THE INFLUENCE OF DIFFERENT pH-TIME COURSES DURING RIGOR DEVELOPMENT ON BEEF TENDERNESS

N. MAGNUS WAHLGREN, CARRICK E. DEVINE* AND EVA TORNBERG
Swedish Meat Research Institute, P. O. Box 504, S-244 24 Kävlinge, Sweden
*Meat Industry Research Institute of New Zealand (Inc.), P.O. Box 617 Hamilton, New Zealand
email; m.wahlgren@ki.scan.se

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***M. longissimus dorsi* from 16 young bulls of the Swedish Lowland breed were used in an experiment where the influence of three different pH-time courses on meat tenderness were studied: fast (pH 5.6, 1h p.m.) medium (pH 5.6, 10 h) and slow pH-time course (pH 5.6, 24 h). The different pH-time courses, as were generated by electrical stimulation performed at different times post-mortem, in combination with same chilling regime, produced significantly different beef tenderness, 3 days p.m., as determined by both sensory analysis and Warner-Bratzler shear force measurements. The medium pH-time course gave significantly more tender meat than the fast ($p<0.01$) and the slow pH-time courses ($p<0.001$). The ageing process, as followed by the decrease in myofibrillar length (light microscopy) closely resembled the lowering in Warner-Bratzler shear force ($r=0.68^{***}$). The differences in tenderness arise most likely from differences in proteolytic activity since all meat showed little muscle shortening, according to sarcomere length measurements. These results suggest that it is of great importance to simultaneously optimise chilling and pH-fall during rigor development for beef tenderness. A combination of low pH and high temperature during rigor development can give substantially lowered meat tenderness.**

Introduction

Tenderness is usually identified by the consumer as the most important palatability trait of beef meat. It is also one of the most variable traits, which can be affected by both ante- and post- mortem factors. An increased knowledge of the factors that influences this variability is of the greatest importance for the meat industry. The aim of this study was to investigate the influence of different pH-time courses, as generated by electrical stimulation at different time p.m. in combination with the same chilling regime, on beef tenderness.

Materials & Methods

The influence of three different **pH-time courses** were investigated: *fast* (pH 5.6, 1h p.m.), *medium* (pH 5.6, 10 h p.m.) and *slow* (pH 5.6, 24 h p.m.). The pH-time courses were obtained by selectively choosing different low-voltage electrical stimulation parameters using the Swedish MITAB system: fast; 80V, 15 Hz, 48 s performed 1 min p.m., medium; 80V, 15 Hz, 30 s performed 30 min p.m. and slow; no stimulation. *M. longissimus dorsi* (LD) muscles from 16 young bulls of the Swedish Lowland breed were cut out three days post-mortem, following the usual chilling regime at the abattoir. This resulted in a centre temperature in the LD muscle of 20°C, 5 hours p.m., 12°C 10 hours p.m. and 4°C 24 hours p.m. which is a temperature profile during rigor giving rise to relatively little warm shortening (less than 15 %, Wahlgren *et al.*1997). The LD muscles were cut into three parts, vacuum-packed and stored at 4°C for 3, 7 and 14 days, respectively. After ageing, the meat was cut into slices for sensory evaluations (1.5 cm), Warner-Bratzler shear force (4.5 cm), myofibrillar fragmentation (5 g) and sarcomere length measurements. The meat for the ***sensory analysis*** was fried in a pan (175°C) to a centre temperature of 70°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). ***Warner-Bratzler shear force measurements*** were undertaken using an Instron® Universal testing machine equipped with a modified Warner-Bratzler blade with a square opening of 26x21 mm and a blade thickness of 1.0 mm. The meat was cooked in a water bath at 74°C for 85 min and chilled to room temperature in ice. The maximum shear force for at least 10 pieces (0.7x1.5 cm), sheared across the fibre direction, was recorded. ***Myofibrillar length measurements*** were made 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 programme Image Pro Plus 3.0 (Media Cybernetic, USA). ***Sarcomere length measurements*** were obtained by light microscopy on muscle fibres teared out from glutardialdehyde fixated meat three days p.m. using the same equipment and image analysis programme as described above.

Results & Discussion

To minimise factors that might have an impact on the results, the young bulls were chosen from the same farmer and slaughtered directly after arrival to the abattoir. They had a narrow weight distribution, 290 ± 19 kg, went through identical chilling regimes and reached the same ultimate-pH (pH_u= 5.50±0.06). The differences in tenderness between the three pH-groups will therefore mainly be due to different pH-time courses during the first 24 hours p.m.. Electrical stimulation performed 1 min p.m. (80V, 15 Hz, 48 s) had by far the largest impact on rigor development, reaching pH 5.6 within 1 hour p.m., (**Fig. 1**). This is most probably due to the fact that the nervous system participates in the transfer of electric current to the muscle fibres and with a increased post mortem delay before stimulation it becomes less responsive (Chrystall & Devine 1992). According to Dransfield *et al.*(1992), one would expect that the combination of a low pH and an elevated rigor temperature, as in the fast pH-time course, will give the most tender meat due to a faster tenderisation process. However, in this study the medium pH-time course gave significantly more tender meat three days post mortem, according to both the ***W-B shear*** force data, (**Fig. 2**), and the **sensory tenderness** scores, (**Table 1**), although the differences decreased with a prolonged ageing. The meat exposed to a fast pH-time course was not significantly more tender than meat exposed to a slow pH-time course (**Table 1**). One can, however, see from the ageing profiles of the W-B shear force data that the meat exposed to the slow pH-time course had a larger tenderisation capacity (not significant) than meat exposed to a fast pH-time course. As the temperature profiles, used in this study, should not induce severe warm shortening (less than 15% according to Wahlgren *et al.*, 1997) the influence of this factor on tenderness was considered to be of minor importance. This was also substantiated by the fact that the ***sarcomere length*** data correlated poorly with the W-B shear force data ($r=0.29$). In fact the group with

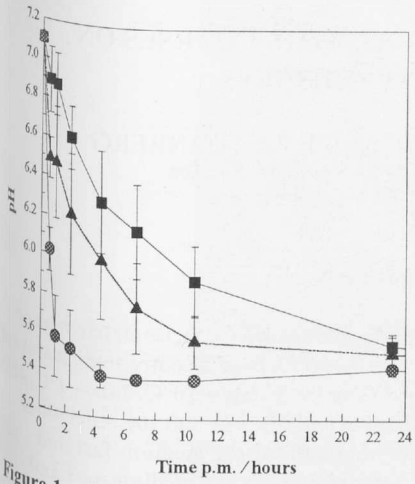

Figure 1. pH (mean±std) as a function of time *post mortem* for the three pH-time courses: ● fast (n=6); ▲medium (n=4)and ■ slow (n=6).

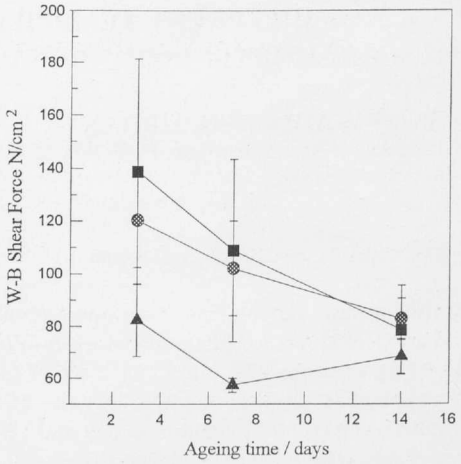

Figure 2. Warner-Bratzler shear force (mean ±std) as a function of ageing time for the three pH-time courses: ● fast (n=6); ▲medium (n=4)and ■ slow (n=6).

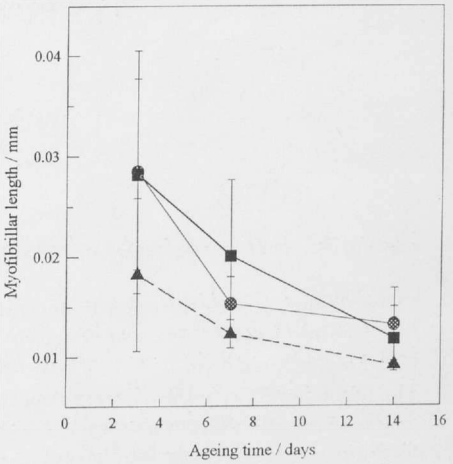

Figure 3. Myofibrillar length (mean±std) as a function of ageing time for the three pH-time courses: ● fast (n=6); ▲medium (n=4)and ■ slow (n=6).

Table 1. Sensory tenderness and sarcomere length 3 days p.m as a function of pH-time course during rigor

pH-time course	Sensory tenderness mean±std	Sarcomere length mean±std (μm)
Fast	4.1±0.9[a]	2.16±0.23[a]
Medium	5.3± 0.3[b]	1.97±0.10[a]
Slow	3.5± 1.2[a]	2.29±0.30[a]

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

highest tenderness had a tendency to have shortest sarcomeres, **(Table 1)**.The differences in tenderness for the three groups is therefore suggested to mainly originate from variations in the proteolytic tenderization process. As suggested by Tornberg (1996) an earlier attainment of lower pH in the rigor process is favourable for the proteolytic process. But it is of importance that the rigor temperature stays low, because the enzymes are more susceptible to denaturation and autolysis the lower the pH at elevated temperatures (>15°C). These two latter phenomena could be the reason for the lower tenderness of the meat exposed to the fast pH-time course in comparison to the medium one.

The ***myofibrillar length*** data gives an indirect information about the proteolytic activity that may have occurred in the meat during ageing. The decrease in myofibrillar length will, however, explain only one part of the tenderization process, i.e. no information is obtained about the breakdown of the cytoskeletal network, suggested to have a large impact on meat tenderness (Taylor *et al.*, 1995). The correlation between myofibrillar length data and Warner-Bratzler shear force data was good (r=0.68***), indicating that the combination of fast rigor development and high temperatures resulted in some inactivation of the proteolytic enzymes responsible for the tenderisation in the longitudinal direction. The correlation between myofibrillar length data and sensory tenderness, 3 days p.m., were, however, much less ($r=0.45^{n.s.}$). This difference between the two methods might be explained by the fact, that in the W-B force measurements, the shearing force always acts perpendicularly to the muscle fibre direction, whereas during chewing the force is more randomly directed against the fibres. The W-B shear force measurements seems therefore to be more discriminatory for structural differences along the muscle fibre.

Conclusions

The results from this study illustrates the importance of a simultaneous optimisation of the rate of rigor development and the chilling regimes. Right combinations of these two parameters will most probably result in meat which becomes tender earlier p.m. and therefore decrease the storing costs.

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