Electrical stimulation and wrapping avoids toughening effect of high *pre rigor* temperatures in beef

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Introduction

Electrical stimulation is used to facilitate tenderisation (Devine *et al*., 2004), through acceleration of the *rigor* process so that detrimental effects of cold shortening through fast chilling and freezing are avoided. However electrical stimulation appears to have other roles so that even when cold shortening is avoided, electrical stimulation can still impact on tenderness (Wahlgren *et al*., 1997). Unrestrained muscle will shorten at the onset of *rigor mortis* (Honikel *et al*., 1983) being strongly dependent on the energy level in the muscle and the muscle temperature *post mortem*. Locker and Hagyard (1963) found that so-called cold and warm shortening took place at *rigor* temperatures above and below approximately 15°C and a high degree of shortening is highly correlated with inferior tenderness. Hence, prevention of shortening - which can be prevented by wrapping (Devine *et al*., 1999; Sørheim & Hildrum, 2002) - is essential to avoid toughening (Locker & Hagyard, 1963). The following experiment was designed to study the effect of electrical stimulation, wrapping and *pre rigor* temperatures on meat tenderness.

Materials and Methods

M. Longissimus lumborum (LL) muscles from 35 steers (n = 70) were subjected to the following *pre rigor* treatments: electrical stimulation (ES: immediately post slaughter (80 V peak, 14.28 pulses s^{-1} for 30 s; NES: no stimulation), wrapping (wrapped/unwrapped) and *pre rigor* temperature (15°C/35°C). At 30 min *post* slaughter, the LLs were boned and taken to the laboratory, where one LL from each steer was tightly wrapped in four layers of polyethylene cling film. LLs were then either *1)* placed in a water bath at 35°C until *rigor mortis* was reached and then placed in water bath at 15°C until equilibrated or *2)* in a water bath at 15°C until equilibrated. All LLs were subsequently aged at 15°C. Samples for shear force were collected at *rigor mortis*, ~12 h, ~24 h, ~40 h, ~70 h and ~90 h *post rigor*, immediately frozen and stored at -20°C. The samples were cooked from the frozen state in a 100°C water bath until an internal temperature of 75°C was reached, placed in an ice-water slurry and when cool, 10 mm x 10 mm cross section samples (n=10) were sheared using a MIRINZ tenderometer. Ageing was indexed to *rigor* to remove disparities due to different times of entering rigor. The statistical analysis was carried out with the Statistical Analysis System version 9.1 (SAS Institute, Cary, NC, USA). The MIXED procedure was applied to calculate the least square means (LSmeans) and standard errors of the variables. A model including the fixed effects of electrical stimulation, wrapping and *pre rigor* temperature as well as their interaction and random effect of wrapping within animal was applied for the variables: shear force at *rigor mortis*, shear force after ageing, and time to reach a shear force of 60 N.

Results and Discussion

Eight muscles (4 animals) were removed due to intermediate or high pH_u values (pHu > 5.73) prior to any further data analysis as this is known to affect shear force unrelated to treatments. The *pre rigor* treatments provided a large variation in individual shear force values at *rigor* (from 46 to 265 N). However, as the meat aged the shear force of all treatment groups decreased and eventually reached acceptable values (Figure 1).

The shear force at *rigor* of ES muscles (141 N) was not significantly different to NES muscles (136 N; $p_{\text{stimulation at } rigor} = 0.56$). However, after ageing the shear force of ES muscles (42 N) was significantly lower than the shear force of NES (52 N; $p_{\text{stimulation after ageing}} < 0.0001$), although the NES muscles reached acceptable tenderness levels after ageing. The shear force of unwrapped muscles at *rigor* (168 N) was higher than for wrapped muscles (110 N; $p_{\text{wrapping at } rigor} < 0.0001$). The aged unwrapped muscles still reached relatively low shear force values (52 N) although being significantly higher than the aged wrapped muscles (42 N; $p_{\text{wrapping after ageing}} = 0.0002$). The $NES_{\text{unwrapped}}35$ muscles had significantly higher shear force over most of the ageing period than its counter-part $NES_{\text{wrapped}}35$. Even so, the $NES_{\text{unwrapped}}35$ muscles eventually reached an acceptable tenderness (56 N) after ageing for 90 h.

Although the mean shear force values for all treatments groups were acceptable after full ageing, there was a large variation in shear force during the ageing period. When using the time to reach 60 N as a threshold for acceptability, these differences became further obvious (Figure 2). Muscles that were either wrapped and/or electrically stimulated reached acceptable shear force values significantly earlier than those that were not. It took

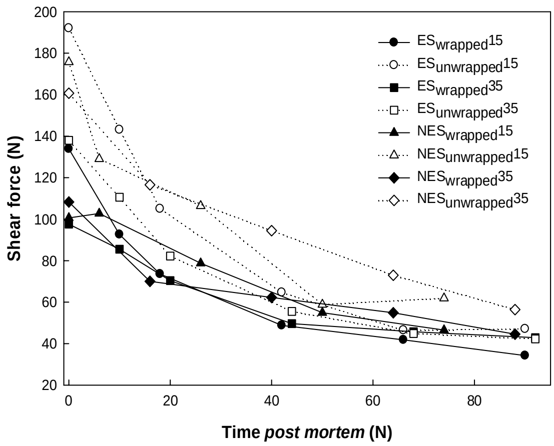

Figure 1 Shear force (LSMeans – error bars have been omitted for clarity) in muscles subjected to electrical stimulation/no electrical stimulation (ES/NES), *pre rigor* temperature of 15°C/35°C and wrapping.

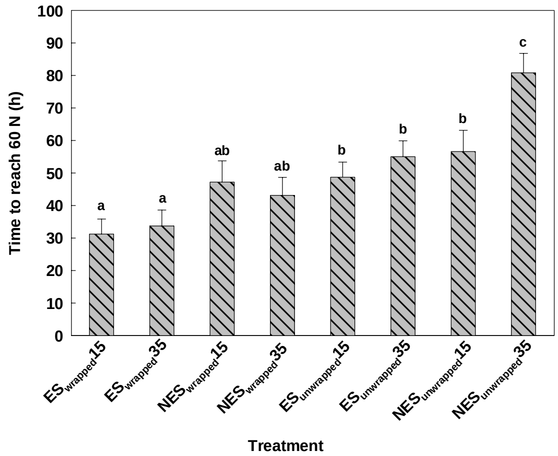

Figure 2 Time to reach a shear force of 60 N (LSMeans & standard error) for muscles subjected to electrical stimulation/no electrical stimulation (ES/NES), *pre rigor* temperature of 15°C/35°C and wrapping. Treatments with different letter are significantly different ($p < 0.05$).

almost three times longer for NES$_{unwrapped}$35 muscles to reach 60 N than for the ES$_{wrapped}$35 muscles. Furthermore, the *pre rigor* temperature only had a significant effect when the muscles were not wrapped or electrically stimulated.

An estimate of the protection provided by wrapping or electrical stimulation can be made for each *pre rigor* temperature. The difference in time to reach 60 N between NES$_{unwrapped}$35 and NES$_{wrapped}$35 was 38 h (~46% of the total ageing time for NES$_{unwrapped}$35 muscles). This indicated that wrapping to avoid shortening was important at high *pre rigor* temperatures. The difference between NES$_{unwrapped}$15 and NES$_{wrapped}$15 was only 10 h (~17% of the total ageing time for NES$_{unwrapped}$15 muscles) indicating that wrapping to avoid shortening was less important at 15°C *pre rigor* temperature. The difference in time to reach 60 N between NES$_{unwrapped}$35 and ES$_{unwrapped}$35 was 26 h (~32% of the total ageing time for NES$_{unwrapped}$35 muscles). This indicated that, at elevated *pre rigor* temperatures, electrical stimulation was almost as effective as wrapping in preventing shortening. The difference in time to reach 60 N between NES$_{unwrapped}$15 and ES$_{unwrapped}$15 was only 10 h (~17% of the total ageing time for NES$_{unwrapped}$15 muscles) indicating that electrical stimulation was as effective as wrapping in preventing shortening at 15°C *pre rigor* temperature.

Conclusion

We conclude that electrical stimulation immediately post slaughter confers a degree of protection from toughening of wrapped and unwrapped muscle at both high and low *pre rigor* temperatures enabling acceptable and fast tenderisation and its use can be beneficial to meat quality, by reducing both high temperature *rigor* shortening and cold shortening.

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