ELECTRICAL STIMULATION: THE EFFECT OF DURATION ON MEAT QUALITY FOR SPECIFIC PRE- AND POST SLAUGHTER CONDITIONS

P.E.. Strydom, K. van Rooyen, S.M. van Heerden, E.M. Visser, J. van Niekerk and H. Snyman
Animal Nutrition and Animal Products Institute: Agricultural Research Council of South Africa, Private Bag X2, Irene, 0062, South Africa (phillip@idpi1.agric.za)

Background

The rate of post-mortem glycolysis in muscle has been shown to be an important determinant of meat tenderness (Takahashi *et al.*, 1984, Smulders *et al.*,1990, O'Hallaran *et al.*, 1997). A slow rate of glycolysis coupled with a rapid temperature decline leads to cold shortening and toughening of the muscle. Electrical stimulation applied within a few minutes of slaughter (high and low voltage) or later on in the slaughter process (high voltage) will accelerate post-mortem glycolysis, thereby avoiding cold shortening (Chrystal *et al.* 1983). In addition electrical stimulation is thought to facilitate further improvement in tenderness via enhancing or accelerating proteolysis (Ferguson *et al.*, 2000, Devine *et al.* 2001) and structural weakening Takahashi *et al.*, 1984, Ho *et al.*, 1996). However, electrical stimulation (ES) is often not utilised to its full potential mostly due to a lack of knowledge pertaining to its interaction with pre- and post-slaughter conditions. For example, ES could enhance the negative effect of poor pre-slaughter management of cattle on meat tenderness (Nortjé *et al.*, 1986). Similarly, too long stimulation times with consequent high rates of glycolysis could induce heat rigor and impair ageing potential especially when combined with slow chilling rates (Simmons *et al.*, 1997, Hwang & Thompson, 2001). Water holding capacity (Butchers *et al.* 1998) and colour stability could also be impaired (Young *et al.*, 1999). Unsatisfactory results often leads to termination of ES by many abattoirs with consequent negative effects on meat quality due to muscle cold shortening. In the present study a scenario typical to certain sectors of industry in South Africa was investigated where optimum pre-slaughter management was in place (no feed withdrawal), the chilling took place at a medium rate and the options of no stimulation or stimulation of different durations were tested.

Objective

To compare the effect of duration of high voltage stimulation with no stimulation in a scenario of a low chilling capacity (slow rate carcass temperature decline) and optimum pre-slaughter management in relation to meat quality characteristics.

Methods

Animals and experimental design: Sixty-three purebred steers were randomly selected from a larger group of animals where they have been fed under commercial conditions on a high quality grain diet for approximately 100 days. The steers, averaged 221 kg carcass weight, had fat depths at the P8 sight ranging from 2.7 to 16.9 mm and were between 13 and 24 months (estimated by dentition at slaughter). The experimental design was a 2x2 factorial design for Warner Bratzler shear force, comprising of two ageing periods (3 days and 21 days) and three stimulation treatments (viz. no stimulation, 15 seconds and 30 seconds). Only the effect of electrical stimulation procedure was evaluated for the other characteristics.

Pre-slaughter treatment: The animals were not fasted prior to transporting them to the abattoir, which took place on the same day as slaughter. The feedlot and abattoir were less than 10 minutes drive apart and therefore the animals had minimum pre-slaughter stress. The two stimulation treatments (400 volts, 12.5 pulses/s, 2A output for 15 or 30 seconds) were applied within two minutes of stunning using nostril and achilles clamps. The sides entered the chillers ca. 60 minutes after stunning. The chiller capacity was limited in terms of wind speed and air temperature. Therefore chilling rate was relatively slow.

Measurement: Each carcass was monitored for pH and temperature of the *M.longissimus* ($11^{th}/12^{th}$ rib) at 1h, 3h, 6h and 24h (ultimate) after stunning. The striploin (*M.longissimus*) was removed between the 12^{th} rib and the 4^{th} lumbar vertebra and used for shear force resistance, drip loss and colour (L*, a*, b* and Chroma) measurements. The muscle was divided in two, vacuum packed and stored for either three or 21 days at 2°C and then frozen at –20°C. Allocation of ageing period alternated between the cranial and caudal ends of the striploin. For shear force resistance measurements, 30 mm steaks were cut from frozen samples, repacked and thawed for 24 hours at 2 °C. Thawing loss was determined. Steaks were prepared to an internal temperature of 70°C according to an oven-broiling method using direct radiant heat (AMSA, 1978) at 260°C. Cooked steaks were allowed to cool down at room temperature to a stabilised internal temperature of ca. 22°C. Six 12.5mm diameter cores per total sample were removed parallel to the fibre orientation for Warner Bratzler peak force measurement. Drip loss was measured by hanging 50 g fresh samples (sampled one day after slaughter) in a vented sample bottle at 2°C for 48 hours.

Results and Discussion

The rate of glycolysis as measured by means of pH differed significantly among the three stimulation treatments ($P<0.05$), with 30 seconds ES showing the fastest rate and no stimulation the slowest. Due to the slow chilling rate, however, even the non-stimulated treatment reached pH of 6 (commencement of rigor) before the muscle temperature reached 10°C and therefore cold shortening was not likely to happen (Pearson & Young, 1989). Although ES of 30 seconds can be regarded as a short duration in practice, carcasses in the present study, reached a $pH < 6$ at 1 hour after stunning. At this time, the muscle temperature was still 37°C, which could potentially induce an earlier activation proteolysis, but also an increased rate of proteolytic enzyme exhaustion (Hwang & Thompson, 2001) and possibly heat shortening (Simmons *et al.*, 1997). The 15 second treatment reached pH=6 closer to three hours when the muscle temperature was 30°C or less. According to Hwang & Thompson (2001) the faster rate of glycolysis (30 s stimulation) will result in favourable early post mortem tenderness values, but impair the prolonged ageing capacity when compared to muscle following an intermediate rate of glycolysis. In the present study the shear values of the 15 and 30 seconds treatments were almost the same at day 3 post mortem. However, with prolonged ageing (21 days) the 15-second treatment had a 0.4 kg advantage over the 30-second treatment, which is in agreement with the findings of Hwang & Thompson (2001) and Butchers *et al.* (1998). Butchers *et al.* (1998) highlighted the fact that the animals were non-fasted similar to our study. Even though muscle shortening was not expected in the non-stimulated group, the two stimulated treatments produced significantly more tender meat after 3 days of ageing. The advantage of stimulated over non-stimulated could be attributed to accelerated proteolysis (Ferguson *et al.*, 2000, Devine *et al.* 2001) and possibly some structural damage due to the high voltage treatment (Takahashi *et al.*, 1984). The significant aging effect and interaction between ES and ageing support this statement. Although the effect of stimulation caused an earlier activation proteolysis, the non-stimulated treatment caught up after 21 days and showed the highest amount of ageing (3.03 kg) followed by followed by the 15 second treatment (2.26 kg), with the least ageing occurring in the 30 second treatment (1.81 kg)($P<0.05$ for) vs. 15 and 30 seconds). Nevertheless, the 15-second stimulation group

still had a slight advantage (P>0.05) over the non-stimulated treatment (0.48 kg). Shortening of the muscle (sarcomere length) was not determined, yet the possibility of cold shortening is probably not a factor to be considered, as reported earlier. Although temperatures at pH=6 for non-stimulated carcasses was not recorded directly, only a few carcasses still had pH values between 6.2 and 6.3 at this at six hours after stunning, when muscle temperature was 19°C. The slight advantage of the 15 seconds treatment over the non-stimulated group at 21 days could also have been the result of the structural damage caused by the stimulation.

Drip loss tended (P>0.05) to increase with longer stimulation, which is in agreement with Butchers *et al.* (1998) and Denhertogmeischke *et al.*, 1997) and can be ascribed to increased protein denaturation due to a combination of high temperature and low pH (Penny 1977).

The lightness in colour or reflectance (L*) as well as the chroma (derived from a* and b*) was significantly higher for the 30-second treatment compared to the non-stimulated treatment, with the 15-second treatment intermediate. Young *et al.* (1999) supported by Ledward *et al.* (1986) found that meat entering rigor at higher temperatures was more reflective (L*) than meat than meat entering rigor at low temperatures, which agree with our findings for different glycolytic pathways. Similarly, Young and Ledward found higher chroma values for early rigor meat. According to Hood (1984), a high rate of glycolysis at high temperature causes a greater degree of muscle protein denaturation. Together with some physical disruption due to ES, deeper oxygen penetration is allowed resulting in a thicker oxy-myoglobin layer (Renerre, 1990). However, the apparent advantage of longer ES duration in this case might not last long due to higher rates of myoglobin oxidation to met-myoglobin having a browning effect on meat sooner (Renerre, 1990).

Table 1: The effect of different stimulation times on glycolysis pathway, meat tenderness, colour, ageing ability and drip loss.

	No stimulation		15 seconds stimulation		30 seconds stimulation		SEM[1]
pH:							
1hour	6.73[a]		6.36[b]		5.92[c]		0.0287
3 hours	6.31[a]		5.78[b]		5.50[c]		0.0469
6 hours	5.99[a]		5.57[b]		5.48[c]		0.0275
24 hours	5.51[a]		5.45[b]		5.44[b]		0.01131
Temperature:							
1 hour	37.7		37.5		37.1		0.322
3 hours	30.1[a]		26.8[b]		27.2[b]		0.533
6 hours	19.4[a]		19.3[a]		16.4[b]		0.372
24 hours	4.5		4.5		4.5		
Drip loss %	1.38		1.59		1.95		0.231
Colour attributes:							
L*	39.0[a]		39.9[ab]		41.3[b]		0.523
a*	15.9[a]		16.7[ab]		17.3[b]		0.395
b*	8.32[a]		8.78[ab]		9.16[b]		0.238
Chroma	17.9[a]		18.8[ab]		19.6[b]		0.449
Amount of ageing (kg)	3.03[a]		2.26[b]		1.81[b]		0.219
Ageing period	3 days	21 days	3 days	21 days	3 days	21 days	
Warner Bratzler shear force[2]	6.73[c]	3.75[a]	5.52[b]	3.26[a]	5.49[b]	3.68[a]	0.1547

[1] Standard error of mean
[2] Interaction between Ageing and stimulation treatment was significant ; P=0.002
[a,b,c] Means in the same row with different letters in superscript, differ significantly (p<0.05)

Conclusion

• In a scenario where pre-slaughter animal stress is limited, over stimulation could lead to impairment of ageing ability of meat. This is especially true if a medium or slow chilling rate is maintained. Under these conditions electrical stimulation should merely trigger the glycolysis process.

• Even though it is often believed that well-rested animals have sufficient glycogen stores to induce a safe rate of glycolysis to prevent cold-shortening, a short duration electrical stimulation still proves to enhance meat tenderness and appearance (on the short term). This seems to be true even when cold-shortening is not expected.

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