SESSION 4. FRESH MEAT TECHNOLOGY

REVIEW: DEVELOPMENTS TO IMPROVE EFFICIENCY IN POST-SLAUGHTER HANDILING AND DISTRIBUTION OF FRESH MEAT

A.A. Taylor

AFRC Institute of Food Research - Bristol Laboratory
Langford, Bristol, UK

The area of post-slaughter handling and distribution of fresh meat covers a wide range of operations from slaughter through to the final portion or product as it reaches the consumer. The industry is continually looking for new technologies or techniques for improving the efficiency of getting meat from the point of slaughter to retail in the quickest and most economical way without detracting from eating quality and consumer satisfaction.

Interest can be focussed on four main objectives:
(a) reducing chilling time and evaporative weight loss,
(b) making usable meat available as quickly as possible,
(c) achieving marketable tenderness as early as possible and
(d) presenting meat to the consumer in a hygienic and attractive form.

I shall consider some of the developments and trends in these areas as they relate to whole meat, and their consequences on meat quality.

CARCASS CHILLING AND WEIGHT LOSS

Beef, lamb and pig carcasses or sides are normally cooled by placing them in a room at a temperature approaching 1°C or 2°C and with little air movement, and leaving them until their maximum temperatures reach some specified level. The amount of heat to be extracted during the first 4 h of chilling is far greater than the average rate over the whole cooling period. In some circumstances, this peak product load may be as high as five times the average requirement (Cox & Bailey, 1977) and few chillrooms are designed with refrigeration to cope with this exceptional demand. As a consequence, air temperature rises and cooling time is increased; in the UK, most abattoirs operate chilling periods of 14 to 16 h for pork and lamb and 36 to 48 h for beef carcasses. Slow cooling during the initial stages has the extra disadvantage of allowing a high rate of evaporative weight loss. Batch chilling systems for pigs can give weight losses over 24 hours of between 1.9 and 3.6% (Gigiel, 1984) and for beef, losses average between 1.1 and 2.0%.

The economic disadvantages of slow throughput and excessive weight loss have encouraged the search for chilling systems which will reduce carcass temperature to 7°C as rapidly as possible without freezing. Much of the initial interest has been with pigs, where smaller carcass size, faster throughput and a higher degree of specialisation offer more obvious advantages with rapid chilling. Work at Bristol showed that the total product heat load of a 70 kg pig carcass can be extracted in 4 hours, using a single-stage process with air at -30°C and 1 m/s (James et al, 1983; Gigiel & James, 1984). After a further 20 h equalisation period in vacuum packs, temperatures in the shoulder and belly were +3°C and -2°C respectively. The average evaporative weight loss from carcasses cooled in this way was 1.1% compared with 2.1% from carcasses cooled overnight in a room at 4°C.

Although rapid pig chilling systems with sub-zero temperatures are little used commercially in the UK, they are in some other European countries and in North America, although initial air temperatures tend to be higher than -30°C. In The Netherlands and Denmark, pig chillers have been designed to use high velocity air at -20°C to extract approximately 80% of the total heat before carcasses pass to equalisation stages with higher temperatures and relative humidities. Weight losses as low as 1% are reported, but to achieve this, it is essential that, after the initial blast chilling stage, air velocities are kept to a minimum.

Because of their larger bulk, beef carcasses present greater problems in rapid chilling. Although the total heat load of a 120 kg beef side to give an average temperature of 7°C, can be removed by 6 h treatment with air at -15°C and a velocity of 3 m/s (James, 1985) and such a system can reduce weight loss to only 0.8%, a considerable proportion of the carcass is frozen and this limits application for producing chilled meat. Some large abattoirs in the USSR were reported by Sheffer & Rutov (1970) to be using 2-stage systems for chilling beef sides. These used air at -10°C to -15°C and 1 to 2 m/s for the first 4 to 8 h, followed by an equalisation period at -1°C and moderate air velocity for 6 to 8 h. Overall weight loss was reported as 1%.

The main problem in applying rapid chilling techniques to large carcasses like beef is excessive surface freezing. For this reason, most accelerated chilling systems proposed for beef use very low temperatures only for the first few hours and follow with one or more stages, progressively increasing temperature to allow equalisation. Some of the rapid chilling systems proposed in the literature for beef, the conditions used, and the reduction in time and weight loss are shown in Table 1 (James & Bailey, 1986).

Table 1. Rapid chilling systems proposed for beef sides. Side weights, time to reach 7°C maximum, total cooling time, and reported weight losses compared with conventional chilling

Cooling conditions*	Side (kg)	Time (h) to 7°C max	Time (h) Total	Weight loss (%) Conventional chill	Weight loss (%) Rapid chill
1	100	18	18	2.25	1.47
2	123	15	20	-	0.88
3	119	14	21	-	1.03
4	118	13	21	2.15	1.12
5	-		10-16	2.0	1.0
6	-	14	21	1.94	1.28
7	120	20	21	1.52	1.08

*

(1) 3 h at -30°C with liquid N_2 injection, followed by gradual increase to 0°C over 4 h (Kerens, 1983).
(2) 3 h at -19°C, 1.2 m/s, followed by 17 h at 0.6°C, 0.75 m/s (Kerens, 1983).
(3) 3 h at -19°C, 1.2 m/s, followed by air gradually increasing to 0.7°C over 7 h, with air at 0.75 m/s (Kerens, 1983).
(4) 2.5 h at -19.5°C, 1.2 m/s: 3 h at -9.5°C, 0.75 m/s, followed by increase to 0°C (Kerens, 1983).
(5) 4 to 8 h at -15° to -10°C, 1 to 2 m/s, followed by 6 to 8 h at -1°C, 0.1 to 0.2 m/s (Sheffer & Rutov, 1970).
(6) 6 h at -15°C, 0.5 to 1.5 m/s, followed by gradual increase to 4°C over 12 h (Union International Consultants, 1984).
(7) 6 h at -15°C, 2.3 m/s, followed by 15 h at 0°C, 0.5 m/s (James, 1985).

All the rapid chilling systems in Table 1 are capable of cooling sides below 7°C within 20 h and show reduced weight losses. In experiments at Bristol considerable crust freezing occurred (James, 1985) and this has hindered widespread uptake of such systems in the UK.

The economic advantages of rapid chilling were evaluated by Bowater (1986) who compared 3 systems for beef chilling which fitted into daily cycles to satisfy production and labour requirements. They were:

(a) Slow chilling: 48 h system
(b) One day cycle: 24 h system
(c) Rapid chilling: within 24 h system.

He identified the principal advantage of rapid chilling as the reduction in weight loss. Prototype tests were carried out at Bristol and CSIRO, Brisbane, using for the conventional 24 h system (b), air at -1°C and 1 m/s. The rapid system consisted of 1 h at -15°C, 2 m/s; 3 h at 12°C, 2 m/s and then 17 h at 4°C. Respective weight losses for the 48 h, 24 h and rapid chill were 2.5%, 1.2% and 0.6% although the last was measured before the 17 h equalisation stage was because condensation occurred sometimes on the cold carcasses during temperature equalisation. In practice, this should be avoided by allowing temperature to rise gradually during the equalisation period.

Nevertheless, these trials gave the basis for estimating the relative economic advantages of the three systems, with full consideration given to the higher capital and running costs of the rapid systems (Table 2).

Table 2. Production cost per head of cattle for 3 chilling systems. Cost per head (£)

System	Capital	Operating	Weight loss	Total
48 hr chill	2.33	0.49	11.00	13.82
24 hr chill	1.66	0.72	5.28	7.66
Rapid chill	3.20	0.52	2.64	6.36

The apparently simple expedient of enhancing initial heat extraction by injecting cryogenic liquid into conventional chillers during the early cooling period has been examined by several workers. Kerens (1983) claimed that addition of liquid N_2 to a beef chiller normally operating at 0°C, reduced air temperature to -30°C and cut the time to reach 7°C maximum carcass temperature from 25 h to 18 h and reduced weight loss from 1.90 to 1.46%. Other workers have used liquid air in the same way, and achieved reductions of between 0.36 and 0.54%. Although the use of cryogenic liquids for chilling is certainly promising their control to avoid surface freezing is difficult and they are currently expensive to use. It must be realised, of course, that where rapid chilling is applied to carcasses, the advantages in reduced weight loss are maximised only if the meat is packed as soon as cooling has been completed. Unnecessary holding periods can lose the earlier advantages.

ACCELERATED HANDLING AND HOT BONING

The cooling conditions proposed for rapid chilling of carcasses are severe enough to lead to cold-toughening in beef and lamb and, some might suggest, even pork. Electrical stimulation (ES) is therefore a sensible prerequisite when considering rapid chilling of beef and lamb carcasses. ES is now an accepted technique in the meat industry and is used in a variety of forms; low voltage ES ranges from 45 v to 90 v peak, while high voltage systems range from 200 v to over 1000 v peak. Duration of stimulation varies from 30 to 64 s with low voltage, and from 60 to 120 s with high voltage. Frequencies vary from 1 pulse/s to 50 or 60/s and their shape and width can differ greatly. Despite the diversity of these parameters, literature suggests that the vast majority of ES systems are effective in reducing pH by about half a unit and advancing rigor sufficiently to avoid cold shortening.

While ES removes one obstacle to rapid chilling, the difficulty of removing heat quickly from the deeper parts of the carcass is still a limiting factor. However, if meat is removed from the carcass while it is still hot, and cooled in vacuum packs, chilling time can be halved and refrigeration costs considerably reduced (Taylor et al., 1980-1). Providing the meat is packed at this early stage, it can be chilled to final temperature without further evaporative weight loss.

By reducing the carcass to smaller pieces, hot boning (HB) may be regarded as a method of achieving better control over chilling rate, and once limitations of carcass size and shape are removed, hot boned meat can be chilled by efficient cooling systems normally used for smaller products. Blast cooling tunnels with variable belt speeds are already in commercial use for continuous chilling of products, and are capable of cooling 8 cm thick pieces of meat from 40°C to 2°C in less than 8 h. Alternatively, systems using immersion, spray or plate cooling used for other food products, could be employed equally effectively with hot boned meat.

There is no doubt that the opportunity exists for a dramatic improvement in the efficiency of post-slaughter chilling of meat, but although the advantages of a combined ES and HB system for beef have been clearly demonstrated by meat scientists throughout the world, uptake of this new technology is still limited. Nevertheless, the potential can be judged by noting the cases where commercial-scale HB operations are being used now.

Hot boning is frequently practised with pigs and beef to provide raw material for processing, as in accelerated sausage manufacture, but examples of hot boning carried out on a commercial scale to produce quality whole meat joints are less common. Factory-scale hot boning to produce this type of beef has been successfully practised for several years at locations in UK, Denmark, Sweden, Finland and Norway, and no doubt in other countries of which I have no experience.

The commercial advantages of HB can be best demonstrated by the experience of a major company in South Africa which has made a serious commitment to hot boning of beef and is in an ideal position to maximise the benefits. The company has its own feedlot, transport, abattoir and boning hall and its own wholesale distribution chain to company-owned butchery outlets in super- and hypermarkets. They have found hot boning so successful in their situation that they have expanded their hot boning rooms to handle 300 beef carcasses per day in a single shift. All carcasses are electrically stimulated, using a 2-stage process. Immediately after bleeding, 32 v are applied for 60 s and then, 12 minutes later, a high voltage of 500 v is applied for 120 s. All carcasses are pH tested at 45 minutes post-slaughter and only those with pH <5.8 (90% of the total) are selected for hot boning.

The hot carcasses spend a maximum of 1 h in the boning room, with strict attention paid to regular sterilising of knives, tables and other equipment. The carcass is cut to primals which are vacuum packed in shrink bags and placed on well-ventilated crates, stacked on trolleys. Conventional carcass chillers have been converted to smaller, more efficient primal joint chillers and the trolleys of meat are put into these with high speed air at 2°C directed through the crates for 48 hours. The meat is then transferred to a conventional holding store at 0°C for a further 24 hours before distribution to retail stores.

The main advantages experienced with this HB operation are:
(1) Reduction in drip loss from both forequarter and hindquarter primals.
(2) Better colour of lean and fat.
(3) Evaporative weight loss during chilling reduced by 1.8% compared with conventionally cooled carcasses.
(4) Yield of primal joints increased by 0.5%.
(5) Yield at retail level increased by 0.5%.
(6) HB is preferred by butchers and productivity has increased by 20% compared with cold boning.
(7) Considerable savings in energy costs.
(8) Saving in capital expenditure by converting conventional carcass chill rooms to provide smaller, efficient chillers for primal joints.

I have concentrated on hot boning carried out at the earliest opportunity, but there are endless other possibilities for what might be termed 'early boning', i.e. before the carcass has been completely chilled. There is growing evidence, particularly from countries exporting into the Community, that many abattoirs are introducing procedures where carcass cooling is interrupted to allow early boning to primals, before final cooling is resumed. This approach to accelerated post-slaughter handling of meat may prove to be the forerunner of hot boning in its ultimate form.

EFFECT OF ES AND COOLING RATE ON TOUGHNESS

Electrical stimulation will continue to be a sensible precaution in any accelerated chilling process, but its value to the industry is not limited to avoidance of cold toughening. If used with slower cooling rates, ES is claimed to promote earlier tenderisation of meat. In a general review on ES, Marsh (1985) states that it has three effects (a) avoidance of cold-shortening (b) tenderisation, and (c) mechanical disruption of muscle fibres. Their relative importance depends on cooling rate, and for (c), the method of stimulation. It is generally accepted that, at cooling rates where cold-shortening is a possibility, correctly applied ES will avoid toughness. The tenderising effect in the absence of cold-toughening or cold-shortening is not so clearly defined. Indeed, Marsh (1986) revised his earlier views and attributed improved tenderness with ES to only two of the effects: avoidance of cold-toughening and fibre disruption. He further claimed that acceleration of pH fall <u>per se</u> retards tenderisation. He concluded that, where cooling is rapid, either high or low voltage ES prevents toughening, but only high voltage ES will cause further tenderisation by fibre disruption. With slow cooling, where cold shortening is not a risk, only high voltage ES produces additional tenderness. Low voltages only accelerate pH fall, which suppresses normal tenderisation and can actually toughen meat. It should be noted however, that the stimulation parameters used in these studies were very different from those commonly used in Europe and Australasia. In particular, the 2Hz pulse frequency of the low voltage system which did not give any fibre disruption is very much lower than the 14.3 Hz of most commercial low voltage units employed in many countries to promote tenderisation.

We have carried out experiments under industrial conditions to evaluate the extent to which the tenderness of some of the muscles in beef carcasses are improved after low voltage ES and either quick or slow cooling. Eight beef carcasses (ES) were stimulated for 60 s immediately after bleeding, with a peak voltage of 90 v at 14.3 Hz, in a routine abattoir procedure. After dressing, 4 of the carcasses were cooled in a room with air at 1°C and 0.2 m/s (quick). The other 4 carcasses were placed in a room with air at 10°C and 0.2 m/s until 10 h post-slaughter (slow), at which time room temperature was dropped to 1°C and remained there until cooling had been completed. A further 8 carcasses were used as non-stimulated (NES) controls and subjected to the same cooling treatments, 4 quick and 4 slow. Mean cooling rates and pH values in the longissimus dorsi muscle are indicated in Table 3.

<u>Table 3</u>. Time, temperature, pH and evaporative weight loss data for quickly and slowly cooled ES and NES beef sides

	quick	slow
Time (h) for LD to 15°C	7.0	10.2
" " " " " 10°C	9.7	15.0
" " " " " 7°C	12.0	18.5
pH (1 h) in LD, ES		5.96
" " NES		6.65
pH (48 h) in LD, ES	5.60	5.64
" " NES	5.67	5.61
Weight loss (%) during cooling (48 h)	1.75	2.06

At 48 h post-slaughter <u>M. longissimus dorsi</u> (LD), <u>M. semimembranosus</u> (Sm) <u>M. pectoralis profundus</u> (PP) and <u>M. triceps brachii</u> (TB) were removed and each divided into 3 portions. These were individually vacuum packed and stored at 1°C until assessment. At 3, 7 and 10 days post-slaughter a sample of each muscle and each cooling/ES treatment was cooked, cooled and texture (shear force) measurement made across the fibres of ten blocks of muscle each 2 x 1 x 1 cm.

Quick cooling reduced the temperature of the whole of the LD and a considerable proportion of the other 3 muscles below 10°C within 10 h of slaughter, conditions which would be expected to cause a certain amount of cold-toughening. By contrast, the delay period at 10°C in the slow cooling treatment meant that no part of the carcass was below 10°C within 10 h. The centre of the LD, in fact, took 15 h to reach 10°C, slowly enough to have avoided the possibility of cold-toughening. The pH values at 1 h post-slaughter demonstrate the effectiveness of the low voltage ES system, with a reduction of more than half a pH unit.

Mean toughness values in Table 4 show that with this moderately quick cooling, ES gave lower shear force values in the LD and TB samples. The improvement in tenderness was less pronounced in the PP and absent or reversed, in the Sm. ES also improved tenderness in the LD, after slow cooling. The other muscles showed very little effect from ES, and no pronounced toughening. This was in contrast to the results of Marsh (1986) where the slowly cooled LD in particular was toughened by low voltage ES. Our trials demonstrate that there is a commercial advantage from ES with slow cooling, and certainly improved tenderness in the loin.

Table 4. Mean toughness values (kg shear force) of quickly and slowly cooled ES and NES beef muscles assessed after cooking at 3, 7 and 10 days post-slaughter

Muscle	LD		TB		Sm		PP	
	Shear force (kgf)							
	ES	NES	ES	NES	ES	NES	ES	NES
3 days								
quick	7.7	10.7	6.0	7.1	9.5	7.8	8.8	9.3
slow	7.8	9.0	7.0	7.3	8.4	8.3	7.2	7.4
7 days								
quick	6.9	9.0	5.5	6.2	7.5	7.4	7.0	6.8
slow	5.9	6.7	6.4	6.3	7.6	6.7	6.5	6.9
10 days								
quick	6.1	7.5	4.9	6.0	6.4	5.8	6.7	7.2
slow	6.2	6.1	5.9	5.9	7.1	6.8	7.0	6.2

The small size of lamb carcasses offers greater opportunity for rapid chilling, but also makes them particularly vunerable to cold toughening. ES was developed to counteract toughening of lamb frozen too early after slaughter, but surprisingly little attention has been paid to the advantages of stimulating lamb carcasses before chilling.

The effect of ES on the tenderness of lamb carcasses cooled at different rates has been examined in a series of experiments at Bristol. Forty carcasses (approx 18 kg) were stimulated, 15 m after slaughter, for 90 s, with a peak voltage of 700 v at 25 Hz. Forty similar carcasses were used as non-stimulated controls. Equal numbers of ES and NES carcasses were subjected to 3 different cooling treatments.

(a) Quick: Air at +1°C and 0.2 m/s
(b) Medium: Air at 3° to 4°C and 0.2 m/s, gradually decreasing over 20 hr to 2° to 3°C
(c) Slow: Air at 10°C and 0.2 m/s until 10 h post-slaughter, then gradually decreasing over further 10 h to +1°C

The quick cooling procedure represented conditions found in chillers typically used in the UK, loaded and operated according to refrigeration design specifications. The medium cooling procedure is common in practice with quick chillers overloaded beyond initial refrigeration capability. The slow cooling procedure is widely used in the UK to avoid the possibility of cold-shortening.

Table 5. Time, temperature and pH data for ES and NES lamb carcasses chilled at quick, medium and slow rates

	quick	medium	slow
Time (h) for 15°C	3.5	4.0	6.5
" " 10°C	4.5	5.5	12.0
" " 7°C	5.9	7.5	15.5
pH (30 m) in LD, ES	6.22 (1 h)	6.49	6.38
" " NES	6.96	7.00	6.95
pH (48 h) in LD, ES	5.49	5.76	5.76
" " NES	5.65	5.73	5.73

The cooling rates of the 3 systems are shown in Table 5. With both quick and medium chilling, the centre of the LD cooled very quickly, reaching 10°C within 5.5 hours. This would be expected to cause excessive toughness in the loin. Even the slow rate produced a rapid temperature drop, reaching 10°C in only 12 h, illustrating the potential danger with small carcasses. The low pH values within an hour of ES demonstrate the effectiveness of the high voltage system.

At 48 h post-slaughter, the loins from each carcass were removed, individually vacuum packed and held at 1°C until assessment. At 3, 7 & 10 days post-slaughter, one loin from each carcass was cooked, cooled and shear force measurements made on 10 blocks from each LD sample, each 2 x 1 x 1 cm.

The mean shear force values shown in Table 6 clearly demonstrate the benefit of ES with quick cooling at 3 days, and even at 10 days post-slaughter. The shear values were relatively low at 3 days with both medium and slow cooling whether

Table 6. Mean toughness values (kg shear force) of ES and NES lamb LD cooled at quick, medium and slow rates, assessed after cooking at 3 d and 10 d post-slaughter

	Shear force (kgf)		
	quick	medium	slow
3 days			
ES	5.4	5.3	4.1
NES	7.7	5.2	5.4
10 days			
ES	4.2	3.3	2.8
NES	5.9	3.5	3.2

stimulated or not. After a further week's ageing, values were lower still, indicating very tender meat. The comparatively tender NES samples from the medium cooling treatment, where the LD was down to 10°C in 5.5 h from slaughter, is difficult to explain, especially since, with quick cooling where the LD was at 10°C only 1 hour earlier, the samples were very much tougher. This unexpected result with the medium cooling rate where the temperature/time conditions were expected to cause cold-shortening, has also been reported by Shorthose et al. (1986) who found that toughness in lamb, except from extremely rapid chilling, was lessened to give acceptable tenderness after about 3 days from slaughter. He concluded that, under the normal chilling and marketing conditions in Australia, ES might not be necessary to ensure lamb of acceptable quality. We did get toughness with even moderately quick chilling and ES had a tenderising effect. There was also a slight tenderising effect with ES and slow chilling. In our experiments, quick cooling also gave much greater variability in shear values within muscles, with some extremely tough samples. ES reduced the incidence of these extreme values and this is important for consumer eating quality. Our experience suggests that the principal advantage of ES with lamb carcasses may be in allowing quick chilling, particularly in the initial stages, without toughening, not only ensuring tender meat, but providing the basis for reduced throughput time and weight loss.

Packaging and presentation of fresh meat

The potential for improving efficiency in the distribution and retailing of fresh meat has been well-recognised by the industry. In the UK, the growing dominance of supermarket and self-service retailing has led to increasing demands on meat producers to supply retail packs of meat, ready to sell without any further in-store preparation. The major supermarket companies now display a proportion of their fresh meat in packaging which keeps it attractive and saleable for nearly a week. Several meat producing companies now have factories where the whole operation is integrated from slaughter through to distribution of long-life retail packs of fresh meat. One factory is already producing half a million packs each week, and is planning further expansion.

Until comparatively recently, the growth of centralised pre-packing of chilled meat was restricted by the meat's poor colour stability, but techniques are now available to prolong the useful storage and display life of fresh meat beyond the one or two days afforded by simple overwrapping on trays.

The method which has received most widespread acceptance, uses mixtures of oxygen and carbon dioxide to maintain an attractive red colour for about a week and keep microbiological growth to an acceptable level.

Commercial use of O_2/CO_2 mixtures for this purpose was first reported in the early 1970's (Brody, 1970) and was the subject of a patent (Georgala & Davidson, 1970) which effectively laid down the guidelines for present-day modified atmosphere packing (MAP) of fresh meat. Since then, various studies have used oxygen concentrations of approx 75% to enhance the bright red colour of the oxygenated muscle pigment, oxymyoglobin, and around 25% carbon dioxide to inhibit the growth of the microorganisms which are normally responsible for the spoilage of chilled fresh meat (Taylor, 1971), (Taylor & MacDougall, 1973), (Clark & Lentz, 1973), (Ordonez & Ledward, 1977), (Siedeman *et al*, 1979), (Partmann, 1980), (O'Keefe *et al*, 1975), (Savell *et al*, 1981).

The effectiveness of this type of packing depends on muscle type and post-slaughter age as well as on environmental factors such as display temperature and illumination. We have carried out factory and laboratory trials to evaluate the quality changes in beef and pork subjected to simulated retail display in MAP.

Beef loin and rump, aged in vacuum for a week at 1°C, and pork loin, 1 day post-slaughter, were used to provide slices which were packed with a mixture of 75% O_2 + 25% CO_2 in sealed retail containers. Samples were held in dark storage at 1°C for different periods up to 2 weeks before a 3 day simulated display at 4°C and 1000 lux fluorescent illumination. At the end of this display period, the samples were assessed alongside control samples which had been held all the time in the dark at +1°C. Samples were assessed for colour, microbiology and incidence of off-odours. Oxygen concentration remained above 50% throughout the period and CO_2 did not drop below 20%.

The changes in redness of displayed and dark stored samples are shown in Fig 1.

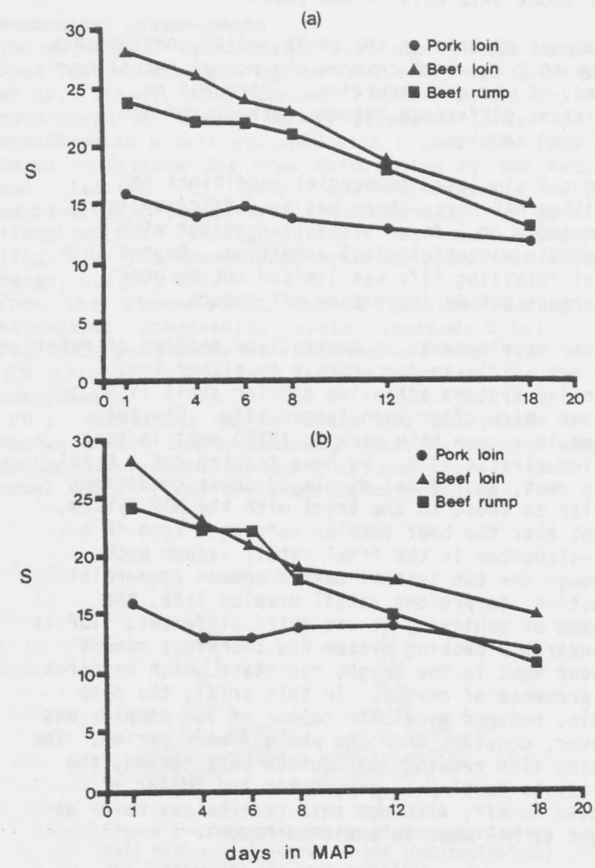

Fig. 1 Changes in redness of MAP meat, expressed as Saturation (S). (a) dark-stored (b) displayed

Redness increases with Saturation (S) value. In beef, S values above 18 may be regarded as red; below 18 the meat is noticeably brown. All the samples lost redness during storage, with the rate of deterioration slightly faster for those which had been displayed. Nevertheless, beef loin did not become noticeably brown until 12 days after packing; beef rump reached this stage in only 8 days; pork samples were still acceptable up to 8-12 days. Displayed samples usually had higher total bacterial counts than dark stored, but patterns of growth were similar. There was evidence that the spoilage of beef rump was caused by lactic acid bacteria. With beef loin, lactic acid bacteria were dominant, but there was also a rapid growth of *Brochottrix thermosphacta* which almost certainly contributed to off-odour development. With pork samples, counts of *B. thermosphacta* were almost as high as lactic acid bacteria, and were again probably responsible for off-odour development. In general, MAP beef and pork samples were showing strong off-odour development after about 8-12 days in the pack.

The amount of drip in the packs varied considerably, but up to 8 d, which covered the normal retailing period, it was not excessive. There was no consistent difference between dark-stored and displayed samples.

Under the simulated commercial conditions for retailing MAP meat, there was no difficulty in achieving 5 or 6 days' attractive colour with acceptable microbiological condition. Beyond this, useful retailing life was limited not by poor appearance but by increasing off-odours.

Further developments in centralised packing of retail cuts are likely to concentrate on either less expensive systems achieving similar shelf life, or systems which offer even longer life. One such system is vacuum skin packing (VSP) meat in gas barrier plastic film. We have carried out a trial using meat, stored and displayed under conditions similar to those in the trial with the MAP system, except that the beef samples were aged from 48 h post-slaughter in the final retail vacuum pack. Although the two systems have a common commercial objective, to prolong retail display life, the methods of achieving it are quite different. VSP is an anaerobic packing system and therefore cannot present meat in the bright red state which requires the presence of oxygen. In this trial, the deep purple, reduced myoglobin colour of VSP samples was however, constant over the whole 4 week period. The samples also retained throughout this period, the ability to develop an oxygenated red colour if exposed to air, although this redness was never as bright as MAP meat in enriched oxygen.

The microbiology of the VSP meat was similar to that normally found with vacuum packed primal joints. Total viable counts tended to be higher at an earlier stage in VSP beef samples, probably because of the 7 days' ageing in the pack, compared to the MAP meat which was aged for 7 days before cutting and final packing. Off-odours in VSP tended to be the sour or fruity odours generally found with vacuum packing. The odour of beef samples was judged still acceptable for up to 3 weeks but the limit was reached earlier with pork. As well as giving longer saleable life than MAP, without major changes in odour or appearance, VSP has another important advantage. Tenderness improves in the pack, so that meat can be put in the retail pack at an early stage after slaughter, and its eating quality will improve during distribution and display. This proposition could be attractive to cutting and packing plants in terms of cost-saving and convenience. By contrast, beef for MAP is likely to require ageing, either on the carcass or as vacuum packed primal joints, for at least a week before retail-packing. The major drawback which must be overcome, however, if VSP is to be a viable alternative to MAP, is that of colour. If the consumer refuses to accept meat which is not bright red, the advantages of VSP for centralised distribution of fresh meat will be worthless.

In this paper, I have discussed only a few of the areas of post-slaughter handling and distribution of meat where there is potential for improvement. The techniques for such improvement have been developed and are available to industry. Increasing competition from other foods has made the meat industry more aware than ever before of the need to reduce operating costs and to make meat more attractive to the consumer. It is, at this time therefore, particularly receptive to new technologies and, if they are economically worthwhile, prepared to introduce them.

References

BOWATER, F.J. (1986). Proc. IIR Symposium 'Meat Chilling', Bristol, 107.

BRODY, A.L. (1970). Modern Packaging, Jan., 81.

CLARK, D.S. & LENTZ, C.P. (1973). Can. Inst. Food Sci. Technol. J. 6, 194.

COX, R.P. & BAILEY, C. (1977). Proc. Inst. Refrig. Session 1977-78.

GEORGALA, D.L. & DAVIDSON, C.M. (1970). British Patent, 1, 199, 998.

GIGIEL, A.J. (1984). Proc. 30th Eur. Meet. Meat Res. Workers, Bristol, 2.8.

GIGIEL, A.J. & JAMES, S.J. (1984). Meat Science, 11, 1.

JAMES, S.J., GIGIEL, A.J. & HUDSON, W.R. (1983). Meat Science, 8, 63.

JAMES, S.J. (1987). Proc. CEC Workshop 'Accelerated Processing', Rome, 1985.

JAMES, S.J. & BAILEY, C. (1986). Proc. IIR Symposium 'Meat Chilling', Bristol, 59.

KERENS, G. (1983). FRIGAIR '83 Symposium, CSIR, Pretoria.

MARSH, B.B. (1985). Advances in Meat Research Vol 1, Electrical Stimulation.

MARSH, B.B. (1986). Proc. IIR Symposium 'Meat Chilling', Bristol, 39.

O'KEEFE, M., HOOD. D.E. & HARRINGTON, M.G. (1975). Proc. 21st Eur. Meet. Meat Res. Workers, Berne,

ORDONEZ, J.A. & LEDWARD, D.A. (1977). Meat Science, 1, 41.

PARTMANN, W. (1980). Slachten und Vermarkten, 80, (10), 305.

SAVELL, J.W., SMITH, G.C., HANNA, M.O. & VANDERZANT, C. (1981) J. Food Protect. 44, (12), 923.

SHEFFER, A.P & RUTOV, D.G. (1970). Bull. IIR Annexe 3, Leningrad, 143.

SHORTHOSE, W.R., POWELL, V.H. & HARRIS, P.V. (1986). J. Food Sci., 51 (4), 889.

SIEDEMAN, S.C., CARPENTER, Z.L., SMITH, G.C., DILL, C.W. & VANDERZANT, C. J. Food Protect. 42, 233.

TAYLOR, A.A. (1971). Proc. 17th Eur. Meet. Meat Res. Workers, Bristol,

TAYLOR, A.A. & MACDOUGALL, D.B. (1973). J. Food Technol. 8 (4), 453.

TAYLOR, A.A., SHAW, B.G. & MACDOUGALL, D.B. (1980-1). Meat Science, 5, 109.

UNION INTERNATIONAL CONSULTANTS (1984). Proc. 30th Eur. Meet. Meat Res. Workers, Bristol, 2.1.