DEVELOPMENTS IN MEAT SCIENCE—5

Edited by

RALSTON LAWRIE

Emeritus Professor of Food Science,
Department of Applied Biochemistry and Food Science,
University of Nottingham, UK

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CONTENTS OF VOLUMES 3 AND 4

Volume 3

Volume 4

PREFACE

In the preface to the first volume in this series, published ten years ago, reference was made to the body of opinion, then developing in some quarters, which sought to implicate meat consumption in the aetiology of a large variety of diseases. Although such views are unproven, producers have tended to react by seeking to alter carcase composition, particularly by reducing the overall level of fatness and the degree of saturation of the lipids. It is thus appropriate that, in the first chapter of the present volume J. W. Savell and H. Russell Cross, of Texas A&M University, USA, should present a reassessment of the factors which affect the composition of the carcase.

Currently, there is interest in ensuring that meat species, which are acknowledged to be less efficient in converting energy into nutrients for human consumers than plants or microorganisms, should be optimally exploited, especially in areas where they alone can thrive. Although the goat has been a source of nourishment for thousands of years, its potential for meat production, both in arid regions and in those more favoured climatically, has not been fully investigated. G. A. Norman, of Booker Tate Ltd, UK, addresses this question in Chapter 2, on the basis of his extensive experience abroad when on the staff of the Overseas Development Administration.

As the self-service, individual-portion mode of presenting meat and meat products for sale gathers momentum, there is an associated increase in consumers' awareness that the eating and keeping qualities of these commodities are determined by the precise location in the carcase from which the meat has been derived. Since meat is the post-mortem aspect of muscular tissue it is thus appropriate that detailed study should be made of the biochemical differentiation of muscular tissue. G. Monin and A. Ouali, of the Meat Research Station, Ceyrat, France, provide a review of this topic in Chapter 3.

The possibility of substituting texturized proteins derived from plant or microbial sources, or from underutilized portions of the meat carcase, in whole or partial replacement for the expensive proteins of muscular tissue, has often involved their prior extraction from an insoluble matrix by alkaline solutions. Such an approach, however, although technically effective, has been associated with the production of lysinoalanine. The latter has been reported to possess undesirable metabolic properties. A new method of protein texturization without the need for high pH extraction, and based on the thermodynamic incompatibility of proteins between different phases, is presented in Chapter 4 by V. B. Tolstoguzov, of the USSR Academy of Sciences, Moscow, who considers its application to meat products.

The pH of living muscle is *c.* 7·2. In its conversion to meat during post-mortem glycolysis, the pH seldom falls below *c.* 5·4, the normal ultimate pH. Whilst meat of high ultimate pH holds water well, and thus has merit in comminuted products, it has disadvantages both in respect of eating quality and of increased susceptibility to microbial spoilage. On the other hand, meat of normal ultimate pH, although more resistant to microbial attack, tends to exude fluid because a pH of *c.* 5·4 is near the isoelectric point of its principal protein constituents. As would be anticipated, however, the meat proteins also have an increased capacity to hold water on the acid side of their isoelectric point. Empirically, this fact has been utilized in making traditional marinaded products with acidulants such as vinegar; but, hitherto, the nature of marinaded meat has not been assessed scientifically. This is the topic of the final chapter, of which the author is N. F. S. Gault, of Queen's University, Belfast, UK.

RALSTON LAWRIE

LIST OF CONTRIBUTORS

H. R. Cross
Department of Animal Science, Texas A&M University, College Station, Texas 77843-2471, USA

N. F. S. Gault
Food and Agricultural Chemistry Department, The Queen's University of Belfast, Newforge Lane, Belfast, BT9 5PX, UK

G. Monin
Institut National de la Recherche Agronomique, Station de Recherches sur la Viande, Theix 63122, Ceyrat, France

G. A. Norman
Booker Tate Limited, Masters Court, Church Road, Thame, Oxfordshire, OX9 3FA, UK

A. Ouali
Institut National de la Recherche Agronomique, Station de Recherches sur la Viande, Theix 63122, Ceyrat, France

J. W. Savell
Department of Animal Science, Texas A&M University, College Station, Texas 77843-2471, USA

V. B. Tolstoguzov
A.N. Nesmeyanov Institute of Organoelement Compounds of the USSR Academy of Sciences, 28 Vavilov Street, V-312, 117312 Moscow, USSR

CONTENTS

Chapter 1

REASSESSMENT OF SIGNIFICANT FACTORS INFLUENCING CARCASE COMPOSITION

J. W. SAVELL AND H. R. CROSS
Department of Animal Science,
Texas A&M University,
College Station, Texas, USA

1. INTRODUCTION

Research in the field of carcase composition has been conducted since the beginning of animal science research, and today it plays a significant role in world research efforts on the production of animals for food. Because of the genetic diversity within and between species, and because of management methods that differ within and between countries, there is large variation in the amount of lean, fat and bone produced by livestock.

Because carcase composition is such an important research area in the worldwide animal and meat science field, and because there is a need to reevaluate the significant factors influencing carcase composition, this chapter will address the carcase composition of beef, pork and lamb. Each species will be addressed separately, but there are many common factors influencing composition among these three species. Not only is it important to investigate composition and direct methods of determining it, but it is important to review some of the indirect methods of estimating carcase composition that are available to those who conduct research in this area. The production of fat is a costly process—much energy is used to produce it and much labor is needed to cut it off. With the competitive nature of the livestock and meat industries around the world, producing more lean and less fat is a major goal needed for simple economic survival.

2. PORK

Excess fat is a commodity that has little market value. Consumer studies continue to reveal that consumers prefer to purchase pork products that have little or no trimmable fat. The retail food industry in the United States is responding to these demands by presenting products to its customers that are closely trimmed of excess fat and often are almost totally boneless. The pork industry worldwide should continue to react to this demand for leanness by producing leaner market hogs and by removing all excess fat before presentation to the consumer.

Short-term, fat is being removed with a knife, whereas long-term, it undoubtedly will be removed through selection and management. With this 'move toward leanness', the swine industry should receive more money for the leaner carcases. Dressing percent (the proportion of carcase to live weight) should become less critical, especially to the extent that it is influenced by fat rather than muscle.

As the value of low-fat, lean pigs increases, it becomes more important for the producer, packer and retailer to be knowledgeable about the composition of the product. If a producer does not know what the product is worth and why it is worth more to the packer, he never can expect to receive 'full value' for that product. The purpose of this section is to provide information as to factors that influence composition in pigs, how to predict or measure differences in composition and how the pork industry has changed over time.

2.1. Historical Changes in Pork Carcase Composition

Significant changes in hog types have been evident in the history of swine production in the US, especially over the past three or four decades. During only part of the last 150 years when swine have been prominent in the meat supply has the type raised been well adapted to the needs of the swine industry and the consumer.

Changes made in swine type were to a large extent the result of fads and fancies, rather than the preferences of consumers. In early American history, until well into the current century, swine were raised for the amount of edible fats and oil produced, with lean meat production receiving secondary emphasis.

Salt pork was one of the principal cured products 50 years ago. Packers paid a premium for heavy, excessively fat carcases, and producers competed for prizes offered for production of the heaviest, fattest, highest dressing hogs. The early Poland Chinas, the white hogs of Chester County, Pennsylvania, and the Jersey Reds all grew to enormous size. Poland Chinas are reported about the year 1842 to have weighed up to 625 kg and Jersey Red hogs to have exceeded 575 kg. As producers became interested in developing definite types for the breeds, greater refinement and quality were emphasized, resulting in a decrease in the size of the hogs.

By the late 1920s, competition from plant-source oils escalated, and pork producers began emphasizing the selection of swine for meat production. The advent of World War II interrupted the move toward the meat-type hog when a dramatic increase in world demand for fats and oils occurred. It was not until the early 1950s that the demand for animal fat declined and renewed selection for a meat-type hog continued. From 1950 through 1975, a steady decline in *per capita* lard consumption was evident.[1]

History tells us that the demands by the marketplace have played a small role in determining the type of hog desired by the producer. Today's producers are beginning to react to the demands of the consumer, and these signals are being reflected back to seedstock producers. Thus, the producer segment now can make correct decisions as to the genetics that best fit the environment and are consistent with consumer targets.

The US Department of Agriculture[2] has sampled the pork carcase population three times: 1960 ($n = 45\,000$ carcases); 1967–68 ($n = 57\,000$ carcases) and in 1980 ($n = 36\,000$ carcases). Because the grade standards were the same in the 1967–68 and 1980 surveys, only those two data sets will be used to make comparisons. In 1980, almost 96% of the pork carcases graded US No. 1 and 2, compared with 50% in 1967–68 (Table 1). Over the 13-year period, carcases grading US No. 1 increased about 64 percentage points to 72%.

Carcase length increased and average backfat thickness (average of three dorsal midline fat depth measurements) decreased during the 13-year period (Table 2 and Fig. 1). During the 13-year span, average backfat thickness improved (decreased) by almost 20%, while carcase length increased by less than 1·3 cm (less than 2% increase).

To better exemplify the compositional differences in pork carcases of different USDA grades, Table 3 lists the yield of major and minor pork cuts trimmed to 0·64 cm or 0·0 cm external fat thickness.[3,4] Table 3 shows that, as the numerical USDA grade increased, percentage ham, loin, Boston butt and picnic shoulder decreased. When the four

TABLE 1
CHANGES IN PORK CARCASE GRADES[a]

USDA grade	Year	
	1967–1968 (%)	1980 (%)
1	8·2	71·7
2	42·1	24·2
3	35·7	3·7
4	12·2	0·3
Utility	1·8	0·1

[a] Adapted from Parham and Agnew.[2]

major lean cuts were trimmed to 0·0 cm external fat, trimmed fat percentages increased with increased USDA grade. These data demonstrate the relationship of fat percentage, carcase yield and USDA grade. With increased pressure from consumers to remove excess fat, compositional attributes between USDA grades became more significant.

According to Topel,[5] leaders of the purebred swine industry have encouraged a type change that has resulted in an increase in fat deposition. Data in Table 4 reveal that limited or no improvements in

TABLE 2
AVERAGE LENGTH AND BACKFAT THICKNESS FOR SELECTED GRADES FOR BARROW AND GILT CARCASES[a]

Grade measure	Year	
	1967–1968	1980
US No. 1		
Length, cm	77·22	78·74
Average backfat thickness, cm	3·81	3·10
US No. 2		
Length, cm	76·96	78·23
Average backfat thickness, cm	4·54	3·96
US No. 3		
Length, cm	77·22	78·23
Average backfat thickness, cm	5·41	4·93

[a] Adapted from Parham and Agnew.[2]

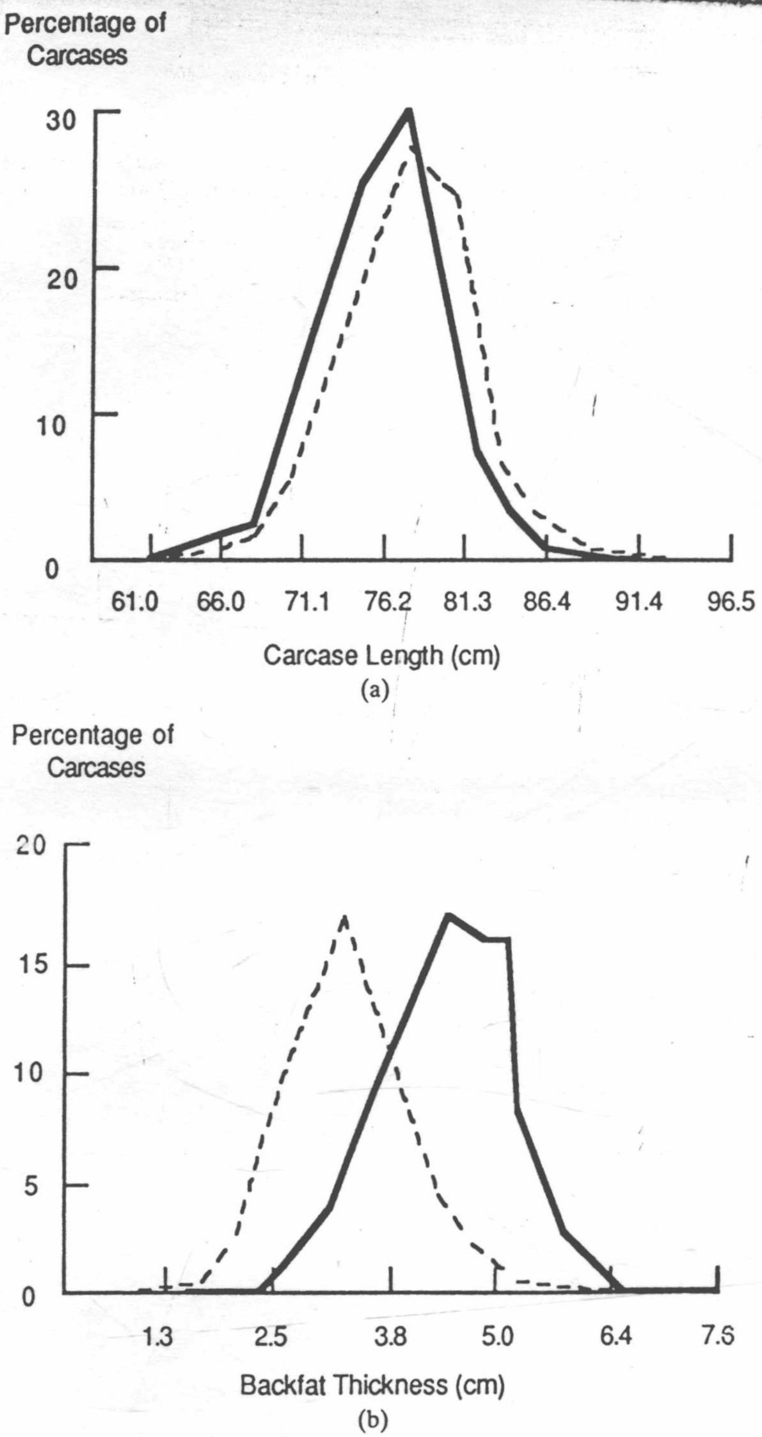

FIG. 1. (a) Distribution of carcase length and (b) average backfat thickness: ---, 1980; ——, 1967–68.

TABLE 3

PERCENTAGE YIELD OF MAJOR AND MINOR CUTS FROM PORK CARCASES OF DIFFERENT USDA GRADES WHEN TRIMMED TO EITHER 0·64 CM OR 0·0 CM FAT[a,b]

Carcase component	*Surface fat trimmed to a thickness not to exceed 0·64 cm (%)*				*All surface fat removed (%)*			
	US No.				*US No.*			
	1	*2*	*3*	*4*	*1*	*2*	*3*	*4*
Ham	23·3	22·1	21·0	20·3	19·3	17·4	15·9	14·7
Loin	21·4	20·6	19·4	18·2	19·0	18·3	17·0	14·8
Boston butt	7·7	7·4	6·8	6·4	7·3	7·1	6·5	5·8
Picnic shoulder	11·0	10·5	9·6	9·0	9·5	8·9	7·9	6·8
Subtotal	63·4	60·6	56·8	53·9	55·1	51·7	47·3	42·1
Ham fat	1·7	1·7	1·9	2·1	5·7	6·4	6·9	7·6
Loin fat	6·4	8·4	10·9	12·9	8·8	10·7	13·3	17·3
Boston butt fat	2·0	2·2	2·5	2·7	2·3	2·6	2·8	3·4
Picnic shoulder fat	0·7	0·8	0·8	0·8	2·2	2·4	2·4	2·6
Subtotal	10·8	13·1	16·1	18·5	19·0	22·1	25·4	30·9
Belly	14·6	15·4	16·3	16·9				
Jowl	4·1	3·7	4·5	4·6				
Spareribs	3·2	3·1	3·0	2·9				
Neckbones	1·7	1·6	1·5	1·4				
Ham lean	0·15	0·12	0·09	0·07				
Hanging tender	0·16	0·14	0·16	0·10				
Sternum	0·38	0·38	0·38	0·38				
Tail	0·25	0·21	0·23	0·22				
Hind foot	1·6	1·5	1·4	1·3				
Front foot	1·2	1·1	1·1	1·0				
Carcase wt, kg	61·5	66·3	64·8	69·4				
USDA grade	1·3	2·4	3·4	4·3				

[a] Adapted from Cross *et al.*[3]
[b] Adapted from Terry and Savell.[4]

carcase length or *M. longissimus dorsi* area were evident from 1980 to 1984. During that period, the fat depth over the 10th rib actually increased by more than 8%.

Thus, it appears that the US swine industry dramatically improved the leanness of carcases from 1967 to 1980—but little change has occurred from 1980 to 1984.

TABLE 4
FIVE-YEAR AVERAGE FOR CARCASE SHOWS[a]

Year	*Total hogs in show*	*Total carcases evaluated at 10th rib*	*Weight (kg)*	*Carcase data adjusted to 105 kg*		
				Length (cm)	*10th-rib fat (cm)*	M. longissimus dorsi *area* (cm^2)
1980	12 787	12 787	100·7	81·5	2·43	33·3
1981	11 970	11 970	100·2	82·0	2·36	33·8
1982	10 438	3 264	104·3	81·8	2·41	34·1
1983	8 969	2 888	104·8	81·8	2·59	33·7
1984	7 637	3 350	106·6	81·5	2·67	33·4

[a] Adapted from Topel.[5]

2.2. Factors Affecting Pork Carcase Composition

Numerous studies have documented gross compositional (fat, lean and bone) differences among pork carcases. These differences are influenced by differences in fat deposition, muscling, sex, breed, etc. Data in Tables 5–15 summarize carcase and yield traits from selected research studies over several decades. Perhaps the only variable that did not show a great deal of change was carcase length. Data from Terry and Savell[4] reveal that (data not presented) carcases with less than 3·3 cm average backfat thickness (three dorsal midline measurements) still contain over 40% separable fat. Thus, it appears that many of today's pork carcases are still too fat, and that there is considerable room for improvement.

2.2.1. Breed Effects

The impact of breed or type on carcase composition has not been widely publicized. Bruner and Swiger[16] conducted an extensive study on over 2500 pigs representing six breeds (Table 6). Their results revealed that Poland and Hampshire pigs generally had less average backfat, higher percentage of lean cuts and larger *M. longissimus dorsi* cross-section areas than did the other four breeds studied. Yorkshire, Duroc and Landrace carcases had the most backfat and smallest *M. longissimus dorsi* areas. Percentage of four lean cuts followed a similar pattern.

2.2.2. Sex-Class Effects

In swine, castration has less effect on growth rate than in cattle and sheep. Castration promotes earlier maturity in pigs than in cattle and

TABLE 5
SUMMARY OF CARCASE AND YIELD TRAITS AMONG SEVERAL STUDIES

Reference	n	*Carcase wt (kg)*	*Carcase length (cm)*	*Average backfat thickness (cm)*	M. longissimus dorsi *area (cm²)*	*Four lean cuts (%)*[a]
Warner *et al.*[6]	79	74·2	—	—	—	—
Hankins and Hiner[7]	240	78·7	—	—	—	42·1
Holland and Hazel[8]	105	64·4	74·2	3·68	21·3	46·5
Cross *et al.*[9]	316	69·3	77·2	3·18	27·7	58·0
Smith and Carpenter[10]	70	65·8	75·7	3·48	28·4	53·0
Cross *et al.*[5]	403	65·8	77·2	3·86	23·9	—
Aberle *et al.*[11]	25	72·0	77·2	3·30	27·7	54·8
Fahey *et al.*[12]	41	72·0	76·7	2·95	33·6	51·1
Edwards *et al.*[13]	359	65·3	77·5	3·78	24·5	57·3
Grisdale *et al.*[14]	185	84·4	84·3	3·28	35·5	—
Bereskin[15]	649	71·1	79·2	2·95	32·9	61·5

[a] Bone-in (0·60 cm external fat trim).

TABLE 6
COMPARISON OF SEX AND BREED EFFECTS ON CARCASE COMPOSITION[a,b]

Item	n	*Carcase wt (kg)*	*Carcase length (cm)*	*Average backfat (cm)*	M. longissimus dorsi *area (cm²)*	*Ham (%)*	*Loin (%)*	*Four lean cuts (%)*
Sex								
Gilt	1 497	66·7	75·9	3·6	27·7	21·0	16·5	54·6
Barrow	1 011	66·7	74·9	3·8	24·5	19·0	15·9	52·9
Breed								
Yorkshire	773	67·1	77·2	3·9	25·2	19·9	16·1	53·2
Duroc	213	66·7	73·9	3·8	24·5	20·0	15·6	53·0
Poland	270	67·6	73·9	3·5	29·0	21·4	16·2	54·9
Hampshire	686	67·1	75·4	3·5	27·1	20·7	17·0	55·2
Spotted	214	67·2	74·9	3·7	26·5	20·5	15·9	53·2
Landrace	352	66·2	77·7	3·6	24·5	20·3	16·3	53·2
Total	2 508							

[a] Pigs removed from test at approximately 95 kg live weight.
[b] Adapted from Bruner and Swiger.[16]

sheep—possibly because of differences in physiological age at castration. In general, the difference in growth rate between boars and barrows is not great.[17] Differences in feed efficiency also are small, but tend to favor boars. Boars equaled or surpassed barrows in feed efficiency in most of the studies in the literature. Prescott and Lamming,[18] citing 12 studies, reported that growth rate and feed efficiency for boars were 0·69 kg/day and 1·50 kg feed/kg live weight gain, respectively, and for barrows, 0·69 kg/day and 1·59 kg feed/kg live weight gain, respectively.

Siers[19] reported that gilts and boars produced carcases that had significantly larger *M. longissimus dorsi* areas and higher ham and loin percentages than did barrows. Mean average backfat measurements in 15 different studies cited by Turton[20] were 3·0 cm for boars and 3·6 cm for barrows at market weight. Prescott and Lamming,[18] citing four to seven references, reported that boars had an average dressing percentage of 74·7%, an average backfat thickness of 3·1 cm and an average *M. longissimus dorsi* area of 26·4 cm^2, whereas barrows averaged 76·1%, 3·9 cm and 25·9 cm^2, respectively.

Studies comparing gilts, barrows and boars have revealed that average backfat thickness, *M. longissimus dorsi* area, and percentage yield of four lean cuts favored boars, gilts and then barrows, respectively.[16,21,22] Differences in carcase length between barrows and gilts are small. Even though differences in leanness, fatness and yield favor the gilt over the barrow, the industry does not consider these differences (leanness) sufficient to justify a price differential in the marketplace.

Seideman *et al.*[17] summarized the boar/barrow differences (Table 7) by stating that the 'advantages of boars in growth characteristics and carcase merit are not as large as those of bulls and rams, but may be worthy of consideration nonetheless. Growth characteristics and carcase merit of boars possibly could be improved; however, before extensive research in the growth of carcase characteristics is conducted, the problem of boar odor should be investigated further'.

2.3. Direct Measurement of Pork Carcase Composition

Measurement of animal and carcase composition is critical to all segments of the meat industry. However, compositional 'endpoints' are not consistent within the field of animal science. Animal nutritionists and geneticists often have reported whole body or carcase chemical composition to discern relative efficiencies when evaluating