SHORT-TERM PRE-RIGOR MUSCLE STRETCHING IMPROVES BEEF TENDERNESS

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***Abstract*—this study tested the hypothesis that stretching pre-rigor muscle for a short period and then allowing the muscle to go through rigor development without restraint will improve the tenderness in the resulting meat. Pre-rigor bovine *M. semitendinosus* muscles were boned out about 30 minutes post-mortem, longitudinally halved and one half was randomly assigned to be stretched (n = 12) with the other halves serving as controls (no stretching or restraint at all). Meat from these muscles were analysed at 48 hours and two weeks post-mortem. Stretched and control samples did not differ in pH. Stretched samples were numerically more tender at 48 hours post-mortem and significantly more tender after ageing for two weeks compared to controls ($P < 0.058$). Stretched samples also had less cook loss at 48 hours ($P < 0.067$) relative to control with the difference becoming insignificant after ageing for two weeks. Sarcomeres were longer ($P < 0.002$) in stretched samples compared to control with significant correlation ($r = -0.6$) between sarcomere length and shearforce values. Stretching did not negatively impact on beef colour except beef aged two weeks from stretched muscles tended to be browner (higher hue angle) compared to non-stretched control samples. The results of the present study proved the hypothesis that stretching bovine muscles pre-rigor will improve the tenderness of the resulting meat even if the muscles were not restrained from contracting during rigor development. The implication is that, short-term stretching of pre-rigor muscles can be used to develop a process for improving the tenderness of individual beef muscles/cuts with minimum enviromental footprint by doing away with the need for using a restraint to prevent the muscle from contracting during rigor development. Because of the preliminary nature of the present study, outcomes of the study need to be further verified using other muscles and controlling for other factors before the process can be commercially implemented.**

***Index Terms*—Color, pre-rigor stretching, sarcomere length, tenderness.**

I. INTRODUCTION

Hot boned muscles, in a pre-rigor state, can be physically stretched to alter their sarcomere length and improve the tenderness of the resulting meat. Manipulating hot boned meat also offers some unique advantages such as portion control, which allows otherwise irregular muscle shapes to be manipulated to produce a regular (usually cylindrical) shape (Farouk, Wiklund & Rosenvold, 2009; Toohey, Hopkins, Nielsen & Gutzke, 2009). When stretching is applied in conjunction with the optimal pre-rigor temperature/pH conditions, improved eating quality benefits are realised. This principle has been used to develop a process including a stretching device described in Farouk et al. (2009) that stretches and restrains individual pre-rigor muscles from contracting during rigor formation. The device was used by Farouk, Graham, Wood & Hafegee (2005) to stretch pre-rigor bovine *M. semitendinosus* by up to 97% resulting in improved tenderness, uniformity, presentation, portion control, and reduced drip loss in the stretched meat.

One important drawback of the stretching process is the need to restrain the pre-rigor muscle from contracting until the muscle is converted to meat. This is currently done by tobacco-style wrapping of the stretched muscle in flexible plastic or by squeezing the muscle into a tube, casing or mould. If the need to restrain the muscle can be eliminated, it will reduce the cost and the environmental footprint of the whole process making pre-rigor stretching a commercially more attractive process, one that could be extended to whole carcasses rather than individual muscles only. The present study was designed to test the hypothesis that stretching pre-rigor muscle for a short period and allowing the muscle to return to a resting state without any restraint will improve tenderness in the resulting meat.

II. MATERIALS AND METHODS

A. Sample preparation

Six steers (age 2-3 years) were included in the study. The cattle were captive bolt stunned, slaughtered and processed with no electrical inputs (immobilisation or electrical stimulation) in order to avoid hastening the attainment of rigor. *M. Semitendinosus* from the two sides of each carcass were boned out approximately 30 min post-mortem at the abattoir. Each muscle was excised, trimmed and halved longitudinally and randomly assigned to one of two treatments; control or stretched. Pre-rigor samples to be stretched (n = 12) were clamped at the two ends of a stretching device at 150mm apart. The device has a stationary and mobile clamps that were moved apart or drawn closer with an Hitachi DS 14DVF3 hand held power drill on high speed. Samples were stretched by 130mm to obtain an 87% stretch, held at that level of stretch for 2 minutes, then released and allowed to contract freely to its resting length. All the samples (control and stretched) were placed loosely in a plastic bag, transported to AgResearch MIRINZ, stored at 15°C for 48 hrs to allow muscles sufficient time to go into rigor. Samples at 48 hrs post-mortem were cut into two pieces and the two sub-samples from each muscle were weighed and then randomly assigned to one of two storage times; 48 h and 2 weeks post-mortem. The 2 weeks samples were vacuum packed and stored at -1.5°C until the end of the storage time and immediately analysed.

B. pH

H of the samples was measured immediately after the muscles were boned out and after 48 hrs and 2 weeks of storage period by inserting a calibrated pH probe (Testo 205 pH meter with combined temperature and pH insertion probe, Lenzkirch, Germany) directly into the meat. Duplicate readings were taken for analysis of each sample.

C. Colour

One steak (2 cm thick) was cut from each sub-sample, tray overwrapped with an oxygen permeable plastic film and allowed to bloom for 2 h at 4ºC before colour was measured using a HunterLab MiniScan XE Plus Colour Meter (Hunter Associates Laboratory, Inc. Reston, VA). CIE L* (lightness), a* (redness) and b* (yellowness) values were measured (D65, 10º) through the package film at three random locations on each steak, averaged and Hue angle (arctan b/a) and saturation $(a^2 + b^2)/0.5$ were calculated (Hunter and Harold, 1987). Each steak was measured on days 0, 1, and 4 of simulated retail display at 3°C under fluorescent lights.

D. Sarcomere length

A small sub sample of meat was removed and frozen from the middle of each sample at 48 hrs post-mortem. Approximately 2mg was then cut finely and placed into 10ml of 0.25 sucrose solution and homogenised using an Ultra-Turrax T25 for 10 seconds. The resulting homogenate was placed on a glass slide and viewed under a microscope using a 100x oil emersion lens for pictures of sarcomeres to be taken using a QImaging MicroPublisher 3.3 RTV microscope mounted camera. The pictures were analysed using Image-Pro Plus 5.1 that had been calibrated to the microscope with 10 pictures taken of 10 sarcomeres giving a total of 100 sarcomere lengths per sample.

E. Cook loss and shear force

Samples were cooked in a waterbath set at 99°C to an internal temperature of 75°C (measured by thermocouples) and then immediately placed in ice-water slurry. The weight of the meat was recorded before and after cooking. After cooking the meat samples were blotted dry and re-weighed. The cook loss was calculated as weight lost expressed as a percentage of the original sample weight. Once cooled, 10mm x 10 mm cross section samples (n=10 from each sample) were cut out from the cooked meat samples and sheared with the MIRINZ Tenderometer (Chrystall and Devine, 1991). The peak shear force was recorded.

F. Statistical analyses

The design was a split plot with 'side' on main plot and stretching treatment on the subplot. Data were analysed using the REML directive of GENSTAT (2005).

III. RESULTS AND DISCUSSION

Pre-rigor muscle stretching effect on meat quality attributes

Short term stretching of bovine pre-rigor muscles had no effect on the pH of the meat 48 hrs post-mortem or after ageing for two weeks (Table 1). All the meat used in the present study reached an ultimate pH value of 5.49 to 5.58, indicating that glycogen levels were normal and glycolysis was complete in all muscles.

Meat from pre-rigor streched muscles at 48 h had longer sarcomere length and lower cook loss compared to controls (Table 1), indicating that 2 minutes stretching of the pre-rigor muscles was sufficient to alter the sarcomere length of the myofibrils such that samples were not able to return to the same length as controls. Stretching resulted in numerical (at 48 h) and significant (at 2 weeks) improvement in the tenderness of beef (Table 1). The improved tenderness is due to the stretching of the sarcomeres as indicated by the longer sarcomere length of the stretched muscles relative to controls. The relationship between sarcomere length and objective and subjective tenderness is well established (Smulders, Marsh, Swartz, Russell & Hoenecke, 1990; Sørheim, Idland, Halvorsen, Frøysen, Lea & Hildrum, 2001). In the present study, sarcomere length had a negative correlation (r = –0.60) with tenderness measured as shearforce. The lower cook loss in stretched samples particularly at 48 h could be due to the reduction in the interfibrillar spaces and the distruption of channels through which moisture is lost that was caused by the stretching of the muscles pre-rigor.

Table 1. Effect of short term bovine muscle pre-rigor stretching on meat quality attributes.				
Attribute/time post-mortem	Control	Stretched	SED	*P*-value
pH				
48 hours	5.51	5.49	0.02	0.565
2 weeks	5.58	5.55	0.03	0.223
Sarcomere Length (µm)				
48 hours	1.72	1.91	0.04	0.002
Cook loss (%)				
48 hours	24.3	21.8	1.23	0.065
2 weeks	25.6	24.9	1.13	0.554
Shear force (KgF)				
48 hours	12.3	10.9	0.80	0.126
2 weeks	7.8	6.7	0.51	0.058

SED = Standard error of difference between means; *P* = statistical significance

Pre-rigor muscle stretching effect on meat colour stability

Stretched samples did not differ in lightness (L*) but were brighter red and yellow (higher a*, b* and saturation) compared to controls on display day 0; the treatments did not differ in these attributes at other display periods (data not shown). Stretched and control samples did not differ in brownness except after two weeks of ageing on display days 0 and 4 when stretched samples appeared browner than control (Table 2).

Table 2. Effect of short term bovine muscle pre-rigor stretching on meat colour stability (Hue angle °).				
Aittrbute/time post-mortem	Control	Stretched	SED	*P*-value
Day 0				
48 hours	33.0	34.2	0.96	0.243
2 weeks	32.3	34.4	0.95	0.055
Day 1				
48 hours	34.5	35.6	0.59	0.095
2 weeks	32.1	33.6	0.94	0.14
Day 4				
48 hours	46.8	45.9	1.60	0.603
2 weeks	33.8	36.6	1.08	0.028

SED = Standard error of difference between means; *P* = statistical significance

The higher a* values in freshly bloomed stretched meat compared to the controls may have been due to a decreased oxygen consumption rate caused by stretching and/or an increase in metmyoglobin reducing activity of enzymes (Ledward, 1985). The difference in enzyme activities might have been caused by differences in the rate of glycolysis (not measured in this study) with the stretching causing the muscles to glycolise faster compared to controls. The data in the present study seem to suggest that the activity of the metmyoglobin reducing enzymes in freshly bloomed samples increased with stretching. Because of this higher activity, the enzymes' capacity to reduce metmyoglobin was decreased more rapidly in stretched muscles relative to controls with longer ageing and display storages resulting in browner stretched samples.

IV. CONCLUSION

Stretching pre-rigor *semitendinosus* muscle by up to 87% of its resting length and holding the stretched muscle for 2 minutes before allowing the muscle to go through the rigor process unrestrained improved the tenderness and reduced the cook loss in the resulting meat.

The outcomes of this study have the following implications for the meat industry: (1) single muscles or cuts can be individually tenderised by pre-rigor stretching without the need to restrain the muscle as is the current practice; (2) the process can be modeled and used in tenderising whole carcasses as previously suggested by Farouk et al. (2009); (3) eliminating the use of a restraint will reduce the cost of pre-rigor stretching and the environmental footprint of the whole process; and (4) there will be an overall cost reduction through hot- rather than cold-boning and faster ageing of packaged muscles.

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