THE INFLUENCE OF DIFFERENT TEMPERATURE-TIME COURSES ON MUSCLE SHORTENING AND BEEF TENDERNESS.

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The influence of four different temperature-time courses during rigor development on muscle shortening (MS), isometric tension (IT) and beef tenderness on *M. longissimus dorsi* were studied. The temperature courses were fast (reaching a centre temperature of 4°C, 5h p.m.), medium-fast (12°C, 5h -- 4°C, 24 h), medium-slow (20°C, 5h -- 4°C, 24h) and slow (30°C, 5h -- 10°C, 24h -- 4°C, 48h). The fast temperature-time course resulted in the highest amount of MS (27%) and IT (cold shortening), whereas the other three courses showed different amounts of warm shortening (9-24%). Minimum MS and IT were obtained for the medium-fast and medium-slow temperature-time course, respectively. The sensory tenderness were significantly higher for the medium-fast and medium-slow temperature-time courses after 7 days of ageing compared to the two other temperature-time courses. After 14 days of ageing only the meat exposed to the fast temperature-time course had unacceptable sensory tenderness. Although the fast and slow temperature-time course resulted in almost similar amount of muscle shortening the isometric tension curves for the two courses differed significantly. An explanation to this observation could be that the isometric tension curves contain information arising both from the muscle contraction and from the tenderization process that seems to occur simultaneously during rigor development.

Introduction

The temperature during rigor development is one of the most important factors for meat tenderness. Studies performed at our laboratory have so far been undertaken at constant rigor temperatures (Hertzman *et al.* 1993; Olsson *et al.* 1994; Devine *et al.* 1996). For *M. longissimus dorsi* these studies have shown that rigor temperatures between 7-15°C are associated with the least toughness (Tornberg 1996). Below and above these temperatures cold and warm shortening together with reduced proteolytic activity accounts for an increase in toughness (Tornberg 1996; Devine *et al.* 1996; Simmons *et al.* 1996). The aim of this study was therefore to investigate the influence of different realistic temperature-time courses during rigor development on muscle shortening, isometric tension and beef tenderness.

Materials & Methods

The influence of four different temperature-time courses during rigor development were investigated: fast (with a centre temperature of 4°C 5h p.m.), medium-fast (12°C, 5h--4°C, 24h.), medium- slow (20°C, 5h--4°C, 24h) and slow (30°C, 5h -- 10°C, 24h -- 4°C, 48h). The fast temperature-time course imitated the fastest chilling regime that can be obtained in a hot-boned *M. longissimus dorsi* (LD) without receiving surface freezing. The other temperature-time courses were similar to existing chilling regimes found at abattoirs in Sweden. The LD muscles from 12 young bulls of the Swedish Lowland breed were excised 45 min. post-mortem and transported to the research facility in less than 1 hour. Muscle strips, longitudinally oriented along the fibre axis, approximately 35 mm long and weighing 1.5-2 g, were attached to the isometric and isotonic recording options of the rigormeter (***Rigotech***®, Reologica Instruments AB, Sweden) using cyanoacrylate glue (Loctite®, superglue) and covered with paraffin to avoid drying out and to exclude oxygen (Hertzman *et al.*, 1993). The ***isometric tension***, IT, expressed as force per unit area, and ***muscle shortening***, expressed as percentage decrease in muscle piece length, were registered every 5 min. All measurements were carried out in duplicate in a closed chamber with a temperature accuracy of ± 0.5°C. Transverse muscle slices aimed for sensory evaluations (1.5 cm) were cut out, vacuum-packed and incubated in a water bath subjected to the same temperature-time course during rigor, thereafter aged at +4°C for up to 14 days. Samples for pH-measurements were taken regularly (Hertzman *et al.* 1993). The meat for the ***sensory analysis*** were cooked in a water bath (74°C) for 60 min reaching a centre temperature of 74°C, and served to the assessors immediately after cooking. The sensory analysis was performed by a trained expert panel of 15 women and men. Tenderness was judged on a nine-point scale (1=very tough, 9=very tender). ***Myofibrillar length measurements*** were performed as described elsewhere (Olsson & Tornberg, 1992). Five grams of meat was homogenised in an omnimixer at 11,000 rpm for 1 min followed by centrifuging at 2°C for 15 min at 1,000 g. The sediment was resuspended in 25 ml of isolation buffer (100 mM KCl, 20 mM K-phosphate, 1 mM EDTA, 1 mM NaN_3, pH 7.0) and diluted 25 times in the same buffer. The myofibrillar length was measured by using light microscopy (Nikon Optihot,) video images (Sony 3 CCD) and the image analysis program Image Pro Plus 3.0 (Media Cybernetic, USA).

Results & Discussion

The four temperature-time courses studied have significantly different **muscle shortening**-time appearance (**Fig. 1**). The fast temperature-time course gave the highest amount of muscle shortening , 27%, but it is not as severe as the one obtained at a constant rigor temperature of 4°C (38%, Olsson *et al.* 1994). The fast temperature-time course is followed by the slow, medium-slow and medium-fast temperature-time courses with different amounts of warm shortening. The fast temperature-time course differed from the other three courses in that the muscle shortening was preceded by a lag-phase, which in turn might be a sign of cold- and warm shortening being due to different biochemical processes. Although the fast and slow temperature-time courses gave almost the same amount of muscle shortening the **isometric tension** curves had quite different appearances (**Fig. 2**). The fast temperature-time course gave the highest amount of IT followed by the medium-fast, slow and medium-slow temperature-time courses. This is indeed a fascinating observation suggesting that the slowly chilled meat, which are exposed to higher rigor temperatures, probably promoted larger proteolytic activity and thereby obtained a lower IT. This observation is further substantiated by the fact that the myofibrillar lengths were the shortest for the slow and the medium-slow temperature-time courses already two days p.m. (**Fig. 3**). These two temperature-time courses also showed the lowest IT values, although they were more shortened than the medium-fast temperature-time course. The curves in **Fig. 2** clearly indicate that the proteolytic processes are not only restricted to the end of the rigor development but also occur during the rigor process. Evidently the RigoTech apparatus, working in the IT mode, seems to be able to measure both the muscle shortening and the proteolytic degradation occurring during the rigor process. This will be further

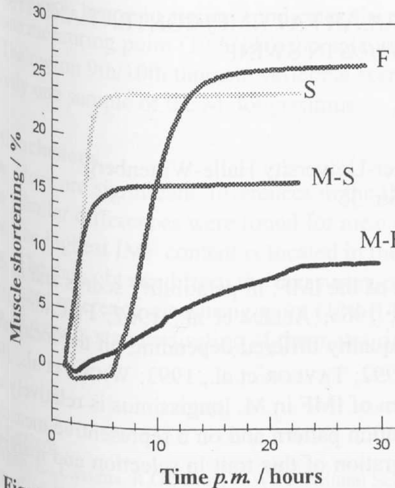

Figure 1. Muscle shortening during rigor development as a function of temperature-time course: F fast; M-F medium-fast; M-S medium-slow; S slow (n=3).

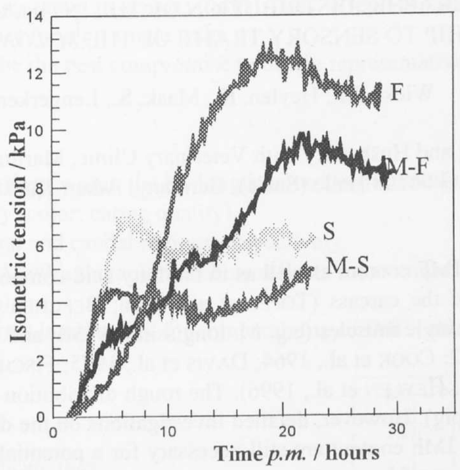

Figure 2. Isometric tension during rigor development as a function of temperature-time course: F fast; M-F medium-fast; M-S medium-slow; S slow (n=3).

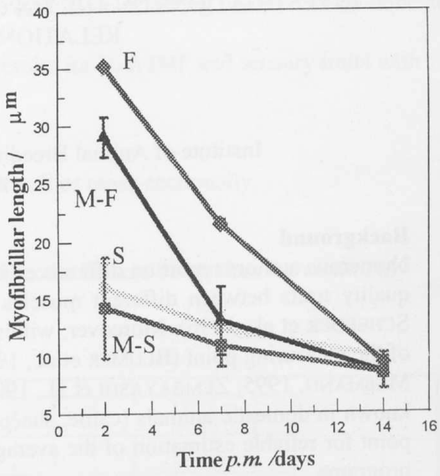

Figure 3. Myofibrillar length as a function of ageing time for different temperature-time courses during rigor development: F fast; M-F medium-fast; M-S medium-slow; S slow, (n=3).

Table 1. Sensory tenderness 7 and 14 days p.m. as a function of temperature-time course during rigor development.

Temperature-course	Sensory tenderness 7d mean±std	Sensory tenderness 14d mean±std
Fast	2.7±0.2[a]	3.0±0.5[a]
Medium-fast	4.3±0.1[b]	5.6±1.1[b]
Medium-slow	4.7±0.6[b]	4.8±0.5[b]
Slow	3.5±0.4[c]	4.5±0.3[b]

[a,b)] Means in a column without a common superscript differ significantly ($p<0.05$).

elucidated in an article to come. The medium-fast and medium-slow temperature-time courses gave meat that were significantly more tender, 7 days p.m. (**Tab. 1**) than the other two temperature-time courses. Furthermore, there was a tendency that the medium-fast temperature-time course gave the most tender meat after 14 days of ageing. Evidently this temperature-time course, with the lowest degree of shortening and a relatively low temperature during rigor, had the highest ageing capacity.

In this investigation, using more realistic temperature-time courses instead of constant rigor temperatures (earlier published from this laboratory), substantially lower amounts of MS were obtained in the cold- and warm-shortening regions. But still the different temperature-time courses have a significant influence on tenderness even after 14 days of ageing. Both the degree of shortening ($r= -0.62^*$) and the myofibrillar length ($r= -0.61^*$) correlated to similar degree to the sensory tenderness after 7 days ageing, whereas the IT, reflecting both the MS and the proteolytic degradation during rigor gave the best linear correlation ($r= -0.77^{**}$). After 14 days of ageing only the degree of shortening gave good correlation with the sensory tenderness ($r= -0.65^*$).

Conclusions

All types of temperature-time courses during rigor development results in muscle shortening or an increased muscle tension. Still the different temperature-time courses have a significant influence on tenderness, due to the combined influence of muscle shortening and tenderization. The RigoTech system, working both in the isotonic and isometric tension mode, can give information from the muscle shortening and the tenderization process that occur simultaneously during rigor development.

References

Devine. C.E., Wahlgren, N.M. & Tornberg, E. 1996. The effect of rigor temperature on shortening and meat tenderness. Proc. 42nd Int. Cong. of Meat Sci. and Tech., 1-6 Sept. Lillehammer, Norway. 396-397.

Hertzman, C., Olsson, U. & Tornberg, E. 1993. The influence of high temperature type of muscle and electrical stimulation of the course of rigor, ageing and tenderness of beef muscles. Meat Science **35** 119-141.

Olsson, U. & Tornberg, E. 1992. The interrelationship between myofibril fragmentation and tenderness for beef meat. Proc. 38th Int. Cong. on Meat Sci. Technology Vol 3, Clermont-Ferrand, France 399-402.

Olsson U, Hertzman C and Tornberg E. 1994. The influence of low temperature, type of muscle and electrical stimulation on the course of rigor mortis, ageing and tenderness of beef muscle. *Meat Science* **37**115-131.

Simmons, N. J., Singh, K., Dobbie, P. M. & Devine, C. E. 1996. The effect of pre-rigor holding temperature on calpain and calpastatin activity and meat tenderness. Proc. 42nd Int. Cong. of Meat Sci. and Techn. 1-6 Sept. Lillehammer, Norway. 414-415.

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

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