. Furthermore, that the female acts in another direction entirely.

During exercise the dog's nose is used far more than any other sensory organ: the head is normally held about 6 in. away from the ground and used rather like a mine detector. Odours presumably from other dog's pads, cats and foxes are picked up rapidly, and recent ones followed as a trail at which time the nose is lowered to within 1 in. of the ground. These usually lead either to the animal itself, a hideout or to deposits of urine/faeces.

As soon as the place where micturition has taken place is discovered a rapid nasal cursory inspection follows. This may lead to more obvious sniffing followed by 'leg-cocking', during which from about 2½ to 15 c.c. of urine may be passed. This is in direct response to the odour detected, and not to any particular marking-out of territory, since micturition does not take place when crossing a field or down lanes where there are not any obvious odours.

When walking at pace the dog's progress is often suddenly halted and he will then turn sharply at right angles to move over and search diligently for a particular odour detected. If micturition is to follow it takes place almost immediately, and in general the dog wants to pass his urine directly on to the odoriferous site. During a walk lasting 1 mile the dog will micturate from 20 to 50 times, the total quantity of urine passed ranging from about 50 to 250 c.c.

(Man's nose is quite oblivious to such smells, since he *cannot* detect these by any normal means.)

If the intensity of the original odour is weak the dog quickly passes on but if it has certain peculiar properties (assumed to be related to bitches) deep sniffing will take place, followed by the dog licking the area and starting to champ his jaws. (No erection of the penis takes place.) In these cases the power of the attractant is very strong and the dog will resist being pulled along by the leash. Before leaving the site micturition may follow, and in some instances 'back scratching' also takes place. This may be half-hearted, both hind feet scratching independently or if the effort is very vigorous the dog's whole body sways backwards, and the fore feet may be used as well as the hind. 'Back scratching' is not usually linked with the presence of another dog's faeces, nor does it necessarily follow defaecation.

Defaecation. Olfactory stimuli appear to stimulate peristalsis, because defaecation quite often follows within a few minutes of the walk commencing: indeed one regular feature of a dog's morning and afternoon walks is the fact that if the animal is healthy and correctly fed defaecation *always* takes place. (This occurs even in the dark, if for any reason the walk has had to be delayed.)

A second evacuation of rectal contents usually takes place a short while after the first, the second lot of faeces then being softer, paler and less voluminous.

During a walk the dog is *not* usually attracted to another dog's faeces.

The relationship between sniffing, micturition, back-scratching and defaecation can be seen from the following example with dog 'C' (a Corgi) which showed the following sequence of events during a 25 minute morning walk:

S = smelling at specific area; M = micturition; SM = smelling immediately followed by micturition; D = defaecation; BS = back scratching the earth.

SM SM S SM SM SM SD SM SM S SM S (faecal) S S SMBS SM S SM SD S SM S S SM S M SM S S S (trail evident) SM SM (both very slight) SM SM S S (trail found again) SM S (high up) S S—pulling hard to look for dogs at neighbouring house—SM S SM—barking at dogs mentioned. Walking quietly across fields with no smells—Home again.

SM—20; S—19; SD—2; SMBS—1; SMBS—1.

Thus, on more than half the occasions when special odours were detected micturition followed. On two occasions defaecation followed the smelling, and only once was 'back scratching' evident.

Later a second walk took place and the following notes relate to the first dog's twin brother, dog 'S':

SM SM SM S (deep) M SMBS SM SDMS S SM SM S Barking at dog S (trail of dog) SM S S M S SM SBS SM S M S S SM S S (deep, jaw champing) S SM S S S (high up hedge) SM S End of walk. (1 mile.)

S—20; SM—16; SDMS—1.

Whilst there is some evidence that more urine is passed during the first half of the walk, it continues throughout, so long as there are the usual odoriferous stimuli, even when the urinary bladder does appear to be almost empty. On occasions the dog will micturate at some fixed object without prior sniffing, but this is unusual.

Vocalisations are extremely rare during a walk, both between dogs exercising together, and with others heard barking in the distance. But if cattle are suddenly spotted just over a hedge barking may take place in an apparent attempt to frighten the cattle and to boost the dog's own ego.

Eyes and ears clearly play a very secondary part during a walk in the case of corgis.

The Value of Walks

(i) They are much appreciated by the dogs themselves who quickly anticipate the time they should commence and then become very excited. (Owner putting on boots, coat, leash, etc.)

(ii) Great enjoyment appears to be associated with particular odours.

(iii) Bladder reflexes are stimulated repeatedly, which may help to reduce the risk of cystitis.

(iv) Defaecation takes place regularly, often with very little apparent stimulation linked with particular odours.

(v) The dog and his handler benefit from the exercise undertaken.

(vi) After the walk water is drunk, but if on the way back fields are crossed with dew on the ground this is often licked by the dog as he walks along.

Conclusions. Whilst a regular walk is obviously of value to dogs, *the opportunity to investigate odoriferous sites at this time is paramount;* and whenever possible the handler should not disturb this particular routine, even though it may mean a couple of dozen stops at particular sites.

If the walk merely consists of leading a dog steadily along a street, pulling on his lead whenever he would normally stop to sniff and micturate, then half the pleasure is undoubtedly lost as well as much of the physiological value (micturition and defaecation). Some veterinarians may argue that this whole procedure is fraught with danger due to infectious diseases, but the risk does not appear to be too serious, and a satisfactory vaccination programme against distemper, hard pad and leptospirosis is perhaps the best answer to this problem.

A Doe giving Birth to a Litter

The following account by D. K. Glister relates to a Matthews hybrid grandparent stock doe housed in a solid floor hutch, February 1966.

The first sign of activity prior to kindling was noted approximately 3 days earlier, when the doe pushed some straw which she had chopped up into one of the corners of the hutch. She then became restless and went off her feed. (A pregnant doe usually rushes to her feed, but when kindling is near although she can hear the stockman feeding the others, she prefers to lie quietly in a corner.) In cases of pseudo-pregnancy (commonplace in the doe) nesting activities take place about the 18th day after mating, which is a significant sign of non-pregnancy.

Prior to kindling the doe breathed faster than normal (55 r/min.), and when lying down on her belly she kept her hind legs outstretched to the rear and her tail raised, but her front paws were normal. About 1 hour before kindling at 11 a.m. the doe broke open the pile of straw, and made it into a raised well or nest which was big enough for her to sit in, but with about 2 in. to spare at the back end. Then she plucked some fur from her chest and more afterwards from her stomach. This first fur was used to mix in with the straw, the finer fur being laid on top to form a cushion below her hind quarters when she was lying down. (Plucking the fur and placing it in the nest took about 1 hour.)

Next the doe had a drink and then bedded herself down in the nest, her breathing rate was faster than usual (85 r/min.) and then soft grunts were heard. Slight muscle movements were seen at the rear half of the abdomen and on each occasion the doe turned her head round.

When kindling was near she shifted from the prone position to one in which she was half-lying, half-sitting on her left thigh. Her right front paw was at an angle of 45° to the back paws, the left front paw being tucked under her dewlap. This position allowed her to get her head underneath her abdomen to lick her vulva, which she did frequently whilst giving birth. This position was assumed rapidly and accompanied by grunting, during which she continually licked her lips and vulva. At one point she appeared to be nudging her teats and ruffling the remaining fur on her chest: possibly it helped to stimulate the flow of milk? At this time respiration was 127/min. and her chest could be seen to heave up and down, whilst during the actual birth she panted.

Parturition began by the doe opening her back legs even further. She then put her head down to her vulva, grunted and appeared to be pulling at something. When she raised her head her nose was tinged with red, and she was seen to be chewing. (Viewing was restricted by the doe's fur.)

After the first opening of the vulva three baby rabbits were born in rapid succession, a pause occurring after about 4 minutes. Might this have been due to the fact that one horn of the uterus had been emptied? During this pause in accompaniment to various squeals and grunts the doe proceeded to lick each baby rabbit in turn, and also to eat the after-birth.

After a couple of minutes she licked her vulva again and grunted. Once more she seemed to be straining and her rear half quivered. The doe again nosed her vulva and when she raised her head it was covered with blood. This was taken to be a sign that the contents of the other half of the uterus (four more rabbits) were now being delivered. Immediately after each was born the baby rabbits were nudged by the doe out of the way so that the next one could be born. When she raised her head it was bloody, and I assumed that this meant she had cut the cord.

When the rabbits were first born they were pushed by the doe to her rear, but when kindling had finished they were brought in turn to the arch made by her front paws. Whilst they were here she proceeded to lick the after-birth off them and give them a good wash. When this had been completed the young rabbits, who had all been struggling to get to her milk, were put by the doe to her udder, each being given a separate teat.

When she had licked each one and let them have a drink she proceeded to clean up her own vulva. She seemed to be eating a lot, and I took this to be the remains of some of the after-birth. Next she cleaned up her face and paws which by this time were carrot-red, and her nose partly covered by blood and pieces of flesh.

When she moved away from the position which she had kept since just before kindling, the baby rabbits set up a great squealing noise and in return the doe grunted. She covered them up with a thin layer of dry straw. (This may have been thinner than usual, because kindling took place in a hutch which was only about 5 ft. from a gas heater.) After seeing to the litter she went and had a long drink herself, after which she ate a little food. Next she groomed herself, walked up and down the hutch, and then laid down alongside the litter. This move was accompanied by squeals of satisfaction from the baby rabbits and grunts from the doe.

Poultry

A further indication of the ease with which behaviour studies can be carried out (in certain instances) applies to poultry, where modern feeding systems employ pelleted feeds instead of mashes. Poultry pellets were marketed in 1928 long before any intimate knowledge had been gained about their effects. The continuous intake of bulky feeds of low nutritional value by some species requires some type of early store house (crop or rumen), although with other animals it may be placed further down the digestive tract (the caecum), as with the horse and rabbit. But the ability to eat highly nutritious pelleted feeds (as is the case with the modern fowl) not only eliminates the need for a crop, but it appears also to be able to do away with gizzard function. More important still it gives the bird more time for developing bad habits (feather pulling) and even serious vices (bullying and cannibalism).

Small hybrids with a high egg potential, like the Thornber '808', must have a concentrated ration (in order to take in the necessary nutrients) but they must not have too much time on their hands. Whilst mashes take longer to consume, they may be unpalatable when prepared with high levels of calcium and, as pellets may be consumed too quickly, a crumble type of feed provides the answer in many situations. No one has yet studied the dynamics of feed size systematically, or whether twice daily feeding gives better digestion (in conjunction with Nature's diurnal circadian rhythm). Is it in fact better physiologically for the hen to use its crop, gizzard or both?

To take another example. Should the lighting pattern for broilers alternate to give both resting (sleeping) and active (feeding) periods, or is there no advantage to be gained from interrupting the usual continuous 24-hour (dull light) day? Accurate observational studies on the behaviour of both layers and broilers would go far to solving these questions, and for good measure, here is another interesting example of bird behaviour linked with poultry farming.

The recent development of the cage system for rearing pullet replacements, has pin-pointed a new problem. Pullet rearers are finding that a high percentage of some breeds may show a defective (crossed) beak by the time they are 16 weeks old. Normally this would be considered to be primarily of genetic (congenital) origin in isolated cases, but this is unlikely to be so when 20 per cent or more of a flock becomes affected.

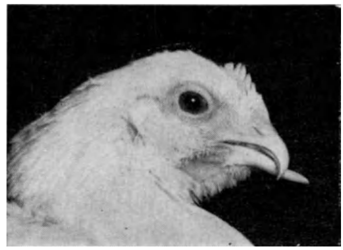

FIG. 115. In an isolated fowl this type of crossed beak is considered to be primarily of genetic origin, but when it becomes a flock problem 'nipple drinkers' may be involved.

Observations have shown that this condition may be linked with a new type of watering system—so-called 'nipple drinkers'. From these the chicks can only obtain a drop of water at a time, but if they are incorrectly sited, the birds do not raise their heads to drink as is customary with fowls, more particularly if the drinking unit is not raised as the chicks grow taller. In many cases, the bird has to *place its head sideways* in order to make the nipples function at a time when the jaws are still not fully ossified. When this is done dozens of times daily, for weeks on end, a crossbeak may result. That is the theory, and now some active, intelligent poultryman must prove the case quickly, otherwise he will find ethologists laying on complex experiments to show which 'drive' is or is not released! Nipple drinkers may also cause fibrous tumours to develop where the bird's head is constantly pressed against the metalwork of the cage.

FIG. 116. This is the type of 'tumour' (seen between the eye and the comb) which may follow the use of nipple drinkers, if these are not fitted correctly so that the bird can drink freely.

Observations on the Use of Nipple Drinkers by Layers

A useful series of observations by my colleague, P. R. J. Sharman, N.D.P. at Stoke Mandeville on Thornber '404' pullets housed in 'Brambell' cages, has provided the following facts. Two 14-hour observation periods began at 6 a.m. on 20th May 1966 and ended at 8 p.m. the following day.

Some pullets were seen to drink by individual pecks (losing contact with the nipple between each peck) at about the rate of two per second (there being a one second pause between pecks); whereas others drank continuously. This latter was a feature when the birds were housed as twins, and may relate to competition. Such birds may slide the nipple between the upper and lower mandibles, or hold it partially on the inside of the lower mandible, or in the angle of the jaw. When two single bird cages are placed back to back, both birds may try to use the nipple at the same time, but this was not seen to take place when the two birds were in the same cage.

Different makes of nipples vary in size and stiffness, so that these factors may influence the time taken to drink.

In general, feeding and drinking appear closely linked, although occasionally a bird will eat for as long as 30 minutes without taking a drink. The following data give a clear indication as to the number and length of the drinking sessions, as well as to the number of pecks (at the nipples):

ONE BIRD TO ONE NIPPLE DRINKER (Pullet C)

Time	*No. of drinking sessions*	*No. of pecks per session*	*Average length of each session (seconds)*
6 a.m.–7 a.m.	13	16	15
7 a.m.–8 a.m.	18	12	10
8 a.m.–9 a.m.	12	11	9
9 a.m.–10 a.m.	21	13	10
10 a.m.–11 a.m.	9	10	8
11 a.m.–12 p.m.	23	14	10
12 p.m.–1 p.m.	4	11	9·5
1 p.m.–2 p.m.	3	4	2
2 p.m.–3 p.m.	5	7	11
3 p.m.–4 p.m.	15	7	3
4 p.m.–5 p.m.	9	15	10
5 p.m.–6 p.m.	6	21	24
6 p.m.–7 p.m.	12	15	14
7 p.m.–8 p.m.	19	14	11

Summary. Pullet C (housed singly) pecked at the nipple drinker over 2000 individual times in the day, between 6 a.m. and 8 p.m. The total time spent drinking was 35 minutes 33 seconds.

TWO BIRDS TO ONE NIPPLE DRINKER

Time	*Bird*	*No. of drinking sessions*	*No. of pecks per session*	*Average length of each session (seconds)*
6 a.m.–7 a.m.	A	3	2	10
	B	3	5	10
7 a.m.–8 a.m.	A	2	14	28
	B	2	2	6
9 a.m.–10 a.m.	A	8	16	31
	B	8	4	8
11 a.m.–12 p.m.	A	6	13	25
	B	15	6	14
2 p.m.–3 p.m.	A	6	20	40
	B	5	4	13
3.30 p.m.–4.30 p.m.	A	1	7	13
	B	16	4	9
7 p.m.–8 p.m.	A	8	4	3
	B	16	3	8

In the case of the pullets housed as twins, one bird (A) spent 12 minutes 41 seconds at the drinker, making contact with the nipple on 399 separate occasions. The second bird (B) made contact 273 times, totalling in all a 10-minute-53-second drinking period.

The numbers of drinking sessions (per 14-hour day) were 169 (C), 65 (B) and 34 (A).

It is hoped that these examples from the common garden slug, pig, rabbit, dog and fowl show how a simple series of observations on animal behaviour can prove fruitful, both to the veterinary and agricultural professions.

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Chapter 37

PAIN PERCEPTION IN ANIMALS, WITH PARTICULAR REFERENCE TO POULTRY

S. A. Richards

Introduction

Considerable interest has recently been aroused by some current practices in the management and slaughter of poultry. The situation therefore calls for a survey of the present position, so that any positive recommendations relating to the humaneness of these procedures can be based upon the most reliable physiological evidence that is available. Some understanding is first required of the nervous organisation in birds, and the following account, therefore, is a brief summary of our present knowledge on the subject of the physiology of pain perception in animals, particularly poultry.

Structure and Function

The central nervous system of all vertebrates is based upon a common structural pattern which has become enlarged and modified in the different groups. The brain is divisible into three major regions, the forebrain (prosencephalon), the midbrain (mesencephalon) and the hindbrain (rhombencephalon). The forebrain is further subdivided into an anterior telencephalon and a posterior diencephalon. Furthest forward are the two olfactory lobes which receive nerve fibres from the nasal regions, whilst the main body of the telencephalon is expanded to form, with its median constriction, the cerebral hemispheres. The roof of the telencephalon (the cerebral cortex) receives the terminations of the main afferent pathways from the periphery, and functions (especially in the more advanced vertebrates) as a complicated correlation and reflex centre. It co-ordinates the events and information from all over the body, initiating appropriate motor activity. The corpora striata, which are ventro-lateral thickenings in the walls of the telencephalon, also function as correlation centres in a similar manner to the cortex, and exert an inhibitory influence over cortical voluntary activity. The ventral and dorsal aspects of the diencephalon develop outgrowths, the pituitary and pineal bodies. The former has well-known endocrine functions with a vital influence upon metabolic activities, whilst the pineal gland frequently degenerates, and its function is obscure. The lateral walls of the diencephalon form the thalamic nuclei which control certain automatic activities and bodily movements, contribute to the functioning of the eyes and also act as relay centres for somatic sensations.

In the midbrain, the optic lobes vary in size in different species in relation to the importance of the eyes, whilst a dorsolateral thickening of their walls, the tectum, represents in the more primitive vertebrates, a correlation centre analogous in function to the cortex and corpora striata of homiothermic forms. In birds and especially in mammals, the tectum is greatly reduced in relative importance, in conjunction with the greater development of the forebrain regions. Ventrally in the midbrain, the crura cerebri form a nervous link between the hindbrain and diencephalon. In birds, and especially in mammals, the textum is greatly reduced in relative importance, in conjunction with the greater development of the forebrain regions. Ventrally in the midbrain, the crura cerebri form a nervous link between the hindbrain and diencephalon.

The hindbrain itself has two important regions, the cerebellum dorsally which continuously modifies motor activity in accordance with the fluctuating information received from peripheral receptors, and a thickened posterior medulla oblongata, which contains complex respiratory and vascular centres. These are often described as automatic, because although they can be affected reflexly, their activity depends chiefly upon the metabolism of their own cells. The medulla passes gradually into the spinal cord which extends for most of the body length and co-ordinates the simpler reflex actions.

The principal structures of the generalised vertebrate brain may be tabulated as follows:

Forebrain or prosencephalon		*Midbrain or mesencephalon*	*Hindbrain or rhombencephalon*
Telencephalon	*Diencephalon*		
Olfactory lobes Cerebral hemispheres with cortex and corpora striata	Thalamic nuclei Pituitary body. Pineal body. Optic chiasma	Tectum with optic lobes. Crura cerebri	Cerebellum Medulla oblongata

The structures are illustrated in Fig. 117

Birds and Mammals

The chief difference between the brain structure of birds and mammals is in the relative proportion of the parts of the cerebral hemispheres. The mammalian brain is dominated by the cerebral cortex, long known to be the seat of intelligence and learning capacity, the convolutions of which become greatly expanded over the other parts of the brain, reaching their highest development in man. Birds, on the other hand, have retained instinct as the basis of their behaviour, and their cerebral hemispheres are relatively smaller than in mammals, and without the furrowed surface. The basal nuclei or corpora striata of the avian hemispheres become the largest dominant centres.

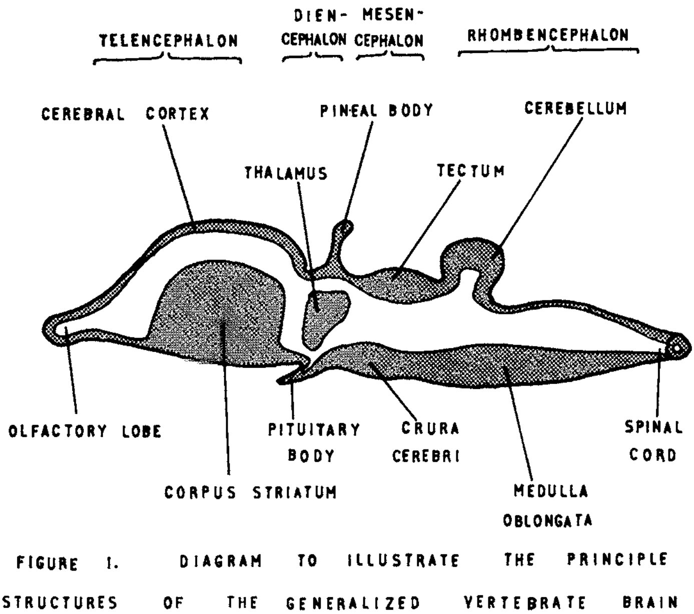

FIG. 117.

In both birds and mammals the thalamus is an important relay centre for sensory impulses, reaching the height of its development at the mammalian stage, where, with the reduction in importance of the tectum, all the impulses of somatic sensation are passed through the dorsal thalamus to the cortex. In birds the sensory impulses are here analysed as pleasurable or painful, and the large thalamo-striatal tracts, conducting in both directions, make possible many of the complicated avian behavioural patterns.

The midbrain is comparatively more developed in birds than mammals, and the large size of the optic lobes reflects the great reliance upon the sense of sight. The tectum, or roof of the midbrain, is not, however, solely concerned with visual impulses; it is still a correlation centre of considerable influence, though its function in birds is to some extent delegated to the corpus striatum, and in mammals very largely to the cortex. The nuclei of the avian midbrain are concerned especially with gravistatic and photostatic functions as they affect the head and body movements, and hence they exert an influence upon the motor regions which regulate muscular control.

It is interesting to note that birds which are considered to possess superior intelligence, such as crows and parrots, have relatively larger cerebral hemispheres than the supposedly less intelligent fowls and pigeons, but it is generally held that despite their complicated behaviour patterns, birds differ in a quite fundamental way from mammals. Having little power for thought or conscious memory, their lives would seem to be a sequence of momentary events, entirely unconnected with any concepts of past or future. The fear exhibited by a chicken is in all probability, simply the fear of a moment, which disappears promptly with the cause. There is nothing to indicate that a bird can worry, or suffer in the psychological sense; nor, so far as we know, can it conceivably fear pain or death.

It is generally held that birds and mammals have descended from reptilian ancestors down widely divergent paths, and the present-day representatives of each group exhibit new, though totally different, levels of nervous organisation.

The Reflex Arc

Almost all animals which possess a nervous system can exhibit a simple form of reflex reaction in which a certain stimulus rapidly evokes a specific response which is independent of experience. The simplest reflex would be one in which a single nerve conductor passed from an environmental receptor to some tissue responsive to the nervous impulse in the conductor. Some such arcs may occur in the vertebrate viscera, but the typical reflex upon which the nervous system of birds and mammals is based is less simple, involving at least two conductors with a synapse between. Reflex function does not depend upon the integrity of the central nervous system as a whole, but can readily occur in isolated segments of the spinal cord. Thus in the pigeon an isolated post-thoracic segment can relay an impulse between pain receptors in the foot and the musculature of the leg, making the withdrawal reflex possible.

Conditioned Reflex

Since every known reflex involves at least one synapse within the central nervous system, there is always opportunity for the interaction of the nervous elements involved in the arc with other events in the system as a whole. In classical conditioning, the conditioned stimulus is generally followed by an unconditioned stimulus which alone evokes a given response. After sufficient presentations of both stimuli in the correct sequence, the first stimulus will replace the unconditioned stimulus and independently elicit the response. If, for instance, the introduction of food into a dog's mouth is accompanied by the ringing of a bell, the bell alone, which normally would have no such effect, will eventually evoke salivation.

Since the conditioned reflex is a simple form of learning process its establishment would be expected to depend upon the integrity of the cerebral hemispheres. Although this is true in the vast majority of cases, it has, however, been demonstrated that conditioned responses of a gross nature may be established in the decorticate dog, whereas attempts to demonstrate that the spinal cord may act as a centre for conditioned reflexes have not been successful. In rats, learning capacity seems to be a function of the cortex as a whole, and depends quantitatively on the residual mass after part has been removed. Whether there are specific parts of the cortex which are concerned with the retention of learned habits is not clear, nor is there yet a satisfactory explanation of the recovery of function which may occur after ablations.

The Spinal Animal

An animal in which the spinal cord has been completely separated from the medulla oblongata, and even a decapitate preparation, can be kept alive almost indefinitely if artificial respiration is provided, and the body temperature maintained. The intact cord, however, exhibits hardly more competence in controlling spontaneous reflex activity than isolated segments, because no additional sense organs are included above those normally distributed to each segment. The spinal animal can make co-ordinated walking movements, and in birds, noxious stimulation still evokes struggling movements with the legs after the cord has been completely separated from the brain.

The Decerebellate Preparation

Removal of the cerebellum in birds causes spasticity of the anti-gravity musculature, so that the animal stands upon its claws. At first there is extreme malposture and little control over movements, though the bird may eat and drink. Later, however, there may be partial recovery, and a decerebellate pigeon may learn to walk slowly and even fly. Small lesions in or near the cerebellum cause a pigeon to rear backwards and lose control.

The Decerebrate Preparation

Section of the central nervous system at the level of the midbrain in birds causes loss of temperature control and righting reflexes, as well as the condition known as decerebrate rigidity, or tenseness of the anti-gravity muscles, which follows ablation of the cerebellum. This condition reflects an imbalance between the excitory and inhibitory influences which in the intact animal maintain the musculature at a certain degree of tone. Many complicated automatic and reflex responses are, however, still possible, including respiration and swallowing, maintenance of high arterial blood pressure, and the various cardiovascular reflexes. The decerebrate duck can still swim, and the pigeon will continue to fly after removal of the entire forebrain.

The Decorticate Preparation

Removal of the cerebral hemispheres leaves the animal still apparently normal with respect to nearly all reflex actions, including those associated with the special senses. The decorticate bird makes no spontaneous movements, but upon stimulation can walk and fly normally, whilst mating and rearing of young are still possible. Food may be picked up, but apparently not recognised, so that the decorticate chick must be fed artificially. A dog or cat in which both hemispheres have been removed exhibits violent signs of fear or rage upon the slightest provocation, but the apparently complex reactions such as increase of heart rate and blood pressure, and erection of hairs, are reflex in nature, and probably result from removal of the cortical control which normally regulates behaviour. A fowl in which only the cortical surfaces of the telencephalon have been removed can still discriminate between a circle and a triangle.

If one hemisphere alone is removed, the general sensations are blunted, whilst muscular movements are weaker on the opposite side of the body. In fact the results of extirpation experiments on birds are similar in many ways to those with mammals, except that lesions in the forebrain areas may be considered to have a rather less severe effect on general behaviour than is indicated from mammalian investigations.

The Pain Pathway

Pain results from the stimulation of specific nerve endings by thermal, mechanical, electrical or chemical agencies. The skin of birds possesses sensory endings much like those of man, and in addition to those responding to painful stimuli, there are also touch and thermal receptors. Pain receptors occur in all parts of the skin, being especially numerous in skin lacking feathers, such as the comb and that around the cloaca and tongue. Any stimuli picked up by peripheral receptors reach the dorsal thalamus by way of the optic tectum and the tecto-thalamic tracts, which are numerous and highly developed in birds. Analysis is performed in the thalamus, and appropriate action, in the form of motor impulses, is taken. Most sensory impulses, including those of pain, enter the brain on the side opposite to that of their origin, and most motor responses leave the brain from the side opposite to their distribution. Hence injury to the left motor area of the brain generally produces paralysis of the right side of the body.

A typical reflex reaction to pain may be observed in the fowl when the skin of one foot is pinched with forceps. An impulse is conveyed from the pain receptors to the spinal cord, by fibres of relatively small diameter and slow conduction rate, which terminate in the dorsal horn of the grey matter. Fibres arising here cross to the ventro-lateral columns of the white matter of the opposite side and form the lateral spino-thalamic tracts, which run up the cord to the superficial aspect of the medulla, before passing medially to join the main sensory path. The afferent fibres then pass via the tectum of the midbrain and end finally in the dorsal thalamus. The course of the pain afferents beyond the level of the thalamus is not fully understood, but it seems likely that interaction with events from the cortex and corpora striata is possible before a suitable motor impulse is generated which passes by motor fibres to muscles controlling the leg. These contract and the foot is withdrawn (flexion reflex); this is frequently accompanied by extension of the contralateral limb (crossed extensor reflex).

The afferent pain pathway is illustrated in Fig. 118.

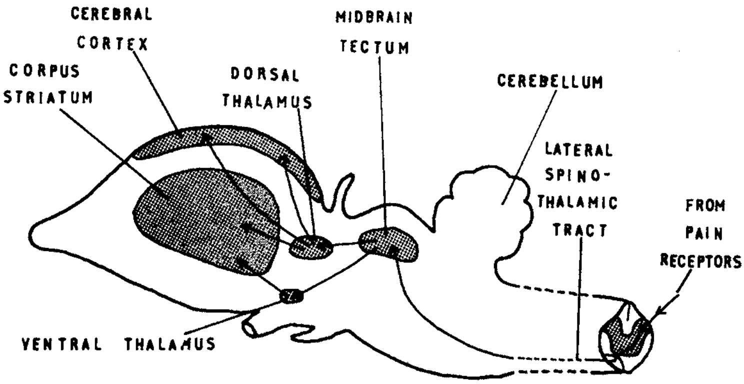

FIGURE 2. DIAGRAM TO REPRESENT THE AFFERENT PAIN PATHWAY IN THE AVIAN CENTRAL NERVOUS SYSTEM

FIG. 118.

The Assessment of Pain

Since pain is primarily a subjective experience it cannot be easily defined or described, despite the measurable physiological responses which generally accompany it. These responses include the reflex withdrawal movements, changes in blood pressure, heart and respiration rate, and sweating or panting. Sherrington's definition of pain as 'the psychical adjunct of an imperative protective reflex' emphasises the value of the response to the organism as a whole, for reflex responses may help to prevent more serious damage, whilst avoidance reactions, often in the form of conditioned reflexes, may avert injury altogether.

All comment relative to the assessment of pain in animals must be derived by analogy from our own experience. Although pain perception in animals may, on grounds of commonsense and observation, appear to be obvious, the present state of our knowledge does not permit any final conclusions.

It has been demonstrated, for instance, that decorticate or mesencephalic cats, no longer possessing the neural mechanisms for pain perception, but with the reflex motor components intact, will still react to pain in the manner of the normal animal. Even a chronic spinal cat will withdraw its limb from painfully hot or cold water, though only the normal animal will do so from the purely tactile stimulus of water at skin temperature. Thus one of the major problems with animals is the selection of pain indicators which will separate the simple reflex response (which is usually taken as in indication of pain perception, but which may actually record only the reception of pain) from the response showing the genuine perception of a noxious stimulus. The observable reflex reaction may be identical in both instances, and yet not only may the threshold for eliciting the simple reflex response be quite different from that for perception of the sensation, but the neural pathways utilised in the two instances may also be distinct.

The assessment of analgesic and anaesthetic substances in animals is also difficult, for an animal's interpretation of given stimuli is always in some doubt, whilst the possibility of confusion between true anaesthesia and a mere neuromuscular blocking effect is often present. Electrophysiological recording from the central nervous system may be the best method of assessing the physical signs of consciousness and pain perception, a technique particularly useful in sub-mammalian vertebrates in which reflex and behavioural expressions of pain are less well defined.

Pain Responses in Poultry

It seems that the threshold of pain is generally higher in birds than in mammals. Suturing and incision, or even massive trauma such as auto-visceration, may produce little apparent concern. On the other hand, the irritation caused by a strapped foot may provoke violent resentment and self-interference. Certain areas, such as the comb, tongue, cloaca and conjunctiva, are more sensitive to painful stimuli than the general body surface, and the procedures especially resented include scraping near the beak or eyes, pricking of the cera, pinching the comb or interdigital skin, stretching of the skin or subcutaneous tissues, and excessive pressure on the digits. Resentment to such stimuli is shown by withdrawal of the irritated part, general struggling, and harsh alarm cries.

Reflex Responses

As already noted, the ability to react to a painful stimulus is not necessarily an indication of the ability to perceive pain. The following responses may therefore be used only as an indication of whether a bird is capable of reacting to painful stimuli:

The Comb Reflex

On pinching a lobe of the comb between finger and thumb or with forceps, the fully conscious bird responds by withdrawal and shaking of the head. This response diminishes by perceptible degrees, i.e. it can be elicited only by harder and harder stimuli as insensibility supervenes, as, for instance, during the induction of anaesthesia. In full surgical anaesthesia there is no response at all. This response is one of the first physical signs of consciousness to return during recovery from anaesthesia, and it would seem that the comb is more sensitive to painful stimuli than the general surface of the skin.

The Pedal Reflex

Painful stimulation of the interdigital skin of the leg results, in the conscious bird, in withdrawal of the affected limb, and sometimes in extension of the contralateral limb. This response may be as reliable a guide to sensibility as the comb reflex, but is frequently inconvenient to apply. In laboratory anaesthesia, this response can be evoked more readily than responses from the rest of the skin with the exception of the comb.

The Corneal Reflex

Irritation of the cornea with a point provokes blinking of the nictitating membrane. This response is not merely a sign of consciousness in the fowl for it persists in full surgical anaesthesia, and under normal conditions its disappearance occurs within a few seconds of the cessation of respiration. Thus the *permanent* loss of this reflex may be taken as an indication of death.

Closure of the eyelids occurs in the fowl during full surgical anaesthesia, and they remain closed on painful stimulation of the body. If anaesthesia is light, however, the eyes, though still normally closed, open when any painful stimulus is applied.

Pain and Electrical Stunning in Poultry

The problem of the assessment of consciousness in fowls stunned by electricity is a difficult one, especially as electrical curarization is known to occur under certain conditions in man and several other species, during which pain can be perceived but reaction to it is impossible. There is every reason to suppose that a fowl is fully unconscious during the electroplectic fit which follows successful stunning. From both laboratory and field observations on broilers and adult hens stunned by high or low voltage apparatus, it seems that the most common and reliable indications of electroplexy in the fowl are as follows:

The eyes are wide open and the corneal reflex is absent.
The head arches towards the back.
The wing feathers are slightly spread, and the wing is extended down and back without fluttering.
The legs are fully extended backwards after initial tremors.

The tail feathers turn up over the back.
No faeces are passed.

When electrical stunning is employed commercially in packing stations and processing plants, it is assumed to reduce or abolish the pain caused by venesection. The evidence to date does suggest that stunning reduces the possibility of feeling pain, but any benefit must be considered in relation to the likely pain of the stunning process itself. It has been demonstrated, for instance, that in cats and dogs killed in an electrocution cabinet in which the current passes either from forefeet to hindfeet, or from a metal collar round the neck to a metal tray on which the animal stands, the unconsciousness which precedes death is due to cerebral anoxia following stoppage of the heart, and not directly to the shock itself. Following a shock of short duration, the animal howled or screamed, and during this period the electroencephalogram was not significantly different, although the heart stopped pumping. Thus a shock of only one second may eventually kill a dog because it sets the heart into fibrillation. With fowls, the possibility that stunning methods in which the current does not pass directly through the brain, may therefore be more painful than venesection without stunning, must be considered.

High Voltage Stunning

Either manual or automatic devices may be employed, consisting of a single electrode high potential source of 400 volts or over, functioning at 50 cycles/sec. A.C., which is applied to the bird's head or neck for a period which depends upon the speed of through-put or upon the time taken to induce electroplexy. In both types of apparatus the current returns to earth through the leg shackles.

Following successful high voltage stunning there is always a period during which the corneal reflex is absent (the state of electroplexy), and it is most unlikely that painful stimuli could be perceived at this time. The doubtful period is from the return of the corneal reflex as the fit diminishes, to its final disappearance at death, brought about by venesection. In practice it seems likely that about 60 per cent of birds stunned in this way are killed outright. Another 15 per cent may, under crowded conditions of automatic stunning, escape the shock, and it is possible that these birds could feel pain for a period of up to at least 120 seconds before death from haemorrhage, by which time they may have entered the scalding tank. Unstunned birds do not generally show any response to jugular severance itself, and it is only some seconds later that violent struggling ensues. A similar reaction occurs, however, in decerebrate birds rendered anoxic, and it is possible that this is entirely a reflex response. Nevertheless, since this is during the period when the comb response is still present, the birds *may* be able to feel pain; either the 'pain' of progressive anoxia, or that possibly produced by the release of nociferous substances at the site of the incision. Because high voltage stunning abolishes or reduces the comb reflex during this period, it may be considered to reduce the possibility of perceiving pain.

Low Voltage Stunning

Manually operated low voltage apparatus, functioning on 50 cycles/sec. A.C. at 90–120 volts and consisting of two stunning electrodes between which the bird's head is placed, is employed in some smaller packing stations. Stunning is for 3–5 sec., during which there is violent quivering and flapping, which continues for 3–9 sec. after application ceases.

The wing flapping which occurs after low voltage stunning does not necessarily indicate an imperfectly applied technique, for flapping occurs even after a bird's head is completely severed. Reflex responses appear to be almost completely abolished after successful application, and recovery between venesection and scalding is rare. Low voltage stunning may likewise, therefore, be considered to reduce the possibility of feeling pain.

It is interesting to note that where 400 volts are employed, the resistance to the current, which must pass through the entire body from neck to feet, is so great that the amperage (13–40 mA) is less than with 120 volts using electrodes on either side of the head (24–120 mA). Although the current passing through the brain is the most important parameter, it is the least well understood, and this is especially true under factory conditions. The available evidence would suggest, that in dry operating conditions, the substantial electrical resistance at the skin-electrode interface may be sufficient to interfere with the induction of acceptable anaesthesia, and that this may contribute to the occurrence of 'missed shocks'.

It is not yet possible to say whether venesection itself is painful. Where electrical stunning is not employed, it would be desirable, pending further information, to ensure that at least 240 seconds elapse between venesection and scalding.

Recent laboratory experiments have shown that low voltage stunning alone causes a reduction in respiration and heart rate together with elimination of the spontaneous electrical activity of the brain. Venesection alone causes an increase in heart rate followed, however, within 1 minute, by an abrupt decrease, and a fall in arterial blood pressure; concurrent with the latter changes is an alteration of electrical activity which suggests loss of consciousness. When venesection followed stunning within 30 seconds, the bioelectrical potentials abolished by stunning did not recover before death from haemorrhage. In general, it seems highly unlikely that a bird could perceive pain during the complete absence of cerebral electrical activity, so that a reasonably accurate assessment of the commencement of unconsciousness after stunning may thus be made. What is much more difficult, however, is to estimate when consciousness may be regained if subsequent venesection is not performed.

Chapter 38

WORLD FOOD PROBLEMS

W. P. BLOUNT

World population is expected to double in the next 40 years but at different rates; in Europe for example, annual growth is likely to be 0·9 per cent contrasted with a world average of 1·9 per cent. This latter figure represents *an increase of about 63 million persons annually*; no wonder some authorities believe that within the next 30–35 years the world will be unable to support itself nutritionally and that famines will result. Even water supplies may be deficient, requiring large quantities from distilled sea water. By 1980 there will be 4000 million mouths to feed and by A.D. 2000 nearly 7000 million, although many sociologists hope that family planning will hold this figure down to more acceptable levels. Between 1961 and 1965 the average rate of growth for world food production rose only 1 per cent, whereas the human population was growing at over 2 per cent. If famines are to be avoided food production should rise to 3 per cent.

ESTIMATED POPULATION GROWTH 1900-2000
(after Steel 1967)

Year	*Population**	*Developed countries* (1)	*Total*	*Under-developed countries* *Asia* (2)	*Latin America*	*Africa*
1950	2497	838 (34%)	1659 (66%)	1297 (52%)	163 (6·5%)	199 (8%)
2000	6907	1448 (21%)	5459 (79%)	4145 (60%)	651 (9·5%)	663 (9·5%)

* millions
Note the increased preponderance of the Asians.
(1) Europe, U.S.S.R., Anglo-America, Australasia and Japan.
(2) Excluding Japan and the Asian portion of the U.S.S.R.
Source: United Nations Department of Economic and Social Affairs: *The Future Growth of World Population.* (Population Studies, No. 28, 1958.)

The number of people in the under-developed regions totals about 2500 millions, 2¼–3 times that of the developed areas. Over 50 per cent of the world's population lives in Asia, and India alone has 450 millions —more than the entire western hemisphere. Two-thirds of the under-developed areas fall within the tropical and semi-tropical belts of Asia and Africa where arable and livestock production have been comparatively neglected and where family planning is unknown.

In thinking of world food problems one automatically excludes the developed countries, but the Food Education Society reported last December that there is considerable evidence that there is malnutrition amongst the elderly even in Britain, mainly in the form of vitamin deficiencies. In some areas, where the disruptive influence of shift working is common, children too may suffer. One answer to both these problems is of course to popularise the consumption of more home produced milk, eggs, fruit and other high quality protective foods.

Land Reform

There are many possibilities for helping to solve world food problems including that of land reform as outlined by Dr. B. R. Sen, at a recent F.A.O. Conference in Rome, taking into account changing economic and social environments. This involves both ideological and emotional factors, well seen in India's current attempts to solve her food shortage problems. Although 32½ million acres are to be sown with new, high yielding varieties of wheat, maize and rice by 1971, such crops will require different management techniques from those hitherto employed —more fertilisers, pesticides and water, partly in relation to a greater vulnerability to various diseases. It has been calculated that five times as much fertiliser will be required, but the central government's policy has been to restrict supplies of these and also of pesticides. Home production of fertilisers represent only 40 per cent of India's needs, the rest having to be imported at high cost in foreign exchange. This demonstrates that one of India's prime needs is for private foreign capital to be invested quickly. From an economic standpoint the production of food of plant origin must come first. Nevertheless, poultry are important, representing the most efficient and economic method for converting grain into meat.

There is another angle to modern food problems (seldom appreciated except perhaps by sociologists) illustrated clearly in the following examples. In one of the under-developed countries the Americans delivered a large tonnage of milo in lieu of wheat, but it was not acceptable to the local populace and remained dumped, unused. This was because the local housewives by tradition had always bought wheat for home cooking purposes. Bread, of course, was not bought from shops but baked at home, and milo was not wheat, and that was that! In West Bengal the Japanese arranged for a trawler to be lent for fishing purposes because the Bengalese are very fond of fish, which forms their main source of animal protein. Many tons of fish were caught and offered in the shops but almost none was sold, simply because these fish had come from the sea and not from the rivers. Examples such as these cannot be grasped readily by those not familiar with local traditions and prejudices.

In tropical West Africa tradition plays a very important part, for example whilst the native requires little persuasion to eat fish, the same cannot be said of meat. This is partly because cattle have been regarded as a source of wealth by custom, and their high price tends to reserve them for important festivals, and also because in many parts, e.g. the

Ashanti, goat meat is preferred to mutton or beef. Furthermore, meat with little or no fat is preferred, perhaps because mature cattle have been killed in the past rather than young ones (Aylward 1966). Goat's meat is also of a more stringy character which encourages chewing which forms part of the pleasure of meat eating.

As high temperatures make hygienic conditions difficult for milk, this suggests that ultra heat treated U.H.T. ('Longlife') may perhaps in time supersede that produced locally from goats, buffaloes and sheep. One assumes that the pestle and mortar grinding of grain by African women will inevitably be succeeded by machine flour milling. (One flour mill in Dakar already has an annual output of 100,000 tons.)

Exporting Surpluses

It would be no problem for British farmers to produce far more eggs and table chicken than we can consume, and within a year or two fairly large quantities would be available for export. We are already producing thousands of tons of extra barley which are being sold to many countries such as Spain, Israel, etc. So why do we not do the same for meat, milk or poultry products and export these to the underfed in India, Africa, etc? Barley is in a sellers' market, however, and the countries importing it are able to pay for it, but the under-developed countries cannot readily pay for imports. But if the peoples of these countries are really hungry will not F.A.O. or some world philanthropic organisation pay for the proteins of high biological value we could produce to excess?

The Minister of Agriculture dealt with this problem when speaking at the International Federation of Agriculture Producers Conference dinner on 3rd May. 'It is sometimes suggested as self-evident that the agricultural products of the developed countries should be free of all restraints so that surplus supplies can be shipped to needier countries. There is obviously a considerable need for food aid. . . . But even with the expanded World Food programme and the new American Food for Peace programme we are beginning to realise that the answer is not simply a matter of transferring surplus foods to hungry mouths. It has been calculated that if the developed countries produced all they could by 1980 this would still not be enough to maintain the worlds expanding population at the present level. It will take a good deal of skill and foresight in many countries to find the answer to this gigantic problem. One thing is clear, the basis of the solution has to be found in the developing countries themselves, in building up their skills and their own agricultural resources. The overall plan for the developed countries must not be to produce surpluses indiscriminately, without counting the cost in real resources. In many cases they can best help by providing the developing countries with means to improve their agricultural production in the form of pesticides, machinery and technical expertise for example.'

Herein lies the truth. We must only produce surpluses for which there is a demand, and for which unfortunately payment can be expected. But we must give freely of our expert knowledge, and we must continue to develop 'know-how' by keeping ourselves up to date, and by instructing and educating those who come from the developing nations of the world—especially the Commonwealth.

Intensive livestock farming in Britain is being carried on solely for economic reasons, but its efficiency may readily create a surplus, of eggs for example. These (having been subsidised), cannot be exported, however, because of G.A.T.T. regulations. In countries where there are serious food shortages they would doubtless be very welcome indeed, but freight charges alone would prove crippling.

An indication of the better diet of the countries where the standard of living is high can be seen from the following:

DAILY NUTRIENT INTAKE
(after Boldingh 1965)

Country	*Total calories*	*Animal protein (gm.)*	*Total fat (gm.)*
U.K.	3250	54	139
U.S.A.	3100	66	140
Italy	2800	29	87
Japan	2250	18	29
India	2050	4	28

Although we ourselves may be able to do little to overcome this disparity in nutrients, it must not deter us from following the trends and developments which already hold out long-term possibilities. Some relate to genetical studies, like the production of high lysine corn, others to the use of waste products like dried faeces (for cattle, pigs or poultry), or to the production of proteins from algae or fungi grown on petroleum, hydrocarbons, etc. Leaf proteins and spun soya ('meatless meats') products offer more immediate prospects, as also does fish flour. Brief notes on these subjects follow.

High Lysine Corn (Maize)

About 50 million metric tons of corn are eaten directly by people in the tropics and semi-tropics, in addition to which corn contributes about 20 million tons of protein annually to the human diet. So that the recent announcement indicating that the protein value of corn can be improved by at least 25 per cent implies that this could add an additional 5 million tons of protein to the worlds protein supply.

The first details about high lysine corn (H.L.C.) were published by Mertz, Bates and Nelson (1964) following a Hybrid Corn Industry Conference in Chicago, 1963. Contributors to the Proceedings of the H.L.C. Conference, Purdue University, June 1966, discussed the subject at greater length. At this meeting it was stated that the correction of the serious protein deficiencies of pre-school children would be likely be make a greater contribution to world development than any other single health measure (including malaria eradication); and also that the story of high lysine corn was of equal if not greater meaning to mankind than a soft landing on the moon. This statement is linked to the fact that half a billion people suffer from food inadequacies, that 1 billion subsist on improperly balanced diets (shortages of protein), and that 3 million children die each year from malnutrition (McGovern 1966).

The earlier discovery by Nelson and Mertz that a single gene was capable of increasing the lysine and other amino-acid components in corn is now hailed as a scientific breakthrough of the greatest nutritional importance. Known as *Opaque-2*, this gene improves the quality of corn to such an extent that rats grow 3½ times as fast:

AVERAGE GAIN (*gm.*) RATS

Age (days)	*Indiana hybrid corn 453*	*Opaque-2 corn*
7	6	19
14	11	42
21	19	68
28	27	98

Actually there is nothing magical about H.L.C. (Opaque-2) because one can duplicate its effects by the proper supplementation of ordinary maize with a balance of the limiting amino acids. The extra lysine present in H.L.C. is fortunately the biologically active L-isomer.

The impact of H.L.C. requires to be studied in relation to man, pigs and poultry because of its marked effects on the diets of these different species.

H.L.C. and Man. The average agriculturalist in the western hemisphere is unaware of the great value of corn in many human diets, and also the fact that there are several hundred varieties of corn with differing agronomic and economic properties.

The Latin American Indian lives primarily on corn and beans and has tended to favour corns with soft floury endosperms, but as these are susceptible to weevil destruction during storage, harder varieties (with much heavier yields) have been introduced from the U.S.A. The most popular Mexican variety, the Tuxpeno is, however, one of the lowest in lysine, and it is therefore hoped to incorporate the O_2 gene into it, as well as into other elite breeding varieties. Hitherto as yields of corn per acre have gone up, so the percentage of protein in the grain has gone down, but this should soon be reversed, in part by the use of suitable fertilisers. Bressani (1966), for example, reported that experiments carried out 5 years ago showed that chicken manure increased the levels of lysine, tryptophan and methionine in corn by about 12–15 per cent.

Tests have already shown that the nutritive value of H.L.C. for children is about 90 per cent that of skim milk, and that processing the corn into masa or tortilla does not alter its high protein quality. Indeed the inclusion of the O_2 gene in common corn appears to be the most practical approach to the problem of improving the protein quality of human diets based on corn.

In several Latin American countries corn contributes from 34–69 per cent of man's total calorie requirement, and 32–58 per cent of the protein; but in Guatemala maize can furnish up to 80 per cent of the calories and 70 per cent of the protein. For such adults 500–600 gm. of corn would be consumed daily, whereas 300 gm. of H.L.C. would provide 93 per cent of the protein and 40 per cent of the calories.

The yield of starch from 100 gm. O_2 corn is lower than normal, 59 per cent *v.* 63·5 per cent, but the endosperm breaks up more easily and therefore gives a higher percentage recovery of starch due to the more open structure of its endosperm. Whilst the fermentation characteristics of O_2 corn are satisfactory, alcohol production is lower than expected and therefore its use would prove an economic liability if used by the distiller.

H.L.C. and Pigs. The protein quality of H.L.C. for pigs is such that when it is supplemented with vitamins and minerals it gives just as good results as an isonitrogenous diet comprising normal corn with soyabean-meal (see facing page).

O_2 corn can be used satisfactorily for either young pigs (8 weeks old) or older finishing stock weighing 120 lb. onwards, particularly as it appears to be more palatable than regular corn.

H.L.C. and Poultry. Because baby chicks cannot be considered comparable to older growing swine, and as their limiting amino acid on a corn soya diet is methionine (which is not a marked component in H.L.C.) feeding trials have not given the same dramatic results as with pigs. But when this amino-acid deficiency is removed by methionine supplementation, O_2 corn produces better gains and feed conversions than normal corn at sub-optimal protein levels. The beneficial effect being mediated solely through the higher lysine content.

Maize Proteins. Corn breeders must presumably establish schemes which will permit the development of high yielding, high protein, high lysine varieties following the incorporation of O_2 into synthetic

SWINE DIETS AND RESULTS (Pickett 1966)
(percentage inclusions)

	1	*2*	*3*
Normal corn	—	97·09	88·80
Opaque-2 corn	97·09	—	—
Soyabean-meal (44%)	—	—	8·44
Mineral-vitamin premix	2·91	2·91	2·76
% protein	11·59	8·60	11·60
% lysine	0·48	0·23	0·46
% tryptophan	0·15	0·09	0·13
Pigs (initial weight)	30·4 lb.	30·7 lb.	30·2 lb.
Daily gain (lb.)	0·94	0·26	0·93
Feed conversion	3·32	6·88	3·23

varieties. At 10 per cent moisture O_2 grain weighs about 56 lb./bushel, the current yield being 80 bushels/acre. The kernels are invariably lighter than normal sibling kernels, but appropriate selection (based on modifier genes affecting kernel size) could change this picture.

Opaque-2 kernels contain increased quantities of bran and germ, the latter accounting for its higher content of fat and ash; percentage yields being germ 35·7 per cent, meals 33·5 per cent, grits 25·4 per cent and feed 5·4 per cent; the meal and the grits representing the endosperm (58·9 per cent). It is the reduced endosperm content which accounts for the smaller kernel, which may be only three-quarters that of normal maize.

Maize endosperm contains four proteins—albumins, globulins, prolamines and glutelins. The glutelin fraction is directly co-related with the lysine content, whereas the zein content is inversely proportional. Apparently the O_2 gene reduces the zein content, with a resultant increase in non-zein protein synthesis (Concon 1966). Thus: lysine content of various copper fractions (gm./100 gm. protein) acid soluble 5·9 (O_2), 1·8 (normal); zein 1·0 (O_2), 0·3 (normal); glutelin 3·7 (O_2), 3·6 (normal). Other data using the Osborne technique shows: albumins and globulins 24·7 (O_2), 14·2 (normal); zein 17·2 (O_2), 48·4 (normal); glutelins 41·3 (O_2), 31·2 (normal).

As corn endosperm is triploid, dosage series can be prepared by selfing the homozygous parents and making the reciprocal crosses.

The O_2 gene is currently being incorporated into tropical varieties of maize, of which 250 have been tested and 5 found to have outstanding complexes invaluable as basic breeding material. One hopes to see corns with 12–15 per cent protein, high lysine contents (0·48 per cent), and excellent agronomic qualities affecting yield, disease resistance, harvest properties and storage qualities favourably.

Thus corn with the O_2 gene present shows a higher ratio of isoleucine to leucine, and whilst methionine remains unchanged tryptophan, arginine and lysine are all increased.

DOSAGE EFFECTS OF OPAQUE-2 AND FLOURY-2 GENES* (Bates 1966)
(gm./100 gm. endosperm protein)

Amino acid	$+++$	$++O_2$	$+O_2O_2$	$O_2O_2O_2$	$fl_2fl_2fl_2$
Lysine	1·7	1·8	2·3	3·6	3·6
Cystine	1·0	1·1	1·4	2·4	1·4
Leucine	16·7	16·5	14·4	10·5	11·7
Arginine	3·1	3·4	3·8	5·1	4·3
Methionine	1·6	1·5	2·7	2·1	2·7
Proline	10·0	11·1	11·9	9·5	7·3

* It is assumed that both genes are affecting zein synthesis.

% COMPOSITION OF NORMAL AND OPAQUE-2 CORN (Pickett 1966)

	Normal Corn	*Opaque-2*
Protein	8·86	11·94
Dry matter	91·9	87·1
Amino-acids		
Arginine	0·46	0·79
Cystine	0·14	0·20
Isoleucine	0·10	0·97
Leucine	0·31	0·37
Lysine	0·24	0·49
Methionine	0·15	0·16
Tryptophan	0·09	0·15

Protein from Petrol

Now that it is known that certain micro-organisms can produce protein using petroleum products as their substrate, many enthusiasts believe that world hunger problems might be overcome simply in this way.

This idea stems mainly from the original researches of M. Champagnat, Director of French B.P. research work, who discovered that micro-organisms can thrive on waxes derived from petroleum gas-oils, and that in so doing they produce proteins with a considerable nutritional potential both for animals and man. It is theoretically possible to produce 1 ton of protein from 100 tons of petroleum oil (utilising 1 ton of wax), and if production units were set up at some of the hundreds of refineries throughout the world this could go far to solving the world protein shortage problem. That is if the 'yeast' protein proved both palatable and acceptable to the people concerned: in any event it should prove of great value to livestock. This work has now reached an advanced stage and an attractive product may soon be marketed. A joint research programme on a similar subject—the development of protein foods from the biosynthesis of yeasts with hydrocarbons—has also been planned by the Esso group (Standard Oil Co., New Jersey) in company with Nestlé, Alimentana, S. Africa.

Particular bacteria, yeasts and moulds are all capable of degrading hydrocarbons for use as sources of carbon and energy, but their differing methods of attack and the biochemical paths chosen are not always understood clearly. Indeed the choice of micro-organisms still forms an important part of the researches now in progress. Other important aspects include oxygen transfer, the development of engineering methods for large-scale cell propagation (including aeration and agitation), a study of the factors resulting in a high yield of cells, i.e. rapid growth, lack of toxicity, etc.

Production difficulties have been great because it is first necessary to substitute the hydrocarbon (petroleum) for the usual sugar medium, and then to supply the oxygen which is absent from petroleum oil. Fortunately yeasts can obtain this from the air, and in favourable circumstances 1 kilo of petroleum can be used as a substitute for 2 kilos of sugar.

The end product (petrol protein), which is practically odourless and tasteless, is pale fawn white and flakey and contains 50 per cent protein prepared from the dried yeast cells, and it has already been shown to be 85–90 per cent digestible in feeding trials with rats.

The table on page 578 summarises some of the important differences which play a part in the production of proteins from petroleum products.

Protein From Methane Gas

In similar vein Shell scientists hope to obtain edible products from bacteria grown on methane, one of the chief components of natural gas. Again it is a white, tasteless powder which results from a 3:1 conversion of methane into microbial protein, and 5 tons of protein can be obtained from about 1 million cu. ft. of methane.

Methane is produced in quantity when poultry manure is suitably fermented (digested), which production also occurs at many human sewage plants. About 70 per cent of the gases emitted is methane which is produced by anaerobic bacterial breakdown. Our own laboratory studies have shown the feasibility of dealing with hen battery manure in this manner, but it would probably be expensive to do so commercially at the present time, although this method has been used practically on some large farms in Germany. Problems of temperature control, circulation of the digest, removal of sludge, addition of fresh manure and gas collection all have to be studied. If a dryer is not used in

	Bacteria	*Yeasts*	*Moulds*
Cell yield	100%	80%	73–96%
Nitrogen content	10–13%	6–9%	5–6%
Essential amino-acid content (dry weight %)	21–31	17–30	9–13
Sulphur amino-acid and histidine contents	lower	higher	higher
Nucleic acid content	higher	lower	lower
Hydrocarbon substrate spectrum	wider	narrower	narrower
Use of methane	yes	?	no
Harvesting by centrifugation	difficult	easier	easier
Aeration and agitation	easier	easier	difficult
Production hazards	growth of bacteriophage	predators	toxin production
Examples:	Mycobacteria Corynebacteria *Pseudomonas fluorescens* *Micrococcus cerificans* Nocardia	Torula	*Candida utilis* and *intermedia* Nocardia

conjunction with the digester the problem of the disposal of the semi-solids also remains important.

It is possible to obtain 1 cu. ft. of methane gas from the excreta of 10 hens/day, with a calorific value of 600 B.t.u./cu. ft. This gas can be used for heating brooders, hot water pipes, etc., particularly if it is washed to remove the CO_2, since this raises the calorific value of the gas to 1050 B.t.u./cu. ft. As the boiling point of methane is high (161° C) very high pressure is required for its storage, the gas usually being compressed to 4,500 lb./sq. inch. (This can also be used as a fuel for motor cars; a Vauxhall Victor saloon at Stoke Mandeville used 4·5 cu. ft./35 miles, the conversion equipment (H. Bate, Brixham) from petrol to methane costing only £5).

In Germany equipment for dealing with the manure output of 50,000 hens costs about £24,000, the manufacturers of the digestion plant being Ferdinand Schmidt, Deutsche Futterkonserierungs-Gesellschaft, Verden, Nr. Bremen.

Dried Faeces

Layers have been fed a ration containing 46 per cent of sun-dried cattle faeces in combination with an equal quantity of maize, 2½ per cent fish-meal, minerals and supplementary vitamins A and D_3. This work was carried out by Preston and Bauby (1966 I.C.A.P.) in Cuba, the cattle having been fed on a maize, molasses and urea diet, but the egg production of the experimental group was lower than that of the controls, 36 per cent *v*. 42 per cent.

If the machines now being demonstrated for dehydrating poultry manure prove economic, there may soon be a surplus of dried manure because it cannot all be absorbed in the fertiliser trade. With this point in mind we recently carried out a small-scale feeding trial using poultry manure dried by the Brookson's method. This product contained 6·43 per cent moisture and 73 per cent organic matter. Layers tolerated up to 15 per cent dried poultry manure in their daily diet, but higher levels caused the appetite to flag. Eggs continued to be laid satisfactorily throughout the 5-week period, and there was no loss of bodyweight. A second feeding trial (7 weeks) using '404' stock, but restricting the manure pellets to 5 per cent gave a similar result, the palatability of the feed increasing as the trial progressed. Whilst it is not anticipated that housewives in this country would purchase such eggs, the reverse might be the case in some of the under-developed areas of the food starved world.

Fish Flour

The current world harvest of marine animals is about 55 million metric tons, some of which is utilised in the production of 15·4 m. tons of fish-meal annually, and part of this comes from small fish which are not well suited for direct human use.

Fish protein concentrates have been envisaged in North America for many years, and the U.S. authority (F.D.A.) has now approved for human consumption a high protein fish flour which may prove acceptable to many millions of the underfed peoples. This fish protein concentrate has been developed over the past 6 years in the laboratory, and large-scale pilot plant demonstrations are now required, for which several million dollars have been allocated. Many types of fish of the hake family (which have formerly been by-passed for human consumption) can now be processed satisfactorily into an odourless, tasteless powder containing over 80 per cent protein. It can be used as a protein supplement in soups, noodles, gravy, cookies, etc. The Secretary of the Interior, S. L. Udall, believes that enough high quality animal protein can now be concentrated to help to balance the diets of 300 million people at a cost of less than a ½ cent/person/day.

It is estimated that 12,000 million pounds of fish could be caught and harvested in this manner once the project really gets under way. If it is accepted that all fish proteins are substantially the same, providing various essential amino acids, then there is just as firm a place for defatted, dehydrated fish flours for human use as there has been for the use of fish-meals in animal nutrition. Such concentrates can be packaged economically and shipped long distances in a stable form at a relatively low cost.

A Swedish company is already extracting 40 tons of protein concentrate per day from their £1 million A.B. Astra factory at Moelindal.

Meatless Meats

Spun protein fibre prepared from such vegetable sources as soya, can be used for preparing speciality meat-like products; and marketing trials using these foods are now in progress in Columbus, Ohio.

The Midwest Research Institute, Kansas City, has produced a high protein concentrate called 'Freedom Meal' for possible use in feeding the world's hungry. It costs less to produce than ordinary cooked cereal and consists of 26 per cent wheat, 26 per cent milo, 20 per cent corn, 15 per cent soya and 10 per cent dried milk, plus vitamins, minerals and proteins.

Leaf Protein

At Rothamsted, N. W. Pirie has devised improved methods for extracting protein from leaves and grasses, although there is as yet little demand for leaf proteins from the developed countries.

Still in the laboratory stage, machine-made leaf protein may soon be produced economically on a factory scale. The machinery used pulps and squeezes the green foliage, and the resultant light coloured powder (after freeze drying) provides 30 lb. of pure protein from 1000 lb. leafage (pea haulms, etc.). This protein is considered to be the equivalent of that present in 180 lb. of beef, *except* that it has only about half its biological value.

Keen attention is now being paid to this subject because edible *animal* proteins derived from one acre of grassland contain only one-tenth the amount of protein obtainable in 'leaf' form, and experimental machines designed at Rothamsted for extracting leaf protein are already in use in India, Uganda and New Guinea. Pirie believes that a single machine, running 8 hours a day, could produce enough protein for 6000 people.

'Double Meat' Production—Ducklings and Fish

In certain European countries, notably Hungary, specialised 'fish ponds' have been developed for the dual production of ducks and fish, an account of which was presented by Szalay (1966) at the 13th World Poultry Conference, Kiev.

Experiments lasting 4 years involving half a million ducks led to the development of this unusual intensive system for meat production which can result in the production of 2·3–5 tons of meat per hectare (1–2 tons per acre).

The ducklings are brooded for a period not exceeding 10 days prior to being taken to training ponds, being transferred at 2–3 weeks of age to the actual fish ponds. The ducks have access to both land and water, but the excreta passed into the pond stimulates the production of

20 per cent additional fish-meat protein, and the total profit for the whole unit is increased by 150 per cent.

Under this system one man can look after from 6000–12,000 ducklings labour costs representing only 3·6 per cent of the total, the same as in broiler production. Pond nutrients reduce the overall feeding costs of the ducklings by 10 per cent, special rations being formulated which only supply 28 grams (1 oz.) of animal protein per 1 kilo liveweight, compared with a normal inclusion of 114 grams (4 oz.). Pond mortality has remained below 2 per cent. The hygiene of the lake bed can be restored by field crop production.

Note: During the winter period it was found more economic to use the duck houses for broiler production.

Developments in Food Production

An excellent account of the progress which has occurred in this field of agricultural endeavour was given by Dr. Emil M. Mrak, Chancellor of the University of California (Davis) at a symposium on 8th May, honouring Dr. A. F. Morgan's 50 years of research in nutrition. Emphasis was given to the fact that one cannot just go into the undeveloped countries, pushing hard present-day ideas as to how land should be developed, and which modern methods to adopt. Presumably in some areas the ox, mule or horse may not necessarily be able to be supplanted by the tractor, although unquestionably sophistication will come, but it may take time. It is sometimes advisable to step on to the ladder of progress gently, rather than rushing one's fences.

Imagine the situation in India where 30 per cent are illiterate, where the birth rate is increasing by 2½ per cent annually (contrasted with 0·8 per cent in Britain) which means an additional 12 *million* mouths to feed; and for the pioneer invester and entrepreneur the advisability of learning one or more of twenty different Indian languages (Patel 1967). This is a country, like many others, where feed wastage from rats and other pests is enormous, and where in fact deliberate efforts are made to salvage damaged feeds so that they can be fed to poultry. It is a country which is primarily vegetarian, and where the buffalo is far more useful for supplying fresh dung for plastering houses, and as a fuel when dried, than it is for providing milk. The average wage is only about £15 per year, contrasted with £40 in Nigeria and £60 in Ghana, upwards of £1000 in England and three times as high in the U.S.A.!

What opportunities; and what a magnificent *long*-term investment for those with vision and enterprise. As a contrast to most other countries there is almost a surplus of vegetable protein and a shortage of carbohydrates and water, particularly when the monsoons fail, a feature which has been responsible for the recent famines in Bihar. And there is a constant cry for fertilisers, so let us hope that British or American engineers will rectify this situation quickly.

Not only must there be more and better food (both suitable and nutritious), but full advantage must be taken of modern methods for preserving it for use during the non-productive season by drying, canning, freezing or by irradiation. In these countries there is unlikely to be an outcry of the Rachel Carson type when more food appears as a result of the judicious use of chemicals for controlling diseases, pests and weeds. In many instances today the actual weight of food consumed by the peasants daily is only about a quarter of that in North America, yet the latter still believe that they *must* grow millions more tons of red meat, fruit, vegetables and milk if they are to retain their present very high standards of nutrition and cater for their increasing populations.

In each country however (under-developed or developed), the greater the population the less land there is available for agricultural use and this must mean intensive farming unless land reclamation is practicable. Mrak has suggested that existing agricultural land would become available if tobacco smoking were to cease, thus releasing ground now occupied for growing other crops. So far there is little or no evidence that the cancer hazard is reducing the smoking of cigarettes, and even if it did the habit is so ingrained, many persons would automatically switch to cigars or pipes; or even some more harmful drug. On the other hand, if hop extracts are to be used in future by the brewing industry, this will cut the present hop acreage by half. Increased production per acre and decreased losses during harvesting and storage must be the aim, neither of which will be possible without considerable capital investment. It also means the introduction and multiplication of new disease resisting varieties of both plants and animals, in the absence of which more drugs and chemicals will have to be used for the same purpose—a greater output. It has been stated (Mrak 1965) that as much as 90 per cent of the populace is engaged in agriculture in parts of the Orient contrasted with 50 per cent in Russia, 7 per cent in the U.S.A. and under 4 per cent in Britain. How long will it be before millions are released from primitive agricultural practices, and what will be their fate?

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Chapter 39

FARMING IN 1976

While there may be few experts in this country who would dare to speculate 10 years ahead, a comprehensive look at American agriculture in 1976 has recently been issued by the editors of *Farming Journal*, Inc., Washington Square, Philadelphia, based on some impressions of their nation-wide staff. The story is worth reading.

The population of the U.S.A. will increase by 32 millions in the next 10 years, against a world rise of 700 millions. About 25 per cent of the present 2 million commercial farm units will have disappeared, but family farms in 1976 will be larger, more specialised and more intensified. Average gross income per farm unit will be about 25,000 dollars (£8900), 50 per cent higher than now. Instead of 6 per cent of the working population being involved in farming, there will only be 3 per cent in 1976.

Dairying

Dairying will still be in the hands mainly of family sized two-man units, but larger Californian-style herds with hundreds or thousands of cattle will also be operating. Whilst some automatic milking machines already on the market stop functioning when the udder is empty, the next most logical step will be to get a machine to take itself off. There will also be easier ways to sanitise teat cups, and the teats themselves will be both disinfected and sealed after milking. Automatic warm water sprays will stimulate milk 'let-down'. Mechanised feeders in stanchion barns will release more labour. Urea, silage and grain will form the basis of the cow's rations without the use of supplementary sources of protein. Hay cubes containing grain will also become popular.

Many dairy cows will be housed in enclosed barns with free stalls, feed-lot and milking parlours all under one roof with forced ventilation. On the assumption that cows can live comfortably on slats, these will have self-cleaning alleys at the rear.

Sex determination will be possible, and breeding programmes will concentrate on improved feed efficiency rather than increased milk production; also upon resistance to disease (mastitis); longevity and speed of milking. (Testing milk samples for protein, solids not fat, butter fat and lactose will take only 60 seconds.) New drugs, new regulations, more careful and better milking techniques will all help to control mastitis. Butter and cream will suffer severe competition from non-dairy substitutes including ersatz milk. Co-operatives will be organised on a regional basis and band themselves together so as to be able to bargain with chain stores.

Beef

Over 230 million Americans will each consume an average of 110 lb. of beef—35 per cent more than today. Regular twinning will be possible in the next 10 years, and with such multi-births will go sex determination. Cross-breeding will be a characteristic feature of feeder cattle ranches—'they breed easier and wean heavier'.

Sheep

Few lambs will ever see pastures: they will be weaned early and finished in dry lot. With the aid of hormones two lamb crops will be possible, and many ewe flocks will be raised fully in confinement.

Hogs

Pork consumption will level off at 60 lb. *per capita* per year. U.S.D.A. figures already show 22 per cent less lard from hogs today compared with those of 1950. Then 235 lb. hogs yielded 35·4 lb. lard whereas, 1965 equivalent carcasses weighed 240 lb. and trimmed 27·8 lb. of lard. Data from testing stations in Idaho showed that 1956 hogs averaged 32·3 per cent ham, compared with 40 per cent in 1965. These valuable commercial trends will continue, more pork being sold in completely processed forms—defatted and without bone.

The number of hogs raised per farm has already increased from 150 in 1950 to 640 in 1965, and by 1976 it will approach 1500. Such family farmers will be specialists, geared up for big volume and small profits per head.

The swing to controlled environments (artificially ventilated) with slatted floors and automatic feeding (involving pneumatic systems) will be marked. Anything in fact to save labour and to make daily chores more pleasant will be encouraged, as this will also release more land for crops. Slatted floors for breeding sows will be linked with the use of drugs to synchronise 'heats' prior to A.I. As with dairy cattle, hog rations will need no supplementary proteins, consisting primarily of corn (maize), vitamins and minerals.

Manure

For all species manure disposal will provide serious problems, but in addition to the now popular liquid system, oxidation ditches, aerobic decomposition (as used in some municipal sewage systems) and chemical treatments combined with filtration and lagoon decomposition may provide part of the answer.

Farmers

Farmers will only work a 5-day week, and many of their management records will be related to some form of computerised record-keeping, mainly operated through their local banks. Computers will also be used for such items as least-cost rations, breeding programmes, age at killing, etc.

The housewife who has not got electronic or infra-red cookers will require ready-to-eat foods, and she will also want 'phono-vision', intercom systems, the use of two-way radios (from fireside to fields), etc.

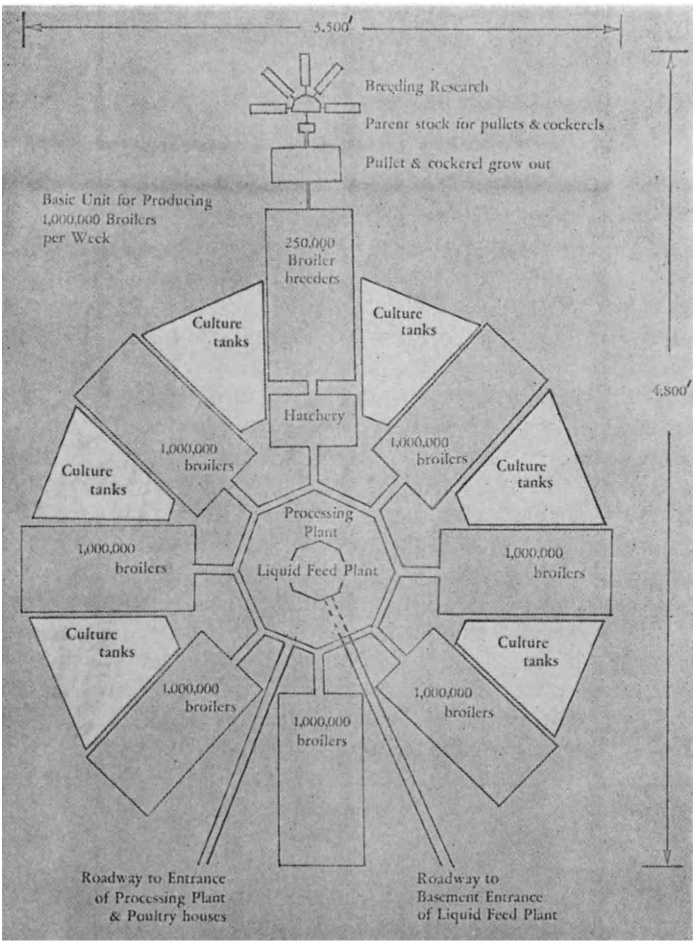

FIG. 119. Farming in 1976.

A far look at broiler production in the States was recently given by Dr. W. H. Garren (1967). He considers that many large broiler concerns will develop gigantic operations, for which purpose it may be necessary to house their stock underground since this would allow a more precise control over certain environmental factors.

The diagram opposite demonstrates how a unit covering 400 acres might produce 1 million broilers a week. To ease the feed-handling situation it is suggested that liquid diets might be used, as this would then give a better control over both nutrient and drug intake. To overcome any shortage of litter materials the broilers might be housed in plasticised tier brooders, a feature which would then eliminate breast blisters.

At killing time the birds would be conveyed automatically to the processing plant in order to eliminate catching, loading and transporting problems. The by-products from the centrally placed processing plant could be pumped to rendering plants outside the unit, or possibly into fish culture tanks.

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