THE EFFECTS OF RIGOR TEMPERATURE ON SHORTENING AND MEAT TENDERNESS

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INTRODUCTION

The phenomenon of muscle shortening, first shown by Locker and Hagyard (1963) in M. sternomandibularis, still appears to be one of the major factors most responsible for meat toughness in M. semimembranosus (SM), M. semitendinosus (ST) and M. longissimus dorsi (LD) (Olsson *et al.*, 1994; Hertzman *et al.*, 1993). Olsson *et al.* (1991) show that temperatures between 7-13°C were associated with the least toughness for SM, while below and above these temperatures, cold and heat shortening accounted for the increased toughness. These studies, however, did not completely explore the range of temperatures from 15-35°C for the LD. The present study therefore evaluates muscle shortening in the range 15-35°C from excised muscles strips using a rigormeter and following tenderness changes with W-B shear-values and with a taste panel in whole LD muscles, one of the pair prevented from shortening to its fullest extent by tightly wrapping it.

METHODOLOGY

Pairs of muscles from the *muscularis longissimus thoracicum and lumborum* (LD) were excised from thirteen 18-month old bulls of the Swedish Lowland breed and were transported to the research facility in under 1 hour. Strips of the muscles, longitudinally oriented along the fibre axis, approximately 35 mm long and weighing 1.5-2 g were attached to the isometric and isotonic recording portions of the rigormeter (Rigotech®) using cyanoacrylate glue (Loctite®, superglue), covered with paraffin to avoid drying out and to exclude oxygen (Hertzman *et al.*, 1993). One of the pairs of the remainder of the LD was tightly wrapped in a cling film overlaid with adhesive tape to its approximate rest length of 50 cm. The other LD was not wrapped. Both LD's were placed in a sealed plastic bag and immersed in a water-bath at the selected temperature. Once rigor was reached, the refrigeration unit of the water-bath was activated to cool the muscle down as fast as possible, so that ageing, was reduced. A sample was removed for Warner-Bratzler evaluation by vacuum-packing 50 mm x 50 mm samples and heating to 74°C in a water. Slices 15 mm x 6.7 mm (1 cm^2 square cross section) were sheared in an Instron® Universal testing machine using a flat steel plate 1 mm thick moving in a 1.5 mm slit and the force in Newtons determined.

The meat samples in rigor, were then transferred to a 4°C room to age for 7 and 14 days, then frozen and stored at -20°C. Before evaluation, the meat was tempered and slices were cooked to 74°C and served immediately to trained panellists, who determined tenderness, on a hedonic scale of 1-9. A portion was cooked identically for Warner-Bratzler determinations.

RESULTS

Instrumental measurements of the rigor process

Isometric tension and isotonic shortening

The maximum isotonic tension for each muscle is presented as % shortening. The isometric tension is at a minimum at 15°C with 0.53 kPa and a maximum of 8.8 kPa at 35 °C and the percentage shortening is also at a minimum at 15°C with 12 % shortening and a maximum at 35°C with 37 % shortening (Fig. 1).

Meat Quality

Warner Bratzler Shear force values

The Warner-Bratzler shear-force data (Fig. 2) show that the wrapped muscle is more tender than the unwrapped muscle for all temperatures except 15°C, where the shear-force values of wrapped and unwrapped muscle are the similar. There is no significant difference in shear-force values on the second day with respect to an increasing rigor temperature, although the difference between wrapped and unwrapped muscles is always present.

Changes with ageing

The shear-force values decreases with ageing through day 2, day 7 and day 14, with the difference between wrapped and unwrapped muscles being usually maintained. A major exception is for rigor at 15°C, where the shear force values for wrapped and unwrapped are almost the same, and less than for any other temperature (Fig. 3). Muscle held at temperatures above 15°C clearly results in a substantial increase in toughness and this toughness can not be aged out.

Sensory evaluation

The sensory evaluation of tenderness can be seen in Figure 3, which mirrors well the Warner-Bratzler values for the corresponding ageing periods (r=-0.81***). However, the differences in tenderness between the wrapped and unwrapped muscles is not that evident as for the W-B-values. The greatest degree of tenderness occurs for meat held at 15°C.

DISCUSSION

The present study shows that prerigor muscle shortens from about 10 to 35 % for LD muscle in the warm-shortening region, when the rigor temperature rises from 15 to 35°C. Comparing the shortening obtained for the LD muscle in the cold-shortening region of 1, 4, 7 and 10°C (Olsson *et al.*, 1994) the amount of warm-shortening at 35°C is more or less the same as the degree of cold-shortening at +4°C.

By combining the results from both the cold- and warm-shortened LD and SM muscle the minimum in shortening is observed at 10-15°C for the LD and about the same for the SM muscle (7-13°C). The implication is that the higher the temperature and the longer the duration at the high temperatures at which the muscle is subjected to before it goes into rigor, the greater is the total shortening. The amount of shortening that takes place will have an important bearing on the subsequent tenderness, with muscles having the greatest amount of shortening being the toughest. This correlation is high for the ST and SM muscle even after 14 days storage (r = -0.81** and r = -0.87**, respectively; Hertzman *et al.*, 1993), whereas the LD muscle does not show this strong dependence in the warm-shortening region studied (r = -0.31$^{n.s.}$). This observation suggests that some other mechanism besides shortening comes more into play for the LD muscle compared to the SM muscle. As LD is a more enzymatically active muscle than SM, proteolysis probably influences the tenderness to a substantial degree and therefore a low correlation is observed.

For rigor temperatures between 20 to 35°C, when the variation in shortening is substantial (15 to 35 %), the tenderness is not dependent on the temperature, but the restraint obtained by wrapping is having a significant effect in improving tenderness. For muscles excised from the carcass when there is no initial restraint, as would occur in commercial hot boning situations, there can be considerable shortening, but if the muscle is restrained to some extent depending on the skeletal attachments, as would occur in normal commercial cold boning operations, then shortening may not be a major problem.

The most striking result from this investigation is that when the meat goes into rigor at 15°C it was much more tender after 14 days ageing at 4°C than meat going into rigor between 20 to 35°C, irrespective of whether or not it was restrained. This implies that the conditions close to rigor at 15°C in some way affects the enzymes responsible for ageing in a beneficial way. It appears that enzymatic break-down and shortening affect meat toughness of LD at temperatures above and equal to 15°C and that these two phenomena are both related to temperature, but in different ways.

REFERENCES

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Figure 1. Isometric tension and % shortening of bull muscle

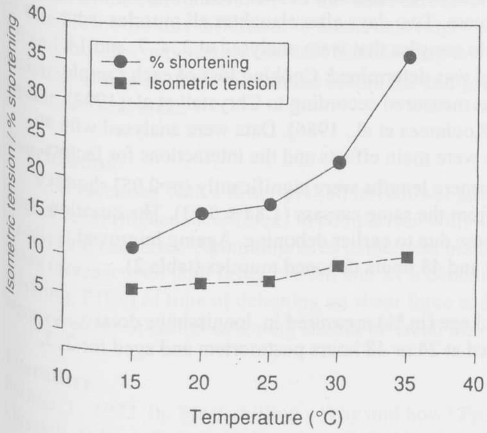

Figure 2. Warner Bratzler tenderness values versus rigor temperature and ageing at 4°C

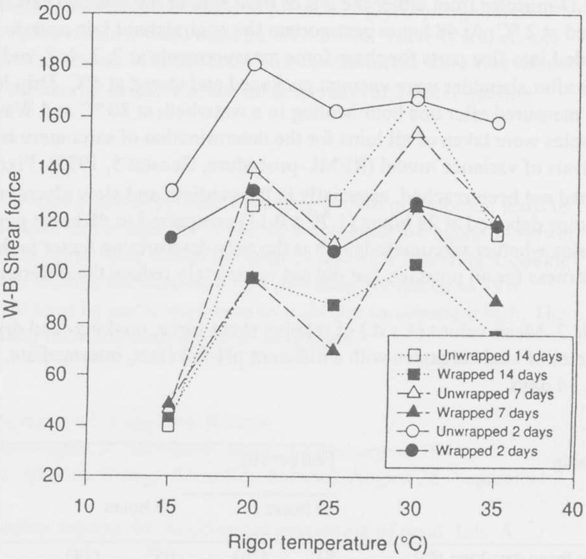

Figure 3. Sensory tenderness as a function of rigor temperature and ageing at 4°C