Biological effects on the quality of red meat with special reference to South African conditions

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Several biologically dependent quality characteristics of meat (appearance and palatability) have been researched extensively in South Africa and some of these findings are discussed briefly in this article. Sound production and management practices may be used to manipulate the many biological factors to benefit the consumer and ensure 'consistently good quality meat at a reasonable price'. Applying technology to remedy poor quality of the final product is costly, making meat more expensive.
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Verskeie biologies afhanklike kwaliteitseienskappe van vleis (voorkoms en smaaklikheid) is omvattend nagevors in Suid-Afrika en sommige van die bevindings word kortliks in hierdie artikel bespreek. Goeie produksie- en bestuurspraktyke kan gebruik word om die groot hoeveelheid biologiese faktore te manipuleer sodat die verbruikers bevoordeel word en om 'konstante goeie kwaliteit vleis teen 'n billike prys' te verseker. Om van tegnologie gebruik te maak om die swak gehalte van die finale produk te verbeter, jaag kostes op en maak vleis duurder.
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The consumer's decision to buy meat and meat products forms the basis of the meat industry (Sybesma, 1983). Consumers have widely diverging expectations of the product of which their own conception of 'value' (Weyers, 1982) is the most important parameter, i.e. the quantity and quality of the product relative to other foods and consumer commodities. In this 'value package' the consumer demands a regular supply of consistently good quality meat at a reasonable price available through an informative and attractive marketing service (Foreshaw, 1982; Weyers, 1982). To appreciate these needs of consumers fully, it is appropriate to define the term 'meat quality' (Figure 1). 'Meat quality' comprises five categories, namely appearance, palatability, nutritive value, processibility and shelf-life. These quality characteristics are influenced and finally established during the different stages or links of the 'meat production chain' (Figure 2) which are part of an integrated system covering the entire range from 'conception to consumption'. Hence, it is evident that the

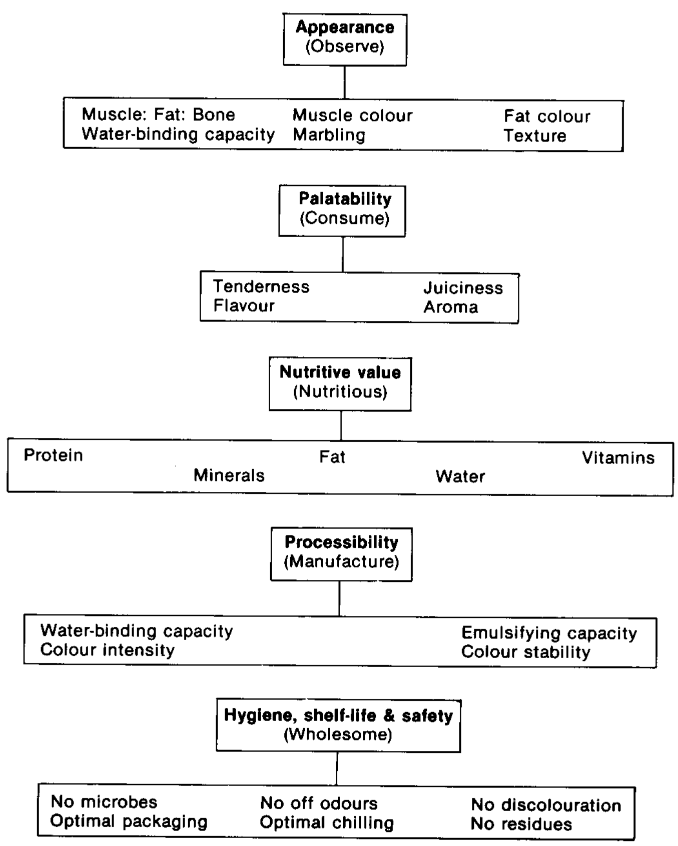

Figure 1 Components of meat quality.

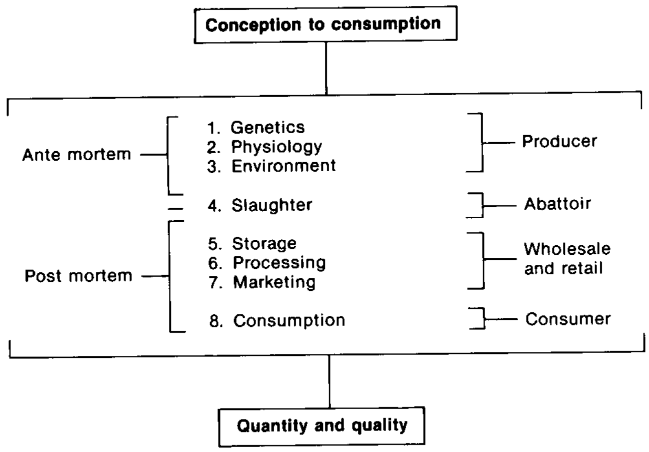

Figure 2 Meat production chain.

quality of meat and meat products is collectively dependent upon the influence of each individual link in the production chain as well as interactions between them. Product quality is therefore determined biologically (genetics, physiology, environment, and partly slaughter) as well as technologically (partly slaughter, storage, processing).

Certain scientists think that in future mainly the quantity of lean meat will be determined by the biological end of the chain (e.g. genetics, physiology and nutrition) and that technological manipulation will ensure that an almost completely consumer's tailored product will be available on the market (Berg & Walters, 1983; Breidenstein & Carpenter, 1983; De Boer, 1982; Chiron, 1983). Other scientists, however, sound a word of warning and caution to the meat industry towards a more realistic and practical approach for the present day and age in which the biological input, as determined *inter alia* by age, breed, sex and management of the meat-producing animal, is still a major determinant of especially fresh meat quality (Sybesma, 1983; Harrington, 1983). The latter group maintain that profitability of the process will dictate whether qualitative deficiencies, which sometimes go hand in hand with the maximum lean yield being produced, could be effectively rectified by applying available technological methods such as using tranquilizers for stressed animals; electrical stimulation of rapidly chilled carcasses to prevent toughening; trimming muscles to remove intermuscular fat, connective tissue, blood vessels, and nerves and then restructuring the muscles into newly shaped joints by tumbling, and then irradiating the meat to ensure more than 10 days shelf-life and finally ensuring optimal appearance with gas packaging.

All these technological processes are, however, costly. Fortunately a great deal of scientific know-how is available regarding the biological variation of the quality of the product. Much of this variation is presently being accommodated in a classification and grading system, which facilitates strategic marketing and hence enabling the meat trade to sell a wholesome, consistently high-quality, product at a reasonable price.

Several of these biologically dependent quality characteristics of meat have been researched extensively in South Africa and certain of these findings will be discussed briefly in this article.

Appearance

Carcass tissue characteristics

Cattle

Effect of breed and age or mass. The production of beef from dairy cattle was investigated thoroughly under intensive conditions. It was found that when four beef breeds, Charolaise, Brown Swiss, Simmentaler and Hereford were crossed with Jersey and Friesland cows the carcasses of the crossbred steers at approximately 16 months of age contained 19,6; 20,2; 22,3 and 28,6% fat in the case of the Jersey crosses in the order as mentioned above (livemass 410 kg; carcassmass 240 kg), and 17,1; 18,0; 21,9 and 27,4% fat in the case of the Friesland crosses with the same sire breeds as above. At similar ages of the two dam types the same level of carcass fat was achieved with Hereford types yielding the fattest, and Charolaise types the leanest, carcasses. Intra muscular fat content was also found to be the highest in Hereford types in the case of both dam type crosses. Friesland progeny were slaughtered at 454 kg livemass and 270 kg carcassmass (Naudé, 1974).

Results of a long-term comprehensive crossbreeding trial where different breeds of sire were mated to Afrikaner cows were reported regarding carcass composition data. Steer progeny were slaughtered at 7 months of age and subsequently at 340, 380 and 440 kg livemass after being stall-fed on a finishing ration. The mean carcass fat percentages of the various crossbred types slaughtered at the four stages mentioned, were as follows: Charolaise 13,8%; Blonde d' Acquitaine 14,1%; Chianina 14,5%; Gelbvieh 15,7%; Limousine 17,2%; Normande 17,7%; Simmentaler 17,8%; Hereford 21,9%. At 440 kg livemass carcass fat content in the order given above was as follows for each crossbred type: 18,2%; 18,3%; 23,1%; 23,6%; 24,2%; 23,7%; 22,0%; 30,9%. The Charolaise and Blonde d' Acquitaine crossbreds yielded late maturing lean carcasses, the Hereford crosses early maturing fat carcasses and the remaining five types were intermediate regarding fat content (Naudé, Mentz, Venter, Nel, Botha, Stiemie & Argo, 1980).

Intensively fed indigenous steers slaughtered at 19 months of age (carcassmasses given in brackets) produced carcasses with the following fat contents: Nguni 25,4% (203 kg); Sanga 24,0% (153 kg); Pedi 28,2% (201 kg). When analysing the results of the study with crossbred beef carcasses as reported in this review it was found that protein maturity of the lean tissue was reached when the average fat content of the carcasses was approximately 18%. This principle was applied in the carcass grading and classification scheme in South Africa. Using regression analysis it was found that a realistic variation for target carcasses would then be between 3 and 7 mm subcutaneous fat measured between the 10th and 11th thoracic vertebrae, 25 mm off midline. When applying these guidelines for carcass fat cover of the serially slaughtered types of some of the animals tested in the beef crossbreeding experiment (Naudé, *et al.*, 1980) the minimum and maximum carcass masses which would qualify for the target grades in the three age categories of the grading system (Super A, Prime B and Top C) are as given in Table 1.

Fat content of the carcasses of 12 different beef breed types, also was a good indicator of lean distribution in the carcasses. A correlation of $r = -0,75$ was calculated between carcass fat content and 'expensive' lean content (round, rump, loin and rib joints) of carcasses. The correlation between carcass fat content and lean of the 'cheaper' ventral cuts (thin flank and brisket) was $r = 0,82$. At the same fat content of the carcass (stage of maturity), virtually no differences in 'cheap' or 'expensive' lean of the widely diverging maturity types were found (Naudé, *et al.*, 1980).

Effect of sex. Intensively reared young bulls are always much leaner than steers of the same age and in a target grade slaughter system could therefore be slaughtered at heavier final masses yielding more saleable meat of the optimal grade.

Table 1 The influence of breed on beef carcass grading in South Africa. Live- and carcassmasses of steers (A-age) required to grade Super

	Livemass (kg)		Carcassmass (kg)	
Breed type	3 mm fat	7 mm fat	3 mm fat	7 mm fat
Hereford	264	364	150	218
Afrikaner	260	384	148	230
Brahman	328	414	198	250
Bonsmara	342	484	207	300
Friesland	342	+	188	+
Simmentaler	384	+	230	+
Charolaise	394	+	238	+
Afrikaner crosses				
Hereford	310	406	185	245
Brahman	322	436	194	263
Simmentaler	302	450	180	275
Gelbvieh	296	484	175	300
Limousine	280	484	162	300
Chianina	328	484	198	300
Charolaise	346	+	210	+
Blonde d'Acquitaine	354	+	213	+
Normande	384	+	230	+

+ Beyond the scope of the experimental slaughtermasses.

Brown Swiss bulls, intensively fed on a ration containing 80% concentrates and 20% roughage, had a carcass fat content of 12% at 450 kg livemass for bulls and 18,7% for steers at ages between 13 and 14 months. When similar animals were fed a 60:40 ratio diet, the respective fat contents were 9,4 and 17,1%. These bulls would therefore have to be fed to higher livemasses to comply with the 18% fat of the target grade. Friesland and Hereford × Friesland crossbred bulls, intensively fed (80:20) and slaughtered at 450 kg livemasses, had carcass fat content values of 17,9 and 18,6% respectively — these two types therefore mature earlier than Brown Swiss Bulls (Naudé, 1974).

Nguni, Sanga and Pedi bulls intensively fed and slaughtered at 19 months of age were on average about 20% leaner than their steer contemporaries. The bull carcasses contained 20,5; 20,0 and 26,4% fat respectively — all of them too fat, especially the Pedi bulls, to qualify for the target grades.

Effect of compensatory growth. Drakensberger type steers were fed on diets resulting in average daily gains of 0 (low); 0,5 (medium) and 1,0 (high) kg for 5 months after weaning, simulating two degrees of winter feeding restriction and a control group growing on a high concentrate diet simulating feedlot conditions. Thereafter all three groups were fed on the latter intensive diet until a slaughtermass of 440 kg. When slaughtered after the 5-month period of feed restriction the carcass fat content in the intensively fed animals was 19,2% and in the low and medium groups the values were 10% and 14% ($P < 0{,}01$). After compensatory growth on the high plane and slaughtering at 440 kg livemass, fat content values were not significantly different (*ca.* 30%) (De Bruyn, 1983).

Effect of growth stimulants. In a feedlot experiment with a representative sample of different frame-type, beef steers, four combinations of growth stimulants were used as implants. The control group (C) received only ionophores in their feed, the animals of the first experimental group (Z) were implanted with 36 mg of Zeranol per animal, the second group (TZ) were implanted with 36 mg of Zeranol plus 140 mg of Trenbolone acetate and the third group (TE) were implanted with 140 mg of Trenbolone acetate plus 20 mg of Estradiol-17β. Results of the trial given in Table 2 indicate that the growth stimulants had a positive effect on the rate and efficiency of lean growth of feedlot steers. These animals were slaughtered at an average carcassmass of 220 kg, with trenbolone acetate plus estradiol-17β giving the best results (De Bruyn, Galloway & Naudé, 1984).

Table 2 Growth stimulant trial with feedlot steers

Treatment	Average daily gain (g)	Feed conversion ratio	Carcass fat content (%)
C	1249	68,0	22,6
Z	1356	62,6	20,1
TZ	1366	63,5	19,2
TE	1455	61,2	18,1

Feed conversion ratio: MJ digestible energy/kg

Carcass classification and grading. Klingbiel (1985) outlined the development of a beef grading system in South Africa and indicated that the fat content of the target grade carcasses was approximately 18% (5 mm subcutaneous fat thickness) which coincided with protein maturity of the carcass lean (Table 3).

In this new grading system only two variables are included, i.e. six fat classes (indicating lean yield) and three age classes (indicating tenderness). Each age class (A = no permanent incisor teeth; B = one to six teeth and C more than six teeth) therefore has six fat classes. Some of the fat classes are grouped together to form a grade within age group, e.g. fat classes 3 plus 4 is grouped as Super/Prime/Top and 5 plus 6 as A2, B2 and C2.

Table 3 Carcass fat content of beef carcass classes and grades in South Africa

Fat grade	Fat class	Fat thickness (mm)[a]	Fat content (%)
Grade 3 (A,B,C)	1	< 1,0	11%
Grade 1 (A,B,C)	2	1,1 – 3,0	13,5%
Super A/Prime B/ Top C	3	3,1 – 5,0	16,0%
	4	5,1 – 7,0	19,5%
Grade 2 (A,B,C)	5	7,1 – 10,0	23,0%
	6	> 10,0	28,0%

[a]Measured between 10th and 11th thoracic vertebrae 25 mm off midline

Sheep and goats

Effect of breed. The carcass composition of lamb carcasses of three sheep breeds and the Boer goat was determined under intensive feeding conditions (Table 4). The Woolled Merino was found to be the fattest sheep breed at comparable carcassmass, followed by the Dorper (Dorset Horn × Black Head Persian), with the South African Mutton Merino (SAMM) the leanest. Boer goat carcasses were intermediate in fat content when compared with the sheep breeds but at all stages fatter than the SA Mutton Merino (Naudé & Hofmeyr, 1981). The distribution of fat in the Boer goat is, however, quite different to that in the sheep carcasses. The percentage subcutaneous fat and especially the thickness of fat at the measuring point (13th thoracic vertebra) was less than in the

Table 4 Fat characteristics of sheep and goat carcasses

Characteristic	Carcass-mass	SAMM[a]	Dorper	Merino	Boer goat
Carcass fat (%)	5	3,5	5,0	7,5	9,0
	10	10,5	13,5	18,0	16,0
	15	16,5	22,0	23,5	21,0
	20	22,0	26,0	32,0	23,5
Subcutaneous fat (%)	5	0,0	1,5	1,5	2,0
	10	3,0	5,0	6,0	4,5
	15	5,0	11,0	10,0	6,0
	20	7,0	15,0	14,0	7,0
Subcutaneous fat (mm)	5	0,5	0,8	0,8	0,0
	10	2,3	3,0	3,8	1,0
	15	4,5	5,0	5,5	1,5
	20	8,7	8,0	8,7	3,0

[a]South African Mutton Merino

sheep carcasses.

The result of these differences in fat distribution is that sheep and goat carcasses are graded according to two sets of grading and classification systems. The target grades for lamb and mutton carcasses contain about 22% fat which coincides with carcass lean protein maturity.

Carcass classification and grading. In a national survey and comprehensive carcass evaluation project of lamb and mutton carcasses in all the classes and grades in South Africa (Bruwer, 1984) it was found that if the subjective carcass fat cover scoring were applied correctly the mean carcass fat content of the target grades Super lamb, Prime B and Top C would be approximately 22% (Table 5). The principles applied for sheep regarding age and fat cover classes are exactly the same as those for cattle.

Table 5 Carcass fat content of lamb and mutton carcass classes and grades

Fat grade	Fat class	Fat thickness (mm)[a]		Fat content (%)
Grade 3 (A,B,C)	1	< 1,0	($\bar{x}$ 0,5)	14,7
Grade 1 (A,B,C)	2	1,0 – 4,0	($\bar{x}$ 2,5)	17,0
Super lamb/ Prime B/Top C	3	4,1 – 7,0	($\bar{x}$ 5,5)	20,5
	4	7,1 – 9,0	($\bar{x}$ 8,0)	23,4
Grade 2 (A,B,C)	5	9,1 – 11,0	($\bar{x}$ 10,0)	25,8
	6	> 11,0	($\bar{x}$ 13,5)	29,9

[a]Measured between the 3rd and 4th lumbar vertebrae 25 mm off midline

Muscle colour, water-binding capacity and texture

Cattle

Effect of breed, age and sex. Feedlot-fed Afrikaner and Friesland bulls and steers were compared between the stages birth to 2 years of age at 4 monthly intervals after weaning at 8 months of age (Boccard, Naudé, Cronjé, Smit, Venter & Rossouw, 1979). Muscle pigment (µg Fe/g) content was determined in five different muscles. There was a constant increase in muscle pigment content from 19,55 at birth to 78,16 µg Fe/g at 24 months of age in Afrikaner cattle and these values for Frieslands were 20,73 to 84,89 (Table 6).

In general, however, Afrikaner cattle had darker muscles than Frieslands. In the age categories examined, very small sex differences were found. Breed and age differences were statistically ($P < 0{,}01$) different in all muscles tested (*M. longissimus thoracis, M. semimembranosus, M. semitendinosus, M. pectoralis profundus, M. biceps brachii caput lateralis*).

Table 6 Muscle pigment content in *M. longissimus thoracis* of two breeds of cattle at different ages

Breed	Muscle pigment content (µg Fe/g) at: Birth	8 months	12 months	16 months	20 months	24 months
Afrikaner	18,44	51,02	57,48	71,91	74,64	79,14
Friesland	20,25	35,71	46,11	45,75	61,22	85,40

Classification and grading. In the grading system used in South Africa before 1981, carcasses were classified in three age categories, e.g. A — no to two permanent incisors; B — three to six teeth and C — seven to eight teeth in the slaughter animals. This was changed slightly in 1981 to one to six teeth in the B group. The muscle pigment content values of the *M. longissimus lumborum* of these three age groups were respectively 56,7; 66,2 and 71,5 µg Fe/g (Klingbiel, 1984).

Effect of stress. Young steers were artificially stressed in an experiment to determine the influence of a number of variables on the shelf-life of displayed meat. A trained panel scored meat from the stressed steers significantly darker ($P < 0{,}01$) and more unacceptable ($P < 0{,}05$) than steaks from the rested controls. Muscle pH was also higher (5,9) in stressed animals than in rested (5,6) animals. Dark, firm and dry (DFD) meat is becoming a serious problem due to consumers' resistance and poor shelf-life of abnormally dark, high pH, steaks (Nortjé, Naumann, Naudé, Naudé, Oosthuizen & Jordaan, 1985).

Sheep

Classification and grading. In the grading system presently applied in South Africa, carcasses of lambs with no permanent incisors are grouped together, then those from animals with one to six permanent incisors (B) and the third group with seven to eight teeth (C). The muscle pigment content (µg Fe/g) was found to be 53,3; 57,9 and 63,0 ($P < 0{,}05$) for the three age groups respectively in the *M. longissimus thoracis* (Bruwer, 1984).

Effect of stress. In a recent survey (Pietersen, 1985) of a condition in sheep identified as 'abnormal rigor mortis' of carcasses which were rigid on the slaughter line before entering the chiller, it was found that the pH of the *M. longissimus thoracis* 24 h post mortem was 6,3 as compared to 5,9 in muscles of carcasses which did not develop early rigor mortis. Indications of transport stress, such as lack of oxygen for sheep on the lower deck of the truck, were found in sheep delivered at the abattoir. Electrical stimulation seemed to deplete the already low levels of muscle ATP of stressed sheep and accelerate the onset of rigor mortis in these carcasses. High pH muscles are usually abnormally dark and associated with DFD meat.

Pigs

Effect of stress. In a country-wide survey conducted by Klingbiel (1974) in South Africa it was found that the occurrence of PSE (Pale, soft, exudative) pork ($pH_1 < 6{,}0$) varied between 5,0% and 28,6% in five of the major factories and

Table 7 Percentage of SA Landrace and SA Large White boars testing positive in a halothane test between 1978 – 1981

	SA Landrace in:				SA Large White in:			
Centre	1978	1979	1980	1981	1978	1979	1980	1981
Irene	11,2	11,2	13,7	7,9	0,0	0,4	0,0	0,7
Cedara	8,2	7,3	11,1	11,9	0,0	0,0	2,1	0,3
Elsenburg	23,6	23,3	15,4	13,2	1,1	0,7	1,7	0,5
Mean	14,4	14,3	13,7	10,9	0,5	0,5	1,0	0,6
Number tested	1 089	1 254	1 180	1 048	376	645	728	791

abattoirs in the country where electrical (90 volts) stunning was practised. In an abattoir where the captive bolt was used for stunning pigs the figure was as high as 71,9%. A large proportion of this variation between centres and between stunning techniques could, however, be ascribed to environmental stress immediately before slaughter.

In a factory trial Klingbiel, Naudé & Van Essen (1974) found that the colour of PSE hams was much paler before cooking (reflectance 44,1) than for normal hams (reflectance 31,9) (pH_1 5,89 vs. 6,89) and yielded 6,6% less cooked canned ham than normal hams.

In the pig improvement scheme in South Africa young boars (8 weeks old) are tested for halothane sensitivity. Results are given in Table 7. A clause in the regulations stipulates that all pigs testing positive are to be slaughtered (Rossouw, 1982). Large White pigs are much more resistant to stress than Landrace pigs (0,6 vs. 10,9%).

Long-term stress in pigs causing DFD (dark, firm and dry) meat to develop, was studied by Heinze, Gouws & Naudé (1983) by means of pH determinations in the *M. longissimus lumborum*. In a sample of 3 477 carcasses they found that 43,1% of the boar carcasses measured, had pH_f values $> 6,0$ whereas this figure was 23,0% for sows and barrows. Animals transported by road were stressed more (33,6%) than by rail (24,2%). Animals resting for more than 48 h before slaughter had less stressed muscles (12,1%) than those that rested for shorter periods (28,3 – 33,1%). The normal resting period at abattoirs, therefore, has no beneficial effect on the quality of meat in terms of colour acceptability and probably shelf-life of meat.

In a series of experiments performed by Mitchell & Heffron (1982) in South Africa, it was found that 'although considerable research indicates that stress susceptibility and malignant hyperthermia are a disease involving membranes with calcium transporting functions, data suggest that the mitochondrial membranes, especially those of muscle, deserve the most attention since an abnormality in them would most easily explain how the stress syndromes are precipitated by drugs on the one hand, and exercise on the other'. Exercise occurring in many forms and levels of intensity in practice is therefore regarded as an important precipitator of the PSE condition in pigs.

Texture and fibre type

Cattle

Effect of breed, age and sex. Dreyer, Naudé, Henning & Rossouw (1977) published results obtained from an experiment with Friesland and Afrikaner cattle regarding muscle fibre characteristics. Animals were slaughtered at birth, 8, 12, 16, 20 and 24 months of age. Muscle fibre diameter increased in the *M. semimembranosus* from 25 to 62 µm whereas this increase for the *M. semitendinosus* (dark area) was between 24 and 75 µm and in the case of the light area of the same muscle it increased from 27 to 80 µm at the age of 24 months. In the *M. semitendinosus* (light area) approximately 54% of the muscle fibres were white with bulls having significantly less white and more red fibres in their muscles, which could be indicative of higher stress susceptibility in the entire male. In all the muscles studied the fibre diameter of bulls at the same age was larger than that of steers. The entire males gained more rapidly, were leaner and were better muscled than steers. The leaner Friesland breed also had larger muscle fibres than the earlier maturing Afrikaner breed (76 vs. 58 µm for the *M. semitendinosus* (light area) of bulls).

Pigs

The microstructure of PSE and normal *M. longissimus dorsi* was studied by Dreyer, Naudé & Gouws (1972) in a histological study in which the muscles of captive bolt stunned versus exsanguinated pigs were compared. The most significant finding of this investigation was the shrinkage (from 64,4 to 54,9 µm or 18,2%) observed in the diameter of muscle fibres. This shrinkage was ascribed to the transudation of moisture from the intracellular to the extracellular spaces.

Ostriches

Six muscle groups of slaughtermass ostriches were analysed for various meat quality characteristics. Muscle fibre diameters ranged from 50 to 85 µm and sarcomere lengths from 1,85 to 2,81 µm. The thawing loss of the different groups of muscle varied between 2,3 to 8,8% but one group which had a thawing loss of 31,7% and also the shortest sarcomere lengths, had the toughest meat (52% score in a taste panel) when compared to the other groups which had up to 70% score. Histological examination demonstrated that large ice crystals had formed in the muscles which indicated a slow rate of freezing which could cause a high thawing loss. Pre-rigor freezing could also cause supercontraction of muscle fibres as demonstrated with the short sarcomere length measurements which resulted in very tough meat (Naudé, Van Rensburg, Smit, Stiemie, Dreyer, Rossouw & De Jager, 1979).

Palatability

Tenderness

The tenderness of meat is determined by the two main types of proteins present in muscles. These are the contractile proteins of which the degree of contraction influences the tenderness and secondly the connective tissue proteins of which the content as well as solubility, when cooked, are the major determinants of tenderness. The role of the contractile proteins are determined *inter alia* by the pre-slaughter environment of the animal, whether stress is present or not, by the rate of chilling post-slaughter, which could cause cold shortening and toughening and this may be prevented by electrical stimulation of the pre-rigor carcass, and finally by the period and conditions of post-slaughter storage which could allow proteolysis of these proteins, causing them to tenderize. The role of the connective tissue proteins regarding tenderness or toughness are determined by the age, breed and sex of the animals which influence the content and solubility of the connective tissue in muscles. Tenderness of highly soluble connective tissue muscles of very young animals may however be completely masked if such carcasses are chilled too rapidly. This problem could be overcome again by electrical stimulation.

Cattle

Effect of breed, age, sex, and compensatory growth. In the experiment of Boccard, *et al.* (1979) it was found that the five different muscles of Frieslands all had a higher collagen content than those of Afrikaner cattle. The hydroxyproline-N-content as a percentage of total-N-content was used as an indicator for collagen. When testing for the solubility of these muscles, however, it was found that those from Afrikaner cattle were more soluble than in the Friesland. The net result was that muscles from Afrikaner cattle with a higher collagen content but also a higher collagen solubility were more tender than those from Frieslands. At birth a higher content of collagen was found in muscles than at weaning (8 months) but towards puberty an increase in collagen content was observed. After 12 months of age very little change was observed in the collagen content of muscles. A consistent increase in toughness was, however, observed as animals became older. The reason for this toughening effect was very clearly demonstrated in this study by the decrease in collagen solubility which was observed between birth (*ca.* 60%) and 24 months of age (*ca.* 30%). In young bulls the decrease in solubility was from 60% to 48% from birth to weaning (8 months) and from 45 to 30% from 12 to 16 months. A decrease of 1,5% per month over the first 8 months of life and 3,75% per month from 12 to 16 months. Severe toughening of meat in young bulls therefore occurs during the puberty stage of development. The changes in steers were not as drastic as in the case of bulls.

De Bruyn (1983) found that when steers were on restricted feeding for 5 months post-weaning and subsequently fed a complete diet until they reached a livemass of 440 kg and then compared with steers which had been fed a complete diet all the time, no differences in either total content or solubility of collagen could be found between the two groups. Compensatory growth therefore did not influence the connective tissue characteristics of these young animals.

Effect of cold shortening and electrical stimulation. Dreyer, Van Rensburg, Naudé, Gouws and Stiemie (1979) chilled carcasses of two mass categories, 120 and 240 kg, at five different temperatures, viz. 0°, 3°, 5°, 7° and 9°C. One side of each carcass was suspended from the hock in the conventional way and the other from the pelvic bone. Muscles from carcasses of 120 kg had a greater chilling rate and as a result had higher shear force values and shorter sarcomere lengths than the 240 kg carcasses. The pelvic-suspended carcasses had a lower shear force of the *M. longissimus thoracis* and longer sarcomeres, hence more tender meat. For each increase in chilling temperature, muscle chilling rate was slower, cold shortening less, and shear force values lower, and hence the meat more tender. Carcasses in South Africa are usually chilled at 0°C and hence all carcasses chill rapidly enough to ensure well-chilled but tough meat from young beef animals.

Meat from carcasses chilled at 0°C which were not electrically stimulated at 500 volt (rms) was 60% less tender than meat from stimulated carcasses (Heinze, Bekker, Coetzer, Pelser & Naudé, 1982). When stimulated meat is aged another 57% increase in tenderization occurs due to proteolytic changes. In unstimulated meat aging improved tenderness by 77% and in stimulated meat the improvement was 55%. These measurements were made on the *M. longissimus thoracis*. Rapidly chilled carcasses therefore do not produce tough meat in South Africa because all the beef from urban abattoirs are from stimulated carcasses.

Carcass classification and grading. Klingbiel (1984) evaluated the grading system in South Africa and found that the meat from carcasses in the three age categories A, B and C were significantly different in tenderness with A-meat more tender than B-meat which was more tender than C-meat. Results of the collagen solubility of this meat substantiated these findings with the respective values being 21,6%, 17,3% and 16,6%. These differences in the three age classes in the different grades are therefore now being graded accordingly because of the prevention of cold shortening by means of high voltage electrical stimulation, and hence prevention of the collagen differences being masked by abnormal myofibrillar contraction.

Sheep and goats

Effect of breed and age. At 1 and 4 months of age the muscle collagen solubility values for sheep and goat lambs were as follows for the SA Mutton Merino, Dorper, Boer goat and Woolled Merino respectively: 48%, 47%, 41% and 40% at 1 month and 41%, 36%, 31% and 27% at 4 months of age. The values at 18 months of age were all between 16 and 21%. Breed as well as age significantly influenced factors responsible for the toughness or tenderness phenomenon (Smit & Naudé, unpublished results).

Carcass classification and grading. In his evaluation of the carcass grading system for lamb and mutton carcasses in South Africa, Bruwer (1984) found meat from animals in the A, B and C age categories to be different in tenderness according to a trained taste panel as well as shear force results and that collagen solubility figures substantiated these findings. On a five-point scale A-meat scored 3,59; B-meat 3,47 and C-meat 2,74 ($P < 0{,}01$) and the collagen solubility values for these three types of meat were 21,25; 20,31 and 18,12% respectively ($P < 0{,}01$).

Effect of electrical stimulation. As was the case with beef undergoing cold shortening when rapidly chilled, the same phenomenon occurs in mutton and lamb which would almost completely mask age differences in tenderness as classified in the grading system. After extensive muscle pH surveys on many lamb and mutton carcasses it was decided by the owners of urban abattoirs in South Africa to stimulate (800 volt rms) all carcasses electrically, and hence prevent cold shortening. The pH of *M. longissimus lumborum* of stimulated (800 volt rms) carcasses 2 h post mortem was 5,92 which was 14% lower ($P < 0{,}01$) than the value of 6,76 of non-stimulated muscles (Heinze, Greyvenstein & Naudé, 1982). In a recent survey by Pietersen (1985) an interesting observation was made on the 0,6% lamb and mutton carcasses which were found to have been stressed on arrival (final muscle pH_f 6,26 vs. 5,92 of non-stressed). When these carcasses are electrically stimulated just after bleeding, rigor mortis sets in on the slaughter line due to early depletion of the already low levels of ATP of stressed animals. The state of rigor stiffness is not resolved and hence the meat could be more tough than in the case of non-stimulated stressed animals.

Conclusions

Many biological factors affect the various quality characteristics of meat. Through sound production and management practices these may be manipulated to the benefit of the producer, by means of the long-term stability in consumers' demand for the product he produces, and especially to the benefit of the consumer being assured of 'consistently good quality meat at a reasonable price'. Applying technology to remedy poor quality of the final product is costly and would render the product more expensive.

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