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Meat Electronics for Goats

Abstract

Previous work has shown that with the use of new mid voltage electrical stimulation (MVS) technology, improvements have been made in the proportion of lamb and sheep carcases that are able to meet recommended pH/temperature windows. The overall objective of this study was to examine the application of this technology to goat carcases. The aim of the first phase of the study was to determine optimal settings using a pre-dressing MVS unit. However due to some processing complications a post-dressing MVS was instead optimised. Results from this phase showed an optimal setting to be 700 milliamperes with a pulse width of 500 milliseconds. This setting was then used in an experiment comparing 32 stimulated and 32 non stimulated carcases from 2 different consignments, killed over 2 days. This was to determine the effects of MVS on goat meat quality with a particular focus on meat tenderness and colour stability during display. Outcomes from this study showed that there was no significant difference between stimulation treatments for initial, 24hour or final loin pH, predicted temperature at pH 6.0, predicted pH at 25 or 18˚C. There was also no significant difference between treatments for shear force measured on loin meat aged for 1, 2, 4, or 21 days or on sarcomere length. There were minimal objective colour differences and no differences for colour display life. There were some differences highlighted due to consignment and this would largely be attributed to the variation in the type of goats processed. Overall the shear force of the loin samples was very high indicating tough meat.

Executive Summary

The first phase of this study (as reported in Milestone report 2) was to monitor initial pH profiles and establish the optimal level of stimulation. A pre-dressing MVS scenario was initially used, however due to problems encountered during initial testing of the unit (such as, increased digesta spill and stiffness of the carcases by the time they reached the chiller); it was decided to shift the stimulation unit so as to apply a post-dressing current to alleviate these issues. It should be reiterated that the results when using the pre-dressing unit showed that compared to no stimulation a pre-dressing stimulation produced a significantly higher predicted temperature at pH 6.0, indicating a faster rate of decline. However a lack of room on the kill floor prevented the relocation of the unit whilst still allowing stimulation pre-dressing hence a post-dressing scenario was subsequently used.

Testing of a post-dressing unit was undertaken and although there was no significant difference between stimulated and non stimulated carcases in the rate of pH decline, the results followed the same trend as the pre-dressing unit. As a result the predicted pH at 25ºC for stimulated carcases was 6.28, whereas for non stimulated it was 6.50. On this basis and because of time restraints it was deemed that a post-dressing application of stimulation would still be effective.

However with the evaluation of pH and temperature decline, meat tenderness (shear force), sarcomere length and various colour traits including colour display life, the results from the final phase of the study showed that there was no significant difference between stimulated goat meat and non stimulated meat. There were some differences highlighted due to consignment and this would largely be attributed to the variation in the type of goats processed. There were limitations as to the type of goats that could be used for this experiment due to weather conditions and market requirements and this may have impacted on the low response to stimulation. Nevertheless there is likely to be significant benefit from applying effective stimulation to goat carcases, because based on the results reported herein, they are liable to produce very tough meat if not effectively stimulated.

Contents

1 Background

The temperature at which point a carcase enters rigor (pH 6.0) can be used to predict meat quality (Geesink *et al.* 2000; Thompson *et al.* 2005). If the carcase temperature falls too fast before the onset of rigor then cold shortening may result (Tornberg 1996) which can have adverse effects on meat tenderness. At the other end of the scale, slow rates of cooling can lead to heat toughening (Devine *et al.* 1999) which in some circumstances can reduce ageing potential (Strydom *et al.* 2005). Electrical stimulation has been identified in many studies as a useful processing technique to improve meat quality traits (e.g. Devine *et al.* 2004; Polidori *et al.* 1999), but adoption amongst goat abattoirs has been minimal.

The Australian Sheep Meat Eating Quality (SMEQ) program identified various temperature ranges for optimal eating quality depending on the market for the product. From this it was concluded that the target temperature range to achieve pH 6.0 should be 18-25ºC for short aged meat destined for the domestic market (Thompson *et al.* 2005). Although not tested on goats it is assumed that this target is applicable to goats and methodologies which prevent carcases from entering rigor at low temperatures will confer quality benefits.

Research has shown that optimal application of meat electronics in sheep can be used to achieve specific quality and commercial benefits including i) Optimal blood collection using low frequency bleeding units (Hopkins *et al.* 2006b); ii) High frequency immobilisation to knock out nerves and reduce OHS risks with out impacting on meat quality (Toohey & Hopkins 2007) and iii) Mid-voltage stimulators to deliver optimal waveforms to accelerate ageing and assist in optimal tenderness (Pearce *et al.* 2006).

Research has also shown that unless domestic sheep abattoirs install some form of electrical stimulation that they may not be able to meet the pH/temperature window specified by the MSA and SMEQ programs for short aged domestic product. A small study has shown that stimulation of goat carcases to accelerate rigor onset can lead to a reduction in toughness even when the meat was aged for 6 days (Baud *et al.* 2006), but there was no attempt to optimise the electrical parameters (pulse width, current and length of stimulation) of the stimulation unit. Optimising the technology is considered very important given the low fat levels of goat carcases which exposes them to fast rates of temperature decline with an increased chance of producing tough meat.

This report details the results of an experimental program which aimed to optimise the current and pulse width of a new generation Mid-Voltage electrical stimulation unit (MVS) applied to goat carcases, at PMB Prime Meats Pty Ltd abattoir, Oberon.

2 Project Objectives

1. To experimentally determine the optimum set of post-dressing stimulation parameters which optimise pH fall.

2. Determine the pH/Temperature profile of sample carcases under “best bet” current and pulse width settings.

3. Quantify the colour and tenderness associated with the post dressing stimulation electronics.

3 Methodology

3.1 Phase 1 (Optimisation of mid-voltage Electrical stimulation)

3.1.1 Animals

In total 215 goats from a number of different consignments were assessed over 4 days. The goats from the different consignments were of varying backgrounds and sex to represent the goats that are processed for the Australian domestic market.

3.1.2 Stimulation Treatments

Initially each consignment was exposed to various levels (current and pulse width) and combinations of electricity using a pre-dressing mid voltage electrical stimulation unit. All treatments were applied for the same length of time (45 seconds). An outline of stimulation treatments, and the number of carcases sampled per treatment for the pre-dressing stimulation treatment is shown in Table 1 and the post-dressing unit results are shown in Table 2.

3.1.3 Measurements

3.1.3.1 Weight and GR

Carcases were trimmed according to the specifications of AUS-MEAT (Anon, 1992). Hot carcase weights were recorded and the GR measured (total tissue depth over the 12^{th} rib, 110 mm from the midline) using a GR knife.

3.1.3.2. pH and temperature

Carcase pH and temperature measurements were taken 60 mins after death and then measured every hour after that with a total of 5 measurements per carcase.

The pH and temperature measurements were taken in the left portion of the m. *longissimus thoracis et lumborum* (LL) muscle at the caudal end over the lumbar/sacral junction. A section of the subcutaneous fat and the m. *gluteus medius* was cut away to expose the LL and after each measurement the area was resealed with the overlaying tissue. Muscle pH was measured using a glass combination pH probe (potassium chloride) Ionode intermediate junction pH electrode, (TPS Pty Ltd., Brisbane, Queensland) attached to a data recording pH meter (TPS WP-80). While muscle temperature was measured using a stainless steel cylindrical probe attached to the same meter. The pH meter was calibrated before use and at regular intervals using buffers of pH 4 and pH 6.8 at room temperature.

3.1.4 Statistical Analysis

Carcase and meat quality traits were analysed using a residual maximum likelihood (REML) procedure (Genstat 9.1, 2006) which contained a fixed effect for treatment (stimulation levels vs. no stimulation), to estimate the means and standard errors of the differences with consignment as a random term. For GR, carcase weight was used as a covariate.

The rate of temperature decline relative to time could not be fitted using a non-linear procedure (due to only having five data points with no ultimate pH) so a linear regression procedure was used to derive the relationship between post-stimulation pH and temperature.

3.2 Phase 2 (Validation of optimal setting)

3.2.1 Animals

For testing the effect of stimulation on meat traits a total of 64 goats from 2 different consignments were killed over 2 days with 1 consignment killed on each kill day. These kill days were 2 weeks apart. The female goats from the different consignments were of varying backgrounds. Consignment 1 goats were sourced from Tilpa and were transported to Oberon with the transport time being approximately 11 hours and then the goats were held in lairage for approximately 36 hours. Consignment 2 animals were sourced from a Dubbo store sale; from there they were transported 3 hours to Oberon and held on green pasture for approximately one week, and then were in lairage prior to slaughter for approximately 12 hours.

3.2.2 Stimulation

Carcases were randomly allocated to either stimulation or non stimulation treatment groups. The stimulated carcases were exposed to a constant current of 700 milliamperes (mA), varying voltage with a peak of 300 volts and a pulse width of 500 milliseconds (ms) using a post-dressing mid voltage electrical stimulation unit. The stimulation treatment was applied after the scales for 45 seconds approximately 45-50 minutes post-mortem.

3.2.3 Measurements and sampling

3.2.3.1 Weight and GR

Same method as phase 1

3.2.3.2 pH and temperature

Carcase pH and temperature measurements were taken 30 mins after death and then measured every hour after that with each carcase measured 5 times and then a 24 hour pH and temperature measurement was recorded. The sampling method and equipment used to take these measurements was the same as phase 1. Final pH was also measured in the M. *Semitendinosus* (ST) approximately 24 hours post-mortem for consignment 2 animals.

3.2.3.3 Final pH

A 1 gram sample was taken from 3 day aged LL samples for the determination of final pH using an iodoacetate method adapted from that of Dransfield *et al.* (1992).

3.2.3.4 Shear force testing

From the LL in kill 1, samples were taken where possible after 2, 4 and 21 days of aging and samples were taken where possible in kill 2 after 1, 2, 4 and 21 days of aging. The samples were frozen at -20°C and subsequently tested for peak shear force using a method adapted from that described by Thompson *et al.* (2005a).

3.2.3.5 Meat colour

The meat colour reflectance of the LL was measured initially on 1 day aged samples using a Minolta colour machine. These colour samples were then aged for 3 days and then measurements were taken twice a day (am/pm) for a further 3 days resulting in 7 measurements per sample. For the initial measurement after 3 days of ageing a fresh surface was prepared by cutting in a transverse direction across the sample and after 30 min a colour reading was taken. Samples were then positioned randomly on black plastic trays and over wrapped with polyvinyl chloride clear film and placed under continuous lighting (1190 Lux) in a chiller at 4ºC. Colour measures were taken with a Hunter Lab MiniScan XE spectrophotometer (Hunter Associates, Reston, VA), Model D45/0-s 6 mm port, set for *L** (lightness), *a** (redness) and *b** (yellowness) using D65 illuminate conditions and a 10 degrees standard observer through a 5mm aperture in the measuring head. The MiniScan was calibrated using both white and black tiles.

3.2.3.6 Sarcomere length

Sarcomere length was tested using laser diffraction as described by Bouton *et al.* (1978)

3.2.3.7 Purge

Samples taken for Warner Braztler shear force testing were used to measure the amount of purge after 3 and 21 days of ageing. The samples were weighed at day 1 and then again after their allocated ageing period was complete and purge percentage loss was calculated.

3.2.4 Statistical analysis

Carcase and meat quality traits were analysed using a residual maximum likelihood (REML) procedure (Genstat 9.1, 2006) which contained a fixed effect for treatment (stimulation vs. no stimulation), to estimate the means and standard errors of the differences with consignment also as a fixed effect. For GR, carcase weight was used as a covariate. For initial loin pH, final loin pH and ST pH, the respective temperatures were used as a covariate.

The rate of temperature decline relative to time could not be fitted using a non-linear procedure (due to only having five data points) so a linear regression procedure was used to derive the relationship between post-stimulation pH and temperature. Colour display life measurements were analysed using a spline analysis where ratio values

of 2 wavelengths 630/580nm (indication of metmyoglobin formation – or the browning of meat) were predicted at various time points.

4 Results and Discussion

4.1 Phase 1 (Optimisation of mid-voltage Electrical stimulation)

There were no differences in both carcase weight and GR between treatments for either the pre/post – dressing stimulation treatments (Tables 1 and 2), showing carcases were evenly distributed across treatment groups. Results from carcases stimulated using the pre-dressing unit in Table 1 show that there was no difference between the different stimulation treatments (currents) for predicted temperature at pH 6.0, predicted pH at 25ºC and 18ºC, but there was a difference between the stimulated carcases and those not stimulated. The greatest difference for predicted temperature at pH 6.0 was between the carcases in treatment 3- 600mA x 0.5ms (21.3 ºC) and treatment 6 – no stimulation (12.2ºC). It should be noted that it was not possible to make realistic predictions for all carcases and these are not shown. Treatment 6 – no stimulation had a significantly higher pH at both 25ºC and 18ºC.

Although there were no significant differences between treatments when using the post-dressing stimulation unit, the results follow the same trend as the pre-dressing unit with the treatment 6 – no stimulation having the lowest predicted temperature at pH 6.0, and highest pH at 25ºC and 18ºC (Table 2).

The predicted pH and temperature decline using a pre-dressing stimulation unit on day 1 is shown in Figure 1. From this figure it shows that there only small differences between the six treatments, with the no stimulation treatment (OFF) being consistently higher. It is also shown that after the initial drop in delta pH there is not much change in pH after that, except for treatment 3 (600mA x 0.5ms). This limited change may be a function of a severe chilling regime and the rapid drop in temperature. On average no treatment meets the recommended pH and temperature window with carcases falling at the cold end of the scale.

Figure 2 shows the predicted pH and temperature decline using a pre-dressing stimulation unit on day 2. Here it is clear that, the no stimulation treatment (OFF) is consistently higher then other stimulation treatments and there were again minimal differences between these other stimulation treatments. In addition on average treatments did not meet the recommended pH and temperature window with all carcases falling on the cold end of the window as in Figure 1.

Table 1. Pre-dressing electrical stimulation unit, predicted means (Ave s.e.d.) of carcase weight (kg), GR (mm), predicted temperature at pH 6.0, predicted pH at 25ºC,predicted temperature at 18ºC, percent of carcases hitting the pH and temperature window, % with pH < 6.0 at 25ºC and % with pH > 6.0 @ 18ºC.

Treatment	1	2	3	4	5	6	Ave S.E.D
Stimulation treatment^	400x0.5	500x0.5	600x0.5	700x0.5	800x0.5	OFF	
Number of animals	32	24	32	32	32	24	176 - total
Number of sampling days	3	3	3	3	3	3	
Traits							
Weight	12.5a	11.8a	12.1a	14.2a	12.4a	12.4a	*0.88*
GR*	4.7a	4.2a	4.5a	5.1a	4.8a	5.1a	*0.45*
Pred temp @ pH 6.0#	20.8b	20.6b	21.3b	18.7b	18.8b	12.2a	*3.22*
Pred pH @ 25ºC	6.22a	6.15a	6.12a	6.16a	6.19a	6.47b	*0.06*
Pred pH @ 18ºC	6.13a	6.06a	6.01a	6.04a	6.12a	6.37b	*0.06*
% hit the pH window	9.3%	21%	12.5%	28.3%	21%	12.5%	18.4 % +
% pH < 6.0 @ 25ºC	28.3%	33%	31.3%	28.3%	33%	0	30.8 % +
% pH > 6.0 @ 18ºC	62.5%	46%	56.3%	43.5%	46%	87.5%	50.9 % +

Means followed by a different letter in a row (a,b) are significantly different ($P < 0.05$), ^stimulation treatment is the current (milliamps) by the pulse width (milliseconds), *Adjusted to a hot carcase weight of 12.56kg, # predicted values for 96 animals, + Average % across stimulation treatment groups not including the off treatment.

Table 2. Post-dressing electrical stimulation unit, predicted means (Ave s.e.d.) of carcase weight (kg), GR (mm), predicted temperature at pH 6.0, predicted pH at 25ºC,predicted temperature at 18ºC, percent of carcases hitting the pH and temperature window, % with pH < 6.0

Treatment	2	3	4	5	6	Ave S.E.D
Stimulation treatment^	500x0.5	600x0.5	700x0.5	800x0.5	OFF	
Number of animals	8	8	8	8	7	39 - total
Number of sampling days	1	1	1	1	1	
Traits						
Weight	11.2a	12.5a	12.6a	11.0a	14.6a	*2.37*
GR*	6.1a	6.6a	7.1a	6.1a	7.1a	*0.54*
Pred temp @ pH 6.0#	16.2a	16.7a	15.1a	14.2a	12.9a	*3.0*
Pred pH @ 25ºC	6.28a	6.28a	6.27a	6.30a	6.50a	*0.09*
Pred pH @ 18ºC	6.05a	6.03a	6.05a	6.10a	6.25a	*0.09*
% hit the pH window	50%	37.5%	37.5%	12.5%	28.5%	34.5%+
% pH < 6.0 @ 25ºC	0	12.5%	0	0	0	3%+
% pH > 6.0 @ 18ºC	50%	50%	62.5%	87.5%	71.5%	62.5%+

Means followed by a different letter in a row (a,b) are significantly different ($P < 0.05$), ^stimulation treatment is the current (milliamps) by the pulse width (milliseconds), *Adjusted to a hot carcase weight of 12.4kg, # predicted values for 38 animals, + Average % across stimulation treatment groups not including the off treatment.

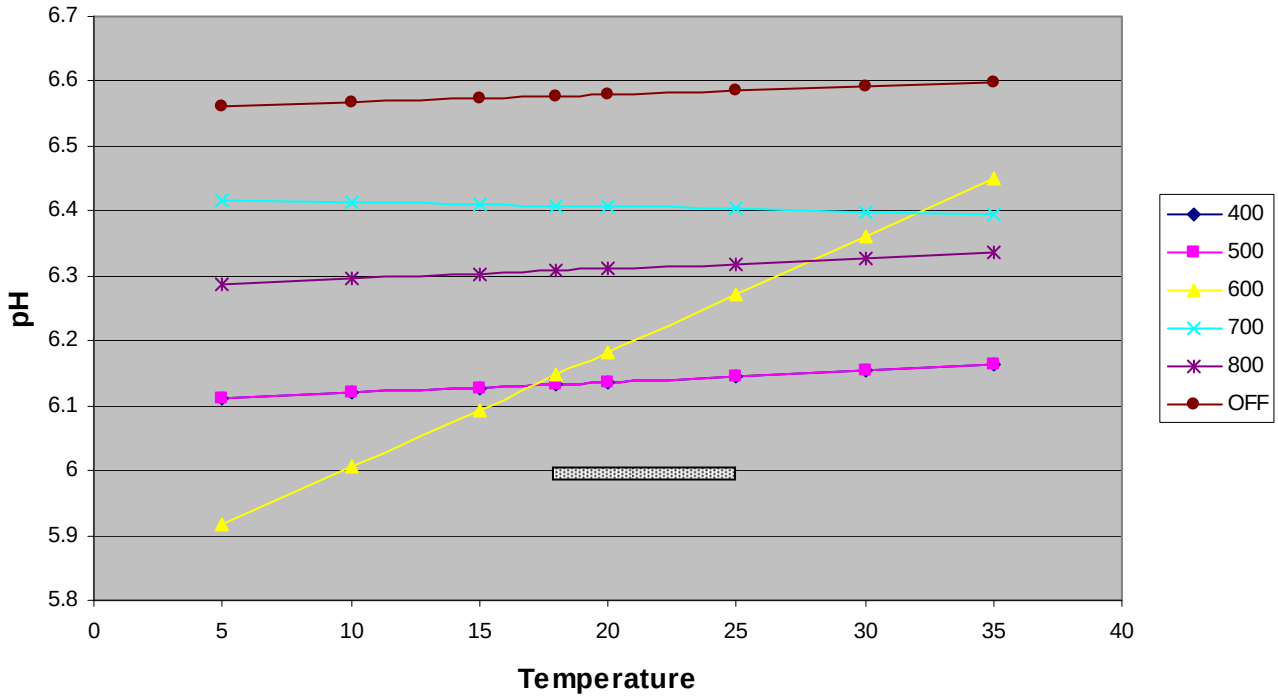

Figure 1. Predicted pH and Temperature decline Day 1 – a comparison of current with a pre-dressing stimulation unit.

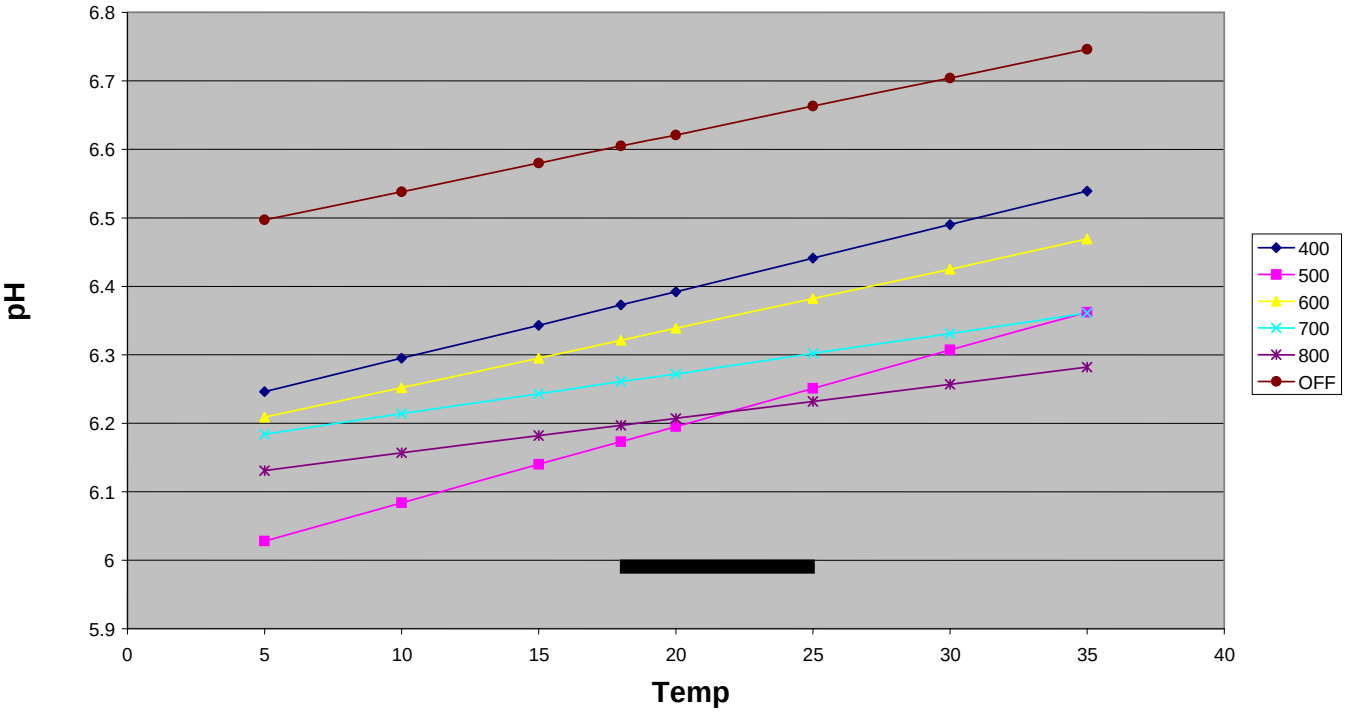

Figure 2. Predicted pH and Temperature decline Day 2 – a comparison of current with a pre-dressing stimulation unit.

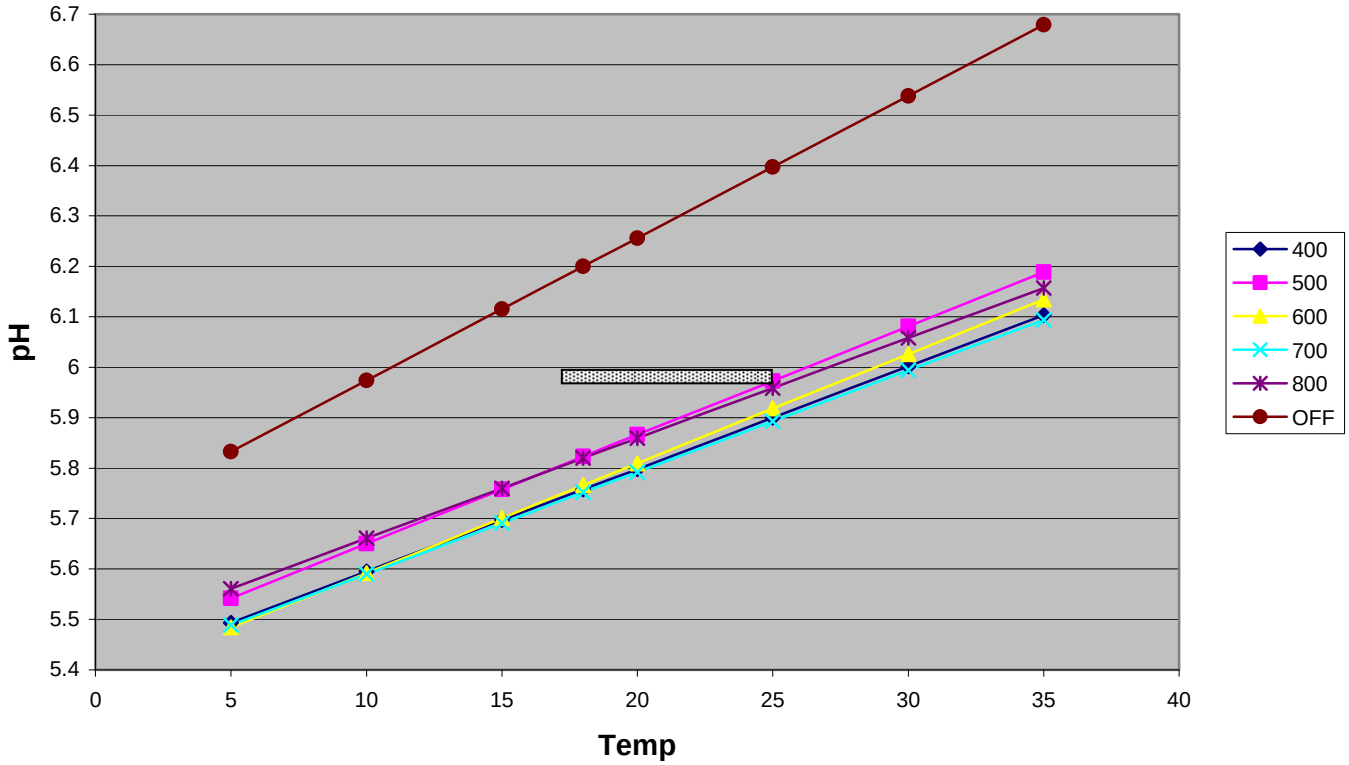

Figure 3. Predicted pH and Temperature decline Day 3 – a comparison of current with a pre-dressing stimulation unit.

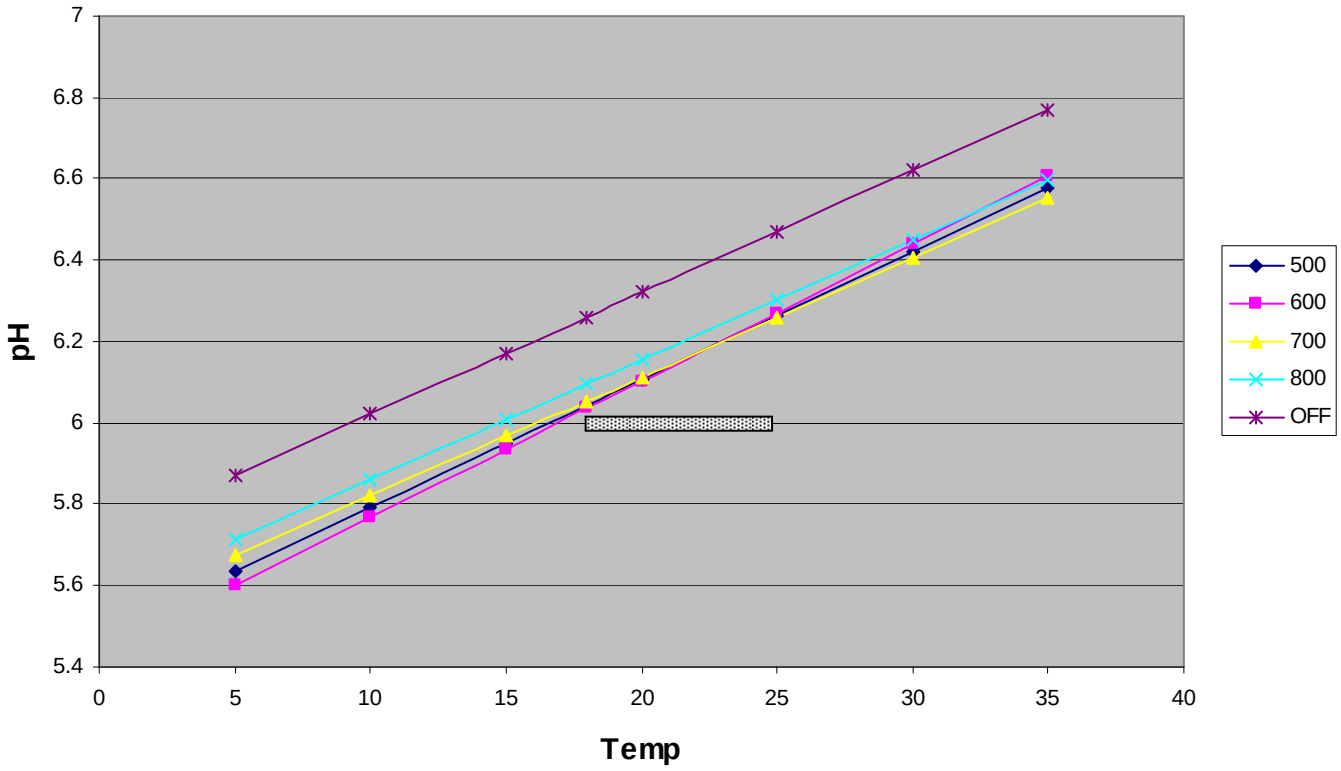

Figure 4. Predicted pH and Temperature decline Day 4 – a comparison of current with a post-dressing stimulation unit.

In contrast to both Figures 1 and 2, Figure 3 shows that on average all stimulated carcases fell on the warm side of the recommended pH and temperature window with minimal differences between them. This may be due to a number of reasons including; less severe chilling and better quality and conditioned goats. This indicates that by using goats with potentially higher glycogen levels in their muscles a more effective response to electrical stimulation could be achieved .The large delta pH drop for the stimulated carcases compared with the non stimulated carcases in Figure 3 illustrates this point. Again the no stimulation treatment was consistently higher with all carcases falling on the cold side of the window further highlighting the positive impact of electrical stimulation.

Figure 4 for shows the predicted pH and temperature decline using a **post dressing unit**. As in all the other figures there is minimal difference between the stimulation treatments except with the no stimulation treatment being consistently higher. The other stimulation treatments all fall just on the cold side of the window.

4.2 Phase 2 effect of optimal mid voltage electrical stimulation on meat quality

There were no differences in both carcase weight and GR between treatment groups as shown in Table 3, showing carcases were evenly distributed across treatment groups. However there was a significant difference between kill day or consignment for both weight and GR. This is due to the variation in consignments rather then a kill day effect. There was no significant effect of treatment,

consignment or their interaction on sarcomere length or the amount of purge measured at 21 days, but there was a kill day effect on purge measured at 3 day with a higher percentage lost during kill 1.

There was no significant effect of treatment, consignment or their interaction on any pH or temperature trait measured. This lack of effect is also shown in Figure 5 which demonstrates that a large percentage of carcases fell at the cold end of the recommended pH and temperature window of 18-25 ºC.

Table 3. Predicted means (s.e.d.) for carcase weight, GR, sarcomere length, initial, 24 hour & ultimate loin pH, final ST pH, purge at 3 & 21 days, predicted temperature @pH 6.0, predicted pH at 18 and 25 ºC, and

	Treatment		
Trait	Stim[1]	No stim	*s.e.d*
Weight (kg)	13.5a	13.8a	0.53
GR (mm)*	4.4a	4.5a	0.33
Sarcomere length (μm)	1.79a	1.76a	0.03
Initial Loin pH^{+}	6.51a	6.56a	0.06
Loin pH_{24}^$^{+}$	5.77a	5.77a	0.05
ST pH_{24}^$^{+}$	5.95a	6.01a	0.06
Ultimate loin pH	5.89a	5.85a	0.06
Purge @ 3 days%	2.6a	2.6a	0.17
Purge @ 21 days %	7.9a	7.6a	0.90
Pred temp @ pH 6.0	9.9a	9.1a	1.23
Pred pH @ 25ºC	6.43a	6.52a	0.06
Pred pH @ 18ºC	6.28a	6.36a	0.06

Means followed by a different letter in a row (a, b) are significantly different ($P < 0.05$), [1]stimulation treatment was at a current of 700 (mA) with a pulse width of 500 (ms). *Adjusted to a hot carcase weight of 13.7. $^{+}$Adjusted for carcase temperature. ^Consignment 2 only .

The predicted temperature at pH 6.0 was low in this study compared with the values given by Baud *et al.* (2006) indicative of a fast chill rate. This partly reflects the fact that goat carcases tend to be lean and light, but also suggests that the chiller settings created a colder environment than used in the study of Baud *et al.* (2006). Despite this there was however a small percentage of stimulated carcases that “hit” the window from the second consignment (Figure 5).

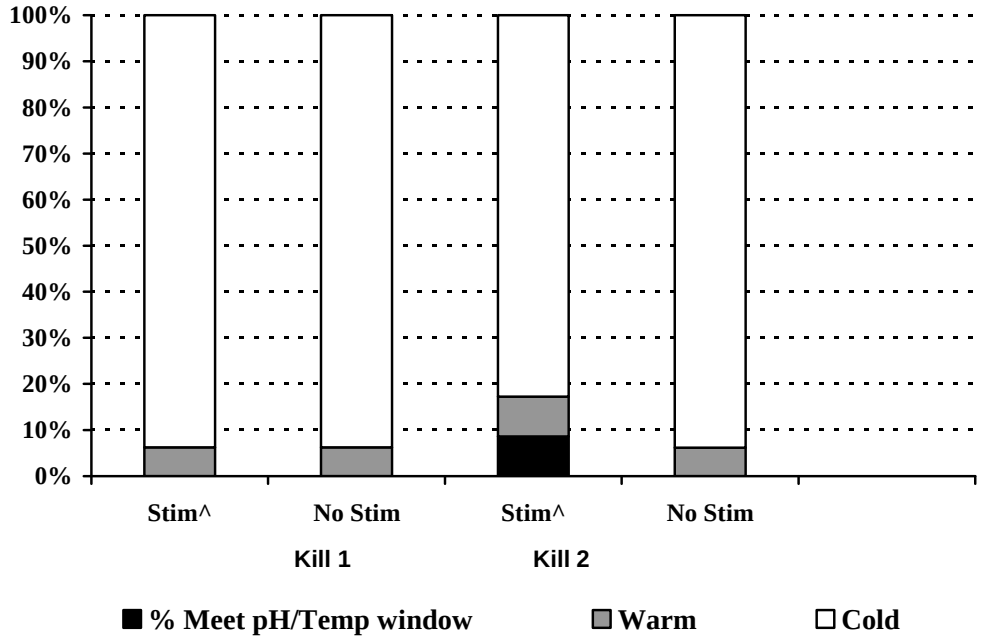

Figure 5. The percentage of carcases that met the pH and temperature window 18-25ºC for stimulated (Stim) and non stimulated carcases (No Stim) for kills 1 and 2.

The lack of difference in the rate of pH fall was an unexpected outcome, based on Phase 1 of the study and previous work in the sheep industry. The lack of response could potentially be attributed to a number of factors. In order for electrical stimulation to be effective the animals need to have sufficient glycogen levels or energy stores in the muscle for the stimulation to cause the muscles to contract and relax. Given the goats were derived from the Western Region of NSW it is feasible that these levels of glycogen were depleted due to previous levels of nutrition combined with pre-slaughter transport stresses, although the sampling of two consignments weeks apart was designed to minimise these likely effects. Glycogen samples have been collected from the second consignment and are currently been examined to confirm this speculation. The measurement of ST pH on the second consignment was also designed to provide some insight into this effect and the fact that the pH values were close to 6.0 indicates that glycogen levels were depleted. For example in young unweaned lamb's levels around 5.8-5.85 have been found in the ST (Hopkins *et al.* 2005) and in the study of Baud *et al.* (2006) the ultimate pH in the loin was 5.60, much lower than found here again suggesting depletion of glycogen pre-slaughter. Although the results of the first phase of the study suggested that post-dressing stimulation would be affective at accelerating pH decline, the differences were not significant. Unfortunately the post-dressing stimulation could not be applied earlier to the carcases due to the slaughter floor layout and compared to the response with pre-dressing stimulation it seems that the delay in the application of the post-dressing stimulation until approximately 45-50 minutes post mortem may have also contributed to the disappointing response in pH.

Table 4. Predicted means (s.e.d.) and the interaction between treatment and kill day/consignment for initial L*, a*, b* Minolta values.

Trait	Consignment	Treatment		*s.e.d*
		Stim	No stim	
L* (24hr)	1	40.5ax	41.4ax	
	2	44.6by	41.1ax	*1.10*
a* (24hr)	1	18.0ax	18.7ax	
	2	19.3ax	19.7ax	*0.72*
b* (24hr)	1	6.21ax	6.75ax	
	2	8.58ay	7.82ay	*0.45*

Means followed by a different letter in a row (a, b) are significantly different ($P < 0.05$), means followed by a different letter in a column (x, y) are significantly different ($P < 0.05$),

There were some significant effects shown in Table 4 on initial colour measures taken approximately 24 hours after death using the Minolta colour meter. The L* value was significantly different between consignments for stimulated carcases with those from consignment 2 having higher L* values. For consignment 2 there was also a difference between treatments with stimulated carcases having a higher L* value and this trend was similar to the results recorded from the L* values for the Hunter Lab MiniScan as shown below. There was no difference in a* values, but there was a significant difference between consignments for b* values for both treatments with consignment 2 having a higher b* value for both treatments.

Table 5. Predicted means (s.e.d.) according to stimulation treatment and consignment (1 and 2) for initial and final ratio, L*, a*, b* values.

		Initial			Final		
	Consignment	Stim	No stim	*av s.e.d*	Stim	No stim	*av s.e.d*
L*	1	35.1ax	36.0ax		36.5ax	38.5ax	
	2	39.4ay	37.3ax	*1.17*	43.0by	39.4ax	*1.26*
a*	1	5.5ax	5.1ax		6.2ax	6.3ax	
	2	4.6ax	5.4ax	*0.68*	7.0ax	8.1ay	*0.61*
b*	1	8.5ax	8.5ax		9.6ax	10.2ax	
	2	9.9ay	9.4ax	*0.53*	12.5ay	11.8ay	*0.62*
Ratio	1	2.6ax	2.5ax		2.2ax	2.2ax	
	2	2.4ax	2.4ax	*0.13*	2.2ax	2.4ax	*0.12*

Means followed by a different letter in a row (a, b) are significantly different ($P < 0.05$). Means followed by a different letter in a column (x, y) are significantly different ($P < 0.05$)

The results from Table 5 show the interaction between stimulation treatments and consignment for the initial (after 3 days ageing) and final display life readings measured, using a Hunter Lab MiniScan. The initial L* values show that there is no difference between stimulation treatments, but there is a difference between days for stimulated carcases only with L* values higher in consignment

2. This trend followed on in to the final L* value, except there was a difference between treatments for consignment 2 with stimulated carcases having a higher value indicating lighter coloured meat.

There were no differences for initial a* values, but at the final measurement there was a difference between consignments within the no stimulation group and a difference between treatments (Table 5). For the initial and final b* values there was no stimulation effect, but within the stimulated carcases, those from consignment 2 had higher b* values. It can be seen in Table 5 that there is no difference between ratio values (indication of metmyoglobin formation or the browning in meat) for treatments or consignments. This is also shown in Figure 6 where a spline has been fitted to show the rate of metmyoglobin formation (ratio) over time. From the graph it can be seen that non stimulated carcases have a higher ratio value (indicating less browning), however this was not statistically different from stimulated carcases.

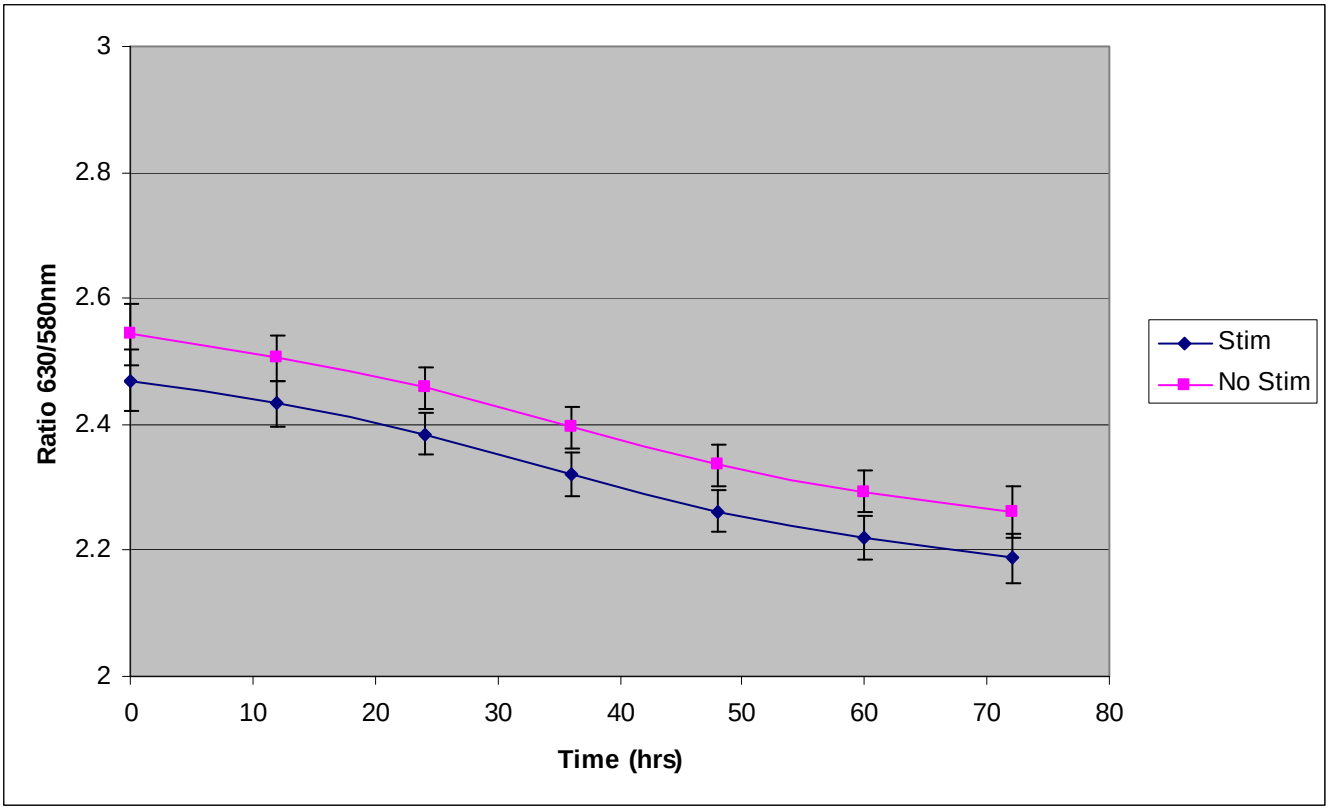

Figure 6. Predictions (± s.e.) using a spline for the rate of change in the spectral ratio 630/580 nm of the loin during display for 72 hours after death for Stimulated and Non Stimulated carcases.

The Warner Braztler shear force results shown in Table 6 illustrate that there was no significant difference between stimulation treatments or consignment. However as expected the shear force results do show that as ageing time increased the shear force decreased. Consignment 2 also showed a trend of having tougher meat, but this was not found to be significant.

Table 6. Predicted means (s.e.d.) according to stimulation treatment and consignment (1 and 2) for Warner Braztler shear in Newtons at 1, 2, 4 and 21 days aged.

	Treatment		Consignment		
	Stim	**No Stim**	**1**	**2**	*s.e.d*
SF @ 1 day*	86.9a	85.7a	*	*	*5.60*
SF @ 2 day	73.7a	76.5a	70.9a	79.3a	*5.28*
SF @ 4 day	67.8a	69.4a	66.2a	70.9a	*4.75*
SF @ 21 day	49.0a	49.2a	45.6a	52.7a	*4.50*

*From animals from consignment 2 only.

The distribution of shear force was investigated (Table 7) where four categories were created to examine whether or not the use of electrical stimulation may have reduced the variation in tenderness within the different aging periods. However based on the percentage of carcases that fell into each of the shear force categories electrical stimulation did not reduce this variation. This outcome is in contrast to previous work in sheep, but is not surprising given the lack of response shown in the pH data. It should be noted that the absolute values for shear force reported here are very high and indicate that as a table meat this goat meat would not on average approach being acceptable unless aged for 21 days. In sheep meat Hopkins *et al.* (2006a) has reported that to achieve a failure rate of 10% or less with consumers then the shear force should be around 30 N or less. Clearly these results highlight the need for effective stimulation of goat carcases.

Table 7.
The percentage of carcases that fell into 4 different shear force categories according to stimulation treatment and days ageing.

Category	**SF 1 day aged***		**SF 2 day aged**		**SF 4 day aged**		**SF 21 day aged**	
	Stim	No Stim	Stim	No Stim	Stim	No Stim	Stim	No Stim
1 = < 30 N	0	0	0	0	0	0	13.8	3.3
2 = 31 – 50 N	0	0	12	13.8	16.1	22.6	51.7	63.3
3 = 51 – 70 N	13	26	32	24.1	45.2	35.5	20.7	23.3
4 = > 71 N	87	74	56	62.1	38.7	41.9	13.8	10.1
# observed	*15*	*15*	*25*	*29*	*31*	*31*	*29*	*30*

*From animals from consignment 2 only.

5 Success in Achieving Objectives

The first objective to determine the optimum setting of a pre-dressing stimulation unit for optimal pH fall was met, however the use of the unit created some processing issues that required a reassessment of the methodology given the specific layout of the abattoir. It was observed that when carcases were subjected to pre-dressing stimulation that this increased digesta spill, resulted in potential danger to workers from the horns of “billy” goats due to significant movement during stimulation and the carcases were becoming stiff by the time they reached the chiller. Based on this outcome it was decided to apply post-dressing stimulation which meant in this abattoir that it was after the scales. This approach was tested and the impact on tenderness and meat colour examined. Although the objectives of the project were met the final outcome was disappointing, but it is contented that this same technology applied in another abattoir would be effective. The slow chain speed in the current abattoir meant the time from death to stimulation was marginal for obtaining an optimum response, but given the problems with the pre-dressing application there was little scope for a different approach.

6 Impact on Meat and Livestock Industry – now & in five years time

Results obtained from this study indicate that mid voltage electrical stimulation technology did not show any significant meat quality benefits. Based on the results of this study at face value, it could be concluded that MVS would have no impact on goat meat quality or the goat industry. However attention on a number of pre-slaughter factors (such as nutrition, on farm curfew and transport time) could potentially improve the quality of goat meat and aid the goat industry. In addition to this it could also be concluded that early application of MVS such as in a pre-dressing scenario would potentially have a positive impact on meat quality and would be applicable to a number of other abattoirs. If the goat industry wants to focus on the quality end of the market then intervention strategies such as stimulation will be required.

7 Conclusions and Recommendations

There were some limitations as to the type of goats that could be used for this experiment due to weather conditions and market requirements and this may have impacted on the low response to stimulation. Due to problems encountered (such as, increased digesta spill and stiffness of the carcases by the time they reached the chiller) during initial testing of the unit when placed in the bleeding area (pre-dressing unit), the unit was shifted so as to apply a post-dressing current to alleviate these issues. However the effectiveness of this type of stimulation may have been inhibited due to the amount of time post-mortem before the application of the current. In abattoirs with a faster throughput this effect would be minimised. Some promising results emerged from the first phase of the study when pre-dressing stimulation was applied and this indicates that in a different setting this type of stimulation would be advantageous. Based on the outcomes of this study it is recommended that experimentation be undertaken in an abattoir where effective pre or post-dressing stimulation can be applied and the constraints of this study avoided. This would provide an equitable assessment of the technology for the goat industry and given the high shear force values found in this study this would seem critical.

From this study it could also be recommended that more education needs to be provided to goat producers regarding pre-slaughter factors that are going to impact on goat meat quality. Some of these factors include nutrition, on farm curfew, handling and transport time. All of these factors can have a significant impact on the amount of glycogen available in the muscle at the time of slaughter. If animals go to slaughter with low levels of glycogen the effectiveness of stimulation will be restricted. The glycogen results for samples taken from the second consignment of the detailed study will be reported to MLA when they become available. This will help to confirm the recommendations made above.

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9 Appendix

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