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Accelerated Processing of Lamb Carcases

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Summary

Accelerated processing of lamb is a new approach to lamb carcase processing. It combines electrical stimulation of carcases with other novel processes, such as on-line splitting of carcases into sides and rapid chilling to permit packing of chilled lamb as sides, primals or retail packs on the day of slaughter, without loss of eating qualities. Electrical stimulation protects the musculature against cold-shortening and consequent toughening. The greatly accelerated overall rate of processing permits the operation of two shifts per day, where desired. Implementation of this process may require commercialisation of some new equipment.

The capital costs of setting up for commercial accelerated processing are such that maintenance of a high throughput would be necessary to guarantee a reasonable pay-back period. Contractual guarantees of access to retail outlets would probably be necessary, whilst processing of older ovine stock for valuable export markets would be necessary to support the capital investment.

A full-scale trial will be necessary to determine properly the commercial potential of accelerated lamb processing.

Introduction

Electrical stimulation (ES) of beef carcases, using either extra-low (ELV) or high voltage (HV) stimulation units, is standard procedure in many Australian abattoirs. The benefits obtainable from the application of ES to beef carcases have been widely published in both industry and scientific publications (Bouton et al. 1980; Powell et al. 1984, 1988; Shaw et al. 1977).

From time to time, meat industry operators have expressed interest in treating ovine carcases similarly to obtain the same type of quality improvements. Experiments have been conducted to determine the effects of electrical simulation on mutton (Bouton et al. 1984; Moller et al. 1983) and lamb (Powell et al. 1986; Shorthose et al. 1986) carcases. For conventionally processed lamb carcases, where chilling conditions are not severe, the use of electrical stimulation was originally considered not to be justified (Powell et al. 1986). The normal, post-mortem ageing processes usually reduce any toughening, which does occur in lamb carcases to the point where this meat is tender within three days of slaughter (Shorthose et al. 1986). However, nowadays there appears to be a considerable amount of conventionally processed lamb which is consumed well within three days of slaughter and the question of electrical stimulation of lamb carcases is being reconsidered.

An obvious situation where electrical stimulation would be appropriate for lamb is the preparation of frozen carcases for export. If lamb carcases are blast frozen shortly after leaving the slaughter floor, severe cold-shortening, with the consequent irreversible toughening, is likely. Some of the musculature may even be frozen pre-rigor, in which case subsequent thawing can lead to extensive thaw-shortening and large amounts of drip loss (Marsh & Thompson, 1957, 1958; Marsh & Leet, 1966; Scopes & Newbold, 1968). Electrical stimulation offers a way to avoid these serious quality problems.

Another situation where electrical stimulation of lamb carcases could offer considerable savings to processors was investigated by the CSIRO Meat Research Laboratory. During much of the year, the price of lamb in Victoria makes the refrigerated road transport of chilled lamb carcases to other states economically attractive. Consequently, at such times many thousands of lamb carcases are freighted from Victoria to Western Australia and Queensland. Under the Australian Standard for Transportation of Meat for Human Consumption, portions less than a carcase must be loaded-out and transported (and stored) at an internal temperature of not more than 5°C. Long distance transport therefore requires a deep meat temperature of less than 5°C for sides and primal cuts at load-out because transport refrigeration systems are unable to reduce product temperature rapidly. Transport vehicles will do little more than maintain the product at load-out temperature.

Western District Meat Packing Co Ltd developed the following product handling scenario:

- lamb carcases to be sawn into sides as they leave the slaughter floor;
- sides to be chilled very rapidly (e.g. reduce the deep butt temperature to about 5°C within about seven hours of slaughter);
- chilled sides to be sawn into shoulders, loins and legs and packed in polyethylene-sheet lined cartons;

- the cartoned product to be ready to leave the processing plant no later than 6 p.m. on the day of slaughter, in refrigerated transport capable of maintaining the cartoned product at a temperature of about 2°C.

The perceived advantages included:

- lamb carcase splitting could be automated with either presently available equipment or other new equipment;
- complete exposure of the inside of each carcase would facilitate better dressing and final trimming;
- a moderate gain in chiller loading capacity could be achieved by 'crossing' hot lamb sides (i.e. all sides facing the same direction);
- on-line lamb carcase splitting permits greatly increased chilling rates, leading to substantial improvements in the efficiency of lamb processing. Saddles are the only cut of lamb not amenable to on-line carcase splitting, but few packers process many lamb saddles;
- the faster chilling of sides of lamb would achieve lower load-out temperatures. The well-chilled and cartoned product would also be protected from recontamination until the cartons were actually opened at the retail outlet, thereby 'saving' some of the shelf-life presently lost;
- cutting the chilled lamb sides into the three basic primals and the subsequent cartoning could be automated to a considerable extent;
- the loading capacity of refrigerated transport, with either cartoned product or sides of lamb, could be increased substantially, subject to prevailing transport regulations.

The only potential problem was that the time-temperature conditions envisaged for the rapid chilling would virtually ensure unacceptable toughening of all the product. It was therefore agreed to conduct a trial involving the key elements of the above process, but with the inclusion of high voltage electrical stimulation (ES) applied within 30 minutes of slaughter. A further trial was conducted to ascertain chilling weight losses with the procedure.

Materials and methods

Trial 1

The lambs used in this experiment had dressed weights in the range 15–20 kg. In all, 20 randomly selected carcases were used. Of these, 10 were electrically stimulated at approximately 25 minutes post-stunning. The live electrode was inserted into the neck of the carcase, and the rail was earthed. ES parameters were 800v RMS, 1140v peak, at 14.3 Hz for 90 seconds. The other 10 carcases were the controls and were not subjected to ES.

After washing, all 20 carcases were sawn into sides at the slaughterfloor weigh station, tagged and conveyed to a chiller. The control sides experienced between one-and-a-half and two hours of chilling in 5–6°C air, whilst the ES sides received about 30 minutes only of this chilling (these different times occurred due to carcase selection and marshalling procedures used by the abattoir). Deep butt temperatures were measured at various times during the chilling processes by inserting the probe of an electronic thermometer (Jenco Model 757KC) into the thermal centre of the deep butt.

All the sides then received about five hours' rapid chilling in air at 0±1°C, (average air velocity off the coils was 2.15 $m.sec^{-1}$ throughout all chilling) after which the sides were sawn into shoulders, loins and legs and packed into cartons lined with polyethylene sheet. These cartons were open-stacked in the same chiller (to permit good air circulation) and held at 0±1°C. At 27 hours post-mortem, longissimus dorsi (LD) samples (core temperatures of 0±0.2°C) were vacuum packed, frozen and stored for subsequent testing.

Trial 2

Twenty-four lamb carcases with dressed weights in the range 11–19 kg were randomly selected during dressing. Of these, 12 were randomly assigned to ES (stimulation parameters as for Trial 1) and the other 12 were processed normally. For this trial, all carcases were stimulated pelt-off, pre-evisceration. All 24 carcases were then sawn into sides, weighed and tagged. The ES sides were then subjected to rapid chilling as described above, while the control sides were subjected to normal overnight chilling.

After an average chilling time of five-and-three-quarter hours, each ES side was weighed, broken into the three basic primal cuts, cartoned and chilled as in Trial 1. The conventionally chilled (control) sides were weighed after approximately 24 hours of chilling and then broken into the three cuts. All the control and test primal cuts were then vacuum packed.

Vacuum-packaged primals (legs, shoulders and loins) from both control and ES sides were held for 35 days at 0°C. The amount of weep was measured in randomly selected vacuum packs of each primal cut, for both ES and control samples, at several intervals up to 35 days.

Results

(a) Chilling rates

Trial 1

The deep butt temperatures for both the stimulated and control sides at various stages during the chilling process are listed in Table 1. The stimulated sides had deep butt temperatures in the range 4.1–6.4°C within seven hours of stunning while the control sides had temperatures within the range of 4.1–6.8°C within eight hours of stunning.

Trial 2

The deep butt temperatures of the stimulated sides were in the range 3.2–5.9°C within six hours of stunning.

(b) Tenderness

The WB shear force measurements reported in Table 2 are means of peak force values for LD muscle samples taken from all carcases in Trial 1. Peak force values are reported because WB initial yield forces are minimal for lamb due to the connective tissue/age effect. The muscles from the stimulated sides were significantly ($P < 0.01$) more tender than those from the non-stimulated sides. Muscles with shear force values <5 kg would be deemed to be acceptably tender by Australian consumers (Shorthose et al. 1986). Thus the majority of the samples from the stimulated sides would be regarded as tender while the majority of samples from the non-stimulated sides would be regarded as tough. The sampling period chosen (27 hours) is the earliest time post-mortem that the meat is likely to be consumed. The goal was to ensure adequate tenderness at this time. The ES samples complied with this requirement, whilst the control samples did not. It is possible, however, that the control samples would also have been tender if they were allowed to age for a further 48–72 hours.

In a similar preliminary trial in which all carcases (dressed weight range 14–17 kg) were electrically stimulated and chilled to deep butt temperatures in the range 4.3–6.1°C within about seven-and-a-half hours post-mortem, LD samples taken 27 hours post-mortem had a mean WB peak force shear value of 3.5 kg and a range of 2.6–5.3 kg, whilst the values for samples taken at 33 hours post-mortem were 3.3 kg and 2.8–3.6 kg respectively – very similar to those obtained in Trial 1. The very tender meat obtained from the stimulated carcases in both the preliminary trial and Trial 1 emphasises the beneficial effect of ES when the severe chilling conditions required for accelerated lamb carcase processing are used. These results also show that ES is a necessary and very effective part of an accelerated lamb carcase processing procedure when very fast chilling rates are used.

(c) Chilling weight loss

Tables 3 and 4 give the chilling weight loss data for the ES and control sides respectively from Trial 2. The data in Table 3 relates to an average chilling period of five-and-three-quarter hours, whilst that in Table 4 is for a full 24 hours of conventional chilling. The animals assigned to the control group weighed significantly more ($P<0.05$) than those in the rapid-chilling group. As this may have affected chilling weight loss, the statistical technique analysis of covariance was used to compare the weight loss in the two groups. The weight loss which occurred during the short, rapid chill was significantly ($P<0.01$) less than that which occurred during the conventional chill. The adjusted mean chilling weight loss of stimulated sides was 0.137±0.007kg compared to 0.172±0.007kg for the control samples.

(d) Weep

Whilst there were variations in weep losses (Table 5), there were no consistent differences between the three different cuts or the two treatment groups.

(e) Carcase splitting

~~During the trial it was estimated~~ that, when lamb carcases are split hot and oriented the same way, chiller capacity can be increased by about four to five percent. Individual abattoirs would have to review the capacity of their refrigeration plant in relation to this increased heat load in the chillers. However, it is clear that the potential exists for a substantial increase in the lamb throughput in some works for a moderate capital outlay.

It was noticed on all 48 sides involved in Trial 2 that the fell and other lower layers of the selvage pulled back from the sawn edge of the backbone immediately the hot carcases were sawn into sides. The extent of this pulling back of the fell varied up to about 50 mm. The commercial significance of this effect is presently uncertain.

Advantages of accelerated processing of lamb

- ### Two shifts per day

Given the fast turnaround of the lamb sides through the chiller, it should be possible to work two shifts per day, thereby markedly increasing the effective return on invested capital.

- ### Increased chiller capacity

An estimated four to five percent increase in chiller loading is achievable.

- ### Increased plant throughput

In many cases, the increased chiller capacity available will permit a similar increase in the number of lambs slaughtered without requiring structural alterations to the plant.

- ### Uniformly tender lamb

The use of ES protects the lamb musculature against cold-shortening and the consequent toughening which may occur.

- ### Reduced surface counts

The greatly increased chilling rate will restrict the growth of microorganisms on the carcase surfaces, thereby yielding meat of enhanced hygienic condition. This has favourable implications for the shelf-life of the meat.

- ### Shelf-life benefits

In the case of interstate transport of sides, boxed primals or retail packs, the rapid initial chilling of the sides to less than 5°C deep butt temperature will improve the quality of the product at out-turn. Despatch on the day of kill rather than 24–48 hours later will effectively increase product shelf-life. Maintaining the transport temperature below 2°C will also enhance product shelf-life. Consequently, an effective 'saving' of some of the two to four days of shelf-life presently lost during interstate transport of lamb carcases is achievable.

- ### The boxed lamb concept

Boxed beef (cartoned, vacuum-packed beef primals) is gradually gaining acceptance as the many advantages, including added shelf-life, reduced storage space, reduced contamination, ease of handling and transport, are seen to far outweigh the packaging costs. Accelerated processing of lamb provides a rapid and cost-effective method for introducing the boxed lamb concept.

• The potential for centralised packing

The sides can be reduced to retail portion size for local or export purposes. Packaging at the abattoir on the day of kill can be achieved if staggered shifts are used. If required, the packaged product could also be despatched from the plant on the day of kill.

• Transport savings

Whether consigned as chilled sides or cartons of either primals or retail ready packs, it may be possible to substantially increase the loading achievable on intra- and interstate transports. Reductions in the unit cost of delivery would then be possible.

• Unit loading

If lamb carcases are boxed at the abattoir as primals or retail ready packs, unit load handling techniques (Chua & Cain 1978) could be used to both load and unload bulk consignments. This would make available significant labour savings, as well as reductions in heavy manual labour and the associated injury risks. However, loading into refrigerated transports as sides, rather than as carcases, would probably require more time.

Discussion

Lamb carcases were processed using the following set of procedures:

- on-line HV ES of carcases within 30 minutes of stunning to preserve tenderness;
- on-line automatic carcase splitting, which facilitated rapid chilling and also saved chiller space and subsequent labour;
- very rapid chilling, to permit reduction of sides to packaged primals or retail cuts ready for despatch on the day of chilling

This accelerated process produced lamb sides with deep butt temperatures in the range 4.1–6.4°C in about six-and-a-half hours post-mortem whilst still retaining excellent eating qualities. The very low WB peak force shear measurements given in Table 1 for stimulated lamb indicate that the chilling of ES lamb sides can be even faster whilst retaining adequate and uniform tenderness.

Since accelerated processing depends on rapid chilling to get deep butt temperatures down very quickly, sides will have to be spaced so as to avoid any side to side contact. In addition to the holding capacity of the chillers, the refrigeration plant capacity may require review to ensure that the greatly increased chilling rates necessary can be obtained.

The number of spaces between sides on chiller rails will be twice that required by the equivalent number of carcases. However, the hot sides 'drop' a little, adopting a slightly flatter profile, which leads to a moderate overall increase in chiller rail loading capacity. This slightly flatter profile does not produce misshapen primals or cuts of lamb. It is necessary to 'cross' the sides on the rail, i.e. all sides must face the same way, in a left-right-left order for the rail loading increase to be achieved.

This accelerated processing system should also be applicable to other smallstock carcases such as veal and goats.

A full-scale trial will be necessary to determine properly the commercial potential of accelerated lamb processing.

Conclusions

Where implementation can be effected, accelerated processing of lamb carcases offers the potential for substantial economic gains. The opportunity exists for much more effective use of invested capital, product of consistently high quality can be produced and there is substantial scope for reductions in operating costs. In addition, the opportunity to move into some areas of value-added processing, such as centralised packaging of lamb in retail ready form for domestic or export purposes, is also possible. A further possible advantage is that finished product can either be stored on-site or despatched on the day of slaughter, as required.

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Dr P.V. Harris, then of the CSIRO Meat Research Laboratory, supervised the laboratory tests on the meat samples collected during the trials. Mr F.D. Shaw of that Laboratory collated and reviewed the experimental results and associated literature.

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Tables

Table 1 Elapsed time versus temperature and chilling regimes for stimulated and control sides

Elapsed time (minutes)	Control sides	Electrically stimulated sides
0	Stunning	Stunning
25		Electrical stimulation
50	Into 5–6°C chiller	
75		Into 5–6°C chiller
105		Chiller reset to 0±1°C (Deep butttemperatures 17.3–19.4°C)
160*	Chiller reset to 0±1°C (Deep butt temperatures 22.1–24.0°C)	
285		Deep butt temperatures 10.7–12.9°C
340*	Deep butt temperatures 10.7–11.9°C	
405		Deep butt temperatures 4.1–6.4°C
460*	Deep butt temperatures 4.1–6.8°C	

Note: * These times correspond to the approximate one hour of additional chilling of the control sides at 5–6°C.

Table 2 Warner-Bratzler peak force measurements and pH values for LD muscles from non-stimulated and stimulated lamb carcases (O teeth)

Parameter measured	Non-stimulated	Stimulated
W-B peak force (kg)*	6.90	3.76
pH**	5.77	5.84

* Least significant difference ($P<0.01$) = 2.54

** Least significant difference ($P<0.05$) = 0.08

Table 3 Chilling weight losses over 5.75 hours for ES sides in Trial 2 (n = 24).

Side number	Hot wt (kg)	Chilled wt (kg)	Wt loss (%)
Mean (Range)	6.54 (5.12 – 8.47)	6.42 (5.03 – 8.33)	1.92 (1.65 – 2.48)

Table 4 Chilling weight losses over 24 hours for non-ES sides in Trial 2 (n = 24).

Side number	Hot wt (kg)	Chilled wt (kg)	Wt loss (%)
Mean (Range)	8.93 (8.15 – 9.63)	8.74 (7.95 – 9.42)	2.08 (1.66 – 2.86)

Table 5 Weep from vacuum packaged primal cuts, as a percentage of the initial weight of the primal cut, after various periods of storage at 0°C.

Days at 0°C	Loins		Legs		Shoulders	
	ES	Control	ES	Control	ES	Control
5	0.33	0.10	0.38	0.52	0.48	0.69
16	0.52	0.60	0.32	0.09	0.22	0.93
29	0.76	0.30	0.91	0.11	0.60	0.22
35	0.41	0.35	0.56	0.42	0.56	0.44