THE EFFECT OF PRESLAUGHTER STRESS AND ELECTRICAL STIMULATION ON MEAT TENDERNESS

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Background

Electrical stimulation improves meat quality by ensuring *rigor mortis* is complete before the meat can cool below 10°C thus avoiding cold shortening (Tornberg, 1996). However, it is unclear if there are other factors linked with electrical stimulation that also improve tenderness. By using identical temperatures during processing for electrically stimulated and non-stimulated muscles it should be possible to determine whether factors other than avoidance of cold shortening affect meat tenderness. Previous studies have suggested that electrical stimulation does not affect the rate of meat tenderisation (Devine et al 2001). In the present study, we have carefully evaluated this further using large numbers of animals and tightly controlled processing conditions. The potential for variable effects of stimulation on a range of ultimate pH values was also examined. Even when there is no pH elevation, stress has been shown to contribute to variability of meat tenderness (Butchers et al, 1998). We have used a wrapping technique so that excised muscles could be placed in water at 15°C to ensure identical processing temperatures for both stimulated and non-stimulated samples (Devine et al 2002a; Devine et al 2002b; Lowe et al, 2002). This technique avoids cold shortening induced toughness and is the optimum temperature for muscle to enter *rigor mortis* (Devine et al, 1999).

Objectives

To determine whether electrical stimulation improves meat tenderness in ways other than by avoiding cold shortening and determining possible interactions of electrical stimulation with ultimate pH effects.

Methods

First cross Merino lambs (n=350) 310 days old, 47.7 ± 5.725 kg, were slaughtered on four separate days over a two week period. Four days prior to the first slaughter, all lambs were weighed and then structurally assessed the following day and then returned to ryegrass/white clover pasture. From this point, lambs had one, three, eight or ten days recovery before being yarded again, kept off feed for 24 hrs and transported for slaughter at a commercial abattoir. This treatment resulted in a range of ultimate pH values.

All lambs were in lairage for 16-20 hrs prior to slaughter and following electrical stunning and slaughter, half of the carcasses were electrically stimulated at 30 min post mortem for 90 s using 1130 V peak (current 2 A) (half sine wave pulses, 10 m s duration) at an alternating pulse frequency of 14.28 pulses s^{-1}. The right *longissmus thoracis et lumborum* (LT) from the rump to just above the 13th rib was then removed, wrapped in cling film and rapidly cooled to 15°C in a water bath and entered *rigor mortis* and aged at this temperature. Small temperature recorders approximately 1.6 cm diameter (DS1921 Thermochron iButton, Dallas Semiconductor Corp., Dallas, Texas USA) were placed in the wrapped muscle to monitor the *rigor* temperature. Each LT was cut into four sections that were held at 14.5°C to age. The 24 h pH (pH_u) was determined using a Mettler-Toledo pH meter with a combination puncture electrode (Mettler-Toledo GmbH Process Switzerland). The time of commencement of ageing was taken as *rigor mortis* (estimated to be 5 h for stimulated 12 h for non-stimulated lambs). At the designated time, 0 h and 72 h, the meat samples were frozen and stored at –20°C before cooking.

The meat was cooked from the frozen state for 35 min in a 70°C water bath, cooled in ice water and 1.5 x 0.7 cm slices were sheared across the grain using a Lloyd Universal testing apparatus set up as a Warner Bratzler shear device.

Results and discussion

Yarding the lambs 1-3 days before slaughter had a negative effect on pH_u. With increasing periods of recovery before slaughter, the lambs with the longest recovery of 8-10 days had an improved lower pH_u ($P<0.0001$) (Starbuck et al, 2002). This provided a good range of pH_u for evaluation of the interactions of pH_u and stimulation on meat tenderness.

The *rigor* temperature over 5 hours was 14.8±0.36°C for stimulated LT and over 12 hours was 14.0±0.45°C for the non-stimulated LT over all slaughter days. These temperatures are close to the optimum *rigor* temperatures and results in minimum *rigor* shortening and maximum ageing (Devine et al, 1999). The ageing temperature was the same for all samples and was therefore not a factor in any ageing differences.

Electrical stimulation clearly decreased shear force (at both 0 and 72 hours) compared to non-stimulated meat if pH_u was below pH 5.8 (Fig. 1). At this pH and above, the values between the stimulated and non-stimulation tend to merge in the 72 h samples. The increase in shear force with increasing ultimate pH is not new and the emphasis is usually focused on the animals with an ultimate pH from 5.8-6.0. This study is concerned with the low "normal" pH_u values and clearly shows that a significant increase in shear values occurs as pH_u increased above 5.5, a relationship that existed with or without electrical stimulation. The large number of animals and precise processing and temperature control provides strong evidence that stimulation *per se* does improve meat tenderness. The pH values above 6.0 are not shown as the numbers are too small to be meaningful, although there is a trend for lower shear force from stimulated animals to occur. The same trend occurred for all slaughter days (data not shown).

When the distribution of shear force values was plotted (Fig. 2) the effect of electrical stimulation resulting in initial lower 0 h shear values is to shift the mean, but this appears to be the result of some non-stimulated samples that age more slowly and do not age to the same extent at 72 hours as the stimulated samples. It could be argued that ageing was not complete for non-stimulated samples, but the ageing durations post *rigor mortis* were the same for both treatments (using *rigor mortis* as the commencement of ageing rather than slaughter times), and other studies have shown that ageing is over 90% complete after holding for 72 h at 15°C (Lowe et al, 2002), a smaller difference than is found here. It appears from the present study that the effect of small increases of ultimate pH could result in a significant increase in shear force: this effect is more than outweighed by the positive effect of electrical stimulation except for intermediate pH muscles, where the differences are smaller. Sufficient samples were not obtained for high pH for non-stimulated samples with which to make a comparison, but this meat was relatively tender before ageing (not shown) and it aged to the same levels as low pH meat.

The commercial importance of this may be most important in some genotypes of cattle where stimulation can dramatically both even out differences in tenderness and decrease shear force values (Hearnshaw et al, 1998), but in most cases the effect of ultimate pH was not recorded.

In this experiment we have largely removed the confounding factor of accelerated *rigor mortis* at high temperatures resulting in accelerated ageing with normal chilling, by immersing in 10-15°C water with a high heat transfer coefficient that equilibrates the temperatures rapidly. Accelerated ageing in some muscle fibres as a result of stimulation is still possible as it took up to 30 minutes for the meat to fall to 15°C and those muscle fibres already in *rigor* as a consequence of stimulation would commence to age, but this does not explain the differences after prolonged ageing. Meat with ultimate pH values below pH 5.7 is generally regarded as in the normal range. Even so, any increase in ultimate pH above 5.5 is sufficient to significantly affect shear values.

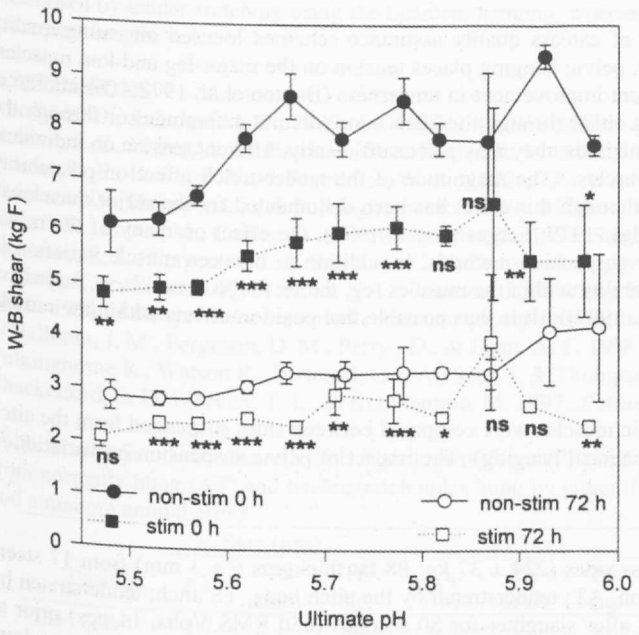

Figure 1. Mean shear force values for successive 0.5 pH ranges for LT samples aged for 0 and 72 h at 15°C with and without electrical stimulation. pH values above 6.0 are not included. The error bars are standard errors. * = p< 0.05; ** = p< 0.01; *** = p< 0.001; ns = not significant

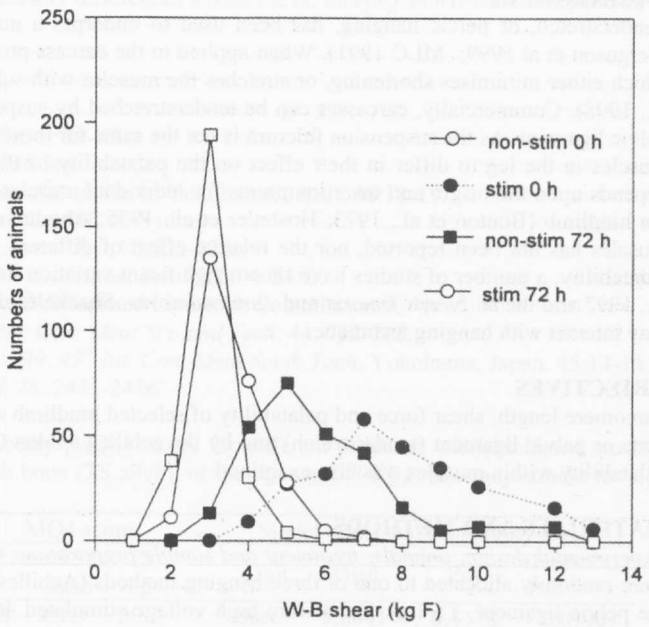

Figure 2. Distribution of shear force values for electrically stimulated and non-stimulated LT samples aged for 0 and 72 hours at 15°C.

Pertinent literature

Butchers A. D. M., Fergusson D. M., Devine C. E., Thompson J. M. (1998). Interaction between preslaughter handling and low voltage electrical stimulation and the effect on beef quality. Proceedings of the 44th International Congress of Meat Science and Technology, pp. 1050-1051 (Barcelona Spain).

C.E. Devine, N.M. Wahlgren and E. Tornberg. (1999) Effect of rigor temperature on muscle shortening and tenderisation of restrained and unrestrained beef *m. longissimus thoracis et lumborum.* Meat Science **51** 61-72

Devine C. E., Payne S. R., Peachey B. M., Lowe T. E., Ingram J. R., Cook C. J. (2002a). Effect of high and low rigor temperatures, on sheep meat tenderness and ageing. Meat Science **60** 141-146.

Devine C. E., Payne S. R., Wells R. W. (2002b). Effect of restraint on sheep meat tenderness with rigor mortis at 18°C. Meat Science **60** 155-159.

Devine C. E., Wells R. W., Cook C. J. Payne S. R. (2001). does high voltage electrical stimulation of sheep affect rate of tenderisation New Zealand Journal of Agricultural Science **44** 53-58.

Hearnshaw, H., Guransky B. G. Gogel B., Thompson J. M., Fell, L. R., Stephenson P. D., Arthur P. F., Egan, A., Hoffman W., Perry D. (1998) Meat quality in cattle of varying Brahman content: the effect of post slaughter processing growth rate and animal behaviour on tenderness. Proceeding of the 44th International Congress of Meat Science and Technology, pp 1048-1049 (Barcelona, Spain).

Lowe, T. E., Peachey, B. M. Devine, C. E. (2002). The effect of nutritional supplements on growth rate, stress responsiveness, muscle glycogen and meat tenderness in pastoral lambs. Meat Science In Press.

Starbuck T. A., Edwards N. J., Hocking Edwards J. E., Devine C. E., Lowe, T. E., Wells R.W., Speck P. A. (2002) Detrimental effect of some on-farm treatment of lambs prior to slaughter on meat ultimate pH. Australian Journal of Animal Production. In Press

Tornberg, E. (1996) Biophysical aspects of meat tenderness. Meat Science **43** Supplementary Issue 175-191.

Acknowledgements

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