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Electrical stimulation and hydration to optimise meat quality

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Abstract

This article discusses research that was conducted to optimise new electrical-stimulation technologies and to elucidate the effects of pre-slaughter dehydration of lambs. A change in lamb processing to a focus on eating quality has increased the uptake of new electrical technologies. Our research was aimed at understanding how carcase response to electrical stimulation is affected by genotype, pulse-width, current, and frequency and time of stimulation. Although seven post-dressing electrical stimulation systems have been installed in abattoirs across Australia and two prototype pre-dressing systems and an immobiliser have been installed at a major export abattoir, more installations are needed. An indicator of animal dehydration status was developed and used at two commercial abattoirs. This study showed that a large percentage of lambs are dehydrated at the time of slaughter, which represents a potential cost to industry of $5 million annually. Although several compounds for prevention of pre-slaughter dehydration in lambs were tested, none were effective.

Introduction

Processing can change the weight, value and consumer acceptance of lamb meat. Eating quality accounts for 68% of the decision of a consumer to repurchase a meat product (Pethick et al., 2005). Two key processing issues were investigated by the Sheep CRC: electrical stimulation and hydration status.

Application of an electrical current to a carcase post-mortem accelerates the onset of rigor mortis. A variety of systems have been developed to utilise this effect to improve the eating quality of meat. The impetus for electrical stimulation of ovine carcases originated in New Zealand and resulted in the introduction of an accelerated conditioning and ageing program (Devine et al., 2004). The history and current state of knowledge of electrical stimulation has recently been reviewed (Hwang et al., 2003; Devine et al., 2004).

Until recently, adoption of electrical stimulation technology in Australia had been slow. This was partly due to technical and work safety limitations of the high-voltage systems that were favoured for high-throughput abattoirs. High voltage systems must be physically isolated to protect workers against electrocution and consume large amounts of energy. They must also be able to stimulate several carcases simultaneously, averaging voltage and current across them.

To avoid these limitations, a new approach was developed in Australia, whereby a controlled amount of electricity in a low-energy form that is safe for workers is administered to individual carcases (Devine et al., 2004). This development coincided with the release of critical control-point recommendations for the eating quality of Australian sheep meat, of which electrical stimulation is one (Young et al., 2005). For short-aged products, the recommendations state that loin temperature should reach 18–25 °C when the pH reaches 6.0 (Thompson et al., 2005). If the carcase temperature falls too fast before the onset of rigor, cold shortening may result (Tornberg, 1996), which can have adverse effects on meat tenderness. Adoption of the pH–temperature target by major supermarkets and quality- conscious processors, together with the availability of new generation electrical stimulation systems, resulted in rapid adoption of electrical stimulation by lamb processors. This article presents an overview of the Sheep CRC contribution to this development.

An important aspect that affects returns from sheep meat is the loss of body water during the pre-slaughter period, including farm curfew, transport and lairage. Although the effects of fasting and lairage have been documented (Thompson et al., 1987; Warriss et al., 1987), the effects of dehydration on carcase weight and the condition of sheep are less well defined. Research was undertaken to develop a simple and practical method for measuring dehydration in lambs, to establish the incidence of dehydration at the time of slaughter under commercial conditions and to investigate methods of alleviating dehydration during the curfew period.

Why stimulate?

Data obtained from three abattoirs in New South Wales, two abattoirs in Western Australia and one abattoir in Victoria during 2004–2005 showed that if electrical stimulation was not used—which, until recently, was general practice—the pH of lamb carcases would not reach pH 6 within the 18–25 °C temperature window under the fast-chilling regimens that are usually applied. Results from Abattoir C in New South Wales (Table 1) indicate that slow chilling would enable the pH–temperature target to be achieved, but temperature requirements for food safety would not be met in time for the carcases to be delivered to retail outlets the next day. When food safety concerns dictate the speed of chilling, the optimal eating quality for short-term-aged product cannot be achieved without electrical stimulation (Thompson et al., 2005).

Table 1. Predicted means for the percentage of carcases that will reach a window of 18–25 °C and pH 6.0 (Experiment 1) at various abattoirs and the effect of electrical stimulation on sensory traits of meat (Experiment 2).

	Experiment 1*		Experiment 2**			
Abattoir	No. of carcases	% in the window		Electrical stimulation Yes	None	s.e.d.
A (NSW)	397	3				
B (NSW)	400	5	Tenderness	66.8	68.6	2.21
C (NSW)	400	57	Juiciness	57.3	59.4	2.25
D (WA)	232	16	Flavour	64.6	66.6	2.01
E (WA)	130	16	Overall liking	65.2	67.6	2.07
F (Vic)	160	0				

*Toohey, E. S., Hopkins, D. L., McLeod, B .M., Nielsen, S.G., unpublished data.

**Hopkins, D. L., Toohey, E. S., unpublished data.

Another important aspect of electrical stimulation is the reduction in variation of eating quality. Data obtained from Fletcher's International abattoir at Dubbo demonstrate this point. At this plant, an immobiliser, spinal discharge and high-voltage system are used during slaughter. In a study on electrical stimulation, each carcase was subjected to the immobiliser and spinal discharge but the high-voltage system was switched on for 40 animals and off for 40 animals (alternating 10 on and 10 off). Samples of loins from each carcase were individually packed and aged for seven days from the date of slaughter at 0–4 °C to simulate transit time to overseas markets and subsequently tested for eating quality.

There was no effect of electrical stimulation on eating-quality traits (Table 1). However, to achieve a rating score of 3 ("good every day"), an overall liking score of 57 had to be achieved. The mean overall liking score for samples that did not achieve a rating score of 3 was 46 for unstimulated samples and 54 for stimulated samples. There was no difference in overall liking score between stimulated (mean = 67) and non-stimulated samples (mean = 71) that were assigned a rating score of 3 or greater. Electrical stimulation reduced the variation of samples that rated less than 3, which is an important finding.

How do new electrical-stimulation systems work?

Traditionally, high-voltage system systems used on sheep carcases applied a fixed voltage that was averaged across all carcases (Devine et al., 2004). Rubbing bars were used to apply high-voltage stimulation to carcases at the completion of the dressing procedure (Morton et al., 1999; Toohey and Hopkins, 2004), but this process poses concerns for work safety. With new-generation systems, each carcase is stimulated individually using segmented electrodes to ensure that each segment only makes contact with one carcase at a time. This allows computer-controlled electronics to give a precise, but adjustable, electrical input to each carcase to match the requirements of particular carcase types while maintaining the delivery of a pre-determined level of current. In effect, a feedback system that detects the level of resistance is used. This approach also reduces installation costs with respect to occupational health and safety because the power levels and pulse widths used eliminate the need for isolation of the unit, a requirement for high-voltage systems.

What are the results?

It has been shown (Table 2) that a post-dressing system can accelerate the onset of rigor mortis (Hopkins et al., 2005) in such a way that stimulated carcases reach a higher temperature at pH 6.0 than would otherwise be the case. A similar response was achieved with a pre-dressing unit (Shaw et al., 2005). The response varies according to the chilling regime and between groups of animals (Table 2). Research to elucidate animal variation has been undertaken.

Table 2. Effect of pre- or post-dressing electrical stimulation and electric current on mean temperature of carcasses (°C) at pH 6.0.

	No stimulation	400 mA	800 mA
Post-dressing	6.0	16.9	21.5
	No stimulation	300 mA	600 mA
Pre-dressing	6.3	15.1	13.6

Work is continuing on the optimisation of post-dressing systems, which are now installed at seven abattoirs. A new pre-dressing system is undergoing validation. A project to install a new immobiliser, electronic bleeding and post-dressing electrical stimulation at Fletcher's International Dubbo abattoir is nearing completion. Optimisation of this system will then commence. Studies have shown that more blood can be captured in the bleeding area (Hopkins, D. L., Shaw, F. D., Baud, S., Walker, P. J. unpublished data) with electronic bleeding than without, which will have positive economic and environmental effects and could potentially increase the ability to induce specific rates of decline in post-mortem pH.

Measurement of dehydration

Management of lambs during the pre-slaughter holding period (curfew) may affect animal welfare, meat yield, meat eating quality and food safety. Management of curfew times is subject to guidelines detailed in codes of practice for the welfare of animals (Anonymous, 2004). These codes specify curfew times, but do not require hydration status to be monitored quantitatively. Consequently, the hydration status of lambs at the time of slaughter and its potential effects on meat yield and eating quality were unknown.

A simple, practical and reliable method of measuring hydration status was developed for on-site use at abattoirs and farms (Jacob et al., 2005). This technique relies on the relationship between the specific gravity of urine and the water content of muscle tissue (Fig. 1). To conserve water during a period of water deprivation, lambs excrete less water via the urine and urine specific-gravity increases. To maintain circulating blood volume, water moves from muscle tissue into the blood and reduces the water content of muscle. Water deprivation and hydration status of muscle tissue can therefore be quantified by measuring the specific gravity of urine.

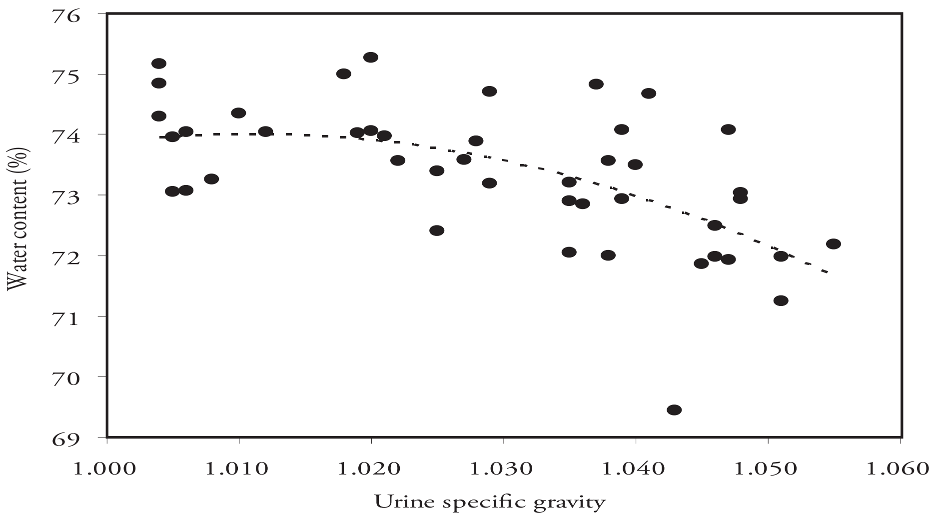

Fig. 1. The relationship between urine specific gravity and water content of *m. semimembranosus* (topside).

The effect of dehydration on meat yield

Urine specific-gravity approaches maximum levels about 24 hours after water deprivation begins. It was observed that muscle weight, volume and water content were reduced and the muscle became darker in colour after 48 hours of water deprivation. These results indicate that meat yield is reduced by dehydration, which may have adverse affects on the appearance of meat. Although there is some evidence that dehydration reduces tenderness, the effect of dehydration on eating quality is not fully understood. Further experiments are planned to compare consumer acceptance of meat from lambs with low vs. high urine specific-gravities.

How Prevalent is dehydration?

Monitoring of the specific gravity of urine at two abattoirs over a 12-month period showed that dehydration may be more common among slaughter lambs in Australia than is realised. Interestingly, the highest the specific gravity of urine did not necessarily occur during the summer, when ambient air temperatures were highest. The results indicate that more work is needed to understand the reasons for such responses and to find ways to encourage lambs to drink during the lairage period.

Solutions to dehydration

Several experiments have been undertaken to investigate ways of preventing dehydration. Various feed and water additives, including commercial electrolyte solutions, salt and betaine were tested to determine whether water retention by lambs could be increased before leaving the property of origin and, in the case of electrolytes, during lairage. None of these strategies were effective in preventing dehydration. Industry will be consulted before further research in this field is planned.

Conclusions

Installation of electrical-stimulation technologies offers processors control over product quality. There is a need to develop these technologies further and to quantify potential improvements in terms of meat quality. Dehydration represents a cost to the sheep industry and viable approaches need to be developed to lessen its economic impact.

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