OPTIMISATION OF ELECTRICAL STIMULATION FOR pH-TEMPERATURE COMPLIANCE

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Abstract- **This paper outlines the development of testing procedures to optimise the stimulation dose from a medium voltage electrical stimulation unit. The aim was to increase the number of carcasses reaching the pH temperature window in compliance with Meat Standards Australia sheep meat eating guidelines which require carcasses to reach pH6 between a carcass temperature of 18-35^{o}C. Settings tests using a range of current and frequency resulted in variation in pH response from which the optimal pH response was selected. Both abattoirs involved in this study now have electrical stimulation units programmed to an optimal setting and monitoring of product quality under the new setting will be ongoing.**

Index Terms- **Lamb, electrical stimulation, pH decline**

I. INTRODUCTION

The Sheep Meat Eating Quality (SMEQ) program which has now been incorporated into MSA Sheepmeat identified that for optimal eating quality the meat destined for the domestic or overseas (air freight) markets should reach pH 6 when the carcass temperature is between 18-25^{o}C (Thompson, Hopkins, D'Souza, Walker, Baud & Pethick 2005) and the range was subsequently increased to 18-35^{o}C. A high percentage of Australian processors have installed Australian designed medium voltage electrical stimulation units (MVS) to comply with this pH-temperature window guidelines to optimise their eating quality (Hopkins, Toohey, Pearce, Richards & Keane 2008). There have been a number of Australian studies conducted to understand the pH variation achieved by using MVS (Jacob, Pearce & Smith 2008; Pearce, Hopkins, Williams, Jacob & Phillips 2008; Shaw, Baud, Richards, Pethick, Walker & Thompson 2005; Toohey, Hopkins, McLeod & Nielsen 2006; Toohey, Hopkins, Stanley & Nielsen 2008). However many of the MVS units have been installed in abattoirs in Australia but there has been little or no follow up or pH decline testing with the abattoir to determine the optimal settings for their plant and the machines have been left on factory settings.

Pearce, Hopkins, Williams, Hocking-Edwards, Jacob, Refshauge, Geesink, Warner, & Pethick (2010) identified that at a number of key abattoirs in Australia the electrical stimulation did not enable compliance with SMEQ pH-temperature guidelines. These abattoirs had poor pH decline performance and thus a low proportion of carcasses reaching pH6 between 18-35°C. The abattoirs with poor electrical stimulation performance identified in the work by Pearce et al. (2010) have had a MVS unit for a minimum of 3 years and prior to this research had not had any pH testing done to determine the effectiveness of their stimulation units.

This paper outlines the process required to identify an appropriate stimulation dose to result in the maximum number of carcases reaching the pH temperature window. It was expected that the stimulation dose would be individual for each abattoir. Testing over a range of electrical stimulation settings will result in a variation in the pH response from which the optimal pH response can be selected. We have selected 2 abattoirs outlined in the study by Pearce *et al.* (2010) that had a poor pH decline response to demonstrate the process of stimulation optimisation.

To understand the abattoirs requirements for electrical stimulation this paper will also discuss the abattoirs processing requirements and current practice. Understanding factors such as chain speed, chilling rates and product classifications (Pearce et al., 2010) can further help establish an optimal stimulation practice.

II. MATERIALS AND METHODS

The following testing procedures to evaluate the effectiveness of electrical stimulation across a number of abattoirs was undertaken as follows:

1. Problem solving at the individual abattoir to identify reasons for poor stimulation response. The stimulation unit was thoroughly checked and the currently used parameters recorded.

2. Understanding key logistical and processing variables at the abattoirs - such as chain speed, chilling regimes, and product classifications.

3. Conducting settings tests to evaluate the best setting for the individual abattoir.

4. Discussions with the abattoir during the testing phase to identify requirements for electrical stimulation and the development of pH testing and auditing protocols. The results of the testing were also discussed.

Measurement of pH and temperature decline

To evaluate the stimulation response through pH decline the methods developed by the CRC for Sheep Industry Innovation (Pearce 2009) for the evaluation of pH decline were used. Our clear aim was to determine if the electrical stimulation at the abattoir was sufficient to achieve a carcass pH of 6 or less over the carcass temperature range 18-35°C.

The pH and temperature of each carcass was measured 4 times post-slaughter: (1) ASAP after slaughter at around 35°C, (2) When the carcasses reached ~ 20°C (3) When the carcasses reached ~ 12°C and (4) Ultimate pH: 24h post mortem. Further details on pH and temperature measurement and carcass measurements are given by Pearce *et al*. (2010).

The rate of decline in pH and temperature during the first 24 h PM is defined by the CRC as (1) the pH of the carcass when the carcass reached 18^{o}C (pH18), (2) the temperature of the carcass when the carcass reaches pH6 (pH6TEMP) and (3) the initial pH (ΔpH). From this information each carcass is then assessed to determine if the carcass reached a pH of 6 between a carcass temperature of 18-35^{o}C (pH6W). The carcass was given a score of 1 (yes reached pH-temperature window) or 2 (no didn't reach pH-temperature window). For effective stimulation: the aim is to achieve a pH18 of less than 6.00, between 18-35^{o}C for pH6TEMP, as a high a number as possible for pH6W and a ΔpH greater than 0.7.

A linear regression procedure was used to derive the relationship between post-stimulation pH and temperature to allow the calculation of pH18 and pH6TEMP. The initial pH was taken as the very first pH reading taken at an approximate carcass temperature of 35°C. This regression algorithm was then used to calculate the pH at 18^{o}C and the pH6TEMP and subsequently the carcass was evaluated to determine if it reached pH6 between 18-35^{o}C. This process was conducted individually for each carcass for each treatment within each consignment. The ultimate pH of the LL was specifically used to determine if the carcass was had a high pH ie, the ultimate pH of the LL was above 6. If so; no value for pH6W was recorded.

It was not possible to calculate a value for all carcasses for pH6TEMP. Some carcases with a slow pH decline reached their ultimate temperature before they reached pH6. These carcases were given blank values for pH6TEMP. It was however possible to calculate a value for the pH of the carcass at 18^{o}C. The pH18 value was used to determine the window compliance pH6W.

Abattoir specifics

Both abattoirs involved in this study had 5 or 6 module (electrode) post dressing MVS units (Applied Sorting Technologies, Melbourne Australia). Further specifications are listed in Table 1.

Table 1. Abattoir specifications

	Abattoir A	Abattoir B
Time stimulated PM	20 mins	24 mins
Chain speed when installed	7 carcasses/min	5 carcasses/min
Current chain speed	11 carcases/min	6 carcases/min
Stimulation time (sec)	25 s	35 s
Chilling regime and time to 7^{o}C	Fast, 150 mins	Moderate, 310mins
Product type	70% lambs: 30% mutton. Majority for export	Majority lambs for domestic market
Time from slaughter to boning	15 hrs	24 hrs

Settings tests

Stimulation settings tests were conducted over several consignments to incorporate a range of carcass types and the carcasses were also placed into the same 'typical' chiller to minimise the effect of chilling on pH-temperature decline:

The settings tested in general were as follows and described in table 2:

- No Stimulation: to establish a base line for the consignment
- Initial setting: to demonstrate the impact of changing settings compared to the currently used settings.

- Highest pulse and current: to record the maximum stimulation response on the unit
- A more moderate current and pulse width stimulation setting- to determine whether the high setting is causing over-stimulation and therefore heat shortening.
- Low current and pulse width stimulation setting: including a low dose allows for a range in stimulation response when compared with the high and moderate settings.
- Modulated setting: 2.5ms, 1A, 10, 15, 25, 10, 15, 25 Hz across 6 electrodes: Pearce, Hopkins, Williams, Jacob and Phillips (2008) demonstrated that this setting could result in a maximal contractile potential and possibly cause fibre breakage of the muscle fibres without causing too fast a pH decline response.

Specific details of the consignments tested and the electrical parameters used are given in Table 2. Both metal and plastic gambrels (hooks that hold the carcass onto a moving slaughter chain rail) were tested at abattoir A but only metal gambrels at abattoir B.

Table 2. Experimental details and treatments

	Abattoir A	Abattoir B
Number consignments tested	5	6
Number lambs per consignment	7 x 2 (metal/plastic gambrel) = 14	10 (only metal gambrels)
Number lambs tested overall	5 x 14 x 5 treatments = 350	6 x 10 x 5 treatments = 300
No stimulation- control	YES	YES
Initial setting	Current 0.4A x Pulse width 1ms Frequency 15Hz	0.2A, 1.5ms, 15Hz
Lowest setting	1A, 1ms, 15Hz	0.4A, 1.5ms, 15HZ
Moderate setting	NO	0.8A, 1.5ms, 15Hz
Highest setting	2A, 2.5ms, 15Hz	1A, 2.5ms, 15Hz
Modulated setting	YES	NO

III. RESULTS AND DISCUSSION

The setting tests at abattoir A successfully identified an optimal stimulation setting (Table 3). The setting of 2A, 15Hz and 2.5ms resulted in the best stimulation response achieving an optimal average pH at 18°C of under pH6. This setting is now in use at abattoir A. No difference in pH decline was observed between the no stimulation control treatment and initial stimulation settings for pH decline and this explains the poor pH declines in previous testing (Pearce *et al.* 2010) ($P<0.05$). Testing identified that the poor pH decline at abattoir A was due to a sub-optimal stimulation response as a result of: (1) The current and pulse width was set too low- this has now been changed from 0.4A to 2A and from 1ms to 2.5ms pulse width and (2) The number of modules was insufficient for the chain speed. The unit was installed to cater for 7 carcasses/min and the abattoir has since increased the throughput to over 11 carcasses/min. This abattoir also has a very fast chilling regime and a higher stimulation was considered necessary to counteract this.

Abattoir A will also be converting from metal to plastic gambrels in the future. The plastic gambrels achieved a 30% better stimulation response compared to the metal gambrels. It is possible that some voltage leakage was escaping up into the chain with the metal gambrels. However the plastic gambrels may result in an inadequate circulation of the current through the carcass driven by the force of the current being drawn into the rails about the gambrels. This has not been thoroughly researched and may be site specific.

Table 3. pH-temperature decline testing at abattoir A - results for pH18, pH6TEMP, % in pH-temp window and ΔpH.

	pH18	pH6TEMP(°C)	pH6W (%)	ΔpH
No Stimulation	6.23	12.57a[#]	0	6.64
Metal 0.4A x 15Hz x 1ms	6.34	13.11a	22	6.53
Plastic 0.4A x 15Hz x 1ms	6.25	12.65a	44	5.58
Metal 1A x 15Hz x 1ms	6.05	18.50b	42	6.34
Plastic 1A x 15Hz x 1ms	5.99	18.96b	64	6.40
Metal 2A x 15Hz x 2.5ms	5.94	21.09bc	81	6.26
Plastic 2A x 15Hz x 2.5ms	5.85	22.37bc	86	6.17
Metal modulated frequency	6.04	20.77b	60	6.28
Plastic modulated frequency	5.87	24.63c	66	6.36

*The aim is to achieve a pH18 of less than 6.00, a pH6Temp between 18-35°C and as high a number as possible for pH6W.
Values down the column followed by different letters have a significantly different pH decline ($P<0.05$)

The setting tests at abattoir B also successfully identified an optimal stimulation setting. The setting of 800mA, 1.5ms and 15Hz resulted in the best stimulation response achieving an optimal average pH at 18°C of under pH6 (Table 4). The pH6TEMP for this treatment was 29.2°C. This treatment was selected over the 1000mA setting, which gave a pH6TEMP of 33°C, on the basis that this may put the carcasses at an unnecessary risk of heat toughening (Thompson *et al.* 2005). This lower current setting of 800mA is now is use at abattoir B. Testing identified that the poor pH decline at abattoir B was due to a sub-optimal stimulation response because current and pulse width was set too low. This has now been changed from 0.2A to 0.8A and from 1ms up to 1.5ms pulse width. It was also identified that the abattoir had undertaken a few in-house modifications and as a result the unit was only delivering half the current output programmed into the unit. The unit was fixed and is now delivering the specified current, but it was unknown how long the unit had been functioning poorly previous to this work.

Table 4. pH-temperature decline testing at Abattoir B- results for pH18, pH6TEMP, % in pH-temp window and ΔpH.

	pH18	pH6TEMP (°C)	pH6W (%)	ΔpH
No Stimulation	6.46	7.5a[#]	2	6.81
Initial setting (CRC decline) 0.2A, 1.5ms, 15Hz	6.20	6.46a	5	6.72
0.4A, 1.5ms, 15Hz	5.88	26.6b	51	6.25
0.8A, 1.5ms, 15Hz	5.80	29.2bc	66	6.19
1A, 2.5ms, 15Hz	5.77	33.0c	82	6.08

*The aim is to achieve a pH18 of less than 6.00, a pH6Temp between 18-35°C and as high a number as possible for pH6W.
Values down the column followed by different letters have a significantly different pH decline (P<0.05)

IV. CONCLUSIONS

This study demonstrated that testing and auditing of MVS units is very important to ensure that optimal results are achieved. Both abattoirs now have electrical stimulation units programmed to an optimal setting and monitoring of product quality under the new setting will be ongoing. Furthermore abattoir A are scheduled to install 2 new module bars and potentially also a pre-dressing stimulation unit which increases blood collection at the start of the slaughter process (Toohey *et al.* 2008) to improve stimulation response at the faster chain speed. It is essential that abattoirs take responsibility for their stimulation units and conduct regular in-house pH testing to ensure the stimulation unit is working optimally. Quality assurance staff may need more guidance to develop their testing procedures and understand their results. The next stage of this project is to confirm the number of carcasses that need to be tested to be confident that a good proportion of carcasses are reaching the pH temperature window within a consignment.

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