IMPROVING BEEF TENDERNESS BY RESTRICTING RIGOR MORTIS CONTRACTION

Kjell Ivar Hildrum, Trond Andersen+, Bjørg Narum Nilsen and Magnus Wahlgren*
MATFORSK - Norwegian Food Research Institute, Osloveien 1, N-1430 Ås, Norway
+ Gilde HedOpp BA, P.O.Box 70, N-2360 Rudshøgda, Norway
* Norway Meat, P.O.Box 396 Økern, N-0513 Oslo, Norway

Introduction

The effects of muscle shortening during rigor mortis on meat quality has been long known (Bendall, 1951). These have been characterized by a number of scientists, - more recently by Olsson *et al.* (1994) and Devine *et al.* (1999). It has lately been observed that restricting rigor contraction will enhance tenderness, - as demonstrated by Koohmaraie *et al.* (1996) in lamb. Devine *et al.* (1999) recorded corresponding effects in beef. The latter authors studied the effects of pre rigor wrapping of beef muscles using cling film in the temperature range 15-35°C, and obtained beneficial effects on sarcomere length, shear force measurements and sensory evaluation of tenderness of aged meat. Of all beef carcasses presently slaughtered in Norway, about 20 % are hot boned. By removing pre rigor muscles from the bones, the muscles become more vulnerable to increased contraction during rigor, which could have negative effects on the tenderness. As a consequence, we were interested in examining the effects of restricting muscle contraction by wrapping hot boned (pre rigor) muscles on tenderness in the lower temperature region where cold shortening will occur.

Materials and methods

Hot boned samples from *m. longissimus (LD)* and *m. semimembranosus* (SM) from 9 non electrically stimulated young bulls (15-18 months) of Norwegian Red were used in this study. The carcasses (273-377 kg) were obtained from a commercial abattoir. The muscles were excised warm after classification (1-2h post mortem). Pairs of LD were excised from all 9 carcasses, while pairs of SM were excised from 6 carcasses. One each of the muscle pairs was tightly wrapped in cling film and plastic packaging tape (5 cm wide), which overlapped approx. 20-30 %. The other muscle of the pairs was not wrapped. For the LD muscles 3 treatments were allocated to the 9 carcasses. Besides the control treatment (no wrapping), one treatment was wrapping, while the last was a combined wrapping and stretching treatment. The stretching was performed manually before wrapping to an elongation of approx.10 % of the original length. The eighteen LD muscles were systematically allocated to the 3 treatments. All muscles were then divided in two equal parts across the muscle direction, vacuum packed in polyethylene bags and subjected to chilling in water baths at 4°C and 12°C between 3 and 24h p.m. At 24h all samples were transferred to 4°C and aged for additional 1 and 8 days.

After ageing, slices of 3.5 cm thickness from each sample were cut across the muscle for Warner Bratzler shear (WBS) force measurements. All samples were vacuum-packed in polyethylene bags, heated at 70°C for 50 min in a water bath and chilled in ice water for 45 min. After recording the cooking loss, the samples were vacuum-packed once again and stored at –1.5°C for 4 days before final analysis. At the day of WBS measurements, the samples were first conditioned at 20°C for 20 min, and then slices of 1 cm thickness were cut along the fibre direction of the muscles. The second cut was also performed in the fibre direction to give the final samples to be measured cross-section dimensions of 1 cm x 1 cm. The approx. length of the samples was 3 cm. Structures of visible fat and sinew were avoided. WBS measurements were performed on 10 replicates per sample, which were cut perpendicular to the fibre direction with the WBS force device (triangular version) in an Instron Materials Testing Machine (Model 4202, Instron Engineering Corporation, High Wycombe, U.K.). The averages of the maximum force were used in the data analysis. Details regarding experimental procedures are given in Hildrum *et al.* (1999).

Samples for sarcomere length were collected from all LD muscles 5 days after slaughter, fixed in a borate solution containing 2.5 % glutaraldehyde and homogenized with a Polytron PT3000 homogenizer. The sarcomere lengths were measured with an image analysing program (Image-Pro Plus 4.0, Media Cybernetics, Silverspring, Maryland, USA) of pictures taken with a camera (Hitachi KP-D50 Color Digital, Hitachi Denshi Ltd, Japan) connected to a light microscope (Leica DMLB, Leica Mikroskopie & Systeme GmbH, Wetzar, Germany). pH in the muscles was recorded at intervals using gel electrodes. The statistical analysis was performed in MINITAB, version 12.

Results and discussion

To give an overall picture of the variability in quality parameters, mean values and standard deviations of the raw data for different variables for the 2 muscles are given in Table 1. As no electrical stimulation was applied, the pH–fall in LD was relatively slow. Chilling at 12°C in LD gave a significant ($p>0.05$) faster pH-fall than at 4°C. No significant difference in pH-fall was recorded between the treatments (Control, Wrapped, Wrapped +Stretched muscles). WBS force values exhibited large variation in both LD and SM. The average WBS force value in LD and SM after 2 days of ageing was not significantly different ($p<0.05$). Between 2 and 9 days LD underwent a significantly stronger tenderization than SM ($p>0.05$).

TABLE 1. MEANS AND STANDARD DEVIATIONS FOR IMPORTANT VARIABLES

Variable	*m. longissimus* (36 samples)		*m. semimembranosus* (24 samples)	
	Mean	St.dev.	Mean	St.dev.
pH_2	6.54	0.18	6.52	0.23
pH_7	6.22	0.23	6.08	0.30
pH_{24}	5.60	0.09	5.60	0.08
Sarcomere length (µm)	1.86	0.35	-	-
WB-day2 (hg/cm^2)	94.7	22.4	100.8	22.0
WB-day7 (hg/cm^2)	54.7	20.1	78.2	18.6

The effect of wrapping on WBS values of LD was highly significant ($p<0.005$) after 2 and 9 days of ageing. Also the effect of chilling rate (4 vs. 12°C) on WBS values of LD was highly significant ($p<0.005$) after 2 and 9 days of ageing (Figure 1). However, there was a significant interaction between chilling rate and wrapping, which meant that effect of wrapping was only significant in samples chilled at 4°C. The effects of slow chilling or wrapping of LD were of similar magnitudes. Wrapping of LD muscles significantly increased the sarcomere length ($p<0.05$) at both chilling temperatures. Additional stretching of the muscles did not significantly increase the sarcomere length any further ($p>0.05$). No significant effect on WBS values was observed by wrapping SM muscles. Chilling rate also yielded a significant effect on WBS values of SM muscles, but only after 2 days of ageing. This means that the tenderness improvement obtained by the slower chilling of SM had been partly compensated for by the longer ageing period.

Conclusions

Restricting rigor mortis contraction of rapidly chilled (4°C) hot boned bovine *m. longissimus dorsi* (LD) by wrapping the muscles tightly with plastic tape, improved tenderness significantly ($p>0.005$), - both after 2 and 9 days of ageing at 4°C. Pre rigor wrapping appeared to be an efficient tool to reduce undesirable effects of cold shortening at fast chilling of LD. The effect of wrapping was of the same magnitude as increasing the chilling temperature from 4°C to 12°C. Stretching the LD muscles in addition to wrapping was not successful. After ageing the wrapped samples had a round, attractive shape. Wrapping of LD caused a significant increase in the sarcomere length of the rapidly chilled muscles. No significant effect of wrapping on tenderness was observed at slow chilling (12°C). No significant effect on tenderness was found by wrapping *m. semimembranosus* (SM) muscles.

References

Bendall, J. (1951) *J. Physiol. 114, 71-88.*
Devine, C.E., Wahlgren, N.M. and Tornberg, E. (1999) *Meat Sci. 51, 61-72.*
Hildrum, K.I., Solvang, M., Nilsen, B.N., Frøystein, T. and Berg, J. (1999) *Meat Sci. 52, 1-7.*
Koohmaraie, M., Doumit, M.E. and Wheeler, T.L. (1996) *J. Anim. Sci. 74,2935-2942.*
Olsson, U., Hertzman, C. and Tornberg, E. (1994) *Meat Sci. 37, 115-131.*

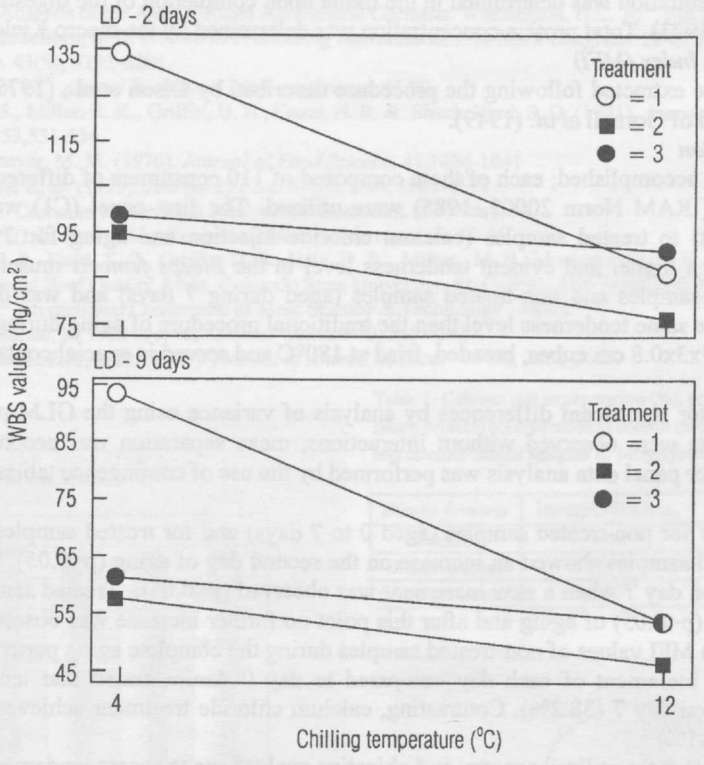

Figure 1. Restricting muscle contraction during rigor by wrapping and stretching hot boned bovine m. longissimus dorsi and the effects on WBS values (Treatments; 1=control, 2=wrapped, 3=wrapped and stretched).