Meat and Meat Products

Technology, chemistry and microbiology

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MEAT and Meat Products

TECHNOLOGY, CHEMISTRY AND MICROBIOLOGY

Alan H. Varnam and Jane P. Sutherland

CHAPMAN & HALL

Preface

Meat has formed a part of the human diet since prehistory and the development of hunting skills. Subsequently, the rearing of meat animals became an important part of agriculture, although hunting remains important today in some societies. Despite the existence in the modern world of wholly vegetarian cultures, restrictions on meat consumption are still largely imposed by economic considerations. Economic limitation of meat consumption is most obvious in developing countries but is also a factor of life in the generally far more affluent developed world. In the developed world, however, dietary choice is much greater and a feature of recent years has been a rejection of meat-based diets. This stems largely from health concerns, although ethical considerations are also involved and pose a growing problem to the meat industry.

The perishable nature of meat and, in earlier years, its highly seasonal availability led to the early development of preservation techniques, such as drying and curing. At a later date, the relatively high cost of meat and the demands of a growing population resulted in the development of products, including sausages and meat pies, that permitted utilization of virtually every part of the animal. These two factors, in turn, resulted in the development of a large meat products industry, which is of considerable economic importance today. This industry has responded to general concerns over meat consumption and more specific concerns over levels of sodium and preservatives, especially nitrites, in meat products by the development of new products designed for the 'health and quality conscious consumer'. In some cases, however, this has led to concerns over the microbiological safety of some modern meat products.

For a number of years, technological developments in the meat and meat products industry have been underpinned by parallel

developments in the understanding of the related chemistry and microbiology. For this reason it is apparent that a full appreciation of the science of meat and meat products requires a knowledge of the three basic disciplines: technology, chemistry and microbiology. The intention of this book is to provide a fully comprehensive understanding of meat science for both undergraduate-level students and those entering the meat industry. This book follows the precedent of earlier books in the *Food Products* series in providing a detailed discussion of manufacturing processes, set in the context of the fundamental concepts of technology, chemistry and microbiology.

The fast-changing nature of the meat industry is fully recognized and reflected in the contents of the book. The strong link with commerce and the wider world is further strengthened by the use of information boxes and * points, while exercises encourage the reader in the application of knowledge to unfamiliar yet realistic situations.

A.H.V.
J.P.S.

A note on using the book

EXERCISES

Exercises are not intended to be treated like examination questions and in many cases there is no single correct, or incorrect, answer. The main intention is to encourage the reader in making the transition from an acquirer of knowledge to a user. In many cases the exercises are based on 'real' situations and many alternative solutions are possible. In some cases provision of a full solution will require reference to more specialist texts and 'starting points' are recommended.

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Contents

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INTRODUCTION

OBJECTIVES

After reading this chapter you should understand

- Meat in the diet of man
- Animals and birds exploited in meat production
- Meat production at farm level
- The composition of meat
- Meat in human nutrition
- Determinants of meat quality
- The structure and function of muscle
- Lipids in meat
- Water in meat
- The colour of meat
- Meat flavour
- Meat as a source of zoonotic pathogens

1.1 MEAT IN THE DIET OF MAN

Although a high meat content is taken for granted in the energy rich diets of the western industrial nations, this situation is not typical and in other areas the meat content of the diet is, of necessity, very low. The situation in many countries today is probably similar to that of the poor in the UK and other industrial countries only a little over 100 years ago.

Although meat eating remains at a high level, there have been distinct changes in the type of meat eaten. The most striking is the rise in consumption of poultry, especially chicken, at the expense of red meats. Initially the driving factor was economic: the poultry industry exploited intensive rearing methods and recently developed processing technology to produce chickens at significantly lower prices than other meats, finally fulfilling the hope of King

Henry IV of France that there should be no peasant in his kingdom so poor as to be unable to have '*tous les dimanches sa poule au pot*'. More recently chicken and other poultry have been recognized as 'healthier' (or possibly less harmful) meats. In the US in particular this has resulted not in an overall change in meat-eating habits, but in an increased utilization of chicken and turkey in processed meats as well as for home cooking. At the same time the success of fast-food outlets means that increasing quantities of beef and, to a lesser extent, other meats are eaten as burgers and similar products, rather than as traditional home-cooked joints. Recipe dishes (ready-meals) also account for an increasing proportion of meat consumption.

Vegetarianism is a long established feature of religious groups such as Hindus and Buddhists. In the western world vegetarianism (by choice rather than necessity) is largely a 20th century phenomenon. Vegetarianism was mainly the result of moral and ethical concerns. These remain today and have deepened with publicity concerning the less acceptable aspects of intensive animal rearing. Vegetarianism is now also driven by health concerns, including claims that meat eaters are at greater risk from some types of cancer as well as by the fact that non-meat dishes may actually be preferred, irrespective of moral or health issues. Substitute meat dishes, including the much maligned 'nut cutlets' were developed to meet demand from vegetarians and products such as burgers made with soya protein and tofu are now available. Many vegetarians, however, consider that it is unnecessary for vegetarian foods to mimic meat dishes and a large variety of non-meat dishes are now commercially available.

It is thought that a relatively high proportion of persons avoiding meat for reasons of health concern, or simple preference, rather than for moral reasons, do not follow a totally vegetarian regimen, but eat meat either as a minority component of the diet, or on particular occasions. This has been referred to as 'quasi-vegetarianism' and is effectively a middle way between a predominantly meat-based diet, in which vegetables are secondary, and a fully vegetarian diet.

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* Epidemiological evidence presented in 1994 has demonstrated a positive link between meat eating and certain types of cancer. Some aspects of the evidence have, however, been questioned. It is not clear whether meat eating as such is a predisposing factor, or other aspects of the 'typical' meat eater's life-style.

BOX 1.1 **Dined on one pea and one bean**

Quasi-vegetarianism is seen as creating a market for 'halfway' meals. These are effectively vegetable based side-dishes, such as noodles and sauce, or combinations of rice and different types of bean, to which meat is added at low level by the consumer. The individual ingredients for 'halfway' meals are already readily available, but preparation can be time consuming. The ideal commercially prepared 'halfway' meal is seen as being shelf stable, easy to use and to allow for individualism. (Sloan, E.A., 1994, *Food Technology*, **48 (2)**, 38.)

Attempts have been made over a number of years to produce meat analogues, intended as a direct replacement of meat for a significantly wider market than that represented by vegetarians. Many of the earlier products were of poor quality but some success has now been achieved.

1.2 ANIMALS AND BIRDS AS SOURCES OF MEAT

In the world as a whole a very large range of animals, birds and even reptiles are consumed as meat. In commerce, however, cattle, pigs, sheep and (to a much lesser extent) horse and goat are the meat animals of overwhelming importance. The most important birds are chickens, turkeys, ducks and geese. All of these animals and birds are domesticated and reared specifically for meat production. In addition animals, birds and reptiles are still hunted for meat. In underdeveloped countries, hunting is often a matter of necessity and subsistence, but in the industrialized nations the shooting of a diverse range of creatures, including wild boar, bears, deer, birds (such as pheasant, grouse and even larks) and reptiles (such as alligators and crocodiles) is undertaken as a matter of 'sport'. In some cases, however, such activities are semi-commercialized, pheasant, partridge, grouse and deer all entering commerce in the UK for example. In the case of deer, significant numbers are now farmed and killed in conventional abattoirs, while there is increased farming of more exotic creatures including kangaroos, ostriches and alligators. Some animals which have only limited food use at present are also considered to have longer-term potential as sources of farmed meat, these include the Giant Amazon River turtle. Although farming of exotic species is most common in the countries of origin, some,

BOX 1.2 **Strong the tall ostrich on the ground**

Ostrich farming was established in the mid 19th century to provide feathers for the hats then in high fashion. The more recent revival of the industry has primarily been to supply meat, imports from African ostrich farms being banned by the UK government because of inhumane practices. Exotic meat such as ostrich can also cause legislative difficulties. According to the American Ostrich Association, the US government is unable to decide whether ostrich (and the other ratite species, emu and rhea) should be classed as poultry or as livestock. (Anon, 1994, *Food Chemical News*, **July 11 1994**, 58).

including ostriches, are increasingly being farmed in the UK and US.

Importation of exotic meat is also increasing, although the total volume remains very small. In the past there has been concern over meat such as kangaroo being illegally used in meat products as a substitute for more expensive meats. The focus of concern has now shifted to possible public health risks. Conditions in producing countries are often unsatisfactory and, especially in the case of meat from reptiles, there is the risk of introducing new, atypical serovars of *Salmonella*.

Despite developments concerning use of exotic creatures as meat, cattle, pigs, sheep and poultry remain of overwhelming importance as meat animals in the industrialized nations. For this reason, this book is largely concerned with meat from these animals, although mention will be made of meat from other species where appropriate.

1.3 MEAT PRODUCTION AT FARM LEVEL

With the exception of pigs, meat may be obtained from animals specifically raised for meat production, or from animals surplus to other requirements. Thus beef may be obtained either from specially raised animals, male and other surplus calves, or cows at the end of their milk-producing career. Similarly chickens may be specially raised broilers, broiler breeders or hens from egg production ('spent' hens). In general meat from older animals and birds is of low quality and widely used for manufacturing.

Production of any meat is concerned with maximizing the yield of 'saleable meat' while providing a satisfactory financial return to producer and processor. Factors such as growth rate and feed efficiency are of major importance to the producer at farm level, while the processor is concerned with meat yield and unit price. The latter is ultimately determined by quality factors, such as colour and tenderness (see page 9). 'Success' in meat production (i.e. satisfying the needs of both producer and processor) depends largely on animal breed, gender and sex status, nutrition and slaughter weight. To some extent, however, there is conflict between the producer and the processor in that breeding programmes in recent years have stressed growth rate and yield at the expense of quality. Use of porcine somatotrophin and beta-androgenic agonists as feed supplements to increase lean meat content are also considered to lead to meat of lower quality. Supplements of this type are used in the US, but not to any great extent in Europe. The importance of quality is increasingly recognized by supermarket retailers, however, and integrated production systems incorporating quality assurance procedures to ensure quality have been developed for poultry and pork (Table 1.1), although only to a limited extent for beef. These require co-operation and contractual agreement between feed compounder, producer, processor and retailer. Systems of this type often also take account of food safety and animal welfare.

1.4 THE COMPOSITION AND NUTRITIONAL VALUE OF MEAT

Although the consumer may choose meat primarily for its aesthetic appeal, or through habit, it is important not to overlook its nutritional value. The composition of lean meat is relatively constant over a wide range of animals (Table 1.2). Variation is most marked in the lipid content, which may be evident as different degrees of 'marbling'.

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* The UK multiple retailer, Marks and Spencer, has undertaken what appears to be the most intensive exercise ever for identifying factors determining meat quality and designing integrated systems spanning primary production to retail sale. In the case of beef, Aberdeen-Angus was the preferred breed, followed closely by beef sired by Charolais or Limousin bulls. Steers were found to produce better beef than heifers or bulls and beef from suckler herds was superior to that from dairy herds. Aberdeen-Angus steers are generally 50–75% Aberdeen-Angus, having a purebred sire and a crossbred mother to promote hardiness and disease resistance in the calf. Meat from these animals is retailed as 'Aberdeen-Angus', while that from steers with a Charolais or Limousin sire is retailed as 'Traditional'. Marks and Spencer has undertaken similar exercises for pork and lamb. (*The Guardian*, July 23, 1994).

Table 1.1 Integrated pork production: Factors specified in quality assurance schemes

Feed	No antibiotics
	No growth promoters
Breed	Emphasis on meat quality and hardiness (outdoor pigs)
System	No sow tethers
Transportation	Keep rearing groups together
	No mixing groups of different origin
	Restrict travel to short distances
	Permit recovery in lairage
Quality measurement	Absence of bruising
	No pale or dark meat
Carcass processing	Use of hip suspension or electrical stimulation
	Longer conditioning times

Note: Data from Truscott, T.G. *et al.* (1983) *Journal of Agricultural Science (Cambridge)*, 100, 257–64.

Table 1.2 Composition of lean muscle tissue of meat animals (%)

Species	Water	Protein	Lipid	Ash
Beef	70–73	20–22	4.8	1.0
Chicken	73–7	20–23	4.7	1.0
Lamb	73	20	5–6	1.4
Pork	68–70	19–20	9–11	1.4

Note: Data from Fennema, O.R. (1985) *Food Chemistry*, Marcel Dekker, New York.

Meat is considered, justifiably, as a high protein food. Of the total nitrogen content of muscle *ca.* 95% is protein and *ca.* 5% smaller peptides, amino acids and other compounds. The quality of the protein is very high, the types and ratios of amino acids being similar to those required for maintenance and growth of human tissue (Table 1.3). Of the essential amino acids, meat supplies substantial quantities of lysine and threonine and adequate quantities of methionine and tryptophan, although the content of these amino acids in meat is relatively low. The biological value of meat protein is 0.75 (human milk = 1.0, wheat protein = 0.50) and the net protein utilization 80 (egg = 100, wheat flour = 52). The digestibility of meat protein, like that of milk and eggs, is 94–97, compared with 78–88 for plant proteins.

Table 1.3 Amino acid composition of meat proteins (g/100 g)

	Beef	Chicken	Lamb	Pork
Arginine	13.7	12.8	12.7	12.2
Cystine	2.6	2.6	2.7	2.6
Histidine	7.5	6.2	6.7	8.9
Isoleucine	10.4	9.5	9.7	9.2
Leucine	16.3	15.4	15.0	14.5
Lysine	18.5	18.4	20.3	19.7
Methionine	5.5	4.9	5.3	5.6
Phenylalanine	9.1	9.2	8.0	7.9
Threonine	9.4	8.5	9.7	8.9
Tryptophan	2.6	2.3	2.7	2.3
Tyrosine	7.8	7.2	7.3	7.6
Valine	10.7	9.8	10.0	9.9

Notes: 1. Values for chicken are based on raw meat only, while those for other species are based on raw, lean (average) samples.
2. Data from Paul, A.A., Southgate, D.A.T. and Russell, J. (1980) *First Supplement to McCance and Widdowson. The Composition of Foods*, HMSO, London.

Meat is of relatively high lipid content. This is of dietary significance in provision of energy, especially for persons engaged in heavy labour, or where overall dietary intake is limited. In the energy-rich countries of the industrialized west, however, the lipid content of meat has been associated with obesity and with atherosclerosis. This is exemplified in the US by the very high energy intake, which can greatly exceed requirements, and the growing problem of obesity. The role of meat should, however, be placed in perspective. Meat consumption amongst affluent Americans is certainly high and largely unlimited by financial constraints. Further, there is a tendency to consumption of high fat products, such as burgers. Meat consumption, however, is only a part of the equation, since the non-meat energy intake is also high and

* Biological value and net protein utilization are parameters of protein quality. The biological value of a protein is the fraction of the nitrogen retained in the body for growth and maintenance. It is determined by nitrogen balance experiments:

$$BV = \frac{IN - UN - FN}{IN - FN}$$

where IN = nitrogen intake, UN = urinary nitrogen output, FN = faecal nitrogen output.

Net protein utilization is the ratio of nitrogen retained and total protein nitrogen intake and is thus influenced by biological value and digestibility of the protein.