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Some important changes in the Australian sheep meat processing industry

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Abstract. In the last 5 years there has been a dramatic increase in the adoption in the Australian sheep meat processing industry of electrical technologies designed to streamline processing and improve product quality. Part of this change was initiated by an Australia-wide audit of lamb tenderness in 1997–98 and the development of a program to establish an eating quality scheme for sheep meat across Australia. Critically, these initiatives coincided with the development of new ways of administering electrical currents to either bodies or carcasses. Underlying this new approach is the electrocution of carcasses individually on segmented electrodes in a dose responsive way with electricity that has short pulse widths and lower voltages. This paper documents the pivotal factors which have contributed to this level of industry adoption and which has seen 14 abattoirs install the new technology. Of these abattoirs only one previously had any form of stimulation and these abattoirs represent more than 70% of the throughput of sheep and lambs on a tonnage basis per year in Australia.

Introduction

In 1997, the Australian lamb industry commissioned the preparation of a situation paper which outlined the status of the eating quality of lamb. One of the recommendations from this paper (Bennett 1997) was to establish a baseline level of industry performance by conducting a national quality audit of lamb at the retail level with particular emphasis on tenderness. A comprehensive study was reported by Safari *et al*. (2002) in which 909 lamb midloins (derived from a cut through the *M. longissimus lumborum* caudal to the 6th lumbar vertebra and caudal to the 12th and 13th thoracic ribs) were purchased from a total of 137 different outlets in Canberra, Melbourne, Perth, and Sydney on four occasions over 12 months. As part of the sampling regime in Canberra and Perth, midloins from lambs marketed through branded lamb alliances were also sampled. The term ‘alliance’ refers to the marketing relationship established between a group of lamb producers and a group of retail outlets, where producers aim to supply lambs to agreed specifications (Hopkins and Considine 1998). For both alliances, lamb was sold under a registered brand at the retail level. On each sampling day, all sampled midloins were deboned and the *M. longissimus lumborum* was removed and denuded of subcutaneous fat before freezing at −20°C. All samples were then transported frozen to the same laboratory for shear force assessment.

The frequency distribution for shear force of midloin samples is shown in Fig. 1. Overall, 20.3% of midloins ($n = 184$) recorded shear force values above 49 N, a threshold above which Shorthose *et al*. (1986) suggested Australian consumers would consider lamb to be unacceptable in terms of tenderness. A higher proportion of lamb sourced from Melbourne and Perth contributed to the percentage of midloins with shear force values above 49 N (42% and 31%, respectively). If the latest estimate of 30 N was applied as a consumer acceptable threshold for shear force (Hopkins *et al*. 2006*a*) then an even higher percentage (49%) of the lamb would have been above the threshold.

Differences in shear force were found between alliance (branded) and generic products in Canberra and Perth but the difference, reported for Canberra samples was not large compared with the difference in Perth (Table 1). The results in Perth suggested that lamb sourced and sold through alliances in that city was probably not consistently meeting consumer expectations in terms of eating quality.

Factors promoting change

As a consequence of the Safari *et al*. (2002) study, several significant developments occurred. The first was the establishment of a multiorganisational program of research to establish an eating quality scheme for sheep meat (SMEQ) across Australia (Russell *et al*. 2005). This program developed standard protocols for testing sheep meat using consumers of sheep meat and examined both production and processing factors that impinge on eating quality. Among those processing factors tested was the impact of electrical stimulation, because based on the results it was evident that an improvement was needed in the tenderness levels of lamb.

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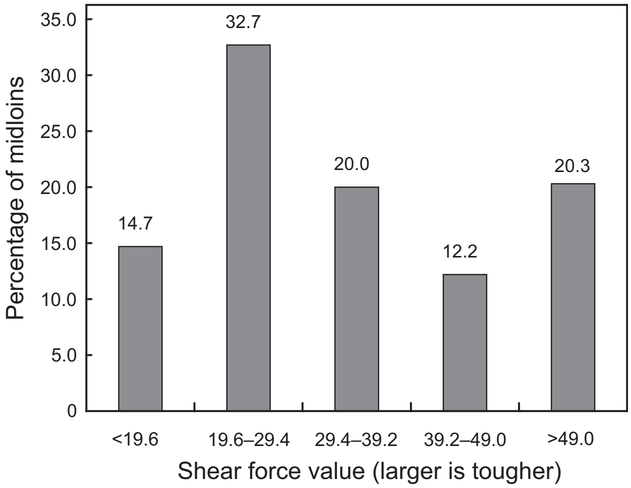

Fig. 1. Frequency distribution of shear force (Newtons) for midloins purchased at the retail level in Melbourne, Sydney, Canberra and Perth. Adapted from Safari *et al*. (2002).

Table 1. Predicted means (*n* is the sample number) for shear force (kg) of lamb midloin samples tested quarterly over a 12-month period between December 1997 and October 1998 in two cities

Adapted from Safari *et al*. (2002). Estimates with the same letter differ by less than twice the s.e. of the difference. To convert shear force values in kg to Newtons multiply by 9.8

	Generic (*n*)	Alliance (*n*)	s.e.d.
Canberra	2.91a (89)	3.31b (79)	0.19
Perth	4.29c (80)	5.11d (80)	0.39
Average s.e.d. within generic	0.28	–	–

The second outcome of the results of the study reported by Safari *et al*. (2002) was that further work was conducted to determine possible causes of the high shear force values of lamb marketed through the Perth alliance. There was likely to be significant cold shortening (Pethick *et al*. 1999) that accounted for the tough lamb meat in Perth and this was addressed by changes in carcass chilling and the installation of high voltage electrical stimulation (HVS).

A brief history of electrical stimulation

Electrical stimulation of muscle from slaughtered animals hastens the process of *rigor mortis*. It does this by causing muscles to undergo work via anaerobic glycolysis resulting in an initial pH fall followed by a change in the rate of pH fall, a response that is influenced by the level of muscle glycogen (Daly *et al*. 2006). The combined effect is that the muscles enter *rigor mortis* before the muscle temperature falls to values producing cold shortening and toughening. A rule of thumb in the prevention of cold shortening is to maintain the muscle temperature above 10°C until pH falls below 6.0. The classical studies of Locker and Hagyard (1963) showed minimal shortening at close to 15°C and this correlated with minimal meat toughness indicating that this should be an ideal temperature for *rigor mortis* to occur. The incorporation of a practical system into the slaughtering process was first used in New Zealand and then Australia to avoid toughness resulting from cold shortening. While electrical stimulation ensures that cold shortening is avoided, aging also starts at a higher temperature and is consequently more rapid. However, evidence suggests that there are other mechanisms involved in tenderisation, such as fibre disruption and modification of the enzyme systems. A comprehensive review of the literature discussing these modes of action has recently been published (Hwang *et al*. 2003) and these modes of action will not be discussed here. Stimulation is now widely used in many other countries with a variety of parameters (Devine *et al*. 2004).

In New Zealand, electrical stimulation was originally used to accelerate *rigor mortis* before the meat was frozen in both sheep and cattle, but now it is more widely used to improve quality. For sheep and lambs, the New Zealand system had the following electrical parameters, 1130 V peak at 14.3 alternating pulses per second applied for 90 s, within 30 min of slaughter. Such high voltage systems need to be physically isolated to prevent workers from electrocution, have large energy requirements, and stimulate several carcasses simultaneously, such that voltage and current inputs are averaged across several different carcasses. This type of system – although very effective at lowering muscle pH (Hopkins and Toohey 2006) – was also not easily installed in abattoirs subsequent to construction. Adoption of this technology in the Australian sheep meat processing industry was minimal and mostly associated with the use of hot boning (Toohey and Hopkins 2006). Therefore, this suggested that new approaches to stimulation were required.

Maximising eating quality

Results from the SMEQ program suggested that there was an ‘ideal’ rate of pH fall and that a target of 18–25°C at pH 6.0 would give superior eating quality for the short aged domestic market compared with slower or faster rates of pH fall (Thompson *et al*. 2005). This outcome was generally consistent with the early studies of Locker and Hagyard (1963), which showed minimal shortening at close to 15°C and a suite of much later experiments that showed maximum tenderness when excised muscle entered *rigor* at these temperatures (e.g. Devine *et al*. 2002). Unfortunately, the evidence indicated that Australian abattoirs slaughtering sheep and lambs would have a very low compliance with the target pH/temperature window recommended by the results of the SMEQ program. Benchmark data obtained from several abattoirs showed that only 18.8% of measured carcasses complied with the window (Toohey *et al*. 2006), with 79.4% of carcasses not reaching 18°C by the time the pH reached 6.0. Of the 18.8% that did comply with the window, the majority were at one abattoir, which had less than ideal chilling (Toohey *et al*. 2006), whereas the other two abattoirs surveyed could achieve only 3% of the carcasses in the window. Clearly, this lack of compliance posed a significant hurdle to the introduction of an eating quality scheme. A major impetus in addressing this challenge was the insistence by large supermarket chains that the principles of the SMEQ program be adopted for the product they purchased (Pethick *et al.* 2006). This requirement ensured that abattoirs had to consider some form of intervention to enable carcasses to hit the 'window'. Interestingly, however, this was not the only impetus and the first abattoir in New South Wales to introduce a new generation electrical stimulation system did not supply a supermarket. The motivation in this case was the quest to supply a quality product to their customers and to this end the abattoir undertook to benchmark the eating quality of the lamb they processed so they could look for an opportunity to improve their product (Hopkins *et al.* 2004). The principles developed in the SMEQ program focussed the sheep meat industry on eating quality and provided impetus for change.

New electrical technologies

Stimulation

Fortuitously for the Australian sheep meat industry, a major breakthrough was occurring in the development of new electrical technologies not just for stimulating carcasses, but also for immobilising bodies and improving bleeding immediately after death. Traditionally, HVS systems used on sheep carcasses have applied a fixed voltage averaged across all carcasses being stimulated (Devine *et al.* 2004). Rubbing bars have been used to apply high voltage stimulation to lamb and sheep carcasses at the completion of the dressing procedure (Morton *et al.* 1999; Hopkins and Toohey 2006), but this process poses concerns for work safety, gives an average electrocution effect and is expensive, although it can significantly reduce toughness in sheep meat (e.g. Hopkins and Toohey 2006). For the new approach, each carcass is stimulated individually using segmented electrodes to ensure that each segment only contacts one carcass at a time. This allows computer-controlled electronics to give a precise, but adjustable electrical input to each carcass to match the requirements of a particular carcass type while maintaining the delivery of a predetermined level of current. In effect a feedback system which detects the level of resistance is used. This approach also reduces the installation costs with respect to occupational health and safety. This is because the power levels and pulse widths used eliminate the need for isolation of the unit, which is a requirement of HVS systems, and these levels comply with occupational health and safety regulations according to the Australian Standard 60479–2002 (Anon. 2002).

The results of Shaw *et al.* (2005) clearly showed that the approach to stimulation did achieve comparable results to a HVS system with the production of lamb meat with a similar tenderness and eating quality level. There was a clear improvement over meat which was not subjected to any form of stimulation and this effect was confirmed in two different muscles as shown in Table 2. Extensive testing and optimisation of this approach has occurred and the system has been designed so that either a predressing (Toohey *et al.* 2008*a*) or a postdressing (Pearce *et al.* 2006*b*) application of the current can be applied shown in Figs 2 and 3. This provides greater flexibility with respect to installation of the unit in existing abattoirs. As shown in Table 3, the predressing system, which uses different electrodes to the postdressing system, can significantly increase the rate of pH decline (Toohey *et al.* 2008*a*). In this study, the predicted temperature at pH 6.0 for stimulated carcasses was 24.8°C and for non-stimulated carcasses was 13.9°C; this translated into much tougher meat for the non-sitmulated carcasses, demonstrating the benefit of stimulation.

Table 2. Mean tenderness and overall liking sensory scores for 2-day-aged loin and rump cuts

Within rows, means followed by the same letter are not significantly different at $P = 0.05$. Data were adapted from Shaw *et al.* (2005)

Trait	Control	New stimulation system	Old stimulation system (HVS)	s.e.d.
		Loin cut		
Tenderness	65.2a	74.6b	76.0b	1.6
Overall liking	65.6a	72.1b	72.4b	1.5
		Rump cut		
Tenderness	48.8a	63.4b	60.1b	1.60
Overall liking	53.4a	63.2b	61.1b	1.50

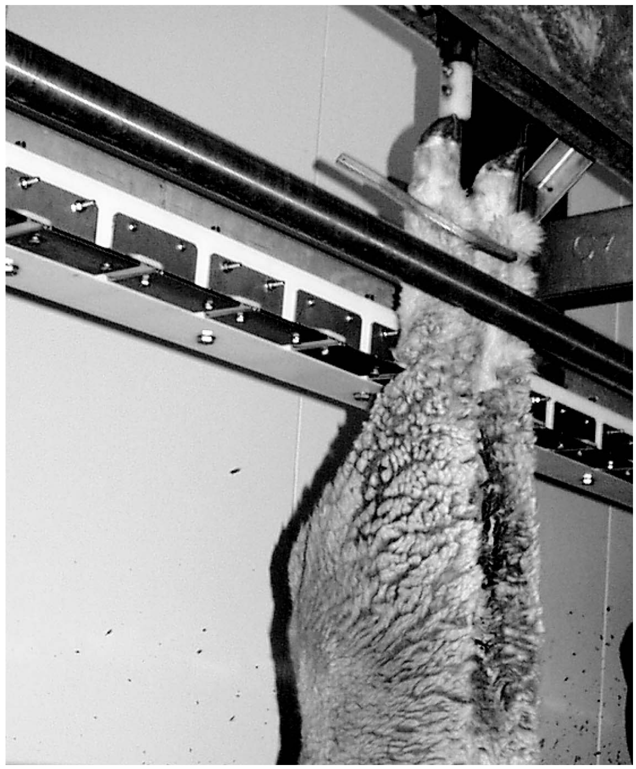

Fig. 2. Photograph showing a predressing electrical stimulation unit with the current administered through the skin on back legs.

Likewise, the postdressing system has been shown to achieve similar results and in one experiment Pearce *et al.* (2006*b*) reported that the best combination of parameters was a current of 1000 mA, with a pulse width of 2.5 ms at 15 Hz and showed that currents of 400 mA were much less effective. In the same paper, it was also shown that if the frequency was altered across the electrodes this could further increase the rate of pH fall. This was examined in a subsequent study using a 6-electrode

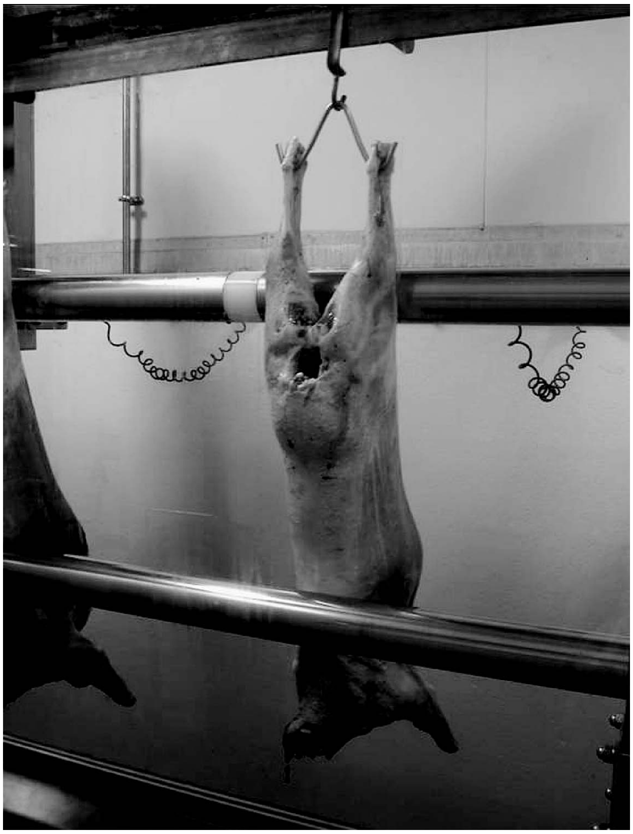

Fig. 3. Photograph showing a postdressing electrical stimulation unit – the separate electrodes can be seen separated by the white insulator and only one carcass is in contact with any one electrode at any one time.

Table 3. Predicted means for carcass weight, GR depth, pH, and predicted temperature at pH 6.0

Within rows, means followed by the same letter are not significantly different at $P = 0.05$. Adapted from Toohey *et al.* (2008*a*)

Trait	Stimulation[A]	No stimulation	s.e.d.
Carcass weight (kg)	21.6a	21.4a	0.37
GR depth (mm)[B]	11.7a	11.0a	0.57
Initial loin pH	6.34a	6.79b	0.04
Predicted temp. at pH 6.0 exp	24.8b	13.9a	1.50

[A]Stimulation treatment was at a current of 800 mA with a pulse width of 0.5 ms.
[B]GR values were adjusted to a hot carcass weight of 21.5 kg.

stimulation unit (Pearce *et al.* 2006*a*). In this case, the current was set at 1000 mA, a pulse width of 2.5 ms and the frequency was set at the following levels: 10, 15, 25, 10, 15 and 25 Hz. In these various studies, the impact on shear force, pH and meat colour stability has been examined. The general conclusion is that irrespective of the system, there is a significant impact on the rate of pH fall, although this does vary according to animal groups and improvements in tenderness particularly for product aged for less than 5 days will be seen with no detrimental effect on colour or the stability of colour under simulated retail display. Pethick *et al.* (2006) contrasted the improvement in shear force between the data published by Safari *et al.* (2002) and data from the SMEQ program, which showed that with electrical stimulation and aging for 5 days, a much tighter distribution could be achieved with a significant reduction in the frequency of samples with a shear force above 49 N. Having said this, it is recognised that whether it is the old or new stimulation technology, there is still variation between carcasses in the response to stimulation (Hollung *et al.* 2007; Hopkins and Toohey 2008). This suggests that there is scope to increase the effectiveness, but much of this variation may well be attributed to animal differences (Simmons *et al.* 1997) as mentioned earlier. In effect, the adoption of these systems could well focus more attention on the feeding and handling of animals before slaughter so as to improve effectiveness a conclusion supported by the recent results of Toohey *et al.* (2008*b*).

Bleeding

As part of the development of the electrode system, it was considered that this technology may help to remove more blood from the carcass in the bleeding area. A study by Hopkins *et al.* (2006*a*) found that the application of a current of 600 mA, with a pulse width of 0.5 ms and a frequency of 10 Hz could increase the amount of blood collected soon after death by 30% and at 14 Hz this could be increased by 11%. Clearly, for those abattoirs that could sell blood meal, there were improved profits to be had from applying such currents to bodies soon after death. An additional outcome of more importance was the decrease in the volumes of water required to wash down the slaughter floor and thus a significant reduction in effluent and thus the biological oxygen demand.

Immobilisation

The application of high frequency currents (2000 Hz, 400 V with a pulse width of 0.15 ms) has been shown to be extremely effective at reducing animal movement immediately after exsanguination and the technology has been installed in one large Australian abattoir. The evidence indicates that this application does not have any detrimental effect on meat quality, particularly pH (Toohey and Hopkins 2007), thus enabling other electrical inputs further down the slaughter chain to be applied to either enhance bleeding or the rate of pH decline. Such immobilisation enables abattoir workers to safely begin processing sheep bodies (within 30 s) of exsanguination and in the beef industry it has reduced worker injuries during shackling after stunning.

Conclusions

Benchmarking the tenderness of lamb and establishment of a system to 'grade' the eating quality of sheep meat were the initial steps in a change of focus for the Australian sheep meat industry. Although it was clear that electrical stimulation *per se* improves meat quality the development of new technology has allowed the installation of stimulation units in abattoirs where previous technology could not be used. One of these advantages is the demonstration that lower voltages can be used to stimulate carcasses and still produce the desired change in the rate of pH decline and also reduce toughness of short aged meat. As outlined in this paper a number of factors converged leading to the changes, a reflection of the significant investment that has been made in the Australian sheep meat industry by research and development organisations.

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