Does high-frequency immobilisation of sheep post-mortem affect meat quality?

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ABSTRACT

This study evaluated the impact of a newly developed high frequency immobilisation unit on meat quality traits of lamb carcases. This was achieved by examining pH and temperature profiles, objective meat colour (*L**, *a**, *b**, ratio values 630 nm/580 nm and chroma), shear force, cooking loss and sarcomere length. In total 80 lambs from 3 different consignments were assessed. The animals were killed over two days and of the 40 killed on each kill day, 20 were exposed to the immobiliser and 20 were not. The results showed that the high frequency immobiliser unit had no effect on sarcomere length and pH except when pH was predicted at 25°C. There was also no effect on shear force and cooking loss percentage, but there were some minimal differences for some meat colour traits. These differences were shown in the final GM (rump) measurements only (7 day aged), where cuts from immobilised carcases had a lower *L** values and higher *a**, *b** and chroma values. Overall the results showed that there were minimal effects of the immobilisation treatment which confirms previous anecdotal evidence. The high frequency immobilisation unit has benefits in that it enables abattoir workers to begin processing the carcases safely within approximately 30 seconds of death with no apparent negative effect on meat quality traits. It also means that other electrical inputs can be used to manipulate pH fall, without immobilisation affecting pH.

Keywords: sheep; immobilisation; meat quality

INTRODUCTION

The application of electrical currents to sheep carcases is becoming an important and useful tool in sheepmeat processing, serving a number of purposes. These purposes include: reducing the variability in sheepmeat eating quality (Hopkins & Toohey, 2006); more efficient processing and faster turn around of product by speeding up the rate at which carcases meet the recommended Sheep Meat Eating Quality (SMEQ) window (Thompson *et al.*, 2005a); and a reduction in animal movement following slaughter allowing safer early stage processing by workers.

A major sheepmeat processor in Australia has installed a full suite of first generation Computer Process Management System (CPMS) electronic technologies including a high frequency immobilisation table, moderate frequency immobilisation at the start of the chain, low voltage electronic bleed and a post dressing medium voltage electrical stimulation unit. There is anecdotal evidence of an improvement in meat colour as a result of this installation. It was not known whether this was due to the installation of the high frequency immobilisation unit or other components of the installation. As outlined by Channon *et al.* (2005), past studies which have examined the effects of high or low voltage stimulation on meat colour have produced contrasting results. Meat colour is an important quality trait to monitor as consumer decisions at the point of purchase are influenced by meat colour more than any other quality factor as consumers use the degree of discolouration as an indication of freshness (Mancini & Hunt, 2005). For this reason it is economically important for retailers to ensure colour is desirable for consumers. Hence the aim of this study was to evaluate the effects of a high frequency immobilisation unit on meat quality traits including pH and temperature profiles, objective meat colour, meat tenderness and sarcomere length.

MATERIALS AND METHODS

Animals

In total 80 lambs from 3 different consignments were assessed. The animals were killed over two days and, of the 40 killed on each kill day, 20 were exposed to the immobiliser and 20 were not. The number of animals that were allocated from each consignment was proportional to the number of animals in that consignment. Each individual consignment was allocated equally to the treatment (immobilised) and control (not immobilised) groups. On day 1, there were 2 consignments processed, from the first consignment 12 animals were assessed and from the second consignment 28 animals were assessed. On day 2, there was one consignment processed, hence 40 animals were assessed. The lambs were of varying backgrounds and breeds and most were sourced from the local saleyards, thus representing the lambs purchased by the processor at the time.

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Electrical treatments

All animals received a number of electrical inputs however only the treatment group was exposed to the high frequency immobilisation unit, exposure being for 25-35 seconds (2000 Hz, 400 Volts; maximum current of 9 Amps over 7 animals; pulse width of 150 microseconds). The control group carcases were removed after head stunning and placed on a table in a horizontal position for approximately 5 minutes until they had stop kicking and then they were placed on the chain. All subsequent electrical inputs were applied to both treatment and control group carcasses. The second electrical input was a moderate frequency immobilisation (800 Hz, 300 peak Volts, a constant current of 1.7 Amps, with a pulse width of 150 microseconds) and all carcases were exposed to this for approximately 5-7 seconds. The low voltage electronic bleed had the following parameters (15 Hz, 550 peak Volts, constant current of 0.8 Amps, with a pulse width of 500 microseconds) and all carcases were exposed to this for approximately 20 seconds. The last electrical input was the post dressing medium voltage electrical stimulation unit which had a constant current and pulse width, but variable frequency across the 6 electrodes modules which are separated by insulators (the frequency for electrodes 1 and 2 was set at 25 Hz, 3 & 4 at 15 Hz and 5 & 6 at 10 Hz, with 300 peak Volts, 1.0 Amp with a pulse width of 2500 microseconds) and all carcases were exposed to this treatment for approximately 30-35 seconds. The carcases are supported by two rub bars one at the top where the electrodes are situated thus making initial contact with the hind quarter and the second rub bar on the forequarter.

Measurements and sampling

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 12th rib, 110 mm from the midline).

pH and temperature

The pH and temperature measurements were taken using the same method as previously described by Hopkins & Toohey (2006). Carcase pH and temperature were measured 30 minutes after death and then measured every hour after that with each carcase measured 7 times. A final pH measurement was recorded in the laboratory. The carcases were chilled in chillers with a daily mean temperature of 6.4°C and an average daily range of 5.2-6.7°C.

Meat sample

The *gluteus medius* (GM) (HAM No. 4790, see Anon. (2005), and m. *longissimus thoracis et lumborum* (LL) (HAM No. 5150, see Anon. (2005), were removed from the left side of the carcase and in addition to this the LL was also removed from the right side of the carcase. Where possible, samples (3 cm steak) were taken from each of the GM's for colour measurement. The left and right portions of the LL were aged for 1 or 7 days and this allocation was performed randomly to ensure portion location did not confound ageing period. From these portions samples were taken to assess the effect of 1 and 7 day aging on tenderness. Further samples were taken from these portions including a 1 gram sample for final pH (7 day aged), a sample for sarcomere length, a sample for drip loss and a slice (3 cm) for colour measurements.

Iodoacetate pH:

A 1 gram sample was taken from the 1 day aged LL and 7 day aged LL for determination of a 24 hour and a final pH. This was determined using an iodoacetate method based on that described by Dransfield *et al.* (1992).

Warner Braztler Shear force testing

The samples taken from the 1 and 7 day aged LL were frozen at -20°C and subsequently tested for peak shear force as described by Thompson *et al.* (2005b).

Meat colour

The meat colour reflectance of the LL and GM from both kills was initially measured on 1 day aged samples followed by measurements taken once a day for 6 days resulting in 7 measurements per sample. For the initial measurement a fresh surface was prepared by cutting in a transverse direction across the samples and then these were positioned randomly on black plastic trays and over wrapped with polyvinyl chloride clear film and placed under continuous lighting (1050 Lux) in a chiller at 4°C. A colour reading was taken 30-40 min after cutting. A Hunter Lab MiniScan XE spectrophotometer was used (Hunter Associates, Reston, VA, Model D45/0-s 6 mm port with 5 mm area viewing) set for L^* values indicating lightness/darkness (higher = lighter meat), a^* values (higher = redder meat), b^* values (higher = more yellow meat) and Chroma defined as $\sqrt{(a^2 + b^2)}$ with a D65 illuminate at a 10 degree standard observer. The ratio values were calculated dividing the percentage of light reflectance at wavelength 630 nm by the percentage of light reflectance at wavelength 580 nm (Jacob *et al.,* 2007). The

MiniScan was calibrated using both white and black tiles.

Sarcomere length

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

Drip loss

The method used was adapted from that described by Christensen (2003). A sample approximately 2 cm thick was taken from the LL ~ 28 hours after death. A cylindrical cut was made using a circular blade knife 25mm in diameter. This sample was placed into a meat extract collecting tube (which captures juices in the bottom of the tube) and the samples were then stored at approximately 4°C for 48 hours. Drip loss results were only recorded for kill 2 in this study.

Statistical analysis

Carcase and meat quality traits were analysed using a residual maximum likelihood (REML) procedure (Genstat 7.1, 2004), which contained a fixed effect for treatment (immobilisation, no immobilisation), to estimate the means and standard errors of the differences, with kill day and consignment as random terms. For GR, carcase weight was used as a covariate and for initial pH, initial temperature was used as a covariate. The rate of pH decline relative to time from the first measurement post-mortem for each carcase was described using data for 7 different sample points using linear regression (Genstat 7.1, 2004). This was used to predict temperature at pH 6.0 (for 63 carcases) with a R^2= 0.74, pH at 25 and 18°C and the rate of pH decline.

RESULTS

Carcase, pH and temperature measures

There was no difference between immobilised and non-immobilised carcases for any trait (weight, GR, sarcomere length, initial pH, 1 day pH (28 h), 7 day aged pH, rate of pH decline, predicted temperature at pH 6.0, predicted pH at 18°C or predicted pH at 25°C, Table 1). There was a significant difference between kill days for most traits listed in Table 1.

Warner Braztler Shear force testing

There was no significant difference between treatments for shear force or cooking loss percentage (Table 1). However tenderness was significantly different between 1 and 7 days ageing (39N and 22N respectively).

Objective colour scores

There was no significant difference ($P > 0.05$) between treatments for meat colour based on L^*, a^* or b^* values, ratio values or chroma values (Table 2) at initial measurement of the LL and GM or final measurement of the LL. However the final GM L^*, a^*, b^* and Chroma values were different ($P < 0.05$) between treatments with immobilised carcases having lower L^* values, higher a^*, b^* and chroma values.

The wavelength ratio of 630nm/580nm is a good reflection of the level of metmyoglobin formation (Jacob *et al.* 2007). Figures 1 and 2 indicate that there was no difference in the rate of formation of this pigment in either the LL or GM based on the ratio values between treatments.

Table 1: Predicted means and standard error of difference between immobilised and non immobilised treatments for carcase weight, GR, sarcomere length, drip loss % (kill 2 results only), pH, rate of pH decline linear, predicted temperature at pH 6.0, predicted pH at 18°C and predicted pH at 25°C for kill 1 and 2.

Treatment	Immobilisation^	No Immobilisation^	s.e.d
Number of carcases	40	40	
Carcase Weight (kg)	22.0a	22.6a	1.25
GR (mm)*	12.4a	12.1a	1.45
Sarcomere length (μm)	1.75a	1.74a	0.05
Drip loss % (kill 2 only)	0.73a	1.87a	0.52
Initial LL pH**	6.30a	6.26a	0.09
28 hour pH	6.16a	6.19a	0.08
7 day aged pH	5.95a	5.93a	0.08
pH slope (rate of pH decline)	0.0197a	0.0167a	0.0036
Pred temp @ pH 6.0 exp#	17.8a	19.8a	3.71
Pred pH @ 18°C	6.09a	6.04a	0.10
Pred pH @ 25°C	6.22a	6.15a	0.08
Shear Force (N)	31.1a	30.4a	3.07
Cooking loss %	14.4a	14.8a	1.14

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

^electrical treatment is a high frequency immobiliser unit

*Adjusted to a hot carcase weight of kg 22.3, **adjusted to an initial temperature of 35.1°C; #predicted values for 63 animals

Table 2: Predicted means and standard error of difference between immobilised and non immobilised carcases for GM and LL initial (1 day aged) and final (7 days aged) *L**, *a**, *b**, ratio (630/580 nm) and chroma values for kills 1 and 2.

	Initial			Final		
	Immobilised	**Non immobilised**	**s.e.d**	**Immobilised**	**Non immobilised**	**s.e.d**
GM						
*L**	33.8a	34.6a	2.1	35.2a	38.6b	2.3
*a**	10.1a	10.0a	0.8	7.8b	7.0a	0.6
*b**	10.6a	10.2a	0.8	11.4b	10.5a	0.4
Ratio	3.5a	3.4a	0.3	1.6a	1.6a	0.2
Chroma	13.3b	12.0a	1.0	13.8b	12.7a	0.9
Loin						
*L**	30.8a	32.2a	1.8	35.2a	36.8a	2.2
*a**	9.4a	9.2a	1.0	7.7a	7.7a	0.7
*b**	10.1a	9.8a	1.1	10.8a	10.0a	0.9
Ratio	3.5a	3.5a	0.2	1.8a	1.7a	0.1
Chroma	13.9a	13.6a	1.2	13.4a	12.8a	1.0

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

Figure 1: Raw data, showing the change in the spectral ratio 630/580 nm of the LL during display for 144 hours between immobilised and non immobilised treatments.

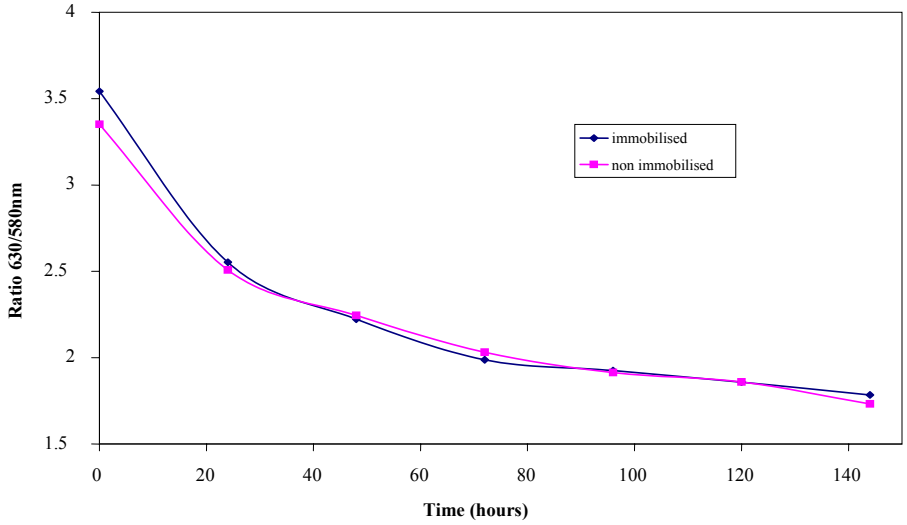
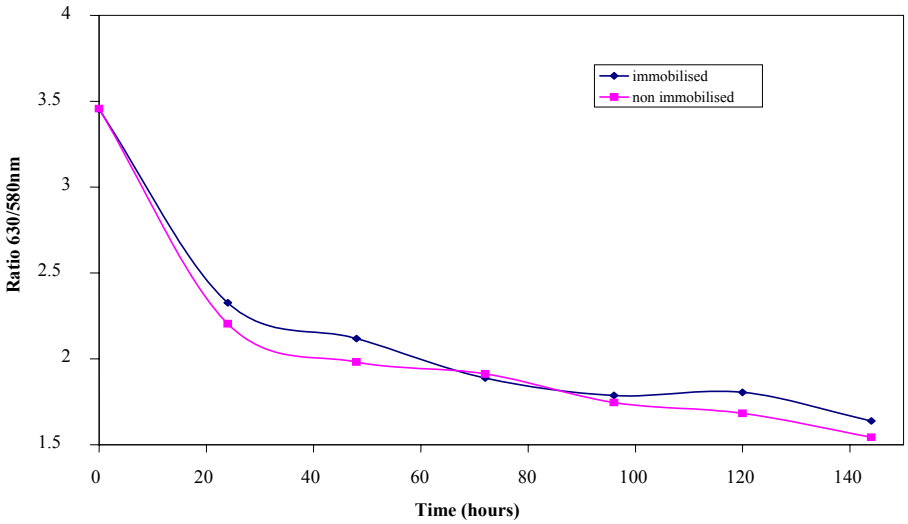


Figure 2: Raw data, showing the change in the spectral ratio 630/580 nm of the GM during display for 144 hours between immobilised and non immobilised treatments.



DISCUSSION

The results of the present study show that immobilisation had no significant effect on any pH or temperature trait. There was notable variation between kill days for most of the traits measured. These differences are most likely driven by the variation in animals processed over the two days. Such variation is typical when lambs are purchased through saleyards and could be reduced by purchasing lambs directly from growers.

Sarcomere lengths indicated that no differential shortening had occurred between treatments. As a shear force value of 40 N is suggested as the upper tenderness/toughness threshold for consumer acceptability based on the recent work of Hopkins *et al.* (2006a), the mean value of 39 N for samples after 1 day of ageing and 22 N after 7 days of ageing in the present study indicates that most if not all samples would have had an acceptable degree of tenderness after 7 days of ageing. This improved tenderness with ageing supports numerous previous reports (*e.g.* Pearson & Young 1989).

There were no significant differences ($P > 0.05$) due to treatment in initial LL and GM colour or final LL colour. However the 7 day aged GM from non immobilised carcases had a lighter meat colour and those from immobilised carcases had a redder and a more yellow colour. It is contended that these differences would not translate into a meaningful consumer response. Based on the raw data shown in figures 1 and 2 there was no difference in display life between treatments for the ratio 630 nm/580 nm value. This is an important finding which indicates no difference in the formation of metmyoglobin according to treatment.

The results obtained from this study show that the immobilisation treatment had minimal effects on pH and temperature, objective meat colour, meat tenderness and sarcomere length. These results confirm some previous anecdotal evidence. There is no doubt that the high frequency immobilisation unit has benefits in that it enables abattoir workers to begin processing the carcases safely within approximately 30 seconds of death with no apparent negative effect on meat quality traits. Therefore immobilisation as tested here can be promoted confidently to industry as a method to improve Occupational, Health & Safety (OH&S) without a detrimental effect on meat quality.

The full suite of electrical inputs used by this processor is a complex system and there is a potential need for further optimisation of each electrical component to determine the individual and cumulative impact on meat quality traits and how best to manage the electrical inputs for different types of carcases. Given that only one component of the system was tested we cannot establish whether the total system has improved any of the traits tested. For example, there may well be benefits for meat colour from the application of electricity for electronic bleeding as shown by Hopkins *et al.* (2006b), but this would need to be tested separately to establish the magnitude of any benefit. It is clear from this study that the high frequency immobilisation unit does not affect meat colour.

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