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Effect of high and low voltage stimulation on tenderness of muscles from slowly cooled beef sides

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Introduction

The effectiveness of electrical stimulation (ES) in avoiding cold-induced toughening in rapidly chilled carcasses is well established (Carse, 1973, Chrystall and Hagyard, 1976) and was the principal reason for its introduction into the meat industry. It is now used in many UK factories to allow full implementation of rapid beef chilling systems, but interest has been expressed more recently in claims that ES has a tenderising effect quite apart from avoidance of cold-shortening. Several studies (Savell et al., 1978; Vandekerekhove and Demeyer, 1978; Johnsson et al., 1978; Smith et al., 1979; Elgasim et al., 1981) have suggested that ES, followed by cooling slow enough to avoid cold-shortening, can considerably reduce the time required for achieving acceptable tenderness in beef carcasses. Although there are no agreed recommendations for the optimal time required for beef ageing, the prospect of reducing it to 3 or 4 days is undoubtedly attractive to the meat industry.

George et al. (1980) found that beef carcasses, stimulated (700 v peak) and subjected to a 7 h delay period before chilling, produced samples of M. longissimus dorsi which became tender earlier than non-ES controls; samples of M. semitendinosus showed only a very slight improvement with stimulation. Unfortunately, much of the evidence in the literature is inconclusive and, in particular, the interaction between carcass chilling rate and pH is not well documented.

This study examines the possibility of early tenderisation in beef carcasses which were stimulated and cooled slowly, and whether or not these conditions had a pronounced effect on other meat quality characteristics such as drip, cooking loss and colour. Five major muscles from stimulated slowly cooled carcasses were examined at 3, 7 and 10 days post-slaughter and their texture and other properties compared with those of corresponding muscles from non-stimulated sides, cooled in the same way.

Because high and low voltage stimulation systems are currently used in UK factories, both were included in this study.

Materials and methods

Ten Hereford x Friesian steers (18-24 months) with carcass weights ranging from 266 to 307 kg were used for this experiment. Five beasts were slaughtered, dressed and split conventionally and, at approximately 50 min post-slaughter, one side of each was subjected to high voltage stimulation (HES). A peak voltage of 700 v at 25 pulses/sec was applied to the side by electrodes placed on the Achilles tendon and the neck muscles for 4 x 30 sec periods. The matching side was taken as the unstimulated control (CON).

The other 5 beasts were stunned, stuck and stimulated for 60 sec during bleeding, using a MEDAL Junior Low Voltage Electrical Stimulation Unit (LES), generating 14.3 unidirectional pulses/sec of 94v peak and 5 msec duration.

The positive electrode was placed in the captive bolt hole and the carcass was earthed via an electrode inserted in the hind leg near the Achilles tendon. Only one side of each LES carcass was used in the experiment.

All sides from each of the 3 treatment groups were held at 15°C until 7 h post-slaughter, before going into a chillroom at -1°C until 48 h after slaughter. Temperatures were recorded during cooling, in the deep hindquarter and deep and surface LD at 10/11th rib (Table 1).

Table 1 Temperatures in carcasses during cooling. Mean values from 5 carcasses are shown.

	Temperature (°C)						
	2h	4h	8h	10h	20h	30h	40h
Surface LD	25	20	17	10	1	-1	-1
Deep LD	29	26	20	15	2	-1	-1
Deep leg	38	37	32	29	15	6	2

pH measurement - Four of the sample muscles were regularly assessed for pH fall. 1 g of each of M. semimembranosus (Sm), M. longissimus dorsi (LD), M. triceps brachii (TB) and M. pectoralis profundus (PP) was removed at 1, 3, 7, 24 and 48 h post slaughter, macerated in 10 ml 5 mM sodium iodoacetate, 150 mM potassium chloride at pH 7, and pH measured on a Radiometer pHM63 digital pH meter.

Cutting and storage - At 48 h post-slaughter all sides were cut to primal joints and 1 kg samples of each of the 4 aforementioned muscles plus M. serratus ventralis (SV) were removed, divided into 3 parts, which were weighed, vacuum packed and allocated to 3, 7 or 10 days ageing at 1°C.

Assessment - After their storage period, the muscle samples were removed from packs, re-weighed to determine drip loss during storage, re-packed and cooked to a centre temperature of 78°C in a water bath at 80°C (taking between 70 and 85 min). They were then cooled in running water at 12°C for 45 min, before being removed from packs, weighed to determine cooking loss and held at 3°C overnight before texture measurement.

Toughness of each sample was determined on 10 blocks, each 15-30 mm long in fibre direction and 10 x 10 mm cross section. They were sheared perpendicular to fibre direction using Volodkervich-type jaws (Rhodes et al., 1972). First yield force (kgf) was taken as a measure of toughness.

Colour was assessed on a freshly cut surface of each raw sample removed from storage. Samples were overwrapped with an oxygen-permeable film and allowed to oxygenate for 1 h at 1°C before measurement on a Hunter Colour Difference Meter. Results were expressed as lightness, hue and saturation.

Results

pH fall

Stimulation produced marked pH falls in all 4 muscles monitored (Table 2). At 1 hour post-slaughter, pH averaged 6.44 for all muscles from HES sides compared with 6.93 for muscles from the corresponding CON sides and 6.14 from LES sides. By 7 hours post-slaughter, HES and LES muscles were near their ultimate pH values; at this time, CON muscles had mean pH value of 6.49. Values at 48 hours were similar for all muscles and averaged 5.6.

Table 2 Post-slaughter pH of stimulated (HES and LES) and non-stimulated (CON) muscles. Means of 5 sides are shown.

		pH				
Treatment	Muscle	1h	3h	7h	24h	48h
HES	Sm	6.63	6.30	5.65	5.51	5.56
	LD	6.43	6.17	5.81	5.73	5.62
	TB	6.43	6.18	5.62	5.54	5.57
	PP	6.27	5.91	5.58	5.51	5.55
CON	Sm	6.99	6.91	6.56	5.74	5.53
	LD	6.94	6.58	6.39	5.79	5.62
	TB	6.97	6.63	5.65	5.92	5.61
	PP	6.82	6.45	6.37	5.76	5.60
LES	Sm	6.11	5.85	5.61	5.57	5.62
	LD	6.04	5.76	5.67	5.64	5.66
	TB	6.53	6.33	5.92	5.61	5.60
	PP	5.87	5.72	5.64	5.57	5.70

Drip and cooking loss

Drip loss increased with storage time in most cases. Loss from all muscles and all 3 assessment times (Table 3) averaged 2.2% for HES, 2.0% for CON and 3.0% for LES.

Table 3 Accumulation of drip (% initial wt.) in vacuum packs of HES, CON and LES muscle samples at 3, 7 and 10 days post-slaughter.

	% drip								
		HES			CON			LES	
Muscle	3d	7d	10d	3d	7d	10d	3d	7d	10d
Sm	2.3	4.7	5.5	[illegible]	2.7	5.6	3.5	5.7	6.5
LD	1.2	2.3	3.0	1.2	2.6	3.0	3.8	3.2	3.6
TB	1.5	2.2	2.6	1.0	2.8	2.7	1.9	3.0	2.9
PP	0.7	1.8	2.0	0.6	1.4	2.1	0.8	2.6	2.6
SV	0.5	1.1	1.5	0.4	1.0	1.2	0.9	1.8	2.1

Cooking losses (Table 4) were unaffected by stimulation, and their magnitude relative to drip meant that their combined average losses of liquid were similar for all treatments.

Table 4 Cooking losses (% wt. before cooking) from HES, CON and LES muscle samples at 3, 7 and 10 days post-slaughter.

	% cooking loss								
		HES			CON			LES	
Muscle	3d	7d	10d	3d	7d	10d	3d	7d	10d
Sm	38.4	38.6	39.3	38.5	39.9	39.5	38.8	39.2	35.4
LD	33.8	36.3	35.6	34.7	36.5	36.9	33.6	34.5	34.6
TB	36.4	37.3	38.3	37.8	40.4	37.5	35.9	34.8	36.1
PP	36.9	35.4	36.1	36.0	35.0	36.8	35.1	34.2	35.8
SV	39.9	38.7	38.6	36.5	38.4	40.9	38.0	39.2	38.3
	Overall mean = 37.3%			Overall mean = 37.7%			Overall mean = 36.2%		

Colour

Electrical stimulation had no effect on the colour attributes, saturation (Table 5), lightness and hue in any of the muscles at any storage time.

Table 5 Surface colour (saturation) of HES, CON and LES muscle samples at 3, 7 and 10 days post-slaughter. Colour was measured after removal from vacuum packs and exposure to air for 1 h at 1°C.

	Colour saturation								
		HES			CON			LES	
Muscle	3d	7d	10d	3d	7d	10d	3d	7d	10d
Sm	15.5	20.5	21.4	14.3	19.8	21.6	18.2	21.0	19.0
LD	16.6	19.7	20.4	15.1	19.1	24.1	16.5	20.2	18.1
TB	17.5	21.6	20.5	15.7	21.9	19.2	18.8	21.0	19.2
PP	16.9	22.4	20.3	15.6	20.5	21.5	14.1	19.0	19.5
SV	16.1	17.3	19.7	15.2	16.8	21.5	15.5	18.2	17.0

Texture of cooked muscles

Mean toughness values for all muscles examined are shown in Table 6.

Table 6 Mean toughness values (mJ) of HES, CON and LES muscle samples, cooked 3, 7 and 10 days post-slaughter.

	Toughness (mJ)								
		HES			CON			LES	
Muscle	3d	7d	10d	3d	7d	10d	3d	7d	10d
Sm	194	175	186	226	204	181	224	220	249
LD	130	134	136	264	236	214	212	174	176
TB	174	170	166	170	169	172	191	184	171
PP	207	189	190	236	203	209	174	187	164
SV	205	166	148	212	181	164	179	149	151

Two analyses of variance were carried out to assess the effect of ES on cooked texture. The first was a side against side comparison of HES and CON samples; the second was a comparison of HES, LES and CON samples. In both analyses, treatments, muscles or storage times differed significantly (p<5%)

when their toughness means differed by more than about 10 mJ.

HES and CON Comparison

Overall toughness (all muscles, all animals, all treatments) at 3 days was higher than at 7 or 10 days. There was no difference in toughness between 7 and 10 days.

Toughness of SV and TB were not influenced by HES. Average toughness of Sm, LD and PP muscles from HES sides was lower than that from control sides.

HES, CON and LES Comparison

Combining results from all three treatments, toughness was highest at 3 days and there was no difference between toughness values of 7 and 10 days.

ES had no effect on toughness of TB. The SV from LES carcasses was more tender than those from CON sides, but no different from HES sides. Stimulation had significant, but inconsistent, effects on the other 3 muscles (Sm, LD and PP). HES gave most tender LD and Sm. PP muscles from LES carcasses were less tough than those from HES or CON sides. Sm muscles from LES carcasses were, averaged over 3 periods, tougher than those from HES or CON sides. LES produced LD of intermediate toughness.

Table 7 Distribution of toughness values of samples (all muscles) cooked 3, 7 and 10 days after slaughter. Approximately 10 replicates were measured on each sample. Each treatment x time combination, therefore, represents approximately 250 measurements (i.e. 2250 measurements total).

		Distribution (% 250 measurements)		
	Texture rating*	HES	CON	LES
3 days	Tender	27	6	13
	Intermediate	63	67	75
	Tough	10	27	12
7 days	Tender	30	15	20
	Intermediate	68	74	70
	Tough	2	11	10
10 days	Tender	37	21	26
	Intermediate	61	70	63
	Tough	2	9	11

*The values given are the percentage of measurements in the "tender" (<0.15J), "intermediate" (0.15 - 0.25 J) and "tough" (>0.25J) categories.

CON carcasses had 6% measurements "tender" and 27% "tough" at 3 days; frequencies for HES were 27% and 10% respectively and for LES were 13% and 12% (Table 7). At 10 days, CON measurements were 21% "tender" and 9% "tough"; frequencies for HES were 37% and 2% respectively and for LES were 26% and 11%.

Discussion

This study shows that electrical stimulation produced earlier tenderness in some muscles. The cooling for all carcasses (Table 1) was slow enough, as in the work of George *et al.* (1980), to avoid cold-shortening, and therefore, under these conditions, ES had a tenderising effect irrespective of its role in reducing cold-shortening.

The rapid pH fall in LES muscles indicates the effectiveness of correctly applied low voltage stimulation. The early attainment of low pH while the carcass is still hot is widely believed to be one of the causes of early tenderisation and therefore the LES muscles might have been expected to be more tender than the HES. However, in this study the contrary was the case and the HES muscles tended to be more tender.

Although the general level of toughness in the muscles used here was low, as would be expected with the slow cooling rate, it varied considerably between animals. Table 7 shows that within each treatment all three categories ("tender", "intermediate" and "tough") of texture were observed, even after electrical stimulation and ageing for 10 days. Superimposed on this was further variability in the effect of ES. The variability can be seen in Table 7 where, although there was a shift in distribution towards more tenderness with ES and time, 2% (HES), 11% (CON) and 10% (LES) of measurements were still classed as "tough" at 7 days, with little improvement after 10 days. Most work reported in the literature has concerned the tenderising effect in the LD and this study showed that the effect of ES was particularly pronounced in that muscle. By contrast the TB was unaffected by stimulation.

The combination of low muscle pH early post-slaughter while temperature is still above 30°C, leads to PSE-like conditions in pig meat, but there was no indication in this study that similar pH/temperature conditions induced in beef by ES and slow cooling had any detrimental effect on relevant quality attributes. Although there were differences in colour between muscles, these and the slight changes in saturation, hue and lightness were not attributable to an effect of ES.

There were considerable differences between muscles in the drip which accumulated during storage, but samples from stimulated carcasses tended to have slightly more drip than none stimulated samples. Cooking losses, which were much greater than drip losses, were largely unaffected by stimulation. Overall drip losses of 2.2% (LES), 2.0% (CON) and 3.0% (HES) were accompanied by cooking losses of 37.3%, 37.7% and 36.2%, so that total losses were similar for all three treatments.

In conclusion, although there was considerable variation in texture between animals, the combination of ES and slow cooling produced earlier tenderness in some muscles than slow cooling alone. Tenderness of unstimulated samples at 10 days was achieved in 7 days with LES and in only 3 days with HES. This advantage was achieved without any marked effect on drip, cooking loss or meat colour.

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