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CARCASS AND MEAT QUALITY

CONSUMER AND RESEARCH REQUIREMENTS FOR THE SEVENTIES

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I work for the Irish meat industry which is export orientated. I have no knowledge of the South African meat industry and will be speaking of European conditions. Indeed, I think, it is fortunate that I am giving this talk at the start of my visit to South Africa because I cannot fall into the trap of allowing a cursory visit and the resulting superficial knowledge to influence what I say.

Consumer and the Market Place

What the consumer and the market place requires should, to a large extent, influence the meat research requirements of the seventies.

In Europe many housewives go out to work before they start to rear a family and after they have reared it. Furthermore it is the exception to find paid help in the house. All the housework and cooking is done by the family. This means that the housewife wants to spend as little time as possible preparing and cooking food in the home. She also does not want to shop daily or even weekly. Family income can be high because the wife's earnings contribute to it. There is therefore a demand for convenience foods with a long shelf life which are easy to prepare and cook. The housewife has the money and is prepared to pay a high price for these foods if they are of good quality and the quality is repeatable.

Like the housewife the catering establishments (restaurants, canteens, hospitals) want to do as little preparation and cooking of food as possible. They show a preference for precooked food which only needs to be heated before serving. They want to buy meat in standard portions which makes stock control, cost control and serving easy. In the food retail trade the high cost of skilled operators, exorbitant cost of retail space, and the emphasis on price, not service, has led to a rapid development of self-service. It is essential in self-service to have the food prepacked. More and more the emphasis is on carrying out all the skilled operations in the factory including packaging in consumer packs. This leads to efficiency in the use of skilled operators and expensive packaging machines. The retailer can then concentrate on making maximum use of his expensive shop premises for display and sale. It also means, particularly in the case of meat, that trimmings and cuts not suitable for retailing are available in the factory for further processing fresh, relatively free of bacteria and in quantity.

Advertising and sales promotion are very much an essential part of efficient marketing. They are the means by which new markets can be opened up and existing ones maintained and expanded. Brand image and brand loyalty can be built up by advertising and promotion and can help in obtaining a premium price and maintaining your share of the market even in a situation of oversupply.

In Europe the emphasis in retailing is on the big general store and the chain of shops. To obtain some of the benefits of size the small retailers are forming groups to buy in bulk and share promotional expenses. This means that wholesale buying is in the hands of a small number of big buyers who will buy in bulk from the processor on specification and will not inspect each individual purchase before striking a price. It is likely that wholesale meat markets are going to become less important. Quality control to produce a standard product to specification will become essential for all meat products.

The challenge of the meat industry is to provide a convenience food which is packaged. It must have as long as possible a shelf-life and must be of repeatable quality. The advertising and sales promotion man can handle this product. The supply must be continuous. If not it places impossible burdens on sales promotion.

Meat Research and Development

Meat Research is concerned with measuring meat quality and quantity and investigating how production methods, processing, storage and transport, display for sale and methods of cooking influence quality. Quality must be defined as the requirements of the consumer, the market place and the processor. Take for example, freshness, which I will define as freedom from undesirable decomposition which can be caused by either bacterial or chemical action or both. The housewife will set a standard for freshness, transport and the market will set a minimum time requirement for maintenance of freshness but the success with which these requirements are met are very much dependent on production, processing and storage factors. An animal exhausted at time of slaughter will produce meat with a high pH and therefore a poor keeping quality. The level of hygiene in the slaughterhouse, cutting room and retail shop will influence keeping quality as will temperature control during processing, transport, storage and display for sale.

It is essential to include development with meat research. Having research workers committed to development makes them very much aware of commercial problems, opportunities and realities. Good ideas produced by research may not be put into operation for years because the research worker was not given the opportunity or encouraged to take some responsibility for development.

Because meat research must be concerned with development, the study of economic efficiency in production, processing and marketing should be closely associated with meat research. This association is essential because efficiencies in these three areas are so intimately related between themselves and with meat research and development aims.

Carcass Quality

The debate on the relationship between live animal conformation, carcass quality and the requirements of the market has caused more heat and bitterness than any other topic in Agriculture. It always reminds me of the bitterness with which the theory of evolution was debated. I often think that many people on both sides of the debate have taken up too rigid a position on this subject, to the detriment of different parts of the meat production processing and marketing industry.

Composition

In Europe meat is an expensive food and is becoming more expensive every day. It is eaten for its lean meat content. Fat in excess of that which is wanted for cooking the meat properly is not required. Therefore, one of the most important attributes of the carcass is its lean meat content.

Table 1

Hot carcass weights, total 'lean meat,' fat and bone as percentage of carcass weight

	Ex-periment	Treatment means and standard errors			F-test
		Friesian	Hereford x Shorthorn	Aberdeen Angus x Shorthorn	
Hot carcass weights	1	536,7 ±1,96	498,1 ±2,20	450,1 ±2,20	***
	2	472,4 ±9,33	476,0 ±8,85	442,4 ±8,85	*
Total 'lean meat' as % of carcass weight	1	71,1 ±0,92	65,8 ±1,10	67,0 ±1,10	***
	2	70,7 ±1,20	67,7 ±0,90	65,3 ±1,00	**
Total fat as % of carcass weight	1	15,3 ±1,20	22,8 ±1,30	21,1 ±1,30	**
	2	14,1 ±1,30	19,4 ±1,00	23,4 ±1,10	***
Total bone as % of carcass weight	1	13,6 ±0,26	11,5 ±0,31	11,9 ±0,31	***
	2	15,0 ±0,34	12,7 ±0,32	11,6 ±0,32	***
Total bone as % of lean and bone in carcass	1	15,9 ±0,26	15,2 ±0,29	15,1 ±0,29	NS
	2	17,5 ±0,39	15,9 ±0,37	15,1 ±0,37	***
'Lean meat': bone	1	5,3 ± 0,11	5,6 ± 0,12	5,7 ± 0,12	NS
	2	4,7 ± 0,16	5,3 ± 0,15	5,7 ± 0,15	***

The British market requires more fat on beef carcasses than is required in the rest of Europe. In Germany they require as little as two millimeters of subcutaneous fat over the roasting joints on the carcasses.

Because of the wide range of fat percentage found in carcasses on the British market, fat percentage is a more important determinant of lean meat yield than is the bone percentage. However, on the Continent of Europe the range in fat content is much lower and therefore the range in bone content assumes greater importance in determining lean meat content. It is important to take this into consideration when developing methods for carcass classification. The data from Harte and Conniffe (1967) given in Table 1 illustrates the point.

Tissue Distribution

The distribution of lean meat within the carcass could be a very important characteristic in determining carcass value if a high proportion of the total carcass lean occurred in the expensive cuts such as the round and the cuts along the back to the fifth rib. Unfortunately, this does not occur. It seems there is very little variation in the distribution of lean meat in beef, sheep and pigs. There seems to be a small effect due to age and sex, but little due to breed. Very young animals have a greater proportion of their total muscle in the limb joints than is the case in older animals. Bulls have a higher proportion of their total lean meat in the muscles of the shoulder (chuck) than castrates (Harte & Curran, 1967). The data in Table 2 (Harte & Conniffe, 1967) shows the small

Table 2

'Lean meat' in each cut as a percentage of total carcass lean meat

	Ex-periment	Friesian	Hereford x Shorthorn	Aberdeen Angus x Shorthorn	F-test
Clod and sticking, fore- and hind-skin	1	21,9 ±0,38	22,3 ± 0,44	21,6 ± 0,40	NS
Clod and sticking	2	13,4 ±0,25	14,7 ± 0,20	14,1 ± 0,22	**
Chuck	1	12,6 ±0,31	12,6 ± 0,36	12,0 ± 0,33	NS
	2	14,6 ±0,38	14,4 ± 0,31	14,0 ± 0,33	NS
Brisket	1	6,5 ±0,26	6,3 ± 0,30	6,3 ± 0,28	NS
	2	6,4 ±0,21	6,3 ± 0,17	6,2 ± 0,18	NS
5th,6th & 7th rib	1	5,7 ±0,14	5,5 ± 0,16	5,7 ± 0,14	NS
	2	5,4 ±0,13	5,1 ± 0,10	5,3 ± 0,11	NS
8th,& 9th rib	1	3,7 ±0,08	3,9 ± 0,09	3,8 ± 0,08	NS
	2	3,6 ±0,09	3,6 ± 0,07	3,6 ± 0,08	NS
10th rib	1	1,8 ±0,07	1,9 ± 0,08	1,6 ± 0,08	NS
	2	1,7 ±0,08	1,8 ± 0,07	1,6 ± 0,07	NS
Plate	1	1,3 ±0,10	1,4 ± 0,12	1,3 ± 0,11	NS
	2	1,5 ±0,08	1,4 ± 0,07	1,5 ± 0,07	NS
Loin	1	6,4 ±0,08	6,4 ± 0,10	6,6 ± 0,09	NS
	2	6,4 ±0,16	6,5 ± 0,13	6,6 ± 0,13	NS
Flap	1	7,5 ±0,12	8,7 ± 0,14	8,4 ± 0,13	***
	2	7,6 ±0,23	8,0 ± 0,19	9,1 ± 0,20	***
Round	1	32,7 ±0,44	31,0 ± 0,51	32,9 ± 0,47	*
	2	31,7 ±0,45	30,8 ± 0,37	30,7 ± 0,39	NS
Fore-shin	2	2,7 ±0,08	2,7 ± 0,06	2,6 ± 0,07	NS
Hind-shin	2	5,0 ±0,11	4,8 ± 0,09	4,6 ± 0,10	*

amount of variation that occurs in lean meat distribution. In France, Dumont and his co-workers have shown that there is very little variation in lean meat distribution in normal Charolais cattle (Dumont, Le Guelte, & Arnoux, 1961). Boccard and his co-workers also working in France have shown similar results for the hind leg of sheep. (Boccard, Dumont, Le Guelte, & Arnoux, 1961). In Australia Butterfield (1963) has shown that there is little variation in muscle distribution in a wide range of beef breeds.

Table 3

Means and standard deviations of dissection measurements on 1042 pigs of two breeds and two sexes

Lean weight in joint (as % of total lean)	Large White		Landrace	
	Barrows	Gilts	Barrows	Gilts
Shoulder	32,78 ± 1,08	32,38 ± 1,08	32,31 ± 1,15	31,85 ± 1,23
Back	25,16 ± 1,14	25,80 ± 1,25	26,09 ± 1,40	26,46 ± 1,21
Ham	26,97 ± 1,00	26,56 ± 0,95	26,90 ± 1,18	26,60 ± 1,02
Streak	15,10 ± 1,22	15,27 ± 1,21	14,76 ± 1,24	15,10 ± 1,22
Number	319	318	201	204

Small differences in distribution of lean meat are of importance commercially. It has not been shown and is highly unlikely that these differences can be picked up by visual examination. It is possible to pick up these differences using very accurate complete dissections on big numbers of animals. The best example I know of this is for pigs and is shown in Table 3. It was published by Cuthbertson and Pearse (1968). It is more than likely possible to breed for this characteristic and with proper breeding control any gain in distribution can be passed on from generation to generation. Any organisation with plenty of money to spend on meat research might try this experiment.

Fatty tissue

The distribution of fatty tissue within the body and the carcass can be of importance commercially and therefore influence quality.

If a particular market requires 4 mm of fatty tissue over the roasting joints it is obvious that it does not want 6 mm over some joints and 2 mm over others. Therefore even distribution of subcutaneous fat is important particularly at lower levels of fatness.

Some fat (intermuscular fat) between the muscles may be desirable. Therefore the correct ratio between subcutaneous and intermuscular fat is desirable.

In some countries, particularly the United States of America, great emphasis is placed on the desirability of adequate marbling (intramuscular fat). Most of the evidence available indicates a very weak relationship between marbling and palatability. There is a better relationship between marbling and scores for juiciness than between marbling and tenderness. The animal system may demand a certain amount of kidney and intestinal fat for protection of organs and energy store. Undoubtedly the market and the consumer does not need these fats.

I am always struck by the fact that in experiments involving carcass data the coefficient of variation for fatty tissue data is always higher than that for muscular tissue and on the other hand in animal breeding work the heritability of fatty tissue is always higher than for muscular tissue. I expect the coefficients are always high in experiments because the genetic material is not well controlled. The high heritabilities for fatty tissue indicate that there must be scope for reducing fat and moving fat around the body and carcass by genetic means. I think this is a subject wide open for research, but first of all we need to develop better objective fat measurement than we have. Then we need to make a thorough investigation of the fat requirements of the market. This is absolutely essential before the development stage of the breeding work is reached.

Tissue Thickness

In most markets a premium will be paid for carcasses with good conformation. In my experience the greatest differential is paid on the French market. The French method of cutting beef carcasses involves the dissection and trimming of a lot of individual and groups of muscles. In light carcasses and in light muscled animals some of these muscles may be so thin that they are nearly commercially useless. With the British method of cutting, a thick eye muscle (*M. longissimus dorsi*) may allow the butcher to include a little more of the cheaper flap (abdominal muscle) and flat ribs with the loin and foreribs thus enhancing the price he can obtain for the carcass as a whole. Furthermore may butchers claim that the eating qualities of thick muscled animals are better than in thin muscled animals. This remains to be proved.

A housewife may appreciate a plump (thick muscle in relation to length) joint of lamb or pork and the plumpness may reduce moisture loss during cooking but I find it hard to believe that in beef carcasses, which are cut into so many consumer joints, the housewife can appreciate plumpness in the joint she buys.

The total weight of lean meat in a carcass divided by some measure of length such as length of carcass or length of leg gives a good indication of muscle thickness both for commercial and experimental purposes (Yeates, 1959). However if one wants to use this index as a measure of shape of muscling (conformation) it must be related to some measure of size (Dumont, 1971) because an index of value in a carcass of small size will give an impression of better shape than the same index value will at a large carcass size. It is better to use carcass length or height as a

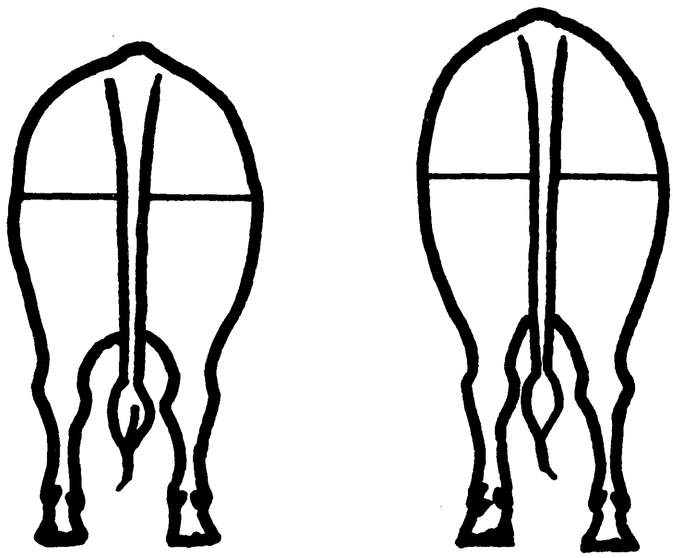

Fig. 1. – *Two types of conformation in steers*

measure of size rather than carcass weight because carcass weights may not be a good representation of size as it includes fatty tissue weights.

It is obvious that thick muscled animals, in most cases, will have a high muscle to bone ratio. However there are some breeds which are light boned which give better muscle to bone ratios than one would expect from measuring the depth of muscle or judging visually on conformation. An example of this is the Limousine (Bergström, 1971).

In discussing the thickness of subcutaneous fat over roasting joints it must be remembered that a given depth of fat over a thin muscle will result in a higher fat to lean ratio or fat percentage in the carcass than the same depth of fat occurring over a thick muscle. Therefore, in thicker muscled animals and in larger carcasses the market may require carcasses containing lower fat percentages. De Boer and Bergström (169) are worth reading on this topic.

Carcass Size

For commercial purposes carcass size can best be described by carcass weight. Although for some purposes carcass size may be better described by carcass length or length of leg or the weight of the muscle plus the bone.

Carcass size is of great commercial importance because it can have a big influence on the size of joint and the thickness of muscling. Different markets have different carcass weight requirements. The Dublin butcher shows a preference for a 400 lb beef carcass. The Paris butcher wants a minimum carcass weight of 800 lb. The London butcher would like something in between.

In breed comparison and nutrition work involving carcass evaluation, carcass weight considerations raise difficult problems. If treatments are compared at 400 lb. carcass weight the carcass data will be very much different to that if the animals were compared at 600 lb or 800 lb carcass weight. You can get big treatment carcass weight interactions. Therefore unless you are very sure that you are breeding or feeding for a definite carcass weight requirement you must kill some animals from each treatment at a number of carcass weights and at least two. There is no justification for and plenty of danger in extrapolation of carcass data from one carcass weight to another.

Conclusions on Carcass Quality

1. The lean meat percentage is the most important characteristic of a carcass.
2. Fatty tissue in excess of that required by the consumer is undesirable. It reduces the lean meat content of the carcass and has to be sold at a very low price. It should be measured as depth and consisting of distribution of subcutaneous fat over the roasting joints and quantity of intermuscular and intramuscular fat required.
3. The consumer and the buthcher requires a particular muscle thickness. This muscle thickness in a small carcass will give the impression of good conformation. The same muscle thickness in a heavier carcass will give an impression of poorer conformation. How important is conformation?
4. There is very little difference in distribution of muscle between the expensive and cheap cuts. Visual appraisal of the animal or carcass will not pick up these differences. It will take very accurate dissection to do so.
5. There is an urgent need, all over the world, to *quantify in objective terms* the carcass requirements of the meat market. This applies particularly to beef and lamb carcasses. It is also necessary to quantify the differentials in price that will be paid for successive increment of the different quality factors. To do this the real requirements of the consumer will have to be measured.
6. Because the heritability of fatty tissue data is high in comparison to muscle tissue and because there is greater variation in fatty tissue distribution and absolute amounts of fatty tissue in animals and carcasses by breeding must be higher than the probability of success in changing lean meat distribution within the carcass. The reduction of fatty tissue in the carcass to no more than that required by the market could have a marked effect on the efficiency with which lean meat can be produced because in energy terms it takes between six to seven times as much food to produce a pound of lean meat as a pound of fatty tissue.

Meat Quality

In discussing meat quality independently of carcass quality, I am conscious that I am doing something which I often criticise. I do it here as a matter of expediency, but I wish to emphasise that both carcass and meat quality are inextricably interrelated. The meat processor, the wholesaler, retailer and consumer have many criteria, other than carcass composition, by which they establish their standards for quality. These criteria include the colour of the skeletal muscle and the fatty tissue, the ability of the muscle to hold water, the tenderness of the meat and its juiciness and flavour.

Colour and Waterholding Capacity of Muscle

It is necessary to discuss colour and waterholding capacity together because many of the biochemical factors which influence one also influence the other.

The consumer prefers different shades of colour in the muscle for the different meats. In veal, a light pink muscle colour is desired. This colour is supposed to be associated with milk feeding and it is expected that it will indicate a particular milk fed veal taste. In beef, a bright cherry-red colour is required. I am sure that the basis of this preference is that the bright red colour is thought to indicate freshness and freedom from bacterial decomposition. However, a dark colour which is discriminated against in beef may indicate that the meat has been well hung and that its eating qualities may be enhanced. On the other hand, dark coloured beef may result from killing an exhausted animal which does not have enough reserves of muscle glycogen to achieve an adequate level of pH twenty four hours after death. It is also possible of course, that dark colour may mean that the meat has been badly stored and that bacterial decomposition is taking place. There is no doubt that in most markets the purchaser is very much influenced by the colour of the lean.

Waterholding capacity

This characteristic in meat is of great commercial importance. It is also important to the consumer. The reduction of moisture loss in beef during cooking by as little as a quarter of a per cent of the carcass weight can be very important commercially. Legs of pork of low waterholding capacity are not suitable for canning as ham because during processing the ham muscles cannot hold their moisture. The moisture escapes to the outside of the muscle bringing with it hydrolised collagen (connective tissue). Hydrolised collagen is gelatine and this is the gelatine which one sees on the outside of canned meats. It is aesthetically objectionable to the consumer.

If beef with poor waterholding capacity is prepacked into consumer packs the meat exudes moisture which will collect as a bloody pool in the pack. This is very objectionable to the purchaser.

In a broad review, time does not permit me to go into details of the factors, which influence the colour and waterholding capacity of meat, nor am I technically competent to discuss them in such detail. My colleague Dr. McLoughlin has done this (McLoughlin, 1965, 1969). However, I would like to discuss some of his findings and indicate the kind of research and development work that I think is needed in the years to come. After death, the pH of the muscle of meat animals falls from a neutral value (7,0) to an acidic one which is normally 5,5. The pH of the pig muscle sometimes falls very rapidly so that it reaches values below 6,0 soon after death, i.e., before the muscle temperature is reduced to below 35°C, when this happens, pale, exudative muscle develops. At temperatures below 35°C, critical pH will be lower. Pale exudative muscle is caused by a denaturation of the sarcoplasmic proteins and their absorption into myofibrillar protein sites which bind water. There is also a masking of the myoglobin colour of the muscle. Reduction of muscle temperature as quickly as possible after death will reduce the risk of pale watery muscle developing. Very rapid cooling of the carcass is not commercially possible. It is therefore important to have muscle in which there is a gradual drop in pH which will allow sufficient time for cooling the carcass before critical pH levels are reached.

The method by which a pig is slaughtered influences the rate of pH fall. McLoughlin (1964) reported that low pH values are reached soon after death if pigs are stunned by shooting through the forebrain using a captive bolt pistol. On the other hand, when pigs were slaughtered unstunned he found a reduction of rate of pH fall. Electrical and carbon-dioxide stunning produced an intermediate acceleration in pH fall.

Breed and type of pig can have a marked effect on rate of pH fall. Pigs whose lean meat production capacity has been improved by breeding tend to have a faster rate of *post mortem* pH fall than unimproved pigs and therefore have a greater tendency to develop pale soft exudative muscle. This can occur also within breeds. McLoughlin (1971) has shown that within a breed the pigs that qualify for the top Wiltshire grades have a somewhat faster rate of pH fall, than those in the lower grades.

As a result of his work on method of slaughter McLoughlin suggested that the rapid drop in pH *post mortem* in pigs may be due to nervous stimuli from the brain entering the muscle at the time of death and causing contraction of the muscle. This suggestion was supported by the fact that administration of curare *ante mortem* slowed the rate of pH following stunning with a captive bolt. He then studied the effect of electrically stimulating the *semitendinosis* muscle in the leg while the pig was under anaesthesia so that the muscle contracted. In pig *semitendinosis* there is a red area where the muscle fibres are predominantly red and a white area where the fibres are predominantly white. Metabolism in red fibres, which are generally considered to be relatively small in diameter, is of the aerobic type which readily oxidises lactic acid while that occurring in the white fibres (which are considered to have a large diameter) is of the anearobic type which accumulates lactic acid. In the absence of electrical stimulation, the rate of pH fall and other changes were much the same in both the red and white muscle area. Following electrical stimulation, the drop in pH in the white fibre area was much faster than in the red fibre (Tarrant & McLoughlin, 1971). The results of McLoughlin and his co-workers are very interesting because it has been reported by Staun (1968) and Dilday, Aberle, Forrest and Judge

(1970) that in the pigs they examined there was an inverse relationship between fibre size and incidence of pale soft exudative muscle. It may be possible that in breeding pigs for enhanced muscle production and development, inadvertently a type of muscle fibre is selected which is predominantly of the anaerobic type.

These results indicate that in breeding for muscle development there may be a limit beyond which it is impossible to progress without encountering pale soft exudative muscle. However it may be possible to avoid this deterioration by selecting simultaneously for improved muscle development and a slow drop in *post mortem* pH (aerobically metabolising muscle). The same end may be achieved by breeding for improved muscle growth and development in beef there may be a danger of developing soft exudative beef.

Age of animal at slaughter and nutritional status influences the intensity of colour. Young animals have a higher coloured meat than older animals. In veal the stored iron in the calf at birth is of importance in controlling muscle pigmentation as is the feeding of the calf (Charpentier, 1966; Saint-Laurent & Brisson, 1968). One of the aims in cattle improvement is to increase growth rate. This, combined with a continuous high plane of nutrition means that beef animals are being slaughtered younger than ever before. Young animals have paler muscle with a more insipid taste than older animals. We all know how insipid broiler chicken is. It may be necessary in the future to breed cattle which, when slaughtered at an early age give beef a good cherry red colour and a full bodied beef flavour.

In the coming years there is urgent need to investigate the possibility of improving the colour and waterholding capacity of meat by developing more efficient stunning and slaughter methods. The rate of pH drop after slaughter can be used to study the success of new methods.

The pH the muscle attains twenty four hours after death and the temperature at which meat is stored from slaughter to consumption also influences waterholding capacity. These need to be investigated. A reliable meaningful method of measuring the waterholding capacity of meat needs to be developed. This would help the development of research work in the field.

The meat colour requirements of the consumer and her sensitivity to small changes in colour need to be investigated. Hegarty (1969) has shown that there is considerable variation between observers in evaluating colour of pork. It may be possible that variation in redness within fairly wide limits may not be of great importance. However, Hood and Riordan (1970) have shown that quite small changes in discolouration resulting from small changes in the ratio of oxymyoglobin to metmyoglobin on the surface of the meat gave rise to a rejection of the meat by the supermarket shopper. This work must be extended if vacuum packaging and consumer packaging of fresh meat is to be developed to its full potential.

Tenderness

It is generally agreed that tenderness in meat is more important to the consumer than flavour. If meat is not tender most of the pleasure of eating it is lost. On the other hand meat can be too tender, lack body and not give that pleasure which is associated with chewing meat. It is of interest, that the new simulated meats, produced from plant and microbial protein lack the pleasurable chewy character of meat. This will militate against their use other than as meat extenders in processed meat products.

The cellular unit of muscle is the fibre which is enclosed in a membrane, the sarcolemma. Bundles of these muscle fibres are held together in a sheath (perimysium) of connective tissue. These membranes and sheaths are intimately connected throughout the muscle and are attached to the tendon. The connective tissue mainly consists of collagen.

During cooking, the connective tissue (collagen) of meat, in the presence of moisture and heat, is hydrolised to gelatine. The thicker the connective tissue sheath and the more insoluble the collagen the greater the cooking time required to convert the collagen to gelatine and so produce tender meat. This in part, explains why muscles with thick connective tissue sheaths from the leg, neck and shoulder are only suitable for stewing and braising while muscle such as fillet and eye muscle from the sirloin which have finer sheaths of connective tissue and less connective tissue (McIntosh, 1961) are suitable for grilling and roasting. Hill (1966) and Bailey (1969) have shown that collagen from older animals was less soluble than that from younger ones. This explains part of the reason why meat from older animals is less tender than meat from younger animals. Calf muscle which is tender contains more collagen than adult muscle. (Wilson, Bray & Philips, 1954; Bendall & Voyle, 1967).

Within the muscle fibre are the myofibrils consisting of interdigitating filaments which slide along one another when the fibrils contract. In life when the fibrils contract they transmit a pull to the connective tissue network and so through the tendon to the skeleton. This produces movement in the limbs.

When the myofibrilar filaments slide along one another they do so by means of a bridge which occurs between one protein filament (actin) and the next (myosin). In life chemical energy produced by the metabolising fibre facilitates the sliding mechanism. However one or two hours after death this production of energy within the fibre ceases and the filaments become locked together at the bridges. This is called *rigor mortis.* During aging of meat *rigor mortis* is resolved and the muscle becomes placid.

If the muscle is contracted when *rigor mortis* de-

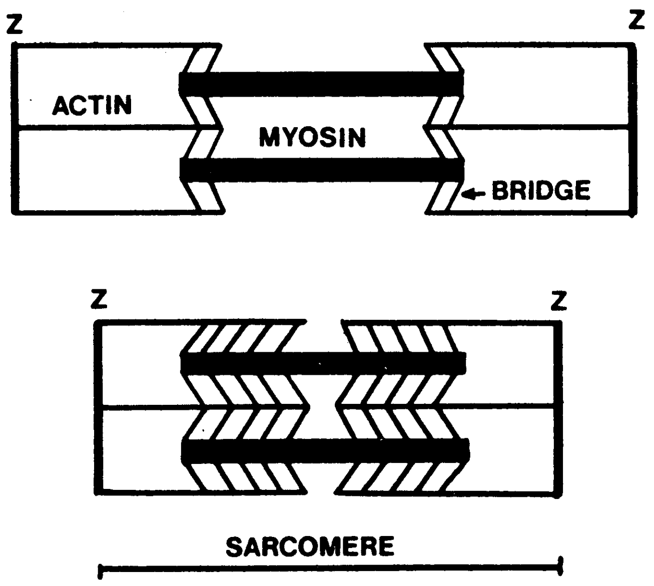

Fig. 2. – *Contracted (below) and relaxed (above) contractile units of the muscle fibre*

velops then the filament overlap at the bridges is extensive and it is generally acknowledged that this causes the meat to be tough. For this reason meat should not be cut from the bone before *rigor* develops because if it is freed from the bone contraction will occur. On the other hand if the muscle can be extended before *rigor* sets in the overlap at the filament bridges will be short and the meat will be more tender. An example of this is the fillet which is stretched when the hot carcass is hung by the leg. During *prerigor* cooling muscle shortens. This shortening occurs to a greater extent at 37°C and 2°C than at 15°C. Therefore too rapid cooling of *prerigor* muscle should be avoided.

Post mortem aging of meat increases its tenderness presumably by physico-chemical mechanisms. It is suggested (Stromer & Gale, 1967, a,b) that this is caused by a break in the sarcomere structure between the *Z*-band and the actin filament. It is also suggested that the bridges between the actin and myosin filaments may also break.

The waterholding capacity of the muscle and the effect of heat during cooking on muscle proteins influences both the tenderness of muscle and its juiciness. Overcooked dried-out meat can be very tough.

The animal production, slaughter, processing, storage and cooking factors influencing tenderness are very complex, (Joseph, 1968 a, b and 1970) it is a difficult research area and is not made easier by the fact that it is difficult to measure tenderness of muscle precisely without using a large number of people on taste panels.

If fresh and frozen meat is to compete successfully for its share of the market against processed meats simulated meats and non meat convenience foods then the uniformity and repeatibility of tenderness in fresh and frozen meat will have to be improved. Any upgrading of muscles from stewing to roasting beef or from roasting to grilling by making it more tender will be of considerable commercial importance. The introduction of vacuum packaging of fresh wholesale cuts has opened up the possibility of varying the temperature and duration of aging of the different cuts.

Meat can be tenderised by the application of proteolytic enzymes of plant or other origin to the meat. In the patented 'Proten' process of Swift's & Co., the papain is injected into the jugular vein of the beef animal before slaughter. At present this is commercially the most successful process. There is plenty of scope for further research and development on this subject.

Flavour

Flavour becomes important once colour, waterholding capacity and tenderness requirements have been met. Establishing the flavours the consumer requires and quantifying these requirements is an enormous problem. Breed, age of animals, sex, feeding and maybe method of slaughter can influence flavour. As we breed and feed animals that grow faster and are slaughtered at a younger age the flavour of meat may become too bland for the consumer and it may be necessary to try and breed for a more intensive meat flavour.

Conclusion

In this review of research requirements on carcass and meat quality I hope I have made the point that there is urgent need to quantify the requirements of the consumer, the market and the processor. If production and processing research is to develop fact must be separated from folklore both in the market place and in the kitchen.

Very few research problems in carcass and meat quality are confined to any one area of the meat industry. The answers are to be found spread over the production, slaughter, processing, marketing and consumer fields of study.

The answer to most meat quality problems lies in the physiology and biochemistry of muscle growth and metabolism in life and the changes in metabolism and structure that occur at and after slaughter.

To have successful meat research, work on production, physiology, slaughter, processing, storage and marketing must be studied in the closest possible association. Economic efficiency studies and development work should bind the whole into an effective research unit.

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