The Effect of Low Voltage Stimulation under Controlled Conditions on the Tenderness of Three Muscles in Lamb Carcasses

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ABSTRACT: Under controlled conditions over 3 slaughters, low voltage electrical stimulation significantly (p<0.05) increased the rate of pH decline in 12 lamb carcasses when applied 15 minutes after slaughter compared to that in 12 unstimulated carcasses. Day of slaughter had a significant (p<0.05) impact on the rate of pH fall, but there was no significant interaction between stimulation and day of slaughter. While stimulation reduced the number of meat samples with Warner Bratzler (WB) shear force values > 5kg, in loin muscle, it did not significantly reduce mean values for any of the three muscles tested (loin, topside, eye of round). The topside was the toughest, followed by the loin and lastly the eye of round. Cooking loss was unaffected by stimulation, but was lower in the topside and eye of round taken from carcasses sampled on the first day of slaughter. Under the chilling conditions used in the experiment electrical stimulation provided little enhancement of product quality.

Key words: Tenderness, Lamb, pH, Stimulation

INTRODUCTION

In many cases low voltage (LV) stimulation of lamb carcasses has not significantly reduced the shear force of cooked meat compared to that from unstimulated carcasses (Shaw et al., 1996; Hanrahan et al., 1998; Hopkins et al., 2000). However in most cases stimulation did reduce the number of tough samples (ie. > 5-kg shear force). Shaw et al. (1996) argued that recent results did not support earlier recommendations that LV stimulation had to be applied soon after exsanguination to be effective, and data presented by Simmons et al. (1997) supported this conclusion. These workers also found that length of stimulation (60 vs 120 seconds) had no effect on subsequent shear force values, and in all treatments apart from the control carcasses there was no effect of length of stimulation on the rate of pH fall, although there was large variation between individual carcasses in the rate of pH fall. In these studies the effectiveness of stimulation was generally not reported and this may explain some of the between carcass variation. Based on their results Simmons et al. (1997) suggested that the response to LV stimulation was determined by the history of the animal rather than the processing conditions.

This paper reports on a study that was conducted under controlled conditions which enabled examination of the effectiveness of LV stimulation and the impact on shear force values for 3 muscles.

MATERIALS AND METHODS

1. Experimental design

Twenty-four wether lambs were slaughtered over 3 weeks, in 3 lots of 8. These lambs were sourced from the same flock and had been run together until slaughter. Two weeks before the first slaughter they were housed on a slatted floor, fed pellets and lucerne hay/chaff. On the morning of each slaughter 10 lambs were taken to the experimental abattoir. Two lambs were used as companion animals to reduce stress on slaughtered lambs. These lambs were returned to the animal house after slaughtering had finished. Lambs were slaughtered using a captive bolt followed by exsanguination. Every second carcass was stimulated with a LV unit, approximately 15 minutes after death (45 V, for 40 seconds, with 36 pulses per second and a pulse width of 25 milliseconds; H.E. Technologies, Qld, Australia). Carcasses were suspended by a gambrel through the Achilles tendon and stimulated using two multi-point probes inserted into the hindlegs and joined together to form one electrode. At the first slaughter the other electrode was clipped to the neck muscles for the first 2 carcasses and thereafter a skewer was inserted into the neck muscles and the electrode clipped the skewer. For the second and third slaughters a metal prong was used to improve current flow. A monitor (Model TP3/4, H.E. Technologies, Qld, Australia) was used to test the effectiveness of stimulation. The carcasses were chilled at 6°C for between 17-22 hours. Temperature decline was determined using Cox recorders (Belmont, NC, USA). Probes were inserted into the m. semimembranosus (SM; to the depth of the femur) and the center of the m. longissimus thoracis et lumbarum (LL).

2. Sampling and measurements

At regular intervals after the commencement of chilling pH was measured in the left hand portion of the LL between the 10th and 12th ribs using an Orion meter with temperature compensation (Model 250 A, Orion Research International, MA, USA) and an Ionode JJ 42 electrode. A minimum of 6 measurements were taken as the pH fell, with one coinciding with a pH of approximately 6.1. After the chilling period carcass weight and fat depth over the LL at the 12th rib were measured and the portion of the LL between the 1st lumbar and the chump was removed from the left side of the carcass. The topside (SM) and eye of round (m. semitendinosus; ST) from the right side of the carcass were also removed along with a portion of the LL between the 12th rib and 1st lumbar on the left side of the carcass.

From each SM and ST a 65-gram block was prepared 1 day postmortem and held at 2.3°C for 1 day. On day 2 these blocks were wrapped in plastic and placed in plastic bags for storage at -20°C exactly
48 hours postmortem. The portions of LL from between the first lumbar and the chump were divided into 2 portions on day 1 and assigned to aging periods of 1 or 2 days based on randomization. Portions to be aged were vacuum packed and held at 2.3°C. The subcutaneous fat and epimysium were removed from the LL portions for preparation of 65-gram cooking blocks which were wrapped in plastic and placed in plastic bags for storage at -20°C until subsequent shear testing. Only portions aged for 2 days are considered in this paper. The portions of LL taken between the 12th rib and 1st lumbar were frozen on day 1.

Ultimate pH was measured on the portion of LL taken between the 12th rib and 1st lumbar after thawing at 2.3°C for 24 hours. Samples for shear testing were cooked from frozen for 35 minutes at 70°C in an 80L waterbath (Hopkins et al., 1999). Cooking loss was calculated by dividing the dry cooked weight by the frozen weight, subtracting this value from 100 and expressing values as percentages.

From the LL and SM muscles, six samples of 1cm² cross-section were cut parallel to the muscle fibres and tenderness measured with a Warner-Bratzler shear blade fitted to a Lloyd texture meter. For the ST muscle only 5 samples could be cut.

3. Statistical analysis

Data were analysed using a GLM procedure in SAS (1996) with terms for stimulation (stimulation vs no stimulation), day of slaughter and the first order interaction term. For the LL, portion was included as a main effect and all first order interactions tested. Shear force and cooking loss of the 3 muscles were tested, as was the time required for the pH to reach 6.1. Ultimate pH was also tested as was carcass weight and fat depth over the LL at the 12th rib. Least square means were compared using the PDIFF statement.

RESULTS

During stimulation of the first 2 carcasses the monitor indicated that the current flowing through the carcasses (~200 mA) was not optimal despite the fact that the carcasses were visibly stimulated and this current was the minimum recommended for the unit. As noted already this prompted a change in how the neck electrode was attached. Of the 2 remaining stimulated carcasses slaughtered on day 1, the use of the skewer resulted in 1 carcass receiving 240 mA. For all subsequent carcasses current was administered at 240 mA. Carcass weight and fat depth of stimulated and control carcasses were similar (overall means of 26.2 kg and 4 mm for carcass weight and fat depth respectively). For pH measured at various times, shear force and cooking loss of the SM and ST muscles the interaction between stimulation and day was not significant (p=0.05). For a number of the traits stimulation and day were significant (p<0.05) as shown in Table 1.

For LL shear force and cooking loss the significance of the main effects is shown in Table 1. None of the interaction terms were significant (slaughter day x stimulation, slaughter day x portion and stimulation x portion), although for the latter term the probability for shear force approached significance (p = 0.06). Stimulation caused pH to drop significantly faster than in control carcasses as shown in Table 1. There was no overlap in the time for pH to reach 6.1 between stimulated and non-stimulated carcasses with ranges of 0.34-2.75 and 3.02-7.82 hours respectively. At 24 hours pH was not significantly (p>0.05) different between treatment groups, although slaughter day had a significant effect (p<0.05). It took on average 8.6 hours for the longissimus temperature to reach 8°C. Stimulation had no significant effect on shear force in any muscle. The number of high shear force values for stimulated LL muscle was reduced however.

DISCUSSION

The data clearly shows that LV stimulation resulted in a more rapid decline in muscle pH, as shown by Hopkins and Ferrier (2000) using the same LV unit under commercial conditions. The time to reach a pH of approximately 6.0 was of the same order of magnitude as that found by Whiting et al. (1981) using a 280/420 V unit and Yanar et al. (1999) using a 350 V unit and less than found by Polidori et al. (1999) who used a 28 V unit. It is noteworthy that day of slaughter had a significant impact on the rate of pH fall independent of stimulation and that there was no interaction between the two effects. Thus the fact that not all carcasses received the maximum current on the first slaughter day can not be implicated in the differing rate of pH fall. This was supported by the fact that there was a difference in the rate of pH fall between the second and third slaughter days. Simmons et al. (1997) suggested that animal history rather than processing conditions was responsible for the variable response of pH fall to LV stimulation found in their work. Lambs used in our experiment had a similar history and were fed and handled the same prior to slaughter so it would seem unlikely that these factors contributed to the variability. Even though ambient temperature may have differed between slaughter days in our experiment, the data of Simmons et al. (1997) revealed that holding muscle at a constant pre-rigor temperature did not reduce the variability in pH fall of stimulated carcasses. Daly (1997) proposed that variability in pH fall after stimulation may reflect differences in the rate at which ATP is resynthesised and that this was likely to be influenced by the parameters of the electrical inputs and the metabolic state of the muscle when stimulated. It would seem the latter aspect may be the more important from our data, but there is no clear explanation for the day effect observed. What it does mean is that processing systems based on LV stimulation will by inference result in variability.
Table 1. Predicted means (s.e.) for meat quality traits for three muscles (m. semimembranosus; SM; m. semitendinosus; ST and m. longissius thoracis et lumborum; LL) from control and electrically stimulated (stim) carcasses with significant main effects indicated

<table>
<thead>
<tr>
<th>Traits</th>
<th>Muscle</th>
<th>Model terms</th>
<th>Stim means</th>
<th>s.e.</th>
<th>Slaughter day means</th>
<th>s.e.</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stim</td>
<td>Day 1</td>
<td>Day 2</td>
<td>Day 3</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Portion</td>
<td>Control</td>
<td>Stim</td>
<td></td>
</tr>
<tr>
<td>Time to pH 6.1 (hrs)</td>
<td>LL</td>
<td>*** **</td>
<td>4.46a</td>
<td>1.04b</td>
<td>0.22</td>
<td>3.64a</td>
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<tr>
<td>Ultimate pH</td>
<td>LL</td>
<td>ns **</td>
<td>5.49a</td>
<td>5.48a</td>
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<td>5.45a</td>
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<tr>
<td>Shear force (kg/cm²)</td>
<td>SM</td>
<td>ns **</td>
<td>5.06a</td>
<td>4.86a</td>
<td>0.37</td>
<td>4.51a</td>
</tr>
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<td>Cooking loss (%)</td>
<td>SM</td>
<td>ns **</td>
<td>16.1a</td>
<td>15.3a</td>
<td>0.63</td>
<td>12.8a</td>
</tr>
<tr>
<td>Shear force (kg/cm²)</td>
<td>ST</td>
<td>ns **</td>
<td>3.81a</td>
<td>3.74a</td>
<td>0.08</td>
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<tr>
<td>Cooking loss (%)</td>
<td>ST</td>
<td>ns **</td>
<td>12.1a</td>
<td>12.0a</td>
<td>0.64</td>
<td>9.8a</td>
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<tr>
<td>Shear force (kg/cm²)</td>
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<td>ns **</td>
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<td>4.54a</td>
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<td>Cooking loss (%)</td>
<td>LL</td>
<td>ns **</td>
<td>18.1a</td>
<td>18.0a</td>
<td>0.64</td>
<td>17.6a</td>
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<tr>
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<td></td>
<td>5</td>
</tr>
<tr>
<td>Number &gt; 5.8 (kg/cm²)</td>
<td>ST</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Number &gt; 5.8 (kg/cm²)</td>
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<td></td>
<td>4</td>
<td></td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

ns; not significant, ** p < 0.05, *** p < 0.001. Values followed by the same letter in a row (a, b, c) are not significantly different (p < 0.05)

The variability in pH fall between slaughter days did not however translate into an effect on shear force. Although stimulation lowered the mean shear force of each of the three muscles tested it did not cause a significant improvement compared with the controls as reported previously for LV systems (Shaw et al., 1996; Hanrahan et al. 1998; Hopkins and Ferrier 2000). By contrast both Simmons et al. (1997) and Polidori et al. (1999) did find a significant reduction in shear force after using LV systems. Interestingly in both these reports 10 measurements were taken per sample for shear force and Hopkins and Ferrier (2000) have discussed the impact of this on the detection of a significant effect, whereby more measures reduces the sampling error. It could be argued that chilling temperature would impact on the response to LV stimulation and in our work the temperature was relatively high compared to that used by Shaw et al. (1996), Simmons et al. (1997), Polidori et al. (1999) and Hopkins and Ferrier (2000) where the range was from –1 to 4°C, but this did not always correlate to a significant improvement in these studies.

Shaw et al. (1996) showed a reduction in the number of ‘tough’ samples in stimulated carcasses reducing the probability of consumers being presented with an undesirable eating experience and there was evidence of this reduction in the LL muscle of our carcasses. There was however no difference for the other two muscles tested. In the work reported by Shaw et al. (1997) there were situations where LV stimulation also reduced the number of ‘tough’ topside samples, but mean values were not significantly lower than control samples. As in our work, Shaw et al. (1997) showed the topside to be tougher on average than the loin as shown in other studies also (e.g. Bouton and Harris 1972).

Comparative data on the shear force of the ST in lambs is not available. However differences between muscles will depend on processing conditions and the age of the animals from which the muscles are taken. For example Shorthose and Harris (1990) showed in beef that the tenderness of ST and LL muscles from young cattle were similar when cold induced shortening was prevented, but the toughness of the ST increased at a faster rate as animals became older.

Given there was no significant effect of LV stimulation on the mean shear force levels in the study of Hanrahan et al. (1998), it suggests that stimulation may have effected juiciness of the meat, given the consumer response. However we found no effect of stimulation on cooking loss in agreement with the results of Shaw et al. (1997) and Hanrahan et al. (1998). There was an effect of day on the cooking loss of both the SM and ST muscles which may have been related to the slower pH fall on this day.

**IMPLICATIONS**

LV stimulation of the waveform and frequency used in this study did not significantly improve tenderness or reduce variability. The lamb industry must investigate and adopt methods that reduce the variability in quality, but this will not always occur when LV stimulation is used. One alternative is HV stimulation.

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