The Tenderness of Lamb Meat after Low Voltage Stimulation under Commercial Conditions

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ABSTRACT: Under commercial conditions, electrical stimulation significantly (p < 0.05) increased the rate of pH decline in lamb carcasses when applied more than 20 minutes after slaughter. While stimulation reduced the number of meat samples with Warner Bratzler (WB) shear force values > 5kg, there was a non-significant trend to reduce the overall mean of shear values for stimulated samples. Of the control samples a number (44%) had WB values above 8.3 kg with no stimulated samples exceeding this level. Meat colour remained unaffected by electrical stimulation. Electrical stimulation provides a means to reduce the variability of lamb meat quality hence improving the product quality reaching consumers.

Key words: Tenderness, Lamb, pH, Stimulation

INTRODUCTION

With increased competition from other protein sources the lamb industry must adopt methods to improve the eating quality of lamb meat. The major characteristic of concern is the tenderness of cooked lamb, which has been found to exceed acceptable levels by up to 15% in surveys of Sydney retail outlets (Hopkins et al., 1995). In fact a more recent study in four Australian cities, has found that on average tenderness exceeds the 5-kg Warner Bratzler (WB) shear force level in 20% of samples (Channon and Payne 1998). With the development of branded lamb products and supply alliances between producers and the processing industry there has also been an increased focus on lamb meat quality Hopkins and Considine (1998). One approach that industry has at its disposal to reduce the level of non-compliance is electrical stimulation. Although high voltage (HV) stimulation has been shown to be effective at enhancing tenderness (Shorthose et al., 1986), the adoption has been low. Shaw et al. (1996) reported that low voltage (LV) stimulation could be used to reduce the mean tenderness of lamb muscles and the variation in tenderness. This type of stimulation is safer and also potentially less expensive, particularly where installation in an existing abattoir is contemplated.

This paper reports on a study that was conducted under commercial conditions to examine whether a LV stimulation system would be useful for lowering the shear force of lamb longissimus muscle.

MATERIALS AND METHODS

1. Experimental design and measurements

Thirty-two lamb carcasses from a lot of 100 sucker lambs were randomly selected in pairs from the slaughter chain of a commercial abattoir. One carcass of each pair was an untreated control and the other was stimulated with a LV unit twenty-eight minutes after death (45 V, for 80 seconds, with 36 pulses per second and a pulse width of 25 milliseconds; H.E. Technologies, Qld, Australia). For stimulation the carcasses were suspended by a gambrel through the Achilles tendon and the gambrel was hung from the hanging rail by plastic hooks. Two multi-point probes were inserted into the hindlegs and joined together to form one electrode. The other electrode was clipped to the neck muscles. The pH of the m. longissimus was measured using a Jenco 6009 meter with temperature compensation and an Ionode IJ42 electrode from the time of stimulation and repeatedly during chilling at 2°C for 9 hours. Temperature sensors (Cox recorders, Belmont, NC, USA) were used to monitor temperature decline in the longissimus muscle of 7 carcasses from each group. Hot carcass weight and GR (total tissue depth at the 12th rib 110 mm from the midline) were also measured.

At approximately 24 hours, pH was measured and the right side loin muscle removed from each carcass between the 12th/13th rib and the chump. Meat colour was measured on the longissimus muscle surface after 30 minutes of blooming with a chromameter Model CR-300 set on the L*, a*, b* system (where L* measures relative lightness, a* relative redness and b* relative yellowness). The chromameter was operated using Illuminant C and a white tile standard (Y=93.1, \(x=0.3135\), \(y=0.3197\)). Three replicate measurements were taken with special effort to avoid areas of connective tissue or intramuscular fat. The samples were then transported chilled to a laboratory where samples of each muscle were denuded of fat and epimysium and 80 gram blocks cooked in a water bath at 80°C to an internal temperature of 76°C. After cooking, samples were cooled under running cold water, for 30 minutes and blotted dry. Cooking loss was calculated by dividing the cooked weight by the pre-cooked weight. From each muscle, five samples of 1cm\(^2\) cross-section were cut parallel to the muscle fibres and tenderness measured with a Warner-Bratzler shear blade fitted to an Instron Universal Testing machine (Model 4301).

2. Statistical analysis

Carcass and meat quality data were analysed using an analysis of variance with stimulation as the main effect (stimulation vs no stimulation). Carcass weight was used as a covariate for GR measures. pH data were averaged across carcasses within treatment groups for each measurement time.
Equations were developed using a non-linear procedure (SAS 1996) to describe the relationship between muscle pH and time, using the function:

\[ \text{pH} = \text{pH}_i + (\text{pH}_f - \text{pH}_i) \exp^{-kt} \]

where \( \text{pH}_i \) = the pH at time of stimulation which taken as 7.1 in all cases and \( \text{pH}_f \) = the final pH (24 hours), \( t \) = the time in hours and \( k \) = rate constant of pH decline. When the parameters of both models were derived pH values were predicted at each measurement time and these results plotted for both treatments.

**RESULTS**

The carcass characteristics of the two treatment groups were similar as shown in Table 1.

<table>
<thead>
<tr>
<th>Traits</th>
<th>Control</th>
<th>Stimulation</th>
<th>s.e.</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot carcass weight (kg)</td>
<td>18.9</td>
<td>19.5</td>
<td>0.39</td>
<td>ns</td>
</tr>
<tr>
<td>GR (mm)</td>
<td>10.6</td>
<td>12.6</td>
<td>0.75</td>
<td>ns</td>
</tr>
<tr>
<td>pH (3 hours post-stimulation)</td>
<td>6.44</td>
<td>6.04</td>
<td>0.05</td>
<td>***</td>
</tr>
<tr>
<td>pH (9 hours post-stimulation)</td>
<td>5.81</td>
<td>5.67</td>
<td>0.03</td>
<td>**</td>
</tr>
<tr>
<td>pH (24 hours post-stimulation)</td>
<td>5.62</td>
<td>5.55</td>
<td>0.03</td>
<td>ns</td>
</tr>
<tr>
<td>Temperature 24 hours (°C)</td>
<td>3.3</td>
<td>3.3</td>
<td>0.04</td>
<td>ns</td>
</tr>
<tr>
<td>( L^* )</td>
<td>35.2</td>
<td>35.1</td>
<td>0.46</td>
<td>ns</td>
</tr>
<tr>
<td>( a^* )</td>
<td>18.0</td>
<td>18.0</td>
<td>0.39</td>
<td>ns</td>
</tr>
<tr>
<td>( b^* )</td>
<td>8.5</td>
<td>8.9</td>
<td>0.26</td>
<td>ns</td>
</tr>
<tr>
<td>Shear force (kg/cm(^2))</td>
<td>7.4</td>
<td>6.6</td>
<td>0.40</td>
<td>ns</td>
</tr>
<tr>
<td>Cooking loss (%)</td>
<td>36.5</td>
<td>37.1</td>
<td>0.88</td>
<td>ns</td>
</tr>
</tbody>
</table>

ns; not significant, ** p < 0.05, *** p < 0.001

Stimulation caused pH to drop significantly faster as shown in Table 1 and Figure 1. The rate of decline was \( k=0.44 \) for stimulated carcasses compared to \( k=0.19 \) for non-stimulated carcasses. At 24 hours however pH was not significantly (\( p > 0.05 \)) different between treatment groups. It took 9.5 hours for the longissimus temperature to reach 7°C. There was no significant difference (\( p > 0.05 \)) between groups for colour parameters, nor was there for shear force. The number of high shear force values for stimulated muscle was reduced however. For example in the control group 7 samples had shear force values above 8.3 kg/cm\(^2\) yet there were none in the stimulated group. In both groups there were 13 samples (81%) with shear force values above 5 kg/cm\(^2\).

**DISCUSSION**

The data clearly shows that LV stimulation resulted in a more rapid decline in muscle pH, as expected. Although stimulation lowered the mean shear force it did not cause a significant improvement compared to the controls as reported previously for LV systems (Shaw et al., 1996), although Polidori et al. (1999) did find a significant reduction in shear force after using a LV system. In this latter case there was a 1 kg difference in shear force between stimulated and control samples after 2 days, which was only 0.2 kg greater than the difference in our study and that of Hanrahan et al. (1998). By comparison Shaw et al. (1996) found a 1.4 kg difference which was not enough to achieve a significant difference at the 95% level. These different outcomes may reflect the greater number of shear measurements taken for each sample by Polidori et al. (1999) leading to a reduction in the error around the mean and thus an increased likelihood of detecting significant differences. It is not possible to determine whether other factors such as the chilling conditions or the type of stimulation may have also contributed to the differences. In the study of Chrystall et al. (1984) it was shown that the level of current had a significant effect on the rate of pH fall and thus the effectiveness of stimulation. This may also be an explanation for the differing responses reported to stimulation. Similar to the results reported by Shaw et al. (1996) there was a reduction in the number of ‘tough’ samples in our stimulated carcasses which would reduce the probability of consumers being presented with an undesirable eating experience. Data presented by Shaw et al. (1996) showed that use of HV stimulation can significantly reduce shear force in agreement with earlier work Shorthose et al. (1986).
The variable response of muscles to both HV, but particularly LV stimulation was evident in the work reported by Shaw et al. (1997). Nevertheless LV stimulation still helps to reduce the incidence of tough meat and under fast chilling conditions will presumably confer the most benefit. Alternative techniques for improving lamb tenderness include aging (Hopkins et al., 1995) or use of pre-rigor stretching methods (Bouton et al., 1973; Hopkins et al., 1999) the latter method producing the greatest benefit of any technique in the shortest time post-mortem.

Aside from the question of stimulation, the data presented here supports other findings (Hopkins et al., 1995) which indicate that when Australian lamb is purchased at the retail level and tested for tenderness it does not all comply to acceptable standards. Adoption of the single strategy of purchasing lambs direct through a marketing alliance and using an aging period of 3 days has been demonstrated to reduce the incidence of unacceptable lamb reaching the consumer (Hopkins and Considine, 1998). Similarly, using electrical stimulation, Hanrahan et al. (1998) showed that consumers found meat from stimulated lamb carcasses to be significantly more tender with better eating quality characteristics. There was no significant effect of LV stimulation on the mean shear force levels in the study of Hanrahan et al. (1998). Given that the consumer sensory panels found the meat to be significantly more acceptable than meat from non-stimulated carcasses this indicates stimulation may have positively effected other sensory attributes such as ‘mouth-feel’ or ‘juiciness’ of the meat. Such attributes, to the authors’ knowledge, are unable to be measured objectively.

In the current study stimulation had no effect on cooking loss nor meat colour measured objectively, which supports the results of Hanrahan et al. (1998) and the majority of results presented by Shaw et al. (1997).

**RESULTS**

Overall stimulation had no impact on raw appearance, cooking characteristics or objectively measured tenderness. The lamb industry must investigate and adopt methods that reduce the variability in quality, an issue likely to attract more attention as an eating quality system for sheep meats is introduced within Australia.

**ACKNOWLEDGMENTS**

We wish to acknowledge the assistance provided by Dr. P. A. Speck and Ms. E. Stephens with data collection and the loan of the stimulation unit by Mr. F.D. Shaw. The former Meat Research Corporation provided some financial support for this study as part of the Branded Lamb Alliance Program.

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