IMPROVING THE QUALITY OF LAMB MEAT THROUGH ELECTRICAL STIMULATION OF CARCASES

M.C HANRAHAN[A], G. FERRIER[B], F. SHAW[C] and D. BROOK[A]

[A] University of Melbourne, Longerenong College, Horsham, Vic 3400
[B] Department of Natural Resources and Environment, Agriculture Victoria, Vic 3685
[C] Food Science Australia, Cannon Hill, Brisbane, Qld 4170

SUMMARY

A selection of second cross lambs (18 to 24 kg, fat score 2 to 3), processed at a country abattoir, were subjected to either high voltage (HV) or low voltage (LV) electrical stimulation (ES) within 30 minutes of slaughter. Warner Bratzler (WB) shear force measurements were made on loin and leg muscles to investigate the effects of electrical stimulation on tenderness. Ultimate pH, meat colour and sensory appraisal tests were also conducted to assess meat quality characteristics.

An untrained (consumer) taste panel found the stimulated meat samples to be significantly ($P<0.05$) more tender with better eating quality characteristics then the unstimulated samples. WB shear force testing showed loins from both treatment groups to be significantly more tender than leg muscles.

Keywords : electrical stimulation, tenderness, meat quality, lamb.

INTRODUCTION

The lamb industry, aware that per capita consumption of lamb meat is in decline and currently at around 11 kg per person per annum, is taking steps to minimise existing variation and improve meat quality. Meat quality is a composite of factors including tenderness, juiciness, flavour, meat colour and texture. Lamb is considered by many consumers as being 'old fashioned', lacking in versatility and inconsistent in quality. Palatability is the main determinant of consumer acceptance of lamb after purchase with tenderness being a major component of palatability (Jeremiah 1996). Conditions pre-slaughter and directly post-slaughter can result in lamb being rendered tough if carcases are not handled correctly. To ensure a viable future the industry has to aim to have production processes that consistently producing high quality meat to effectively deliver what industry customers and consumers want.

Lamb meat is naturally tender due to the young age of the lamb at slaughter, but tenderness is affected by the extent of muscle contraction occurring after slaughter, the pH of the meat, and the degree and method of cooking. These factors affect the two different components of muscle, the connective and the contractile tissues (MRC 1996). The toughness of connective tissue is influenced by factors such as age and sex, while the tenderness of the contractile muscle is primarily influenced by pre and post slaughter handling techniques, such as transportation and chilling temperature (MRC1996).

In the pre-rigor state, muscle fibres are free to move. During rigor at room temperature (approx 15ºC) muscle fibres will contract by about 10% of their resting length. When the muscle is subjected to more rapid cooling a much larger contraction of the muscle is experienced. With greater contraction the meat will become tougher (Husband and Johnson 1985). When a muscle shortens 40% of its original length it will be four times as tough as it was initially (Marsh and Leet 1966). Cold shortening occurs when the unrestrained skeletal muscle fibres contract before rigor mortis has been achieved.

Electrical stimulation (ES) speeds up metabolic processes in the muscles after death. It causes muscles to spasm, resulting in a rapid depletion of glycogen reserves and exhausting their power to contract. This results in pH levels decreasing at a faster rate, with the muscle then entering rigor mortis in a shorter space of time than if it were not stimulated. A faster rate of glycolysis reduces the time for adenosine triphosphate (ATP) reserves to be metabolised reducing the time which must elapse before chilling if thaw rigor is to be avoided (Chrystall 1980).

Both high voltage (HV) and low voltage (LV) ES of lamb carcases are considered to be effective methods for improving the quality of lamb by increasing the tenderness of meat reaching consumers. For safety reasons, a LV system is more attractive in commercial works. The purpose of the present study was to examine meat and eating quality as assessed by objective measures and a non trained (consumer) taste panel of meat from carcases, processed through commercial works, receiving either HV (800V) and LV (45V) ES early post-slaughter.

MATERIALS AND METHODS

On two separate slaughter days, second cross lamb carcases were electrically stimulated at a commercial abattoir. Lamb carcases, in the weight range of 18 to 24 kg and fat score 2 to 3, were selected at random from one kill lot on each day. Thirty lambs (15 stimulated and 15 controls) were sampled in each trial. ES was applied to carcases approximately 20 minutes after slaughter just after entry into the chiller area.

Trial 1 used HV (800 V) ES for 60 seconds. The HV ES unit was temporarily situated in the chiller and the current was applied through two electrodes. One electrode was attached to the neck while the other was connected to the metal gambrel which was supported on a plastic hook and slide, insulating the carcase from the railing above. Lambs in this trial came directly from paddock to the works.

Trial 2 used LV (45 V) ES for two periods of 40 seconds. The LV ES was applied to two lamb carcases at once. In applying the LV ES two multi-pronged probes connected together to form one electrode were inserted into the upper leg muscles. The other electrode was connected to the neck. Lambs in this trial came from saleyards to the works.

Following comercial practice of overnight chilling, both the left and right side *M. longissimus lumborum* (LL) and right side *M. semimenbranosus* (SM) were removed from each carcase and objectively evaluated for tenderness, pH, meat colour and cooking loss.

The right side LL and SM were used for measurements of tenderness, pH, meat colour and cooking loss 24 hours after slaughter while the left side LL was used for sensory analysis 72 to 96 hours after slaughter.

Tenderness was measured on cooked samples (Bouton *et al.* 1978) using a Warner-Bratzler (WB) shear blade fitted to an Instron Universal Testing machine (Model 4301). Meat colour was measured using a Minolta Chroma meter set on L*, a*, b*, (where L* measures relative lightness, a* relative redness, and b* relative yellowness).

The left side LL were stored at 3ºC until preparation for taste panel appraisal Loins were oven grilled in fan-forced convection ovens (Sanyo) set at 180ºC for approximately 15 minutes to an internal temperature of 76ºC. Twelve untrained panellists were provided with four randomly allocated samples of loin at each sitting and asked to assess samples for flavour (very poor to excellent), aroma (very poor to excellent), tenderness (very tough to very tender) and overall appeal (very poor to excellent) (Cox 1994). Panellists scored each attribute on continuous 100 mm scalars. Data were analysed by an analysis of variance (Genstat 5, Release 3.1).

RESULTS

Tenderness, cooking loss and colour

HV ES significantly ($P<0.001$) decreased the WB shear force values of both LL and SM muscle samples (Table 1). In contrast LV ES did not significantly affect WB shear force values in the LL or SM. Significant difference ($P=0.024$) could be demonstrated in loins of Trial 2 when one extremely tender sample in the LV Control group was excluded from analysis. This sample had a WB shear force value of 2.75. Both HV ES and LV ES were able to increase the number of low values (<6 kg shear force) in LL by more 20% (results not shown).

Overall, cooking loss was found to be significantly greater in muscles from carcases given HV ES, however no significant effects were observed in muscles from carcases treated with LV ES (Table 2).

Table 1. Effect of high and low voltage electrical stimulation on Warner-Bratzler shear force (kg) values of *longissimus lumborum* (LL) and *semimenbranosus* (SM) muscles

	Trial 1		Trial 2	
	Control	HV ES	Control	LV ES
LL	5.11[a]	3.39[b]	7.53 (7.96)[A]	6.74
SM	6.68[a]	5.38[b]	7.77	7.43
Overall	5.90[a]	4.39[b]	7.65	7.09

[a,b] Values within rows are significantly different ($P<0.001$)
[A] Mean value of LV Control if outlier value ignored.

HV ES was found to significantly increase the redness (a* value) of meat (Table 3) while no significant effects of HV ES or LV ES electrical stimulation were observed on ultimate pH values. For both trials, mean pH values were 5.60 and 5.63 in ES and control groups respectively. One sample in each of Trial 1 and Trial 2 had ultimate pH greater than 5.8.

Sensory appraisal

Panel members gave significantly higher tenderness scores for meat from both HV and LV electrically stimulated lamb carcases (Table 4). Panel scores for flavour, aroma and overall appeal were not found to be significantly different between treatment groups.

DISCUSSION

HV ES significantly decreased ($P<0.001$) the Warner-Bratzler shear force measurements of both the LL and SM samples. This result is consistent with previous research (Shaw *et al.* 1996). Unfortunately, a direct comparison between the HV and the LV ES could not be conducted within this trial due to the impracticality of setting up the two ES units within the works for one kill lot. This resulted in two different lots of lambs being used for each trial. The HV ES trial was conducted on lambs having been bought direct off a local farm while the lambs used in trial 2 for LV ES were purchased from the saleyards. The added handling stages associated with saleyard selling may have resulted in extra stresses which minimised the effectiveness of ES in this trial. While HV ES did significantly improve tenderness, there was no significant difference between the controls and the stimulated group in Trial 2 when the LV ES unit was used. Although LV ES did not cause a significant reduction in the mean value for Warner Bratzler shear force, it did reduce the number of samples with high (> 8kg) WB shear force values. For the LV control group, 50% of samples had high WB shear force values, but for the LV ES group only 20% of samples had high values. Therefore LV ES could be expected to lead to a reduction in the amount of tough, or very tough, product available to the consumer.

Table 2. Effect of high and low voltage electrical stimulation on cooking loss (%) of LL and SM muscles

	Trial 1		Trial 2	
	Control	HV Stim	Control	LV Stim
LL	31.5	32.8	32.5	31.8
SM	31.4	33.3	33.4	31.9
Overall	31.5[a]	33.0[b]	33.0	31.9

a,b Values within rows are significantly different ($P<0.001$)

Table 3. Effect of high and low voltage electrical stimulation on a* values (redness) of LL and SM muscles

	Trial 1		Trial 2	
	Control	HV Stim	Control	LV Stim
LL	14.7	15.5	13.2	13.5
SM	14.8	15.2	14.9	15.0
Overall	14.8[a]	15.3[b]	14.1	14.3

[a,b] Values within rows are significantly different ($P<0.05$)

Table 4. Effect of high and low voltage electrical stimulation on taste panel tenderness scores of LL muscles

	Trial 1		Trial 2	
	Control	HV Stim	Control	LV Stim
Tenderness score	60[a]	68[b]	48[A]	56[B]

[a,b] Values within rows are significantly different ($P<0.001$)
[A,B] Values within rows are significantly different ($P=0.05$)

HV ES caused a significant increase in cooking loss values for both the LL and SM muscles, but no effect could be found with LV ES in Trial 2. Meat colour was found to vary significantly when HV ES was applied. The redness (a*) value was significantly different overall, with values being higher in the stimulated group. A positive result on meat colour is important because consumers choose meat which is attractive to the eye when purchasing, rating colour as one of the most important attributes (MRC 1996). In Trial 2, using LV ES had no significant effect on meat colour.

Taste panel appraisal of meat tenderness showed significant differences in tenderness scores between control and stimulated carcases in both HV ES and LV ES trials. It is interesting that a difference was able to be shown by the taste panel assessment while no significant difference was shown in the WB shear force in the LV Trial. This result may reflect the problems of attempting to measure objectively the complexity of eating quality in a single measure such as Warner-Bratzler shear force. Also of note is that the panel attributed lower tenderness scores to meat from Trial 1 than from Trial 2, thus supporting our contention that the extra handling stages for lambs in Trial 2 compromised product quality. This was shown by both WB values and panel scores for tenderness. Samples for sensory appraisal had been aged for either three or four days which may have enhanced differences attributable to ES, making them more apparent in sensory analysis but not evident in the WB shear force results.

This investigation found HV ES to be more effective than LV ES in improving the tenderness of lamb meat when measured by Warner Bratzler shear force. In contrast, in both Trials an untrained sensory panel was able to discriminate meat from stimulated and non-stimulated control carcases on the basis of tenderness. Although no direct comparison has been made between the HV and LV Trials, HV ES appears more likely to be successful at providing the most consistently tender meat, but incorporation into exisiting commercial processes may be hampered by safety and capital costs. Although LV ES did not significantly lower the values of the WB shear force for the muscles sampled, significant difference was affected by an extremely tender control sample and may have additionally been affected by different processing pathways of the two trials. Both WB shear force values and panellists' tenderness scores indicate a poorer quality product being processed in Trial 2 compared with Trial 1. Overall ES can significantly improve eating quality when included at the processing stage of getting lamb meat from the farm to the consumer.

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REFERENCES

BOUTON, P. E., FORD A. L., HARRIS, P. V. and SHAW, F. D. (1978). *J. Food Sci.* 43, 1992.

CHRYSTALL, B .B. (1980). *Ann. Technol. Agric.* **29**, 679-683.

COX, R. (1994). Marketlink Sensory Taste Panel Resource Book. (Meat Research Corporation: Sydney).

HUSBAND, P. M. and JOHNSON, B. Y. (1985). *CSIRO Food Research Quarterly* 45, 1-4. JEREMIAH, L.E (1996). Meat Focus International Sept. 1996, pp 306 – 308.

MARSH, B. B. and LEET, N. G. (1966). *J. Food Sci.* **31**, 450-9.

MEAT RESEARCH CORPORATION (1996). Processing and Retailing of Large Lean Lambs. (Meat Research Corporation: Sydney).

SHAW F D, EUSTACE I J and WARNER R D. (1996). Proceedings 42nd International Congress of Meat Science and Technology, p. 410.