A report for Eblex on the effects of post-slaughter treatments on mutton quality

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R.I. Richardson

Division of Farm Animal Science
School of Clinical Veterinary Science
University of Bristol,
Langford, Bristol, BS40 5DU,
Tel 0117 928 9291, ian.richardson@bristol.ac.uk

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The effects of post-slaughter treatments on mutton quality

Summary
Forty-eight 5-6 year old barren ewes which had been grazing grass and then had had 4-5 wks of concentrate supplement were delivered to the University of Bristol abattoir in December 2011. They were slaughtered in batches of ten. The first three carcasses were processed as normal, split and alternate sides hip suspended or kept as achilles-suspended controls. The second three were processed, split and alternate sides either high voltage electrically stimulated (HVES) or kept untreated as controls. The final four were low voltage stimulated during bleeding post-slaughter (LVES) and then, after splitting, one side was also hip suspended. All carcasses were put into the chiller after splitting. The pH and temperature of the loin muscle was monitored. All sides that were electrically stimulated had a faster rate of pH fall in the first hour than those kept as unstimulated controls. None of the stimulated sides had a pH below 6.00 before the temperature fell below 35ºC. Loin muscles boned from the carcass the morning following slaughter were divided in two and aged for 7 or 14 days. Samples were scored by an experienced sensory panel.

- HVES of a side, but not hip suspension of a side alone, produced meat that was more tender than the control side of the same animal.
- LVES alone produced meat that was more tender than control animals from the same kill.
- Adding hip suspension to low voltage electrical stimulation did not improve tenderness further.
- Ageing meat to 14 days post-slaughter improved tenderness over 7 day aged meat whatever the other treatments.
- Ageing controls from 7 to 14 days produced meat as tender as the 7d HVES or LVES meat, but ageing combined with HVES produced more tender meat than its aged control equivalent.

Ageing mutton to 14 days post-slaughter produced more tender meat than that aged 7 days, but low or high voltage electrical stimulation will improve mutton tenderness over non-stimulated controls, particularly if only aged for 7 days before consumption. Aging for a further 7 days will confer extra advantage. Hip suspension does not appear to have any benefit for mutton loin muscle tenderisation.

Introduction

Consumer research on red meat eating quality has shown that the most important attribute in determining acceptability is tenderness, but when tenderness is increased and variability decreased then flavour increases in relative importance (Warkup et al., 1995). Low voltage electrical stimulation (LVES) was developed to counter cold shortening toughening in beef and lamb (Chrystall and Hagyard, 1976) though now the interpretation is more that stimulation exerts its main effects through inducing early *rigor mortis* and thus allowing ageing to begin at higher temperatures (Devine et al., 2001). Hip suspension, aitch bone suspension or tenderstretch (HS) of a carcass, rather than hanging from the achilles heel, improves tenderness by stretching muscles and avoiding cold shortening (Bouton and Harris, 1972; Bouton et al., 1973). HS has been widely adopted in Ireland and the UK (Tarrant, 1968) as a means of ensuring more tender meat and combinations of electrical stimulation (ES) and HS together with ageing, also known as conditioning or maturation, have been adopted as part of the blueprints for tender beef, lamb and pork developed by MLC (now EBLEX, BPEX, QMS and HCC; Warkup, 1993).

These systems have been further developed in Australia and are summarised in Meat and Livestock Australia publications as: LVES or high voltage electrical stimulation (HVES) should be used unless ageing times longer than 10 days (e.g. when exporting meat) can be employed when meat should enter rigor (pH 6.0) at 8-18ºC, otherwise with ES at 18-25ºC. HS can be employed alone with a minimum of 5 days ageing. Mutton, well trimmed of fat, is as well appreciated as hogget meat, possibly superior in flavour but tougher than lamb for loin, although leg cuts are always inferior (MLA website). This information is published in research papers reviewed by Hopkins (2011).

Whilst a number of studies have shown that ES is effective, it is very important to understand all the conditions of pH and temperature decline, particularly with LVES, as the correct rate of pH decline and ageing can produce tender meat without ES. In such circumstances, animal history can have a greater effect than ES (Hopkins, Littlefield and Thompson, 2000). Hence, whilst Davel, Bosman and Webb (2003) found no effect of LVES on consumer acceptance of mutton (sheep had two permanent incisors, no age given), two papers by Turkish authors showed more positive effects of ES and ageing in older sheep. Five year old ewes were used which had been fed on grass supplemented with concentrates. Ageing for 7 versus 1 day significantly improved instrumental and sensory panel tenderness ratings (Yanar and Yetim, 2001). In a later experiment they studied the effect of LVES on tenderness of meat from 3-5 year old ewes. ES significantly improved tenderness as rated by taste panel and instrumental texture for loin but not m. *semimembranosus* (Yanar and Yetim, 2003). Møller et al. (1983) showed that HVES was beneficial when muscles were not restrained by stretching. HVES, HS and HVES/HS muscles were all significantly more tender than the non-treated controls but not from each other. In one of the few experiments comparing both young lamb and older mutton, Thompson et al. (2005) showed that age category (lamb vs mutton) had the greatest effect on tenderness followed by muscle type, ageing and muscle suspension. The highest sensory scores were obtained for muscles from carcasses going into rigor (pH 6.0) at around 21°C for normally hung carcasses whilst HS negated any effect of temperature at rigor. The specific effect of ES was not reported, but was used to produce rigor at different temperatures. Tenderness was improved by ageing the meat 5 days instead of two with little further improvement when aged to 14 days. They concluded that if temperature at rigor was controlled then HS was not necessary, though it would be a safeguard at extremes of rigor attainment temperature. Similarly, Bouton, Harris and

Shorthose (1984) showed that when rigor was attained below 15ºC then ES prevented shortening-induced toughening in mutton carcasses, but above 15ºC, ES had the same effect as a few days ageing.
Mutton is tougher than lamb and may require further ageing. Thompson et al. (2005) showing benefits up to 14 days. Ageing mutton for 9 days significantly improved Warner-Bratzler texture, whilst a further small reduction was noted after 21 days ageing. However, a similar reduction was obtained after 2 days, when the carcasses were pelvic suspended, as was obtained after 9 days ageing (Bouton et al., 1973).

Experimental plan.

Forty-eight sheep were assembled by the buyer of a Midlands-based abattoir. These sheep were 5-6 year old barren ewes which had been grazing grass and then had had 4-5 wks of concentrate supplement. They were delivered to the abattoir at Langford in December 2011 and held in lairage overnight. On the day of slaughter they were stunned in batches of ten. The first three carcasses were processed as normal and split at which point one side (right for first batch, alternating thereafter) was high voltage electrically stimulated (HVES) for 45 seconds. The other side was used as a control (untreated). The next three carcasses were also not stimulated in the bleed tunnel, but after splitting one side was hip suspended, the other left untreated as a control. The final four carcases in the batch were low voltage electrically stimulated (90v for 60 seconds), one minute after bleeding commenced. After splitting one side was also hip suspended the other left as Achilles hung. These treatments were repeated for a total of four batches, to give 12 carcasses for the C/HVES and 12 for the C/HS treatments as shown in table 1. A further 11 carcasses were subject to LVES and alternate sides either hip or achilles suspended. Three of these carcasses were used to train the sensory panel, giving a total of 20 experimental sides for the HVES/HS treatments as in table 1. One hour after slaughter pH and temperature were measured and this was repeated at 2 and 3 hours post-slaughter for some carcasses so that we could determine the temperature at which the muscles went into rigor.

Following chilling, at 18-24h post-slaughter, the whole of the loin muscle was boned out of each side and divided into two. The proximal and distal portions of each loin per treatment were allocated alternatively to either 7 or 14 days ageing in vacuum bags at 1ºC, after which time they were frozen until used for sensory assessment.

The day before sensory assessment, samples were thawed initially at room temperature (6 h) and then kept at 4 _C overnight. On the morning of sensory assessment, the loin was cut into 2.0-cm-thick steaks which were placed under a domestic grill (Tricity Double Oven and Grill, Model 2142, Thorn Domestic Appliances, England, UK) and cooked, turning every 3 min, to an internal muscle temperature of 75 °C as measured by a thermocouple probe (Comark, Model 9001, fitted with a K type thermocouple, Stevenage, Hertfordshire SG1 2TA, UK) inserted into the approximate geometric centre of each steak. Panel assessors were selected and trained according to BS 7667 (BSI, 1993) and received additional training in the tenderness, juiciness and flavour of mutton. They scored attributes were scored on an 8-point scale for tenderness (1 = extremely tough to 8 = extremely tender), juiciness (1 = extremely dry to 8 = extremely juicy), lamb flavour intensity (1 = extremely weak to 8 = extremely strong), abnormal flavour intensity (1 = extremely weak to 8 = extremely strong) and the hedonic measures flavour liking (1 = dislike extremely to 8 – like extremely)and overall liking (1 = dislike extremely to 8 – like extremely).

Table 1. Work plan as carried out

n	20				12				12			
during bleeding	LVES											
after splitting	HS		NHS		C		HVES		C		HS	
aged (d)	7	14	7	14	7	14	7	14	7	14	7	14

C = control; LVES = low voltage stimulation; HVES = high voltage stimulation; HS = hip suspension; NHS = no hip suspension

Control and either hip suspension or HVES was compared within a carcass (n=12). The 24 controls were used in comparison with the 20 LVES sides which were either HS or NHS. The least comparison was between 12 HS and 20 LVES/NHS and 20 LVES/HS samples, but this is the least important comparison.

Results

The cold carcass weights for the HVES/C, C/HS and LVES/HS animals were 31.0, 30.4, 29.4 kg respectively. These were not statistically significantly different (Table 2). The values ranged from 23.9 – 38.6 kg and the range distribution is shown in Figure 1. The stimulated sides had a significantly lower pH than the non-stimulated sides. The pH of the LVES sides was not significantly different from HVES sides. Side temperatures were not significantly different between treatments. The important parameter is that no side should cool below 10-12 ºC before the pH has dropped below 6.00 to avoid cold shortening. Lamb carcasses and loin muscles are small and cool quickly Those sides not electrically stimulated were cooling fast enough to give some carcasses whose pH was still above 6.00 three hours after slaughter when the temperature was approaching 10 ºC. Equally, when stimulated, the pH should not drop below 6.00 before the muscle has cooled below 35 ºC. It can be seen from Table 2, that at one hour post slaughter, the loin muscle temperatures had dropped below 30ºC but the pH values were still above 6.00, so there was little chance of heat shortening and toughening.

Table 2. Cold carcass weight and one hour post-mortem temperature and pH at the centre of the loin muscle.

	HVES	C1	HS	C2	LVES/C	LVES/HS	p
pH	6.33^{a}	6.76^{b}	6.74^{b}	6.75^{b}	6.19^{a}	6.16^{a}	<0.001
t °C	27.3	26.6	26.9	26.3	27.7	27.4	ns
CCWT kg	31.0		30.4		29.4		ns

CCWT mean 29.8±3.20 stdev range 23.9-38.6

[ab] values with different superscripts are significantly different($p<0.05$)

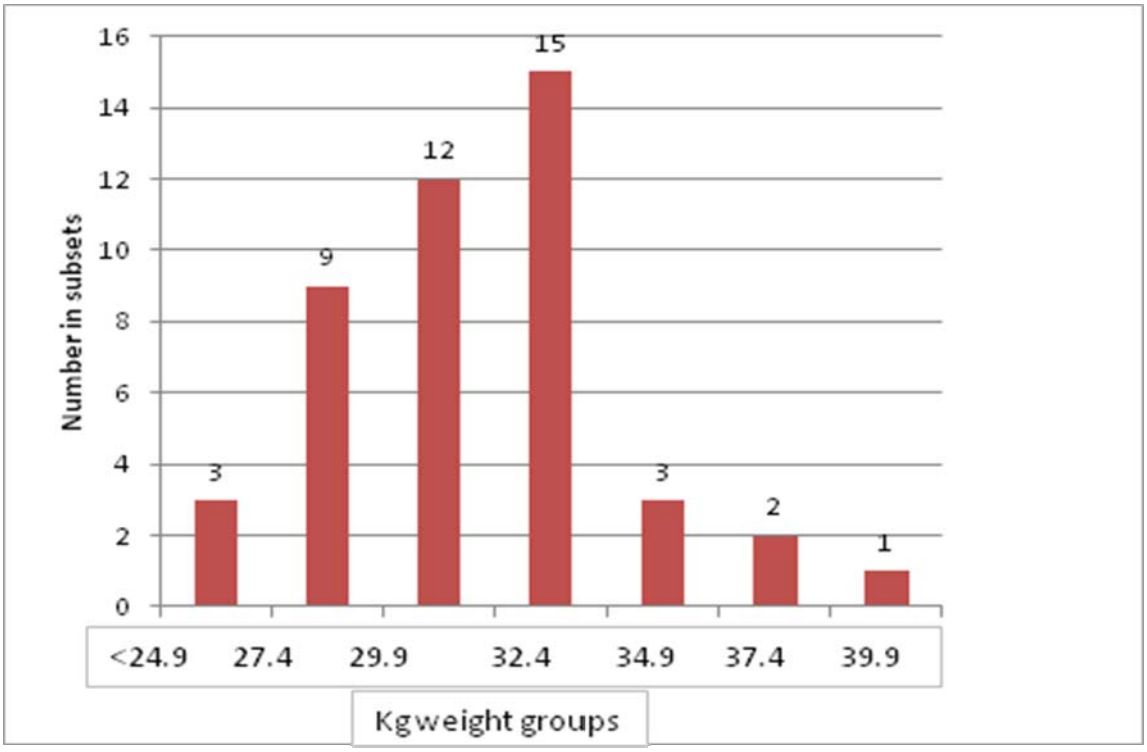

Figure 1. Distribution of ewe cold carcass weights

Table 3. Effect of HVES or hip suspension on the eating quality of griddled mutton loin steaks.

	control 1	HVES	control 2	HS	p	lsd
Tenderness	4.82[a]	5.14[b]	5.00[a]	5.01[a]	0.049	0.227
Juiciness	5.36	5.33	5.48	5.40	0.231	
Lamb Flavour	4.67	4.76	4.82	4.75	0.764	
Abnormal Flavour	2.33	2.26	2.15	2.28	0.479	
Flavour Liking	5.34	5.42	5.61	5.45	0.120	
Overall Liking	5.01 [a]	5.25 [ab]	5.39 [b]	5.24 [a]	0.051	0.278

[ab] values with different superscripts are significantly different($p<0.05$)

The direct comparison between opposite sides within the same carcass is very powerful for showing whether HVES or hip suspension (HS) produces more tender mutton. The control 1 vs. HVES comparison shows that HVES does indeed produce more tender meat whilst the Control 2 vs. HS comparison shows that HS does not improve the tenderness of the loin samples. There appears to be an anomaly in that the control 2 samples were significantly preferred more overall than the control 1 and HS samples which seems to be governed by a non-significant flavour trend. As the Control 1 and Control 2 are not significantly different from one another for tenderness, they were combined for further comparisons.

In Table 4 it can be seen that ageing time had a big effect on tenderness of the mutton loin steaks, with most 14 day samples being significantly more tender than their 7 day aged equivalents. The 7 d HVES samples are almost significantly more tender than the Control 7 day samples. When the two controls were analysed separately, then the HVES 7 day and HVES 14 d were significantly more tender than the control 7 and 14 days respectively (not shown).

Table 4 Effect of post slaughter treatment and ageing time on eating quality of griddled mutton loin steaks.

treatment ageing time	Control 7 days	Control 14 days	HS 7 days	HS 14 days	HVES 7 days	HVES 14 days	p	lsd
Texture	4.72[a]	5.10[b]	4.82[a]	5.20[b]	4.98[ab]	5.30[b]	<0.001	0.326
Juiciness	5.39	5.44	5.44	5.36	5.25	5.41	0.44	
Lamb Flavour	4.73	4.75	4.76	4.74	4.69	4.83	0.99	
Abnormal Flavour	2.15	2.34	2.39	2.17	2.24	2.28	0.43	
Flavour Liking	5.53	5.43	5.35	5.56	5.35	5.49	0.74	
Overall Liking	5.18	5.22	5.15	5.32	5.15	5.34	0.85	

[ab] values with different superscripts are significantly different($p<0.05$)

Table 5. Effect of LVES, with or without HS, or ageing time on eating quality of griddled mutton loin steaks.

	LVES					
	HS	NHS	p	7 days	14 days	p
Tenderness	5.22	5.16	0.365	5.06	5.32	<0.001
Juiciness	5.40	5.47	0.278	5.40	5.47	0.278
Lamb Flavour	4.69	4.69	0.979	4.67	4.71	0.694
Abnormal Flavour	2.13	2.17	0.646	2.14	2.16	0.793
Flavour Liking	5.55	5.46	0.393	5.52	5.49	0.720
Overall Liking	5.33	5.26	0.504	5.26	5.33	0.504

In Table 5 it can be seen that in a direct comparison between sides, adding HS on top of LVES did not further enhance the tenderness of loin steaks. In a 2x2 analysis days but not treatment were significantly different, with ageing for 14 days improving tenderness over ageing 7 days from slaughter.

Table 6. Effect of LVES with or without HS in comparison to the control carcasses on eating tenderness of griddled mutton loin steaks.

		LVES						
	C	HS	NHS	p	lsd	7 days	14 days	p
N	48	40	40			64	64	
Tenderness	4.91[a]	5.23[b]	5.15[b]	<0.001	0.154	4.94	5.25	<0.001

[ab] values with different superscripts are significantly different($p<0.05$)

In Table 6 the values for the control are compared with the LVES with or without HS samples. In this comparison the control are different animals slaughtered on the same day in the same batch. As LVES is performed post-stun in the bleed area on the whole carcass we cannot produce a within carcass control. The trained sensory panel is very experienced and prior tests have shown that they have very good repeatability. To ensure as close a comparison as possible, LVES samples were in panels alternating with panels containing C/HVES or C/HS samples. The effect of age was tested within panel. Hence, a comparison of between animal and between panels should be reliable. Only tenderness showed a significant difference. LVES, with or without HS, samples were more tender than the controls.

Table 7 shows all the results combined in the one table. The same provisos as above apply. There were no statistical interactions so effect of treatment and effect of ageing are shown separately. In this comparison HS and HVES alone are not significantly different from the combined control, but see table 3 for a direct comparison with their own individual controls. LVES with or without HS were significantly more tender than the combined controls. The results for HVES and LVES samples are not different.

Table 7. Effect of treatments or ageing time overall on eating quality of griddled mutton loin steaks.

	C	HS	HVES	LVES/HS	LVES/NHS	p	day7	day14	p
Tenderness	4.91[a]	5.01[ab]	5.14[ab]	5.23[b]	5.15[b]	<0.001	4.93	5.25	<0.001
Juiciness	5.42	5.40	5.33	5.40	5.47	0.413	5.38	5.43	0.299
Flavour	4.74	4.75	4.76	4.69	4.69	0.950	4.71	4.74	0.622
Abn Flavour	2.24	2.28	2.26	2.13	2.17	0.506	2.21	2.22	0.860
Flavour liking	5.48	5.45	5.42	5.45	5.46	0.833	5.46	5.48	0.749
Overall liking	5.20	5.24	5.25	5.33	5.26	0.778	5.21	5.31	0.972

[ab] values with different superscripts are significantly different($p<0.05$)

Whilst we cannot do a direct comparison, this panel tested several hundred lamb samples over the summer of 2011. The scores they gave for those lamb samples were very similar to those given here. The tenderness of the lamb samples was slightly higher, numerically of the order of 5.3 to 5.7, starting at the upper end of the mutton scores. However, comment from the panellists was that they found these mutton samples very acceptable and only occasionally noted some stronger more 'offally flavours' which are often comments for well aged meat. A full list of comments was: slightly acidic, slightly bitter, oily taste, slightly soapy, slightly livery, slightly kidney, sharp vinegar, metallic and fishy. Not all panellists chose to comment and comments only applied to a minority of samples and did not produce high abnormal flavour scored, as witnessed by the results above.

Conclusion

Electrically stimulating old ewe carcasses produces a more rapid pH fall as for lamb carcasses. All sides that were electrically stimulated had a faster rate of pH fall in the first hour than those kept as unstimulated controls.

None of the stimulated sides had a pH below 6.00 before the temperature fell below 35ºC, thus there would be no heat shortening, toughening of the muscle and increased drip from the meat if stored in vacuum bags.

The results from the professional sensory panel showed:

- HVES of a side, but not hip suspension of a side alone, produced meat that was more tender than the control side of the same animal.
- LVES alone produced meat that was more tender than control animals from the same kill.
- Adding hip suspension to low voltage electrical stimulation did not improve tenderness further.

- Ageing meat to 14 days post-slaughter improved tenderness over 7 day aged meat whatever the prior treatment.
- Ageing controls from 7 to 14 days produced meat as tender as the 7d HVES or LVES meat, but ageing combined with HVES produced more tender meat than its aged control equivalent.

Ageing mutton to 14 days post-slaughter produced more tender meat than that aged 7 days, but low or high voltage electrical stimulation will improve mutton tenderness over non-stimulated controls, particularly if only aged for 7 days before consumption. Aging for a further 7 days will confer extra advantage. Hip suspension does not appear to have any benefit for mutton loin muscle tenderisation.

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