MEAT QUALITY - THE IMPACT OF RESEARCH

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I. INTRODUCTION

In this discussion, the term quality will be applied to meat in its broadest sense in that it implies those characteristics both consciously detectable and automatically assumed by the consumer. Consequently, in addition to possessing agreeable texture, flavour, juiciness and appearance, a good quality meat will have high nutritive value, be free from significant numbers of microbes capable of causing food poisoning and from harmful chemical or physical contamination.

Having set a broad definition of quality, availability of space makes it necessary to impose some restrictions on the definition of meat-and the matters to be discussed will largely apply to that part of the skeletal musculature of meat animals which becomes the range of high-value primal cuts (or table meats). Microbiological quality, flavour, appearance and freedom from chemical and physical contamination of manufacturing meats and edible offal are important, but in general, texture, tenderness and juiciness are of no practical significance.

II. MUSCLE'AND MEAT

Meat is derived from the muscular and associated fatty tissues which are attached by tendons to the skeletal structures of the animal. A simplified diagram of skeletal muscle structure is given in fig.1.

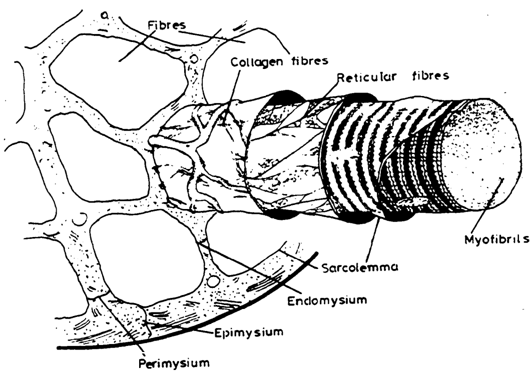

Fig. 1. Diagramatic representation of skeletal muscle showing' major structural elements.

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The major features of muscle affecting eating quality of meat are the contractile elements (or myofibrils), the connective tissue sheaths surrounding muscle fibres (bundles of myofibrils), the sum of the fibres which goes to make up the whole muscle, and fat.

In life, the contractile elements lengthen and shorten as the muscle does work and such changes can still occur for some hours after death. Associated with shortening and lengthening of the contractile elements are changes in the orientation of the sheets of connective tissue which are laid across each other in a "criss-cross" pattern. These changes alter the amount of connective tissue to be severed by cutting or biting through a piece of muscle (fig.2).

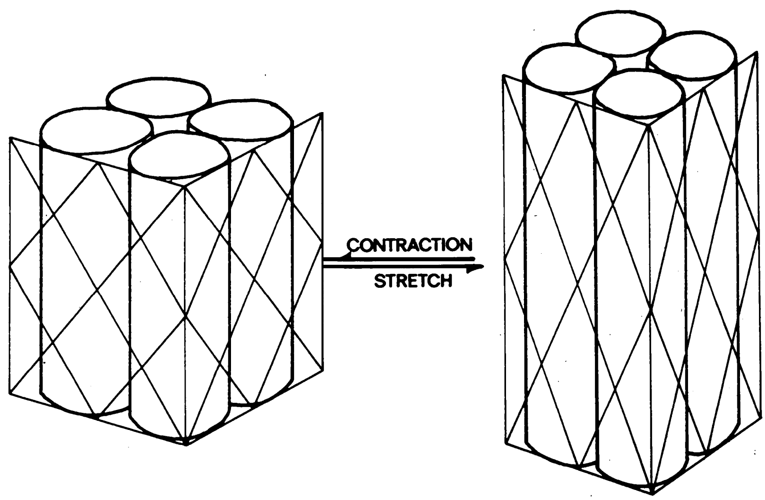

Fig. 2. Diagramatic representation of the change in orientation of connective tissue with change in myofibrillar contraction state. The network surrounding the myofibrils depicts the "criss-cross" arrangement of sheets of connective tissue.

III. FACTORS AFFECTING THE MAJOR QUALITY ATTRIBUTES

(a) Contraction state

After death, the muscles change over a period-of about 24 h, from a state of plasticity and high extensibility to one of relative inextensibility and firmness. These changes of rigor mortis can occur without change in muscle length and involve the formation of cross-links between the contractile proteins of the myofibrils. However, since the muscles are still capable of shortening after death there may be an increased packing density of the contractile proteins and toughening of the meat.

The degree to which post mortem shortening occurs depends upon the restraint imposed on individual muscles by attachment to skeletal structures. Consequently, muscles removed from the warm carcass will shorten more and give rise to tougher meat than will muscles remaining attached to the bone.

A further complication arises from the fact that post-mortem shortening of the contractile elements of muscle is temperature-dependent. For example excised beef neck muscle shortens by 25-30% of its original length if rigor changes are allowed to occur at body temperature (38°C). As the temperature is decreased, the degree of shortening is reduced until at 15°C it is only 1245%. However, upon further reducing the temperature prior to the completion of rigor changes, the degree of shortening again increases and can reach 50% at 0°C. This phenomenon is known as cold shortening.

A more dramatic shortening occurs if muscles are frozen before rigor changes are complete. In this case shortening occurs upon thawing and in an unrestrained muscle may be as much as 75% of the excised length.

Both thaw- and cold-shortening can occur when the muscles are attached to the skeletal structure since different muscles are restrained to different extents by their tendon-bone attachments.

The importance of these phenomena lies in the requirements of regulatory bodies that carcasses shall be cooled as quickly as possible to 10°C or less to minimize the growth of food poisoning bacteria. Over-enthusiastic attempts to cool meat quickly or over-rapid freezing of warm meat can result in considerable toughening due to cold- and thaw-shortening.

(b) Connective tissue state

The state of connective tissue is apparently of greater importance than its absolute amount. Thus, whilst it is accepted that meat toughness increases with animal age, e.g. veal is more tender than beef, the muscles of the calf contain a higher proportion of connective tissue than do the same muscles in older cattle. As an animal grows to maturity and beyond the collagen within connective tissue becomes more highly cross-linked and as a consequence more resistant to thermal degradation. At the same time, it must be acknowledged that in comparing muscles from any one animal, those muscles having a large connective tissue content (e.g. stewing meats) require more cooking to achieve tenderness than do those with a lower proportion of connective tissue (dry cooking cuts).

(c) pH

In life, the glycogen reserves in muscle are fully oxidised to carbon dioxide and water in providing energy for doing work, but the absence of an active circulatory system after death results in the muscle quickly becoming anaerobic. Consequently, although glycogen continues to be metabolized, the end-product is now lactic acid and the pH of the muscle falls. The final pH achieved is determined by the amount of glycogen present in the muscle at slaughter and this ultimate pH is related to tenderness, colour, flavour and keeping qualities of the meat.

The tenderness of cooked meat is positively correlated with the ultimate pH reached in the muscle. This is probably largely due to the fact that the higher the pH, the smaller the moisture losses during cooking for any given cooking temperature. Again as the ultimate pH rises, the colour of the meat changes from the aesthetically desired light to bright red colour to a much darker purplish-red colour. This effect is said to be due to there being more water associated with the muscle proteins, as pH rises from the isoelectric point, resulting in tighter packing of the fibres and a greater barrier to oxygen diffusion. In addition, the cytochromes of muscle cells are more active at higher ultimate pH and these two factors tend to lead to the replacement of the bright red oxymyoglobin with purplish-red myoglobin.

Flavour also changes as the ultimate pH of the muscle rises. The decrease in "meaty" flavour as assessed by taste panels, and associated with increasing ultimate pH from 5.5 to 6.5, is reflected by a change in the nature of the major flavour volatiles from sulphur-containing to nitrogen-containing constituents.

Finally, the higher the pH of meat the more easily do spoilage microbes grow. Consequently the keeping properties of high pH meat are inferior to those of meat of low ultimate pH.

A problem which has so far arisen only with pigs is related to the rate at which the ultimate pH of the meat is reached. Some pigs express their tendency to unusual excitability just prior to slaughter and are killed in a state of hyperpyrexia. Consequently, rigor reactions take place rapidly at the high carcass temperature, and considerable precipitation of sarcoplasmic proteins forces fluid from the muscle tissue resulting in a pale, soft and exudative (PSE) meat.

Juiciness is a further quality factor in cuts of meat which are dry fried, roasted or grilled. This character has two components, one being an initial wetness associated with the release of meat fluids on chewing and the other a "sustained juiciness" attributable to fat. The water-holding capacity of the muscle proteins is influenced by pH, being minimal between pH 5 and 5.5. As well as influencing juiciness, this characteristic is said also to be related to the amount of fluid lost as "weep" during the storage and transport of meat in a chilled state.

(d) Microbiological status-

During the process of killing, removal of hide, skin or pelt, cooling and cutting up of the carcass, there is an unavoidable contamination of meat with a variety of microbes. The two major consequences of such an occurrence are firstly the possibility that bacteria causing food poisoning, such as salmonella and staphylococcus, may grow to dangerous levels and secondly, the storage life of the unfrozen product is limited by growth of spoilage bacteria.

IV. CONTRIBUTIONS OF RESEARCH

In addition to making substantial contributions to knowledge of muscle structure, biochemistry and microbiology, meat research has contributed to presenting the end user with a better and safer product and has indicated ways in which the producer and processor may achieve the best possible outcome from their efforts.

(a) Tenderness

At the farm gate and within any one species, the most important factor is age. For a given market weight, the younger the animal, the lower the degree of cross-linking in the connective tissue and therefore the more tender the meat - given good processing. There may also be differences in tenderness due to breed although this factor is not yet well defined and the situation is complicated by evidence indicating within-breed heritability of tenderness as well as between breed differences. For example, a taste panel evaluation of the 'tenderness of meat from different breeds rated Devon, Angus and Hereford above Shorthorn and very much above Brangus and Brahman. On the other hand, cattle from five sires and dams within the same breed yielded meat with wide variations in tenderness. Observed between and within breed differences may well be due to stress susceptibility influences. Thus more research is needed before selection for tenderness can be properly initiated.

Sheep have so far shown no differences between breeds in terms of any of the meat quality attributes including tenderness.

Although it has long been believed that castrated males yield the most tender meat, recent research indicates that meat from entire or cryptorchid male sheep and entire male cattle have tenderness equal to that of their castrated counterparts provided the animals are slaughtered prior to or just about the age of physical maturity and pre-slaughter stress is avoided. Female animals are generally less acceptable in the marketplace not because of decreased tenderness but for overfatness.

The several factors associated with the live animal notwithstanding, the major potential influences on meat tenderness lie in the area of processing. Cold shortening and thaw rigor pose the most important problems, but a number of solutions have been found.

It is possible to minimize the effects of cold-shortening by programming the chilling phase of carcass processing so that the temperature of the musculature is reduced quickly to 12 or 15°C and held there until the rigor processes are substantially complete. This is only a partial solution however, because different thicknesses of the muscle at different parts of the carcass and variations in fat cover between carcasses give rise to different rates of cooling. Consequently, unless the line of animals being processed is quite uniform, it is not possible to devise a chilling programme suitable for all carcasses.

A better alternative is "altered posture" processing. Instead of carcasses or sides being hung conventionally from the Achilles tendon, they are instead hung from the pelvic girdle. The hind legs are then in an attitude at right angles to the body of the carcass and virtually all muscles in the hind quarter and along the backbone are held in tension by their skeletal attachments (fig.3).

Under these conditions, very rapid chilling can take place without danger of cold-shortening in the muscles which give rise to the valuable table cuts. This technique has been widely promoted in this country for beef and sheep meat processing under the name of Tenderstretch.

In another technique developed in New Zealand, sheep carcasses are subjected to high voltage electrical stimulation for a period of about one minute immediately after bleeding. This method relies upon electrical current causing muscles to contract and use up their reserves of glycogen resulting in the rapid accomplishment of the rigor process and allowing accelerated chilling or freezing.

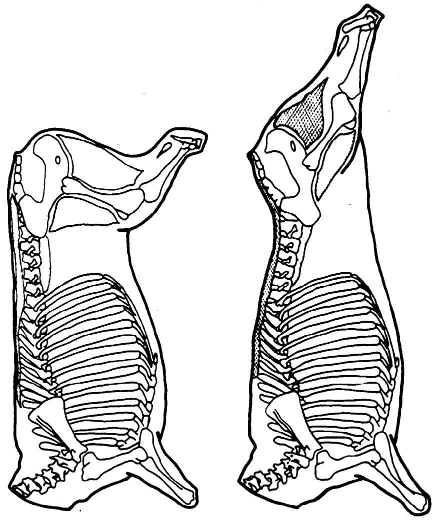

Fig.3. The influence of pelvic hanging (left) of carcasses and conventional hanging by the Achilles tendon on the tensioning of major muscles

In addition to processing techniques, measures can be taken to actively tenderize meat. The traditional method is to age or "ripen" meat by holding it in a cool place for some days post mortem. Meat which has not been subjected to cold-induced shortening will become much more tender if held at a temperature of 0°C for three weeks. At higher temperatures ageing is more rapid but the temperature should never exceed 7°C, above which food poisoning bacteria can multiply. Cold-shortened muscles will tenderize less upon ageing and not at all if shortening has been to the extent of 40% or more of the muscle rest length.

Tenderizing may also be accomplished by the use of proteolytic enzymes. The difficulty with this technique is in obtaining adequate penetration of the meat tissue to ensure even tenderizing effects. This can be overcome by injecting the proteolytic enzymes into the circulatory system of the animal shortly before slaughter, but the offals need special processing. There are also at present legislative difficulties in relation to the use of enzymes in this country.

(b) Colour and flavour

These two quality attributes are largely affected by pre-slaughter factors and minimizing pre-slaughter stress is important in ensuring good quality meat.

Stress may be induced by transporting the animals to the slaughter facility and young or weak animals may become exhausted causing low muscle glycogen levels at slaughter. The result is that the pH decrease in muscle after death is less than normal, producing an undesirably dark colour and possibly a modified flavour. Sheep are 'more susceptible than cattle to transport stress, and pigs are even more so.

The use of goads, dogs, whips and wooden batons just before slaughter can over-excite the animal and reduce glycogen reserves in the muscle. The sequelae for meat quality are the same as for transport stress. In both types of stress the temperament of the animal is important.

Excitability probably accounts for the observation that bulls often yield dark meat. However, with an adequate knowledge of proper pre-slaughter handling bull beef is as acceptable as steer beef, and advantage can be taken of the better growth efficiency and lower fat cover of the entire male.

Flavour is also to some extent related to age in that young animals give rise to rather bland meat. Entire mature males, particularly pigs and sheep, give rise to strongly-flavoured meat. In pigs, "boar-taint" has been shown to be due to the presence of adrogenic steroids and it is possible that the strong flavour of mature ram meat has similar origins.

Off-odour and flavour problems also arise as a result of grazing legumes such as lucerne and clover and forage crops such as rape, vetch and Glycine and from ingestion of weeds. Removal of the animals from the offending pastures and grazing on grass for one to two weeks prior to slaughter will eliminate these flavour problems. In some cases the ability of a pasture species to induce flavour changes in meat is related to the season during which grazing occurs.

(c) Microbiological quality

The food poisoning bacterium Salmonella is important from the point of view of public health. Only a small proportion of sheep and cattle on the farm are infected with these organisms. However, after leaving the farm, animals in this country generally pass through saleyards and holding areas which become heavily contaminated from the faeces of infected animals, resulting in a high incidence of infection in the digestive tract and of external contamination on the fleece or hide. In addition, if ruminants are briefly starved and then refed, salmonella present in the gut grow very rapidly. Recommendations have been made for pre-slaughter holding of sheep on elevated slatted floors and cattle in easily cleaned concrete pens to reduce the chances of cross-contamination.

During dressing of slaughtered animals, it is difficult to avoid contamination of the carcass with microbes from the hide or pelt. The use of "pasteurization" techniques can kill between 99 and 99.9% of bacteria on the carcass surface without affecting the appearance of the meat.

The discovery that high concentrations of carbon dioxide inhibit bacterial growth allowed Australia in the 1930's to change its exports of beef from the frozen to the chilled form. Since then the export of vacuum-packaged boneless beef has become important and so has a knowledge of microbial metabolism. Initially, export of the vacuum packed product was plagued with problems related to the development of a green discolouration of the meat. Certain bacteria were found to grow and produce hydrogen sulphide on meat with a pH of 6.0 or more. The green pigment was identified as sulphmyoglobin a product of the natural meat pigment and hydrogen sulphide. As a result of recommended pH and hygiene quality control techniques vacuum-packed chilled meat can now be expected to have a shelf life of at least ten weeks.

(d) Other relevant research

This brief review has been restricted to quality aspects of meat. There are however, a few quantitative considerations which should be mentioned.

Having satisfied quality criteria, the quantity of saleable lean meat on any one carcass is of prime importance and there is a need for a more precise and objective method for yield prediction. Extensive studies have shown that accurate prediction can be achieved if carcass weight, length and back fat thickness are known. If animal age and sex are added to this information, the facility then exists for predicting the most suitable outlet for the meat from each carcass.

A factor seriously affecting the value and yield of a carcass is the presence of bruising induced prior to or at slaughter. It has recently been shown that this problem, which costs the Australian beef industry about $20 million a year, could be roughly halved if cattle were dehorned.

V. MAJOR RESEARCH OBJECTIVES YET TO BE ACHIEVED

Prediction of meat quality from measurements on the raw product is not yet possible. The complexities of meat structure together with the massive and variable changes which take place during cooking have so far proven insuperable obstacles.

Preservation of meat is still largely in the chilled, frozen, canned or cured form. Despite extensive research, an economical technique for producing air-dried or freeze-dried meat which retains its nutritive value and is acceptable after reconstitution has yet to be found.

The meat industry is extremely labour-intensive and there is a great need for the introduction of mechanical handling and automatic processing. The heterogeneity of the input to the meat processing plant is a major problem in achieving automation which is particularly needed for removing pelts and hides and for removing meat from the skeletal structures.

By-products of the meat industry are of considerable economic significance. Apart from offals traditionally accepted as being edible, the remainder of the non-meat portion of the carcass, except for hide or pelt, is currently directed to a rendering system to produce tallow and meat- or meat and bone meal. The potential exists for the recovery of proteinaceous materials, pharmaceuticals and biochemicals from these by-products which, apart from blood plasma, insulin and the bile acids, is not yet being realized.

Finally, there is a need to assess the magnitude of the challenge posed by the development of plant and microbial protein preparations designed to partly or wholly replace meat. There is a requirement for knowledge to be accumulated on how best to exploit the properties of meat and the unconventional proteins for the benefit of all concerned.

VI. SOURCE MATERIAL

LAWRIE, R.A. (1974), "Meat Science" (Pergamon Press Ltd.; Oxford).