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Validation of mid voltage electrical stimulation of lamb carcasses

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Executive summary

Previous studies have shown that the effectiveness of electrical stimulation (ES) post slaughter on improving the sensory eating quality attributes of lamb is influenced by the specific design specifications of the ES system. MLA has developed a mid voltage electrical stimulation system for lamb that has a number of operational advantages over conventional ES systems. This study assessed the effect of the MLA-designed mid voltage ES unit installed at Colac CRF on lamb eating quality.

Sixty sucker lambs were processed at Colac CRF in a 3 × 2 factorial study designed to assess the effects of electrical stimulation and product ageing on lamb eating quality. Lambs received either no stimulation (control), low current stimulation (constant current 400mA peak, 14Hz or pulses/second, 1 millisecond pulse width, maximum voltage 300V peak) or high current stimulation (constant current 800mA peak, 14Hz or pulses/second, 1 millisecond pulse width, maximum voltage 300V peak) approximately 20 minutes post sticking. The stimulation current was applied to the dressed carcass via rubbing bars. At 24 hours post slaughter, loin muscles from both sides of the carcass were boned and randomly allocated to either a 2 or 4 day ageing treatment. After ageing for the nominated period, eating quality of the loin was assessed both objectively by measuring shear force values and subjectively using sensory consumer panels in accordance with established SMEQ protocols.

The electrical inputs from the stimulation unit significantly affected the rate of muscle pH decline post slaughter. Stimulated carcasses (from both the low and high stimulation treatments) reached rigor (pH 6.0 or less) around 4 hours earlier than non-stimulated carcasses. Consequently, non–stimulated (control) carcasses reached rigor at around 5°C compared to 17°C for high and low ES carcasses.

The sensory eating quality of the control 'base-line' samples (no stimulation, 2 days ageing) was surprisingly high. These samples had a mean overall liking score of 62.8 with almost all being assessed as at least of "good everyday eating quality". In an electrical stimulation study done 12 months previously using the "skin on" ES system the mean overall liking score for the control 'base-line' samples was only 52.1. In the present experiment, the pH/ temperature window recorded for the non stimulated lamb carcasses in the study (i.e. loin temperature of around 5°C as they reached muscle rigor) would be expected to trigger some degree of cold shortening in the muscles. The product from the control group had a high intrinsic level of eating quality which might indicate unknown production reasons which minimised cold shortening. The high initial values meant that there was limited scope for further improvement either by electrical stimulation or ageing. Thus, in contrast to the previous study, there was no positive effect of electrical stimulation on sensory eating quality even though a hard chilling regime was used. Similarly, ageing had no significant effect on the overall liking score. If the product is already good, it is difficult to improve it further.

Contents

1 Background / Description

Previous studies have shown that the effectiveness of electrical stimulation (ES) post slaughter on improving the sensory eating quality attributes of lamb is influenced by the specific design specifications of the ES system. MLA has developed a mid voltage electrical stimulation system for lamb that has a number of operational advantages over conventional electrical stimulation systems. An initial study (Shaw et al. 2000) of the first prototype of the MLA-designed electrical stimulation system was conducted at VIAS Meat Research and Training Centre, Werribee. It compared the eating quality attributes of lamb receiving either no stimulation post slaughter, high voltage stimulation at the end of the dressing procedure or low voltage stimulation to wool on sheep immediately post sticking (MLA “skin on” system). The results demonstrated a significant improvement for both objective and consumer sensory assessments of lamb eating quality for lambs receiving either electrical stimulation treatment post slaughter when compared to non stimulated lambs. However, this system had not yet been automated to operate at commercial chain speeds and required manual placement of the probes on each lamb carcass.

To facilitate the commercial uptake of the MLA electrical stimulation system by industry MLA has installed a commercial prototype at CRF Colac. The prototype was engineered to operate at commercial chain speeds on “skin on” sheep immediately post sticking. The effectiveness of the MLA electrical stimulation “skin on” unit to improve lamb eating quality was assessed in a study conducted at Colac CRF in September 2002. Electrical stimulation was found to have a positive effect on lamb eating quality with the results summarised in MLA project report SNGI.004. To improve operational efficiencies and reduce the capital cost of the MLA designed ES units MLA have since modified the design of their electrical stimulation system at Colac CRF. In contrast to the “skin on” system the new mid voltage ES unit is located further along the processing chain and operates directly on the carcass after pelting and evisceration. By operating directly on the carcass the new mid voltage ES system eliminates the problem of optimising current flow through woolly sheep. The new system should provide more precision in the delivery of the optimal amount of electrical energy to individual carcasses. Consequently a second study was commissioned by MLA to specifically evaluate the effect of the ES unit on lamb eating quality.

2 Objectives

The objectives of the project were to:

- assess the objective and sensory eating quality attributes of non stimulated and electrically stimulated lamb (400 and 800 mA) processed at CRF Colac
- evaluate if there is an interaction between electrical stimulation treatment and product ageing time (2 and 4 days) on objective and sensory lamb eating quality.

3 Approach / Methodology

3.1 Animals

A total of 60 lambs (5 months of age) were processed at Colac CRF in this study. All lambs selected were second cross from the one vendor weaned for at least 2 months and had been grazing clover pasture prior to slaughter. Table 3.1 summarises the on farm production and pre-slaughter transport history of the lambs selected for the study.

Table 3.1: On farm production history of lambs used in the study

	Vendor group
Kill date	20/10/03
Owner/ Location	Keith
Body No's	
Month of birth	May
Weaning status (sucker/ weaned)	Weaned
Sex	Mixed (20 wethers, 40 ewes)
Sire breed	Poll Dorset
Dam breed	BL/ Merino
Shearing status (shorn, unshorn)	Unshorn
Time off feed (pre-transport)	24hrs
Trucking time	5.5hrs
Lairage time	14hrs
Feed History (last 4 weeks prior to slaughter) i.e crop, irrigated pasture, grain etc	Clover pasture.

3.2 Treatments

A 3 × 2 factorial study was designed to assess the effects of electrical stimulation and product ageing on lamb eating quality.

- ***Electrical stimulation:*** The 60 lambs were processed in six blocks of 10 lambs with electrical stimulation treatment applied post-exsanguination. Lambs in blocks 1 & 6 received low stimulation (constant current 400mA peak, 14Hz or pulses/second, 1millisecond pulse width, maximum voltage 300V peak). Lambs in blocks 2 & 5 received no stimulation (controls). Lambs in blocks 3 & 4 received high current stimulation (constant current 800mA peak, 14Hz or pulses/second, 1millisecond pulse width, maximum voltage 300 V peak). The electrical current was applied to the dressed carcass approximately 20 minutes after stunning and sticking. The total duration of application of the current for each carcass was approximately 35 seconds.
- ***Ageing:*** *At 24 hours post slaughter, loin muscles from both sides of the carcass were boned and randomly allocated to* either a 2 or 4 day ageing treatment.

3.3 Carcass Measurements

Individual carcass measurements recorded on the day of kill included carcass weight, GR fat depth and loin pH and temperature profiles for the first 7 hours post slaughter. At boning (24 hours post slaughter), loin ultimate pH and meat colour (CIE L*, a* & b*) were also recorded.

3.4 Meat cuts

Loin (*M. longissimus thoracis et lumborum*) muscles from both sides of the carcass were boned from the 60 lambs at Colac CRF boning room at 24 hours after slaughter. Cutting lines used to remove the muscles complied with SMEQ protocols. The first 15cm of each loin at the cranial end was labelled, vacuum packed and aged in accordance with time allocated then tested for Warner Bratzler (WB) shear force.

The balance of each loin (approx 25cm) was vacuum packed, labelled, and airfreighted in styro foam boxes to Cosign, Coffs Harbour, for completion of the nominated ageing period and preparation for sensory testing.

3.5 Sensory Protocols

Sensory eating quality assessments were conducted on the loin muscles for 54 lambs processed with the loins from one lamb per block group excluded from sensory testing due to a 108 loin limit per sensory pick. An independent recruitment company recruited consumer groups from a broad range of socio-economic backgrounds. These consumers were screened to include only individuals who eat lamb a minimum of once per week and had a preference for lamb cooked to a medium degree of doneness. Socio-economic and demographic data were recorded for consumers in the taste panels.

Sensory attributes of the cooked lamb were recorded on tasting sheets. These had four 100 mm lines that were anchored by the words very tender/very tough for tenderness, very juicy/very dry for juiciness and extremely like/extremely dislike for flavour, and overall liking.

In addition to marking the four line scales the consumers placed a tick in one of four boxes to indicate the general rating of the sample. Category choices were:

- Unsatisfactory
- Good everyday
- Better than everyday
- Premium

Lamb loin samples were cooked on a Silex grill and each consumer presented with a total of seven warm samples served over a 35 minute session. The first sample was a link product designed to allow equilibration of the consumer scores. The data from this sample was subsequently discarded in the analysis after consistency in scoring between link steaks was observed. Following this, a further six samples were presented to each consumer. The experimental design used in the taste panels was a latin square, where five samples from each cut were presented in different positions in a minimum of three different sessions, with each sample to be tasted by two consumers. Previous analyses have shown that taste panel design (ie order and session) and demographic effects have a minimal effect on the sensory scores.

Completed sheets were collected after each sample to ensure that scores were not modified retrospectively. Completed score sheets were double entered and cross-checked prior to forwarding for entry onto the database.

The 10 sensory scores for each sample were then averaged to provide a palatability score for each trait for each cut.

3.6 Statistical Analysis:

Carcass traits (weight, GR fat depth, sex), objective meat quality traits (pH, colour, shear force) and sample mean sensory scores were analysed using an analysis of variance procedure (Genstat 5.4.1, 1997). Electrical stimulation and ageing time were listed as treatments. The data was blocked for kill group and carcass with stimulation treatment applied to six kill groups and ageing treatment applied across loins from each carcass. No co-variates were fitted.

4 Results

4.1 Carcass and sensory traits

Table 4.1 summarises the carcass and sensory measurements recorded for the 60 lambs used in the study.

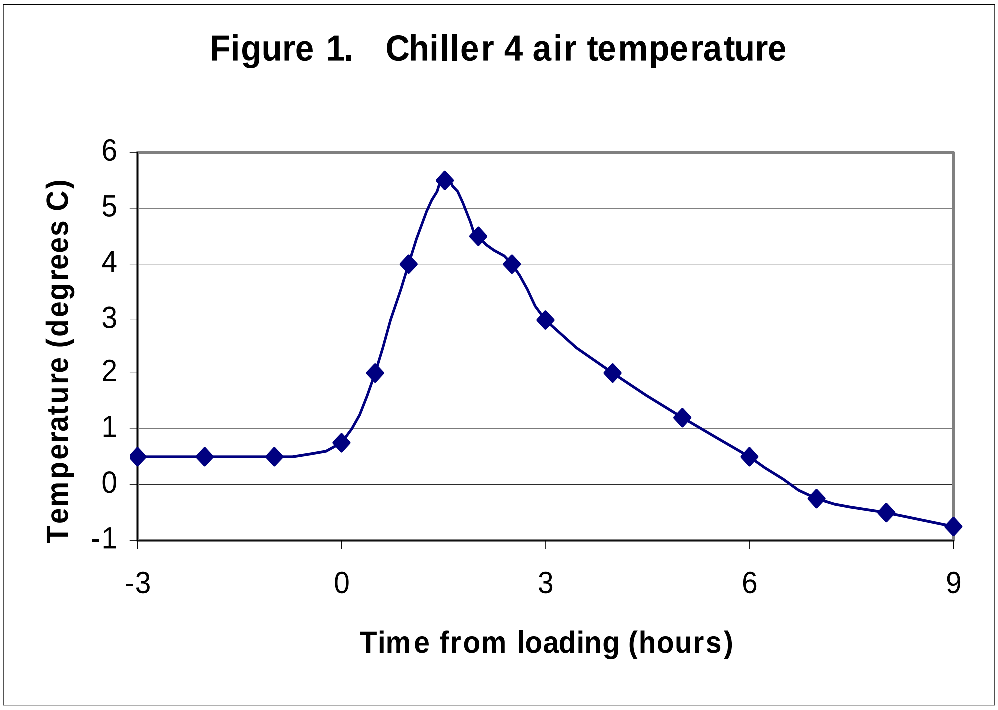
Table 4.1 Data statistics for carcass & sensory traits of lambs processed for the electrical stimulation study

TRAIT		MEAN	STD DEVIATION	RANGE
• **Carcass**				
Carcass Wt (kg)		20.0	1.5	15.6 to 22.6
GR fat depth (mm)		16	3	9 to 25
Meat colour (CIE L*)		35.1	1.7	31.5 to 38.8
% dark (L* < 30)	Nil			
Meat pHu (24hrs)		5.50	0.05	5.39 to 5.67
% high pH (pHu >5.8)	Nil			
Sex	40 ewes 20 wethers			
• **Loin Sensory Traits**				
• **(2 & 4 days ageing)**				
Flavour		65.3	6.9	46.0 to 79.7
Juiciness		54.8	8.9	35.6 to 75.9
Tenderness		62.7	9.7	38.9 to 81.3
Overall Liking		64.3	7.1	44.5 to 77.6
SEQ*		63.4	7.1	45.2 to 76.6

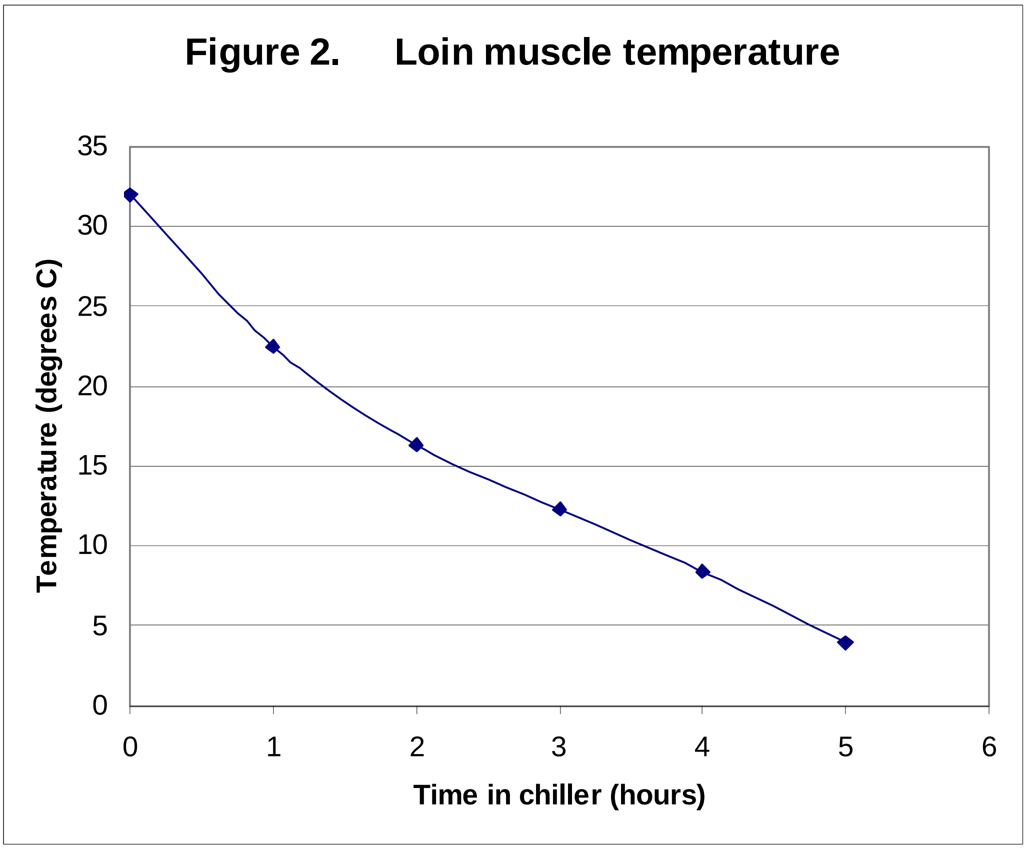
*SEQ= 0.4 (overall liking)+ 0.3 (flavour) + 0.2 (tenderness) + 0.1 (juiciness)

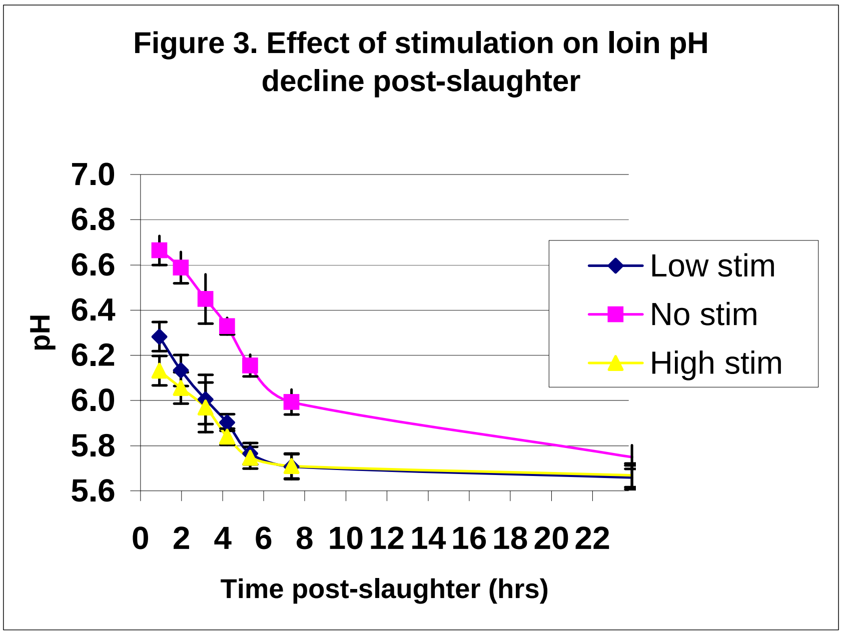
4.2 Chilling regime:

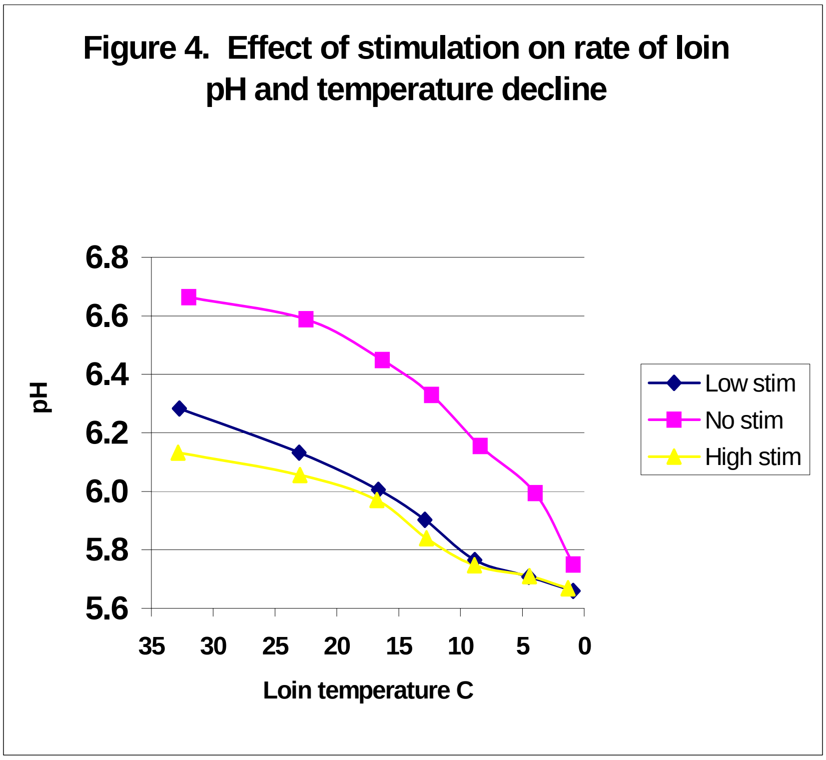
Figure 1 is a representation of the chiller air temperature while Figure 2 shows the decline in loin temperature for the non-stimulated group. The temperature decline did not differ significantly between the three treatment groups. The mean loin temperature after 5 hours chilling was less than 5°C which indicates a rapid rate of chilling.



4.3 Muscle pH/temperature decline







The pH of loin muscles from both the low and high stimulation groups were significantly lower ($P<0.001$) at all measured time points in the first 6 hours post slaughter compared with those from non stimulated group (Figure 3). For the control (non-stimulated) group, muscle pH 6 was reached at temperatures of around 5°C while for the stimulated groups this pH was reached at temperatures of around 17 to 20°C (Figure 4).

4.4 Muscle pH and meat colour

Table 4.2 Effect of electrical stimulation on muscle pH, temperature (°C) and meat colour

	Nil Stimulation	Low Stimulation	High Stimulation	S.E.
pH 24 hr	5.75	5.66	5.67	0.03
Temp 24 hr	0.88	0.89	1.3	0.10
pH 48 hr	5.52	5.46	5.50	0.01
Temp 48 hr	5.1	5.06	5.31	0.47
Colour L*	34.16	35.33	35.67	0.35
Colour a*	12.81	14.58	14.62	0.20

The mean muscle pH values, at either time, did not differ significantly between the three treatment groups. Stimulation caused a statistically significant ($P < 0.01$) improvement in meat colour. The increased a* and L* values indicate that the meat will be redder and lighter although it is doubtful that this change would be of commercial significance.

4.5 Lamb eating quality results

Table 4.3 summarises the treatment effects of electrical stimulation and ageing time on objective muscle tenderness and consumer sensory eating quality traits.

Table 4.3 Effect of electrical stimulation (ES) treatment (High, Low or No stimulation) and ageing period (A; 2 or 4 days) on WB shear force values (kg) and sensory attributes of lamb loins.

	High ES		Low ES		No stimulation		s.e.d.	P value		
Ageing	2d	4d	2d	4d	2d	4d		ES	A	ES x A
WB shear force	3.55	2.32	3.35	2.06	4.11	2.79	0.25	ns	<0.001	ns
SEQ	63.55	62.49	62.67	64.68	60.92	65.78	1.80	ns	0.08	0.09
Tenderness	61.12	64.20	62.25	66.16	57.25	65.33	2.45	ns	<0.001	ns
Liking	64.92	63.06	63.36	65.52	62.81	66.22	1.84	ns	ns	ns
Flavour	65.89	63.44	65.14	65.59	64.13	67.74	1.77	ns	ns	0.07
Juiciness	55.88	53.92	53.42	55.51	51.09	58.99	2.09	ns	0.05	0.01

- *Effect of electrical stimulation*

Whilst there was a positive trend for electrical stimulation to reduce loin muscle WB shear force values of stimulated compared to non stimulated carcasses (Table 4.3) the differences were not significant (P=0.096).

Consumers rated all sensory attributes of electrically stimulated lamb comparable to those of non stimulated lamb. There was a significant interaction between electrical stimulation and ageing treatments for juiciness (P=0.01). Similar interactions for flavour (P=0.07) and SEQ (P=0.09) approached significance. This suggests that the improvement gained from ageing the lamb from 2 to 4 days was greater for non stimulated carcasses compared to stimulated carcasses for these 3 traits. However the sensory eating quality scores for stimulated and non stimulated lamb did not differ after 4 days ageing.

If the results are assessed on a consumers rating of the product as being either unsatisfactory (1 & 2 star) or good everyday or higher (3, 4 & 5 star), loins from both high, low and non stimulated carcasses performed comparably at either 2 or 4 days of ageing (Table 4.4).

Table 4.4 Effect of electrical stimulation on the percentage of lamb loin chops rated by consumers as good everyday or better

Days ageing	% lamb loin chops rated as good every day or better (n=1078)			Significance
	High ES	Low ES	No stim	
2d	82	83	83	ns
4d	83	84	85	ns

- *Product ageing*

Ageing lamb loins for an additional 2 days post-slaughter (from 2 to 4 days) was found to significantly (P<0.001) reduce shear force values (Table 4.5).

Ageing lamb from 2 to 4 days improved consumer sensory score for juiciness (P<0.05), tenderness (P<0.001) and SEQ (P=0.08) but not overall liking or flavour. Consumers scored the 4 day aged loins 2 SEQ units higher compared to the 2 day aged product.

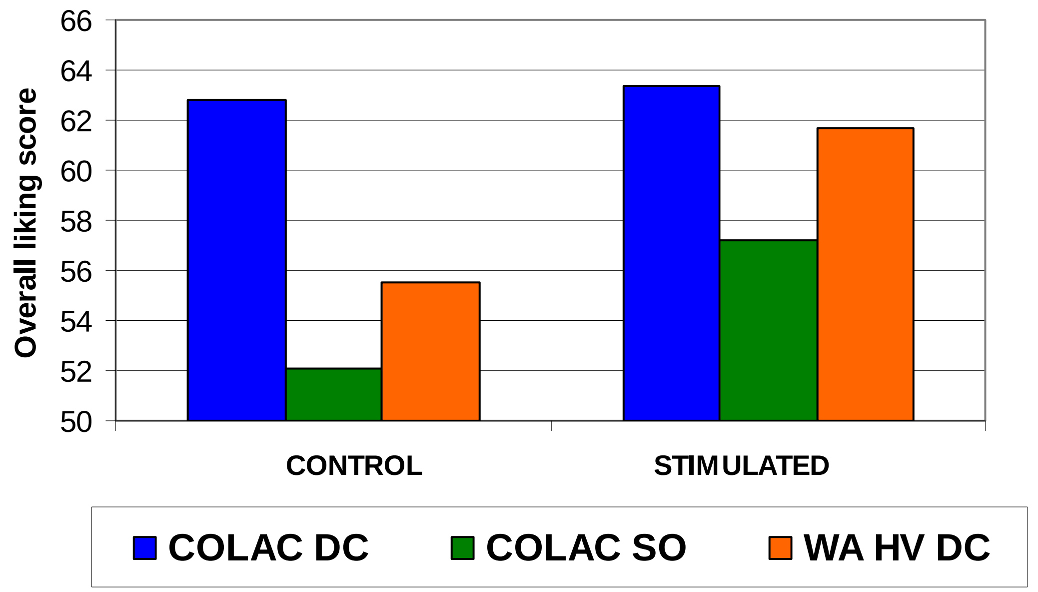
Table 4.5 Effects of product ageing effects on lamb eating quality

Trait	2 days ageing (n=30)	4 days ageing (n=30)	Significance (sed)
• *Objective*			
Shear force	3.67	2.39	P<0.001 (0.08)
• *Sensory*			
SEQ	62.38	64.32	P=0.08 (1.08)
Tenderness	60.21	65.23	P<0.001 (1.39)
Liking	63.70	64.94	ns (1.19)
Flavour	65.05	65.59	ns (1.03)
Juiciness	53.46	56.14	P<0.05 (1.33)

5 Discussion

In this experiment it was not possible to demonstrate a statistically significant improvement in eating quality as a result of stimulation. It is believed that the major contributing factor to this result is the high values recorded for the control 'baseline' (no stimulation, 2 days ageing) group. Figure 5 compares the results of this trial (Colac **D**ressed **C**arcass) with those of 2 previous trials. One of the previous trials (Colac **S**kin **O**n) (Baud et al 2002) was similar to the present trial except that the electrical current was applied not to the dressed carcass but through the wool immediately post sticking (MLA "skin on" system). The other trial (**W**est **A**ustralia **H**igh **V**oltage **D**ressed **C**arcass) involved the application of a high voltage to the dressed carcass (Shaw et al. 2004). In all three trials there were 2 stimulation treatments. For clarity, only the results of the most effective stimulation treatment are displayed in Figure 5.

Figure 5. Consumer 'Overall liking' scores for 3 stimulation experiments (2 day aged samples)



The overall liking score for the baseline samples in the present trial (Colac DC) is greater than those for the other two trials. Although stimulation has little additional effect on the Colac DC samples, they still have a higher overall liking score than the stimulated samples from the other trials.

The consumer tenderness scores also indicate the initial superiority of the Colac DC samples (Table 5.1). The table shows a 9 or 10 point superiority in tenderness scores for the baseline (no stimulation, 2 days ageing) group, in comparison with the previous trials. Thus, the initial product in the present study appears to be of better quality than that in the previous studies. Under such circumstances there is minimal scope to further improve it either by electrical stimulation or ageing.

Table 5.1 Mean Consumer Tenderness Scores for 2 day and 4 day aged samples for 3 trials.

	No stimulation		**Low stimulation**		**High stimulation**		**SE**
	2 days	4 days	2 days	4 days	2 days	4 days	
Colac DC	57.2	65.3	62.2	66.2	61.1	64.2	2.5
Colac SO	46.7	56.8	55.4	63.7	52.5	58.8	2.6
WA HV DC	48.2	55.9	58.5	61.6	55.7	63.6	2.6

Note. The WA HV DC samples were aged for 5 days, not 4.

Table 5.2 Mean Temperature at pH 6 (°C) for the three trials.

	No stimulation	**Low stimulation**	**High stimulation**	**SE**
Colac DC	5.1	17.1	20.0	1.6
Colac SO	6.3	15.1	13.6	1.0
WA HV DC	11.9	30.1	38.9	1.1

With a temperature of 5.1°C at pH 6 one would expect toughness due to cold shortening. The product from the control group had a high intrinsic level of eating quality which might indicate unknown production reasons which minimised cold shortening.

In contrast to the previous studies there was no positive effect of electrical stimulation on sensory eating quality even though a hard chilling regime was used. Clearly the electrical input from the stimulation unit significantly affected the rate of meat pH decline post slaughter. Stimulated carcasses (from both the low and high stimulation treatments) reached rigor (pH 6.0 or less) around 4 hours earlier than non-stimulated carcasses. Consequently, control carcasses reached rigor at around 5°C compared to 17°C for high and low ES carcasses. The pH/ temperature window recorded for the non stimulated carcasses in the study (i.e. loin temperature of around 5°C as they reached muscle rigor) would be expected to trigger some degree of cold shortening in the muscles. However, the product had a high intrinsic level of eating quality. This is illustrated by the fact that between 82 to 85% of the product was rated as good everyday or better by consumers for all combinations of electrical stimulation and ageing treatments used in the study (Table 4.4). At this level of eating quality performance there is limited scope for further improvement (Figure 5). If the product is already good, it is difficult to improve it further.

6 References

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