THE INTERACTION BETWEEN TYPE (HIGH OR LOW VOLTAGE) AND TIME (3 OR 40 MINUTES POST-STUNNING) OF ELECTRICAL STIMULATION ON BEEF

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Background

Electrical stimulation of carcasses post-stunning is used to increase the rate of pH fall to avoid cold shortening in muscle (Davey *et al.*, 1976). In practice, low voltage stimulation is applied immediately after slaughter, whilst high voltage stimulation is applied anywhere from 20 minutes to one hour after slaughter. Comparisons between the systems have shown that the high voltage system generally produces more tender meat (McKeith, F.K., 1980; Aalhus *et al.*, 1994), although many of these comparisons were confounded by differences in rigor temperature. Where high and low stimulation were applied at the same time there appeared to be little difference between rate of pH decline and ultimate tenderness (e.g. Eikelenboom *et al.*, 1985). The relationship between rate of pH fall and temperature decline appears to be critical, with an optimum rate of decline producing the most tender meat (Pike *et al.*, 1993). Too fast a decline in pH, coupled with high muscle temperature, appears to be associated with a slight increase in toughness due to rigor at high temperatures, which resulted in adverse effects for proteolytic enzyme activity and possibly heat shortening (Unruh *et al.*,1986).

Objective

This study investigated the effect on meat quality of high (HV) and low (LV) voltage stimulation applied at either 3 or 40 minutes post-stunning.

Methods

Animals and Experimental Design: Thirty eight pasture-fed steers and heifers which were the progeny of three sire breeds (Angus, Brahman and Piedmontese) crossed with Brahman X Hereford crossbred cows were allocated within sire type and sex to a 2x2 factorial design. Treatments comprised type (HV or LV) and time (3 or 40 minutes post-stunning) of electrical stimulation. Mean age, live weight and carcass weight of the cattle were 660 days, 444 kg and 270 kg, respectively. Stimulation treatments at 3 minutes post-stunning were applied to the whole body for 40 seconds immediately after bleeding via electrodes inserted in the nostril and rectum. Stimulation treatments at 40 minutes post-stunning were applied to the left side of the carcass for 55 seconds via two multi-point electrode probes inserted into the muscles at the proximal end of the Achilles tendon and lateral aspect of the scapula. The output of the HV (800 volts RMS of continuous alternating polarity) stimulation unit consisted of bi-directional half sinusoidal pulses of 10 msec width. The output of the LV (70 volts peak) stimulation unit consisted of uni-directional square wave pulses of 7 msec width. The frequency of the waveforms of both the HV and LV units was 14.3 pulses per second with a average current of 7.2 and 1 amps.

Measurements: Cattle were slaughtered over a 6-day period with a random selection of animals from each genotype x sex cell being slaughtered each day. Cattle were stunned with a captive bolt, dressed on a cradle system then placed in a 1 °C chiller ca. 50 minutes after slaughter. Temperature and pH were monitored every 15 minutes in the caudal end of M. *longissimus thoracis et lumborum* (LD) until muscle reached ultimate pH. The following day the LD section from the 5th thoracic vertebrae to the last lumbar vertebrae was removed. The epimysium was removed, and from the cranial end four 250g samples (100x30x70 mm) were cut, vacuum packaged and aged for 1, 3, 7 or 14 days. These samples were used for objective meat quality evaluations. The next two 25mm steaks were cut and aged for 1 or 14 days for sensory evaluation. For the objective and sensory samples, loin position (cranial and caudal) was randomized between animals. Samples were aged at 1°C for the required ageing periods, prior to freezing at –20°C.

For the objective measurements, frozen steaks were cooked in a water bath for 60 minutes at 70°C. The objective measures of shear force and compression were made on the cooked samples according to the procedures described by (Bouton *et al.*, 1971). For sensory analysis, frozen steaks were thawed for 6 hours prior to cooking to an internal temperature of 70°C using an electric clam bake griller. Sensory samples were allocated to sessions using an incomplete randomized block. Warm 15 mm cubes were presented to trained 11 panelists who tasted six cubes at each of 14 sessions for tenderness and juiciness. Drip loss was measured by hanging 85 g of muscle in a plastic bag at 1°C for 24 hours. Sarcomere length was determined using the Helium-Neon laser diffraction technique on unfixed muscle (Bouton *et al.*, 1973).

Statistical Analyses: The pH/time relationship was modeled using the exponential function $pH(t) = pH_\infty + (pH_0 - pH_\infty)e^{-kt}$, where pH(t) was pH at time t, pH_0 was the pH at t=0 and pH_∞ that at $t = \infty$, k was the rate constant of pH decay. This equation was fitted using a non linear statistical package and the coefficients used to predict pH at specific times (e.g. pH at 45 minutes). Adjusted taste panel scores (predicted means for the animal*ageing effect) were obtained using a mixed model which contained fixed effects for tasting order, animal, ageing, loin position, animal*ageing and random effects for session and taster. Objective and sensory measurements were analysed using a mixed model which contained fixed effects for stimulation type, time of stimulation, ageing, sire breed, sex, all significant first order interactions ($P<0.05$), and a random effect for animal (stimulation type*stimulation time*sire breed*sex). All effects except ageing and ageing interactions were tested on the animal term, whilst ageing and ageing interactions were tested against the residual error. Drip loss, cooking loss and sarcomere length were analyzed using a generalized linear model that contained terms for stimulation type, stimulation time, sire breed, sex and significant ($P<0.05$) first order interactions.

Results and discussions

Electrical stimulation of carcasses 3 minutes post-stunning by either HV, or LV systems resulted in a faster rate of pH fall (pH_{45}, $P<0.001$) and a deterioration in eating quality compared to HV, or LV stimulation at 40 minutes post-stunning. Muscle from the 3 minute treatments had shorter sarcomeres ($P<0.001$, Table 1), higher drip losses ($P=0.09$), lower juiciness scores ($P=0.17$) and was tougher ($P<0.05$) than meat from carcasses stimulated 40 minutes post-stunning (Table 1). There was a significant stimulation*time interaction ($P<0.05$) for sensory tenderness score, due primarily to the lower tenderness rating for 3 minute HV treatment compared with the other treatments. Ageing effects were highly significant ($P<0.001$), with tenderness increasing as ageing period increased. As ageing did not interact with time or stimulation effects ($P>0.05$) their effects are not reported in this paper. The loss in meat quality as a result of rigor shortening is consistent with those reported by Unruh *et al.* (1986). The lack of an effect for type of stimulation agrees with the results of Eikelenboom *et al.* (1985) and suggests that the previously reported advantage of HV compared with LV stimulation systems was largely a function of the longer time delay post-stunning in applying the high voltage systems.

In this experimental condition, the pH at 45 minutes (pH_{45}) was found to have the highest relationship with peak force values at all ageing times. Although there was a significant time of stimulation effect on pH_{45} there was considerable overlap between individual animals within the 3 and 40 minute treatments. Therefore pH_{45} was used as a covariate for those traits in which the time effect was significant. The inclusion of pH_{45}, in these analyses reduced the peak force difference due to time of stimulation from 0.48 to 0.12 kg ($P>0.05$), but had no effect on the magnitude of sarcomere length, drip loss or tenderness score differences. This suggests that the time effect on peak force was largely a function of the faster rate of pH fall with the 3 minute compared with 40 minute stimulation treatments, whereas the effect on sarcomere length, drip loss and sensory tenderness scores was independent of pH_{45}. The magnitude of the correlation between pH_{45} and peak force at days 1, 3, 7 and 14 days ageing increased commensurate with ageing duration. Correlations between pH_{45} and peak force were –0.24, -0.28, -0.32 and –0.47 for 1, 3, 7 and 14 days aged, respectively. The higher negative correlation between pH_{45} and peak force in the longer aged meat samples was consistent with the hypothesis of Simmons *et al.*, (1996). That proposed a reduction in the proteolytic activity of the calpains, and therefore a decrease in the ageing potential in rapidly glycolysing muscle which reaches a low pH at high temperatures. It is interesting that time of stimulation had a marked effect on sarcomere length (Table 1), and that this difference was not related to pH_{45}. Simmons *et al.*, (1996) also suggested that sarcomere length on tenderness was independent of the effect of low pH at high muscle temperatures.

Conclusions

Electrical stimulation immediately post-stunning resulted in very rapid glycolysis, which was shown to have a detrimental effect on objective meat quality by producing tougher meat, which had a higher drip loss. Rigor at high temperature resulted in a reduction in ageing potential of the meat. High and low voltage stimulation at 40 minute post-stunning was more favorable in terms of meat quality than stimulation at 3 minutes post-stunning. When applied at the same time post-stunning there appeared to be little difference in meat quality traits from carcasses stimulated with either high or low voltage systems.

Pertinent literature

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Table 1. Predicted means for the effect of type of electrical stimulation (Stim), time of stimulation (Time) and their interaction on objective and sensory measurements of the LD muscle.

	3 minutes		40 minutes		Av.	Significance		
Measurement	HV	LV	HV	LV	s.e.	Stim	Time	Stim*Time
Objective								
Peak force$^{\phi}$ (kg)	4.36	4.21	3.71	3.90	0.22	n.s.	*	n.s.
Compression$^{\phi}$ (kg)	1.77	1.69	1.62	1.75	0.08	n.s.	n.s.	n.s.
Drip loss (%)	1.2	1.07	0.86	0.84	0.15	n.s.	P=0.09	n.s.
Cooking loss$^{\phi}$ (%)	20.0	18.75	19.71	19.95	0.54	n.s.	n.s.	n.s.
Sarcomere length (μm)	1.74	1.77	1.95	1.86	0.03	n.s.	***	P=0.08
pH_{45} (pH at 45 minutes)	5.80	5.98	6.31	6.31	0.098	n.s.	***	n.s.
Sensory ψ								
Tenderness$^{\phi}$ (1-100)	58.0	67.2	69.0	66.3	2.4	n.s.	*	*
Juiciness$^{\phi}$ (1-100)	57.0	58.1	60.4	60.01	1.8	n.s.	n.s.	n.s.

ϕ Means were adjusted for ageing time (1, 3, 7, 14 days), sire breed and sex effects

ψ 0=extremely tough or dry, 100 = extremely tender or juicy, * $P<0.05$, *** $P<0.001$, n.s. non- significant.

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