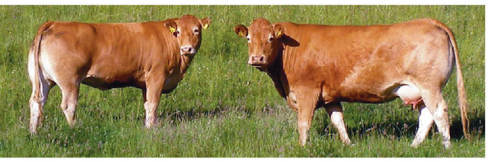
GRACEY'S
MEAT HYGIENE

ELEVENTH EDITION









Edited by

DAVID S. COLLINS

ROBERT J. HUEY

WILEY Blackwell

Gracey's Meat Hygiene

This book is dedicated to the memory of two great veterinarians

Dr Joseph Forde Gracey (1918–2001)
and
Dr James Andrew Storrar (1947–2006)

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Eleventh Edition

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Preface

The aim of the book's authors is to maintain the standard of the previous edition and to produce a textbook which is of practical use to the veterinarian working in the slaughter and meat processing industry.

The world of meat hygiene has undergone a lot of changes since the publication of tenth edition in 1999. While we have introduced the concepts of 'system control' and integrated food safety management, we have kept this to a high level and attempted to keep clear of the legislation which is subject to frequent change.

We have chosen to remove much of the text in the previous edition on animal disease, which is covered more comprehensively in other texts. In chapters on microbiology and pathology, we have also provided details that the front-line veterinarian should know and again concentrated on principles rather than specific detail.

While building on the work of those who have contributed to the previous editions, we have introduced new authors and new chapters to the book to reflect current trends. Chris Loughney builds on the work of Stan Brown in updating the sanitation chapter, Malcolm Taylor assisted with the editing of the work of Bill Reilly and others on microbiology and Glenn Kennedy produced a completely new chapter, with a new approach on the complex area of residues of veterinary medicines and contaminants.

Reflecting the increasing importance and changes in the priorities of society, Rosemary Lee has produced a comprehensive chapter on health and safety for all staff working in the potentially hazardous environment of the meat slaughter establishment. Her practical and authoritative text is a must read for all with a responsibility for management of staff in this workplace.

D.S. Collins & R.J. Huey

Acknowledgements

This edition is dedicated to two public health veterinarians, Dr J.R. (Joe) Gracey and Dr J. Andrew Storrar.

Both these men were passionate about Veterinary Public Health and Animal Welfare.

Joe qualified in 1942 from the Royal (Dick) Veterinary College and after a period in John Boyd Dunlop's private practice, he of tyre fame, in Belfast, served in the Royal Army Corps in Burma during the Second World War reaching the rank of Major.

He obtained his PhD from Queen's University in 1959, having taken the subject of his thesis a survey of livestock diseases in over 600 farms and 18 abattoirs. The abattoir records which he produced were the precursor of the centralised meat inspection recording system which now prevails throughout Northern Ireland. The results were used at that time to identify means of increasing production and furthering animal welfare on farms long before the concept of integrated meat inspection systems had even been considered by other regions.

In 1961, he became Belfast City Veterinarian and was internationally known as an authority on meat hygiene, veterinary public health, animal husbandry, humane slaughter and for his involvement with Belfast Zoo.

He was appointed a fellow of the Royal Society of Health and a fellow of the Royal College of Veterinary Surgeons.

He was also responsible, with others, for the design of the Belfast Meat Plant at the Duncrue Complex which replaced the old victorian abattoir at Stewart Street, Belfast.

Joe was a team player and understood the necessity of bacteriologists, engineers, meat plant operators, farmers, transport and personnel administrators working together to achieve satisfactory outcomes in the running of a food processing business.

It is often said of Joe Gracey that he was a man ahead of his time, and even in semi-retirement, he was pursuing the possibility of better identification and recording of animal disease and production data with the use of the latest developments in computerised information technology.

Throughout his career, he had demonstrated unflagging zeal and infectious enthusiasm for the great benefit of those who had been privileged to work with him and of the veterinary profession as a whole.

Andrew qualified in 1978 from the University of British Columbia at Saskatchewan, Canada. He returned to the United Kingdom where he joined his father's practice in Chester. In doing so, he became the fifth generation to be a veterinarian, one of his sons continuing as the sixth-generation veterinarian.

Andrew became especially involved in meat hygiene when he was the Official Veterinarian for several meat slaughter and processing establishments, one of which carried out slaughter on many casualty animals. This provoked Andrew to explain the welfare applications of handling animals between farm and slaughter with particular interest in farm emergency slaughter. Andrew was the first president of Veterinary Public Health Association to serve for four terms and was for several years the Association's representative of the British Veterinary Association's Animal Welfare Foundation.

Like Dr Gracey, Dr Storrar was also a Major in the Royal Army Veterinary Corps. He served with the corps as a veterinary officer not only in support of the regulars but also in support of humanitarian and emergency relief operations with the UK Civil Affairs Group and within Medical Intelligence.

It had been Dr Storrar's intention to assist the book's authors with the text for the eleventh edition. He commenced this work during his illness which took him from us much too soon.

The authors also wish to thank the many colleagues throughout the 'meat hygiene' community who have assisted with the production of this eleventh edition.

In particular, the authors wish to acknowledge the help and cooperation they received from the many associations, firms and individuals of the previous editions of 'Meat Hygiene' who continued with their support in preparing this eleventh edition.

Members of the Agri-Food and Biosciences Institute, Northern Ireland, were very generous with their time in advising on pathology, bacteriology and animal production. The authors thank Tony Patterson, Helen Hartley, Ronald Annett, Alistair Carson, Francis Lively and Elizabeth Ball. Glenn Kennedy and Malcolm Taylor kindly contributed to sections on residue detection and microbiology respectively.

The staff of the Department of Agriculture and Rural Development for Northern Ireland (DARDNI) have assisted with the production of a number of chapters. Jean Wales, John O'Neill, Pat Treanor and David Cassells assisted with their knowledge of legislation and

operational practice. Anne Lacey helped with the chapter on exotic meat production. The Department's senior Health and Safety advisor Rosemary Lee lent her significant expertise to the new 'Health and Safety' chapter.

Joe Lawson and Mark Elder of Moy Park Ltd., UK, shared their knowledge of poultry matters as did Roy Driessen, Marel Stork Poultry Processing and Margaret Hardy, St David's Poultry Team, Dungannon, UK.

Conor King, Managing Director of Enisca Ltd., an engineering company specialising in effluent and water treatment, lent his significant expertise to the chapter dealing with meat plant infrastructure.

Jim Ross, previously with Food Standards Agency, Northern Ireland, and now with the Food and Veterinary Office of the EU Commission, gave statistical advice.

As longstanding members, past presidents and long-term supporters of the UK Veterinary Public Health Association, the authors have profited from the accumulated knowledge of members and the excellent scientific meetings they organise. In particular, the authors would wish to mention Jason Aldiss, Jane Downes, Kenneth Clarke and Milorad Radakovic. In addition, advice on practical meat hygiene was offered by members of the Association of Meat Inspectors, particularly Peter Watson and Ian Robinson.

The development of digital photography has permitted additional illustration of this edition with again a significant contribution being made by staff from the DARDNI, namely Graham Fallows, John Hood, Harold Moore, Sarah Jackson, David Armstrong and Stephen Coogan. The authors are also grateful to all those who provided useful photographs which have not been included either due to space constraints or due to difficulty in making the illustrations relevant to the text.

Illustrations and advice have also been received from Karen von Hollenberg, Hal Thompson and Ron Siddle.

Finally, authors David and Robert both wish to thank their long-suffering families who had to withstand years of evenings, weekends and holidays in the company of 'the book'. In particular, Peter Huey, Robert's son, is acknowledged, who with his knowledge of IT helped to get this work over the line.

1

The food animals

HEALTH is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.

World Health Organisation chronicle (1978)

Meat is normally regarded as the edible parts (muscle and offal) of the food animals which consume mainly grass and other arable crops, namely, cattle, sheep, goats, pigs, horses, deer, reindeer, buffalo, musk oxen, moose, caribou, yak, camel, alpaca, llama, guanaco, vicuna, etc. In addition, poultry have become a major meat-producing species, while rabbits, guinea pigs, capybara and various game animals and birds provide a substantial amount of protein, particularly in localised areas. Fish and other seafood have also been an important part of man's diet since earliest times.

Although, theoretically, hundreds of animals could supply meat for human consumption, in practice, only a relatively small number of species are used today. This is all the more remarkable since it represents in general the instruction of the Levitical law of the Old Testament, most of which is in accord with modern sanitary science. The animals suitable for the food of man had to part the hoof and chew the cud. Only those fish with fins and scales were wholesome. It is true that today we eat pig, rabbit and hare, but it is recognised that they are subject to parasitic infestation. There appears to be little doubt that the dangers of trichinosis and of Cysticercus cellulosae were recognised 1400 years before the birth of Christ. In many parts of the world, horseflesh forms an important article of human diet. The Danes reintroduced the consumption of horseflesh into Europe during the siege of Copenhagen in 1807; slaughter of horses for human consumption is now well established in Denmark, Belgium, Holland and Germany.

All the above animals, including fish, are converters, that is, they utilise green vegetable material with varying efficiency to produce protein. Even micro-organisms can be classified as converters in that they use carbohydrates from plants to make protein from simple nitrogenous compounds. Especially when an animal eats something which is inedible for man or could not easily be made into food for man, it is considered valuable as a source of food; so when pigs and poultry, and even other animal species, are used as scavengers to eat scraps, by-products, etc., they are very useful indeed. However, when food which could be utilised by human beings is fed to livestock, the question of efficiency becomes more problematic. Nevertheless, other factors, such as the production of manure for fertiliser usage, variety in the human diet, etc., have to be borne in mind.

Not only did the Creator command the earth to 'bring forth grass, the herb yielding seed and the fruit tree yielding fruit after his kind' (Genesis 1:11). He also 'made the beast of the earth after his kind, and cattle after their kind, and everything that creepeth upon the earth after his kind' (Genesis 1:25). For both plant and beast, 'God saw that it was good' (Genesis 1:12 & 25). They were both to be used as food for man.

In more recent times, efforts have been made to domesticate certain *wild animals*, although many of these have been used as food since ancient times. In Africa and Russia, elands are being domesticated, as well as antelope in the latter country. Kangaroos are being kept for meat in Australia, and in South America, the large rodent capybara, which is a semi-aquatic vegetarian, is being used as a source of meat, although it is not especially palatable. There are probably many other wild species which could be utilised in meat production and would have some advantages over the domesticated

Gracey's Meat Hygiene, Eleventh Edition. Edited by David S. Collins and Robert J. Huey.

animals since they exist on less valuable land, need only rough grazing, are more disease resistant and act as a tourist attraction. Some problems, however, arise in connection with feeding, protection from predators, slaughter and meat inspection.

Recent innovations have included the breeding of wild boar in England and buffalo in Germany, France and Poland. Wild boars introduced from Germany and Denmark into England are used to produce purebreds as well as crosses with established breeds of pigs. Differences in quality and flavour are said to exist between the wild variety and the various crosses. Litter sizes average six piglets and only one litter is produced yearly. Slaughtered at 12–14 months, wild boar has a live weight of about 59 kg and a dead weight of around 45 kg. The meat is very lean with an acceptable flavour, but stress is sometimes associated with abattoir slaughter, which may necessitate on-farm handling. In Great Britain, the keeping of wild boar is subject to the Dangerous Wild Animals Act.

Buffalo meat is said to be more tender, leaner and gamier than beef, with lower levels of cholesterol. Although expensive in France, it is cheaper than beef in Canada. The name buffalo is often applied to the bison (*Bison bison*) of North America, a different species of the order Bovidae. There are several species; the Indian buffalo (*Bubalus bubalis*), sometimes called the water buffalo or arna, is the only one to be domesticated. It is found in many parts of the Old World, with significant numbers in Hungary, Italy and France.

The future for meat and meat products will depend mainly on consumer demand and the prices at which they can be profitably produced. As living standards rise, so also does the consumption of meat. Factors such as the cost of production, feed conversion efficiency, land use and availability, consumer taste, price to consumers, diet, attitudes of people to meat production methods, use of protein from non-animal sources, etc. will all play a part in determining future demands.

Procedures such as genetic engineering, embryo transfer, sexed semen, cross-breeding and twinning will continue to be utilised in attempts to produce more productive livestock with improved milk and meat quality. But if close attention is not paid to the vital importance of disease resistance, we may well see the development of stock susceptible to existing and novel conditions, some of which may have serious public health implications. Consumer attitudes must always be borne in mind by research workers and those engaged in the agriculture and food industries, which will only prosper in a climate of real consumer confidence in the quality and safety of food.

In order to address this point, much food from animals is produced under 'Farm Quality Assured Schemes'. These provide customers with some assurance that the animals have been reared in a manner which involves animal welfare and environmental issues and are fit to produce wholesome, safe food products. This complements the 'farm-to-fork' approach to meat production with control over all the nutritional, welfare, housing and other management factors, as well as ensuring the traceability of the food product. Veterinarians have a pivotal role in this discipline, both on the farm and at the meat plant.

Dietary factors

Concern about the amount of fat, especially saturated fat, in the diet, has been given prominence in the Western world due to the adverse effects on human health. According to the Living Costs and Food Survey (2011), the amount of dietary energy derived from fat was 38.1% for UK adults, with 14.2% of this energy being from saturated fats. While these values are lower than 20–30 years ago, the amount of fat in British diets is still higher than current recommendations. The Scientific Advisory Committee on Nutrition (SACN) states that the amount of dietary energy derived from saturated fat should not exceed 11%.

Steps have been taken to have legislation which require total fat and saturated fatty acid content labelling on a wide variety of foodstuffs. While much of the intake of fat is derived from milk and dairy products, meat and meat products, margarine, cooking fat and salad oils, some comes from vegetable sources, where it is either produced in a saturated form, for example, coconut oil, or converted into such during manufacture. An increase in dietary unsaturated fatty acids has been shown to reduce the risk of cardiovascular disease (CVD) and possibly some cancers, asthma and diabetes. It is possible to modify animal diets to increase the amount of unsaturated fatty acids in meat, milk and eggs and to decrease the n-6:n-3 fatty acid ratio (Woods and Fearon, 2009).

The sources of fat in the average British diet are given in Table 1.1.

If people respond to the SACN recommendations and there are indications that this is already the case, there will be major changes in food consumption which will inevitably have an impact on production methods in agriculture, especially in milk and livestock production, despite the fact that not all is known about the aetiology of the most common cause of death in most industrialised countries. In the United Kingdom, in 2006, 30% of all deaths in men and 22% of all deaths in women under 75 were ascribed to CVD. Factors such as heredity, blood pressure, obesity, blood haemostasis, physical inactivity, water hardness, smoking and alcohol consumption are also involved in the causation of this serious condition.

Table 1.1 Average British diet fat consumption (g/person/day) (FAOSTAT) 2009

Food group	Consumption (g/person/day)
Milk and dairy products (excluding butter)	21
Meat	36.5
Fish	1.5
Eggs	2.8
Total fats (including butter and vegetable oils)	60.3
Fruit	0.7
Vegetables	0.5
Cereals	4

Source: Reproduced with permission from FAO (2011). © FAO.

Consumer demand is now for leaner meat in smaller, waste-free cuts, which is easy and quick to prepare. On the livestock breeding and rearing side, changes have taken place with emphasis on animals which produce leaner carcases. Appropriate grading and certification standards are applied in meat plants. Quite apart from the health aspect, overfat stock are too costly to produce, and farmers will have to realise that energetic competition will have to be faced from vegetarians (sincere and insincere), 'animal welfarists' and a wide range of branded convenience and 'health foods', many not based on a meat content.

In the United Kingdom, the annual consumption of meat and meat products, which represent about 26% of the total household expenditure on food, amounted to approximately £16 037 million in 2011.

It is estimated that only 60% of the world's population eats 18 kg or more of meat per year, which is regarded as the nutritional minimum. The remaining 40% represents some 1500 million people who consume less than this amount. This stark fact is exemplified by countries in equatorial Africa and OPEC where the average annual consumption is only 10 kg per head and in the underdeveloped countries of Asia where it is as low as 3 kg. Table 1.2 shows the average annual meat consumption per person in the European Union (EU) (FAOSTAT).

World livestock production

In general, those countries with the highest meat consumption rates are also the major producers. Some parts of the world such as Argentina, Australia, New Zealand and Denmark are large exporters of meat and meat products, while the United States, Britain and Germany import large quantities, although the former also have a considerable export trade as have many other countries.

Table 1.2 Annual consumption of meat in the EU (kg/person/year) (FAOSTAT) 2009

	Bovine	Sheep and goat	Pig meat	Poultry
Austria	16.4	1.1	65.6	17.9
Belgium	18.0	1.6	33.6	21.5
Bulgaria	4.9	1.7	23.4	21.4
Cyprus	5.8	6.0	37.6	26.9
Czech Republic	8.0	0.2	44.7	25.1
Denmark	26.0	1.1	48.3	18.9
Estonia	12.5	0.6	26.8	19.4
Finland	18.2	0.5	35.5	18.8
France	25.5	3.3	31.0	22.3
Germany	12.8	0.8	54.6	17.3
Greece	18.1	13.1	27.7	13.7
Hungary	4.6	0.1	43.8	26.4
Ireland	22.1	4.2	33.6	26.0
Italy	23.6	1.3	42.8	17.3
Latvia	6.5	0.3	34.8	19.5
Lithuania	4.6	0.2	50.6	22.6
Malta	20.7	1.5	30.5	26.0
The Netherlands	18.1	0.9	34.0	22.7
Poland	4.9	0.1	50.4	21.4
Portugal	18.3	2.4	42.9	28.7
Romania	7.8	3.2	31.9	21.0
Slovakia	5.0	0.2	36.2	17.4
Slovenia	20.8	1.0	39.5	26.5
Spain	14.3	2.8	48.9	27.5
Sweden	24.9	1.4	36.0	15.4
United Kingdom	19.8	5.29	26.2	32.2

Source: Reproduced with permission from FAO (2011). © FAO.

Many factors operate to determine levels of food animal populations, economics playing the principal role, but disease outbreaks, weather conditions, overproduction, consumer preference, feed availability, etc. are also important reasons, along with trade barriers imposed by individual states, often on ill-defined, even unjustified, grounds.

Beef production globally, in the next 20 years, is expected to rise by only by 6%: 61 million tonnes carcase weight in 2010 and 64.5 tonnes in 2025.

Sheep meat production on a global basis is rising slowly, primarily as a result of rising production in China. Expected improved world prospects for the wool trade had encouraged extra production in Australia. In eastern Europe and countries of the former Soviet Union, production continues to contract. World pork consumption has increased by 27% from 1997 to 2005 with China being the largest producer (Orr and Shen, 2006).

Poultry production continues to expand throughout the world, but growth rate has slowed somewhat in the

past year. Annual poultry meat production was reported to be 79.4 million tonnes in 2008 (FAOSTAT).

UK meat plants and throughputs

In 2008, 28.8 million animals (cattle, sheep and pigs) were slaughtered in the United Kingdom (Department of Food and Rural Affairs (DEFRA), 2008). Latest estimates indicate that there are approximately 360 abattoirs in the United Kingdom which is a significant reduction from the level of 2062 abattoirs, reported in Great Britain alone in 1968 (see Table 1.3, Table 1.4 and Table 1.5).

Cattle

In 2011, the world cattle population was 1399.9 million with 195 million buffaloes (Food and Agriculture Organisation of the United Nations (FAO), 2011). The numbers in the main countries are as follows (in millions): Brazil, 212.8; India, 210.8; United States, 92.7; China, 83; and Ethiopia, 53.4.

In the United Kingdom, beef and milk account for about one-third of the total agricultural output. Britain now produces almost 80% of its beef requirement, compared with about 50% just before the Second World War. The remaining 20% is imported mainly from Ireland and Argentina. About 52% of the home-produced beef is derived from the dairy herd, that is, from calves reared for beef. Specialised beef cattle and their crosses provide 48% of the home kill.

Table 1.3 Total throughputs (2008) in the United Kingdom

Animal group	Number slaughtered ('000)
Cattle	
Prime cattle (steers, young bulls and heifers)	2 028.4
Adult cattle (cows and adult bulls)	559.2
Steers	999.2
Heifers	758.9
Young bulls	270.3
Cows	541.4
Adult bulls	17.8
Calves	44.2
Sheep	
Ewes and rams	2 344.5
Other sheep and lambs	14 352.4
Pigs	
Sows and adult boars	235.0
Clean pigs	9 191.8

Source: Reproduced with permission from DEFRA (2008). © DEFRA.

Breeds

In Britain's dairy herd, the Holstein/British Friesian is the dominant breed. About one-third of mature dairy cows and almost half of the dairy heifers are mated with beef bulls, mostly Limousin and Angus and a smaller proportion with Belgian Blue due to concerns regarding incidence of calving difficulties with the latter breed, in order to increase the beef potential of calves not required as dairy herd replacements.

Exotic breeds have been introduced into the United Kingdom in an attempt to improve beef production. The first of these (in 1961) was the French Charolais, which is typical of the large cattle breeds of western Europe with their mature body size, rapid growth rate and lean carcases. Charolais and Belgian Blue, are, however, liable to some difficulty in calving, often necessitating caesarean section, but this is apparently regarded as an acceptable risk by many farmers. British Charolais, through selective breeding, have easier calvings.

Other breeds which have been imported include Blonde d'Aquitaine, Brown Swiss, Limousin, Murray Grey (which was developed in Australia but has been in the United Kingdom for decades and is now widely considered to be British), Piedmontese, Romagnola, French Salers and Simmental. The Luing was evolved from Beef Shorthorn and Highland cattle on the island off the west coast of Scotland.

British breeds have been exported to many other countries to improve local strains, as live animals, frozen embryos or semen.

Throughout the world, there are numerous breeds of domestic cattle used for meat and milk production and also in some cases as draught animals (see Fig. 1.1, Fig. 1.2, Fig. 1.3, Fig. 1.4, Fig. 1.5, Fig. 1.6 and Fig. 1.7 for cattle bred for beef). Most are humped Zebu cattle or cross-breeds of these with cattle of European origin. In addition, the domestic buffalo, the water buffalo of Asia,

Table 1.4 Throughputs in the United Kingdom by species in 2009

Species	England	Scotland	Wales	Northern Ireland	Total
Cattle	1 467 185	499 811	144 856	453 726	2 565 578
Sheep	9 509 298	1 527 533	3 933 577	582 299	15 552 707
Pigs	7 025 834	592 898	30 198	1 354 767	9 003 697
Poultry	694 773 788	50 654 143	47 734 287	102 076 083	894 238 301

Table 1.5 Numbers of approved red meat slaughterhouses (RSL) and poultry meat slaughterhouses (PSL) in the United Kingdom in 2009

Type \ Country	England	Scotland	Wales	Northern Ireland	Total
RSL	207	37	25	13	282
PSL	74	5	4	7	90
Number of establishments	281	42	29	20	372

Source: Reproduced with permission from United Kingdom Food Standards Agency. © DEFRA.

Figure 1.1 Friesian bulls.

Figure 1.2 English Longhorn.

Figure 1.3 Blonde D'Aquitaine.

is an animal of great importance mainly in the Far East (India and China) but is also found in the Caribbean, Middle East and the former USSR (it has to be distinguished from the buffalo of North America, which is not a buffalo at all but a bison, and from the African wild buffalo, which has never been domesticated). Many consider that the full potential of the water buffalo as a meat and milk producer has not yet been realised. A breed of Droughtmaster cattle (*Bos taurindicus*) has been developed by cross-breeding the Zebu or Brahman

Figure 1.4 Hereford.

Figure 1.5 Salers.

Figure 1.6 Simmental.

(*Bos indicus*) of the tropics with British beef breeds, notably Shorthorn and Hereford (*Bos taurus*). The Droughtmaster is said to combine the hardiness and disease resistance of the Zebu with the productivity

Figure 1.7 Limousin.

and early maturity of the British breeds. Since 1974, Droughtmasters have been exported from Australia to many tropical countries including Nigeria, Ghana, Pakistan, New Guinea, Solomon Islands and Taiwan.

Systems of beef production

Beef production systems vary from almost range conditions to semi-intensive and intensive units. The efficiency of animal production is the ratio of output to input: the main outputs are meat, milk, hides, fur and by-products, and the principal inputs are feed, land, labour, capital, energy and water.

In the United Kingdom, consumer demand has dictated that meat be lean with a minimum of fat cover, tender, nutritious, palatable and, not least, relatively inexpensive. Accordingly, it is now the custom to slaughter not only cattle but all animals and poultry at much earlier ages. The economically important beef production systems in Britain usually involve slaughter of cattle at between 15 and 24 months of age. Even lower slaughter ages are adopted for certain specialist beef systems; for example, in the so-called barley beef system, calves are weaned early and fed concentrates ad lib to slaughter at 11 months of age and 400 kg, with an overall feed conversion ratio of 5.5:1. At the other extreme, there may be a high utilisation of grass with a lower overall live weight gain, with animals slaughtered at 2 or more years of age at carcase weights of 499 kg and over. A popular intermediate system is 18-month beef in which autumn-born calves are fed through the winter, kept on grass from 6 to 12 months of age and then finished during their second winter on hay, silage and feed grains.

In Britain, the term 'fatstock' used to mean exactly what it said. The meat industry was traditionally based on well-finished animals with substantial fat depots. However, the term fatstock is no longer appropriate;

'leanstock' or 'meatstock' is more suitable. Changes in the grades of fatness of livestock will probably be promoted by the production of intact males; use of bulls for larger, leaner, late-maturing breeds on the dairy herd; and genetic selection of types with efficient feed conversion rates, rapid growth rates and less fat.

Most male cattle in Britain today are reared as castrates (steers or bullocks) (80% of male cattle are reared as castrates), with the remaining 20% finished as young bulls, and these percentages have remained constant over the period 1998–2008 (DEFRA, 2008). The practice of castration was adopted to prevent indiscriminate breeding, to make animals more docile and less dangerous to man and to facilitate fattening. Only the latter factor can be regarded as significant today, since modern husbandry methods for the most part eliminate the breeding problem and present consumer demand is for lean meat. While bulls are more dangerous to handle than steers, experience has shown that the problem has been over-emphasised. It has also been well demonstrated under experimental and practical farm conditions that bulls grow faster (by 12%), convert food more efficiently (by 8%) and produce heavier (by 10%) and leaner carcases than steers. Bull beef production is much more important in Europe, especially in Italy, Germany and eastern Europe, than it is currently in Britain.

In Europe, bulls are reared in intensive feedlot systems largely based on maize silage and also in grass-finishing systems with slaughter ages of 24–30 months. The main breeds are Simmentals and Friesians. In New Zealand, grass-finishing systems have been used over the last 25 years.

In the period from 1985 to 2005, the production of bull beef in the United Kingdom increased by 66%. However, between 2005 and 2008, production has decreased by almost 40% (DEFRA, 2008). Some sections of the meat trade have considered bull beef to be of inferior conformation and tenderness as well as being subject to dark, firm and dry (DFD) meat. However, trials have shown most of these objections to be ill judged. In fact, young bull carcases are heavier and leaner than steers of the same age. Careful handling of young bulls will obviate the DFD problem (which is not confined to bulls), and chilling efficiency will offset any tendency to meat toughness, bull beef being inclined to cool more rapidly than steer beef.

Young bull beef must be distinguished from the inferior product supplied by old cull bulls, which is much darker in colour. Investigations by the UK Meat and Livestock Commission on groups of young bulls and steers transported and slaughtered under comparable commercial conditions have shown that bull flesh is only marginally darker than that of the steers, and there are only a few dark cutters among the bulls. The solution is to avoid pre-slaughter stress by gentle, efficient handling, keeping social groups intact and providing for immediate slaughter. Some of the other meat trade criticisms can be ascribed to pure conservatism. In the United Kingdom, full use is made of grassland and grass products in cattle-rearing systems, unlike in certain EU countries, for example, Germany, where bulls are housed for beef production. In the United Kingdom, prime stock is 49.3% steers, 13.3% young bulls and 37.4% heifers. In Europe, over 50% of prime stock is young bulls.

Growth promoters

Probiotics are benign bacteria which are administered by mouth to animals (calves, lambs and piglets) sometimes at birth and/or after disease. The introduction of a probiotic into the digestive tract is claimed to ensure more efficient feed conversion, earlier slaughter and a healthier animal. Unlike antibiotics, which often kill useful intestinal micro-organisms and create undesirable residues, probiotics are said to be natural products without any side effects.

Prebiotics are ingredients that stimulate the growth and/or function of beneficial intestinal micro-organisms.

Definitions

Bull

An uncastrated bovine.

Heifer

A female up to its first calf.

Cow

A female which has had one or more calves.

Steer or bullock

A castrated male (usually castrated at 6–12 weeks old).

Stag

A male bovine castrated late in life, therefore presenting a more masculine conformation than the bullock.

Sheep

Figures produced by FAO (2011) indicate that there are 1.04 billion sheep on a global scale. The principal sheep-producing countries in the world are the following (in millions): China, 138.8; India, 74.5; Australia, 73; Sudan, 52; Iran, 49; the United Kingdom, 31.6; New Zealand, 31.1; Pakistan, 28; Ethiopia, 25.5; South Africa, 24.3; Turkey, 23; and Spain, 17.

Sheep were probably among the first animals to be domesticated by man. They can be found under a wide range of environments throughout the world, and, just like goats, their system of husbandry has changed very

little over the centuries in most countries. In the main, this can be classed as an extensive grazing system, the most natural for the three main species of meat animals: cattle, sheep and pigs. This system probably explains why sheep have the fewest lesions and condemnations at post-mortem compared with cattle and pigs, at least under UK conditions.

Various breeds are adapted to living in areas of high altitude where wind, rainfall, low temperatures and snow are common. The hill ewe lives a very hazardous life exposed to these adverse elements, and with low food intake, especially during pregnancy, it is little wonder that up to one-third of body weight can be lost and that neonatal mortality is high. Indeed, of all the farm animals, the relative mortality rate is highest in sheep. Other breeds can be found in desert or semi-desert regions where high temperatures or fluctuating high and low temperatures predominate, with arid conditions and sparse vegetation. With some breeds, such as those kept under lowland conditions in Britain, stocking rates can be as high as 20 ewes and their lambs per hectare; under hill and other extensive systems, the rate may be as low as one sheep to 20 hectares.

The quality of forage consumed by sheep varies from good grass under semi-intensive husbandry to low-quality (high-cellulose) plants, such as thorn scrub, rushes and heather, where the stock are relatively few in number. The ability of sheep to eat plants of little use to man and to survive in places which cannot easily be cultivated is very much in their favour. On the other hand, except for specialised breeds like the Finnish Landrace and Russian Romanov, which can produce over three lambs per ewe a year, low reproductive rates, difficulties with husbandry (e.g. fencing and labour) and the disposition towards carcases of fairly high fat content are definite drawbacks. It has been shown that with housing of ewes and subjecting them to artificial photoperiods and hormone treatment, they can produce a lamb crop every 8 months and an average of 2.2 lambs per ewe yearly. Unless fecundity can be improved by suitable breeding methods and leaner carcases ensured, it is possible that in many hill areas sheep may be replaced by goats or deer.

In addition to meat, sheep produce wool and, in some countries, milk, which is used in the making of cheese.

In the United Kingdom, there are some 50 breeds of sheep classified by habitat and type of wool. They are kept mainly for meat production, with wool as an important secondary product. Two major systems of sheep farming exist: hill sheep farming, by far the larger of the two, where the sheep are hardy and thrifty, small in size, long of wool, late in maturity and low in fecundity; and lowland sheep farming, in which short-woolled breeds predominate, possessing characteristics of early maturing, higher carcase weights and superior lambing percentages.

True hill breeds include the North Country Cheviot, South Country Cheviot, Scottish Blackface, Swaledale, Welsh Mountain, Exmoor Horn, Herdwick, Rough Fell, Derbyshire Gritstone and Lonk. Hill flocks provide store stock for fattening on lowland farms along with cast ewes which are retained for a year or two for further breeding. The famous Halfbred, which is the product of the Border Leicester ram and the Cheviot ewe, is one of the foremost utility sheep in Britain. Although the flesh of the Border Leicester carries an excessive amount of fat, its prolificacy and milk yield potential when blended with the hardiness of the Cheviot make the resulting cross an excellent animal, the dams bred to Down rams being very popular for fat lamb production in lowland areas. Another example of this close association between hill and lowland breeds is the use of the Border Leicester ram on Scottish Blackface ewes, the cross being known as the Greyface. Another Halfbred, the Welsh Halfbred, results from the crossing of the Border Leicester with Welsh Mountain ewes. The Mule is a cross-bred ewe which has grown in popularity in the United Kingdom; it now makes up 20% of the UK ewe flock. The term Mule covers a number of Blue-faced × hill breed ewe crosses. The most common of these are the Blue-faced Leicester × Scottish Blackface cross and the Blue-faced Leicester × (Welsh) Hardy Speckled Face. Reported prolificacy levels are higher in Mules than Greyfaces. Where certain hill sheep, for example, Scottish Blackface ewes, are grazed on lowland pastures, the good feeding can result in up to 200% lamb crops.

Lowland breeds are represented by the short-woolled downland types (the Suffolk, Dorset Horn and Dorset Down, Southdown, Oxford Down, Ryeland and Shropshire) and the long-woolled breeds of Leicester (Lincoln Longwool, Kent or Romney Marsh, Wensleydale and the Blue-faced or Hexham Leicester). The three most common terminal sires used in the industry at present are Suffolk, Texel and Charolais.

The Dorset Horn, a white-faced short-woolled sheep, has a much-extended mating season and can produce three crops of lambs in 2 years. In this way, it resembles the Merino. Breeds like these along with Finnish Landrace (high prolificacy), East Friesland (good milking potential) and the Île-de-France (excellent carcase quality) could feature in cross-breeding programmes. It is possible that many of the present British breeds may disappear with the development of new hybrids: it is certain that some 50 breeds are unnecessary for successful sheep production. Indeed, this has already taken place with the appearance of the Colbred sheep, named after Oscar Colborn, a Cotswold farmer who crossed Cluns, Dorset Horns, Suffolks and East Frieslands in order to

increase fecundity, mothering ability and carcase quality. More recently, French Texels, Beltex, Berrichon du Cher, Rouge de l'Ouest and Charolais have been imported for crossing purposes. The Cambridge breed of sheep is another recently developed breed which is very prolific.

British breeds of sheep are not found extensively in Europe, although Cheviots and some lowland types occur in Scandinavia, but many have found their way to other parts of the world. In Australia, about 75% of the 126 million sheep are Merinos, the remainder being crosses with certain British breeds. In New Zealand, the Romney Marsh predominates, followed by Corriedales, Merinos and Southdowns and their crosses. In the United States, the Rambouillet is the main representative of the Merino, and a lot of cross-breeding occurs, with larger sheep units under confined systems of management becoming more important. However, it is doubtful whether sheep grazing in the United States will expand very much. In South Africa and the USSR, the most important breed is the Merino. Fat-tailed and fat-rumped sheep are found in the Middle and Far East; the Awassi breed is an important coarse wool type in the eastern Mediterranean and Iraq, where the wool is used mainly for making carpets.

In some parts of Europe, milk or dairy sheep are of significance: the common breeds are East Friesland (Holland), Cochurro, Lancha and Mancha (Portugal and Spain).

In recent years, more attention is being given to the production of fine wools, cashmere and mohair which the textile industry needs and presently has to import. In addition to sheep, Angora goats and rabbits, alpacas and llamas also produce quality fibres. Judicious crossing of British sheep with Merinos, for example, Merino de l'Ouest from France, produces sheep capable of high lambing percentages, good growth rates and carcase quality as well as fine fleeces.

In addition to better feeding methods, improvements in sheep production are currently centred on the use of hormones to increase the number of lambs born and out-of-season lambing, hybridisation to produce a superior stock of leaner types, oestrous synchronisation, early weaning and artificial rearing of lambs. Intensification on grass and fodder is possible as long as farmers are aware of the problems involved.

In the United Kingdom, the demand for young and small carcases means that lamb is the more important product. Lambs are usually slaughtered at between 36 and 50 kg live weight giving a dressed carcase of 17–23 kg. 'Mutton' is derived from lambs not attaining a finished condition before weaning and from ewes, wethers, hoggets and rams.

As in the case of cattle and pigs, use has been made of entire ram lambs to produce leaner carcases. Work carried out at the Meat Research Institute, Bristol, and in New Zealand has shown that carcases from entire ram lambs grade about one fat class lower than those from ewes at the same weight without deterioration in eating quality. The entire ram lambs had lower values of subcutaneous and intramuscular fat, and a higher proportion of the total fat in the rams was deposited subcutaneously where it can be removed by trimming – an important commercial consideration. Some 30% of the New Zealand kill is now composed of entire ram lambs, non-castration being encouraged.

Research work on carcase and meat composition and tenderness of meat from ram, wether and ewe Dorset Down-cross and Suffolk-cross lambs slaughtered at 20 weeks of age showed that differences in meat quality were very small, tenderness of ram meat being ensured by efficient refrigeration control. The fact that the rams, especially the Suffolk crosses, grew faster, yielded larger joints and had good carcase conformation in addition to meat tenderness would indicate potential for ram lamb production in the United Kingdom (Dransfield *et al.*, 1990). When the adverse aspects of castration – namely, sepsis, which often leads to pyaemia and sometimes death – the improvement in welfare and labour and equipment costs are considered, the lead given by New Zealand would seem a good one to follow.

The desirable features required by the butcher in both lamb and mutton carcases of any breed are short stocky plump legs, thick full loin, broad full back, thick fleshy ribs with a wide breast and shoulder, a good depth of chest cavity, a short plump neck and overall lean content (Fig. 1.8, Fig. 1.9 and Fig. 1.10).

Definitions

Lamb

A sheep from birth to weaning time (generally at 3½–4½ months old). Butchers apply a more generous interpretation to the term 'lamb' and use it to denote a sheep from birth until shearing time the following year; by this interpretation, a sheep 13 months old is still classed as lamb.

Hogget

A 'lamb' in its second year, often with two permanent incisors replacing the lamb teeth.

Tup or ram

The uncastrated male.

Wether

The castrated male sheep (usually castrated before 1 week of age with a rubber ring or at 3 weeks to 3 months old by other methods).

Figure 1.8 A ewe and lambs.

Figure 1.9 A Blackface ram.

Gimmer

A female which has not yet borne a lamb.

Ewe

A female which has borne lambs.

Cast ewe

One which has been removed from the breeding flock.

Pigs

According to the most recent world census data, 2011, there were 963 million pigs worldwide. The leading 12 pig-producing countries in order of numbers slaughtered are the following (in millions): Republic of China, 672.3; United States, 111; Germany, 59.7; Vietnam, 44.2; Spain, 41.7; Brazil, 34.9; Russian Federation, 29; France, 24.8; Philippines, 24.3; Poland, 22; Denmark, 20.9; and Japan, 16.4. The number of pigs slaughtered worldwide was 1382.6 m (FAOSTAT). Over the past decade, pig production in China, the United States and Vietnam has grown significantly. In 1997, in the Netherlands, a severe outbreak of classical swine fever led to a major culling programme which removed 40% of the Dutch annual production (6% EU total annual output) during that year. Since then, the Dutch government has decided to introduce stringent new legislation which limits the size of the national herd to 80% of the 1996 herd size.

Pig breeds

A breed is defined as 'A group of animals that has been selected by man to possess a uniform appearance that is inheritable and distinguishes it from other groups of

Figure 1.10 Sheep being moved into lairage.

animals within the same species'. In essence, a breed relies on being recognisable because it possesses a number or combination of features, for example, coat colour, body conformation, head shape, etc.

As the pig was domesticated, it was selected for a variety of different characteristics such as fertility, mothering ability, muscle and fat deposition, durability and amenability to handling under a variety of husbandry systems. This process continues today on two distinct levels. There are those who breed *pedigree* pigs with the aim of preserving the 'purity' of their breed and the *commercial* pig-producing companies and pig farmers who use cross-bred varieties to utilise hybrid pigs to optimise production traits. Through selection, there are now estimated to be some 300 different breeds of pigs.

Unlike some species, the pig has suffered little from man's selection to maximise production and appearance. The most noted exception was the introduction of the halothane gene following the introduction of the Piétrain breed. This breed was chosen with the aim of increasing muscle production via the double muscle gene carried naturally by the Piétrain breed. However, pigs which carry the double recessive halothane gene tend to drop dead if stressed, and those that do survive and are slaughtered express a high frequency of pale, soft and exudative (PSE) muscle tissue such that the meat appears pale and suffers from high drip loss, making it less suitable for processing and sale. For many years after this gene was introduced, the commercial breeding companies tested breeding stock by exposing all potential breeding pigs to the anaesthetic gas halothane because it was found that if 10-week-old pigs which were double recessive for this gene were exposed to this gas, they would become rigid; pigs not carrying the gene retained a relaxed posture. Recently, a gene probe has been developed which is cheaper and more welfare acceptable. This new test has also made it possible for the breeding companies to retain some of the benefits of this gene in terms of muscle production without the risk of pigs being stress susceptible and producing PSE meat.

More recently, breeding companies in the United Kingdom and France have imported and experimented with genes introduced by crossing European breeds with the Meishan breed which originates in China. The Meishan is a highly prolific breed with the potential of producing up to 30 piglets per litter. The aim is to introduce the genes for prolificacy while retaining the leaner carcase characteristics of the European breeds.

Pig breeds in the United Kingdom

In the United Kingdom, pedigree pig breeding is carefully recorded by the British Pig Association (BPA), which began keeping breeding records in 1884 when the association was known as the National Pig Breeders Association (NPBA). The aim of the NPBA was to 'maintain the purity and improve the breeds of swine in the United Kingdom of Great Britain and Ireland by the means of livestock inspection and herdbook recording all pedigree pure-bred pigs'.

Figure 1.11 Middle White.

Today, the BPA recognises 14 pedigree pig breeds: Large White, Landrace, Welsh, Berkshire, British Hampshire, British Saddleback, Duroc, Gloucester Old Spot, Large Black, Middle White, Tamworth, Mangalitza, Oxford Sandy and Black and Piétrain (Fig. 1.11, Fig. 1.12, Fig. 1.13 and Fig. 1.14). The main breeds used commercially are Large White, Landrace, Duroc, Hampshire and Piétrain.

Commercial breeding companies in the United Kingdom supply approximately three-quarters of all the replacement gilts bought by commercial pig farmers. These companies use pedigree pigs at the top of their breeding pyramids to produce cross-bred grandparent and parent pigs.

Increasingly, the force which has been driving the selection made by the breeding companies is coming from the retail sector where the demand is for a leaner, 'healthier' carcase which produces a tender, succulent meat not showing signs of PSE or excessive drip loss and which has sufficient intramuscular fat to provide flavour. Added to this is a new demand which places emphasis on the production system used, with the requirement being for what are termed 'high-welfare' production systems but which equate to loose housing systems. These demands influenced the choice of breed used by the breeding companies in their breeding programmes. For example, although the traditional crosses of the White breeds still account for 84% of all commercial indoor production, sales of Duroc crosses to produce hardier pigs, more suited to the more demanding outdoor environment, are on the increase.

Pig production

The United Kingdom, with some 25% of its pigs outdoors, has the highest percentage of *outdoor production* in Europe. The availability of suitable outdoor sites will

Figure 1.12 Gloucester Old Spot sow and litter.

Figure 1.13 Saddleback.

probably limit further development since pig welfare can be severely compromised if pigs are put on to sites where the rainfall exceeds 750 mm/year and the land is not free draining or relatively flat. In fact, much of the outdoor rearing of pigs has now ceased in the United Kingdom since farmers have discovered that the environmental conditions were too severe and too difficult to manage.

European Council Directive 91/630/EEC set out the 'minimum standards for the protection of pigs'.

Figure 1.14 Large Black.

This legislation was incorporated into UK law by SI 2126 'The Welfare of Livestock Regulations 1994'. However, the UK legislation not only implemented the European Directive but added the abolition of stalls and tethers by 1 January 1999. Some of the other European countries decided to address other aspects of production; for example, in the Netherlands, fully slatted flooring systems were phased out by 2006.

The imposition of legislation on production inevitably affects the way pigs are produced. European legislation has been passed in an attempt to reduce the environmental impact of agriculture: Integrated Pollution Prevention and Control Directive (IPPC Directive 96/61/EC) and the Nitrates Directive (Directive 91/676/EEC). The IPPC Directive aims to reduce all pollution emissions to air,