The effect of different electrical immobilisation and stimulation procedures on meat quality of beef

A.C. Lombard[1], N.V. Johnson[2], J.M. McGurk[2], T.L. Cummings[2], C.C. Daly[2] & N.J. Simmons[2]*

[1]Department of Animal Sciences, Stellenbosch University, Private Bag XI, Matieland 7602, South Africa.
[2]Carne Technologies Ltd, PO Box 740, Cambridge 3434, New Zealand.
*Email: nicola.simmons@carnetech.co.nz.

Abstract

Electrical immobilisation (EI) is used to control animal movement after electrical stunning, while electrical stimulation (ES) is used to induce rapid tenderisation. Excess stimulation, however, can have detrimental effects on meat quality. Forty steers were electrically stunned, and slaughtered and then electrically immobilised (EI) for 20 seconds using either low (LFEI) or high frequency (HFEI). After carcass dressing, electrical stimulation (ES) was applied using either high voltage (HVES) or mid voltage (MVES). Meat quality measurements were made from the M. *longisimmus* after 1, 5 and 9 days of chilled storage. The LFEI followed by HVES produced significantly greater drip during storage and shear force values when compared to the HFEI followed by either HVES or MVES, attributable to different rates of pH decline post mortem. Results indicate that meat quality depends on effective control of all electrical inputs to the carcass post mortem, and that standard LFEI followed by HVES can result in reduced quality attributes, in particular purge and shear force.

Introduction

The two main determinants of post-slaughter processing outcomes are rate of pH and temperature decline. Muscle pH and temperature interact continuously during rigor development to affect both the muscle contracture (Tornberg, 1996) and proteolytic enzyme activity (Dransfield, 1992). The pH, however, can be manipulated independent of temperature by electrical stimulation and this gives rise to the opportunity to manipulate meat quality outcomes.

Electrical stimulation tends to decrease shear force values compared to non-stimulated meat (Strydom, Frylinck & Smith, 2005), but the extent of this effect depends on the amount of electrical inputs applied. As ageing progresses the differences between electrical and non-stimulated samples decrease (Strydom, Frylinck & Smith, 2005) and can disappear completely if enough time is allowed (Chrystall & Daly, 1996) and cold induced contractions are avoided.

If carcasses receive excessive amounts of stimulation, shear force values after ageing are higher in the stimulated carcasses compared with non-stimulated treatment, especially when chilling is slow (Geesink, Mareko, Morton & Bickerstaffe, 2000; Koh, Bidner, McMillan & Hill, 1987). In addition, excess stimulation can reduce water-holding capacity (Smulders, Eikelenboom & van Rudérus, 1981) and colour stability (Unrah, Kastner, Kropf, Dikeman & Hunt, 1986). The effects of excess stimulation can be attributed to the coincidence of high temperatures and low muscle pH, conditions known to denaturate muscle structural proteins (Offer, 1991) and accelerate the autolysis of calpains (Simmons, Singh, Dobbie & Devine, 1996). Severe rigor contractions also occur if rigor is attained at high carcass temperature (Hertzman, Olsson &

Tornberg, 1993) and this can be expected to affect the capacity to tenderise.

The purpose of this project was to quantify meat quality attributes that develop from different processing conditions to assist in defining appropriate specifications and to evaluate the effect of excessive electrical stimulation.

Material and methods

Forty steers were electrically stunned (head only, 2Amps, 50Hz, 2 seconds), followed by a throat cut and thoracic stick. Carcasses were electrically immobilised (EI) using either low (14.3 Hz, 90V for 20 seconds) or high frequency (800Hz, 110V for 20 seconds) EI within 5 minutes of slaughter. After carcass dressing, electrical stimulation (ES) was applied using either high voltage (HVES) (1140 V, 14.3 Hz) or mid voltage (MVES) (300 V, 14.3 Hz, 1 ms pulse duration). pH measurements were taken at 30 minutes, 1.5, 2.5, 3.5, 4.5 and 24 hours post-mortem in the LD and the temperature decline was determined at 15 minute intervals. After 24 hours, the LD was cold boned and used for meat quality assessment at day 1, 5 and 9 following chilled storage at 4°C.

At each of the days, shear force, drip loss during storage and retail display, cooking loss and water-binding capacity was measured. Evaluation of tenderness was measured using a Digital Tenderometer™. Samples were cooked in a water bath at 100°C in weighted plastic bags until the internal meat temperature reached 75°C. The portions were then removed and immediately chilled on ice. Ten bites (10 x 10 mm square cross-section at right angles to the fibre axis) per sample was taken and measured for shear force and used to give an average shear force value for the sample.

Cooking losses was determined as the percentage of weight loss after the cooking process. Drip losses during storage were measured as the percentage of weight loss during cold storage at 4 deg. Drip losses during retail display was measured as the percentage of weight loss during mimicking of retail display at 5 deg. The water-binding capacity was determined by calculating the ratio of meat area and the liquid area after pressing 500 mg fresh meat sample on a filter paper sandwiched between two Perspex plates and pressed at a standard pressure for 1 minute. Photos were taken and the areas were measured by means of Image J Version 1.38.

An ANOVA was used to test for statistical differences between treatments (MINITAB® Release 14).

Results

The mean pH at various times (hours) post mortem in the LD are presented in Table 1. LFEI significantly reduced the pH after 0.5 and 1.5 hours ($p < 0.001$). Differences continued during post mortem decline, but after 24 hours, all treatments had reached final pH (pH_u), and did not differ significantly between treatments.

Table 1. pH decline of *M. longisimmus*

	Treatment					
Time (h)	HF HVES	HF MVES	LF MVES	LF MVES	SEM	p - value
0.5	6.428a	6.484a	5.946b	6.059c	0.041	0.001
1.5	5.779a	5.899a	5.707b	5.881a	0.019	0.001
2.5	5.623ab	5.669ab	5.586a	5.709b	0.016	0.031
3.5	5.524a	5.595ab	5.549ab	5.621b	0.013	0.033
24	5.461a	5.451a	5.472a	5.445a	0.014	0.912

A summary of the meat quality characteristics is shown in Table 2. It is evident that LFEI combined with HVES had significantly higher shear force values at days 1, 5 and 9 when compared to the HFEI with either HVES or MVES. Cooking losses between treatments did not differ at day 1 but tended to be greater at day 5 and 9 in the HFEI treatments. HFEI MVES had a significantly higher cooking loss than LFEI MVES at day 5 and 9. At day 1, WBC was lower in LFEI MVES than the other treatments ($P<0.05$). Treatment effects were lost by Day 5, but WBC was highest in the HFEI treatments at day 9 ($p<0.05$). Storage for 5 and 9 days produced more drip loss in the LFEI treatments compared with HFEI treatments ($p < 0.05$). Drip loss during retail display was unaffected by the treatments .

Table 2. Summary of meat quality characteristics

Quality trait	Timepoint	Treatment				SEM	p - value
		HFEI HVS	HFEI MVES	LFEI HVS	LFEI MVES		
Shear force	Day 1	113.493a	121.809a	148.302b	120.625ab	4.60	0.034
	Day 5	74.395a	77.250ab	102.335b	78.645ab	3.67	0.022
	Day 9	56.498a	62.694a	89.321b	66.274a	2.89	0.000
Cooking loss	Day 1	29.754a	31.609a	28.679a	28.244a	0.502	0.076
	Day 5	30.129ab	32.606b	26.800ab	26.245a	0.834	0.016
	Day 9	27.375ab	28.117b	27.136ab	24.576a	0.464	0.034
Retail drip	Day 1	0.951a	1.167a	1.560a	1.457a	0.118	0.263
	Day 5	0.652a	1.06a	0.907a	0.998a	0.082	0.314
	Day 9	0.724a	0.747a	0.727a	0.732a	0.053	0.999
Storage drip	Day 1	1.124a	1.626a	2.765b	2.791b	0.181	0.000
	Day 5	2.066a	2.252a	3.082b	3.383b	0.198	0.044
WBC	Day 1	259333a	233715ab	265088a	198292b	6635	0.000
	Day 5	269760a	294252a	260454a	251266a	6142	0.072
	Day 9	283821ab	288428a	263930ab	238354b	6651	0.025

Conclusions

HFEI is an effective method of controlling carcass movement after electrical stunning in cattle. These results also show that this intervention produces a slower pH decline compared with conventional LFEI, allowing better management of post mortem processing conditions. LFEI combined with HVES resulted in higher shear force values throughout the ageing period, an effect that can be attributed to the rapid pH decline while the carcass temperature is still high. The mechanism may be due to loss of calpain activity through rapid autolysis (Simmons, Singh, Dobbie & Devine, 1996), or rigor shortening (Hertzman, Olsson & Tornberg, 1993).

The results confirm that early and rapid reduction of muscle pH leads to a lower water-binding capacity. This is particularly noticeable following LFEI, which lowers the pH before dressing and increases the time interval between stimulation and cooling the carcasses in a chiller. The reduced WBC can be attributed to denaturation of myosin and soluble sarcoplasmic proteins (Offer, 1991).

It is evident that keeping the pH high during dressing of the carcass improves meat quality and offers the opportunity to optimise processing specifications to produce meat for diverse markets. In addition, it identifies that excessive electrical stimulation, for example using the standard LFEI followed by HVES used in some New Zealand plants, can reduce meat quality, particularly through reduced tenderness and increased purge losses.

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