2:19

Effect of early post-slaughter handling and storage conditions on tenderness of bull Longissimus dorsi.

BUTS, B.[1], CLAEYS, E.[1] and DEMEYER, D.[1,2]

1. Onderzoekscentrum voor voeding, veeteelt en vleestechnologie, University of Ghent, Melle, Belgium.
2. Instituut biotechnologie, University of Brussels, Brussels, Belgium.

Introduction

The effect of different animal or carcass characteristics or treatments on tenderness of beef has been the subject of many investigations.
From many of these studies it can be concluded that eating quality is predominantly determined by post-slaughter handling (e.g. Bouton et al., 1978; Dransfield et al., 1982).
Lochner et al. (1980) first showed that tenderness was closely related to muscle temperature in the very early post-mortem (VEP) period. Since then a number of arguments have been presented by Marsh et al. (1981) and Marsh (1983) to support these results. Especially the combination of a high temperature in combination with a relatively high pH shortley after slaughtering seems to be necessary for optimal tenderization according to Marsh (1983).
In the present work we studied the relationship between temperature and/or pH during the VEP period and beef tenderness.

Material and methods

Seventy seven one year old bulls (mean values ± SE for live weight : 471 ± 5 kg and dressing % : 61.3 ± 0.2%) were slaughtered on 13 different days in the slaughterhouse of our laboratory after captive bolt stunning and pithing.
In order to be able to check if minor differences in slaughtering procedure did affect tenderness, the time frame of the different slaughtering stadia was noted in order to quantitate their eventual effect.
Left and right hand carcass halves were subjected to different cooling regimes. Left sides were transferred to a cooler at 3°C (air speed ca 0.5 m/sec), wereas cooling of right sides was delayed to obtain differences in carcass temperatures in the VEP period : 35 halves were transferred to the cooler ca 2.5 h p.m. while cooling of the others was delayed until ca 4 h p.m. Temperature was measured 7.5 cm deep in the centre of the Longissimus dorsi (LD) part corresponding with the 8th thoracic rib 1h, 2h and 4h p.m. using a thermocouple connected to a portable temperature meter (Technotherm 9503, Instrulab, Brussels, Belgium). There after temperature was recorded continuously until 24h p.m. using thermocouples (Pt 100, 1/3 Din, Degussa,Brussels, Belgium) connected with a Honeywell recorder outside the cooler (accuracy : ± 0.15°C).
Carcasses were always hung at the same site in the same cooling room, in order to achieve nearly identical cooling conditions for all carcasses.
The pH was measured with an Ingold combination electrode (Weilheim, BRD) attached to a digital pH meter (knick portamess 651, Knick, Berlin, BRD) at 1h, 2.5h, 4h and 24h p.m. at a depth of ca 5 cm directly in the LD (each time mean value of 5 measurements).
Of each carcass side the LD (8th thoracic rib) was removed 24h p.m., Göfo reflectance (Göfo, Göttingen, BRD) measured and after trimming of fat samples were vacuum packed in polyamide laminated polyethylene (Sidamil-X typ EAK 41, Sidac, Ghent, Belgium, Belgium) and subsequently cooled (4°C) for 7 days.
Eight days p.m. drip loss was determined and cuts were subsampled for sarcomere length determination.
Cooking loss and Warner-Bratzler peak shear force was determined after cooking of the 2.5 cm thick LD cuts.

Methods:

Bag drip was measured as follows : the LD samples were weighed before vacuum packing wiped with a cloth after removal from the package (8d p.m.) and weighed again. The ratio of the weight-difference to the initial weight x 100 is called the drip percentage. Cuts (2.5 cm thick) were heated in open plastic bags by immersion (1h) in a waterbath at 75°C and bags were cooled subsequently under running tap water to room temperature.
Cooking loss was determined by weighing before and after cooking.
Warner-Bratzler peak shear force (WB-shear mounted on an Instron 1140, Instron ltd, High Wycombe) were determined perpendicular to the fibre direction on 1.27 cm diameter cork-bore samples obtained from the heated cuts.
Measurements of 15 to 30 cores were averaged. Sarcomere Length (SL) was determined on fresh subsamples (ca 10g) fixed in 2.5% glutaraldehyde using laser diffraction as described by Vandendriessche et al. (1984). Measurements of 20 different fibres per sample were averaged.

Results and discussion

Table 1 shows mean temperatures (± SD) and ranges for left and right carcass halves at different times p.m.
It is clear that temperature is significantly higher for the right halves in comparison with the (control) left halves.
In table 2 the meat quality characteristics are shown. As can be seen from this table there was a considerable variability in WBS values for both sides, similar to the variability reported (Buts et al., 1984).
Although 2.5, 4 and 6 hour temperatures readings were significantly higher for the right carcass halves compared to the left, tenderness was not affected as is reflected by the mean (± SD) WBS ratio right over left : 1.01 (± 0.13). WBS is not correlated with temperature at 1h, 2.5h, 4h and 6h p.m. (figures not shown).
Also slight differences in the time frame of the slaughtering procedure could not account for the variability in tenderness observed.
As can be seen from figure 1 there is a minor shift towards a lower WBS ratio right over left (control) sides with delay before cooling. This is also illustraded by the mean values ± SD for the 2.5h and 4h group respectively 1.03 ± 0.13 and 0.98 ± 0.13 (not significantly different). It is also clear from table 1 and figure 1 that slight differences in carcass side temperatures in the VEP period caused by deleyed cooling do not seem to be a major cause of tenderness variability. While WBS is not correlated with carcass (side) temperature in the VEP period it is slightly negatively correlated with time to reach 10°C (data not shown). This finding could mean that carcass temperature when final pH is reached is important for tenderness. This underlines the

importance of temperature not merely in the VEP period, but until the installation of rigor.
WBS is slightly positively correlated with pH at 1, 2.5, 4h p.m. (data not shown). These correlations indicate that at a lower pH at these times p.m. the meat is more tender 8 days p.m. This is in contradiction with the theory of Marsh (1983) that a relativelly high pH in combination with a high temperature in the VEP period is necessary for optimal tenderization.
As could be expected temperature and pH are significantly correlated both for left ($r = -0.359$ and -0.510 at 2.5 and 4h p.m. respectively) and right ($r = -0.339$ and -0.411 respectively) carcass sides. This means that post mortal glycolysis is hastened when temperature is higher. This illustrates another controversial aspect of the VEP-period theory of Marsh (1983) : when temeprature is higher in the VEP-period, pH will fall faster and so the period with a high temperature and relatively high pH will be much shorter!
It must be noted that although cooling conditions were very moderate. Warner-Bratzler shear force was negatively correlated ($p < 0.05$) with sarcomere length (-0.311 and -0.421 for left and right carcass halves respectively). As WBS is only measured 8 days p.m. (when ageing is completed) whe were not able to study an eventual acceleration of tenderization at the beginning of the ageing period by high VEP period temperatures.
Although our experiment did not allow a complete test of the VEP period theory, our results serve arguments that contradict important aspects of this theory. On the other hand, the work of Marsh will continue to stimulate further research on meat tenderness.

Acknowledgement

This research was supported by the I.W.O.N.L., Brussels.

References

Bouton, P.E., Ford, A.L., Harris, P.V., Shorthose, W.R., Ratcliff, D. and Morgan, J.M.L. (1978). Meat Sci, 2, 301.
Buts, B., Claeys, E. and Demeyer, D. (1984). Proc. 30 th Europ. Meet Meat Res. Workers, 69.
Dransfield, E., Rhodes, D.N., Nute, G.R. Roberts, T.A., Boccard, R., Touraille, C., Butcher, L., Hood, D.E.
Joseph, R.L., Schön, I., Casteels, M., Cosentino, E. and Tinbergen, B.J. (1982). Meat Sci., 6, 163.
Lochner, J.V., Kaufman, R.G. and Marsh, B.B. (1980). Meat Sci., 4, 227.
Marsh, B.B. (1983) Reciprocal Meat Conf. (AMSA), 36, 131.
Marsh, B.B., Lochner, J.V., Takahashi, G. and Kragness, D.D. (1981). Meat Sci, 5, 479.
Vandendriessche, F., Buts, B., Claeys, E., Dendooven, R. and Demeyer, D. (1984). Proc. 30th Europ. Meet of Meat Res. Workers, 110.

Table 1 : Mean temperatures (± SD) and temperature range 7.5 cm deep in the L.D. at different times p.m.

	1h p.m.		2.5h		4h		6h	
	Mean(SD)	range min-max	Mean(SD)	range min-max	Mean(SD)	range min-max	Mean(SD)	range min-max
L	39.8±0.8	37.4-42.4	34.0±1.5	29.6-37.9	27.7±2.0	22.9-35.6	21.4±1.5	17.8-26.8
R	39.7±0.7	37.7-41.9	34.9±1.5	31.1-39.6	29.0±1.9	25.2-33.2	22.7±2.0	19.3-29.0
Level of significance	N.S		*		*		*	

Level of significance : * : at least $p \leq 0.05$, N.S. = not significant : $p > 0.05$ (paired t-test)

Table 2 : Mean (SD) meat quality characteristics for both left and right sides.

	Left		Right	
	mean(SD)	range min-max	mean(SD)	range min-max
WS (N)	49.0 (12.6)	25.9-87.6	49.2 (14.0)	31.3-98.8
SL (μ)	1.97 (0.18)	1.45-2.47	1.90 (0.17)	1.48-2.52
Göfo	73.5 (5.0)	59 -86.5	73.3 (5.2)	62.5-86
Drip (%)	3.00 (1.2)	1.45-7.79	3.09 (1.1)	1.24-7.57
Cooking loss (%)	32.5 (2.8)	16.8-28.2	21.9 (3.0)	13.4-30.4

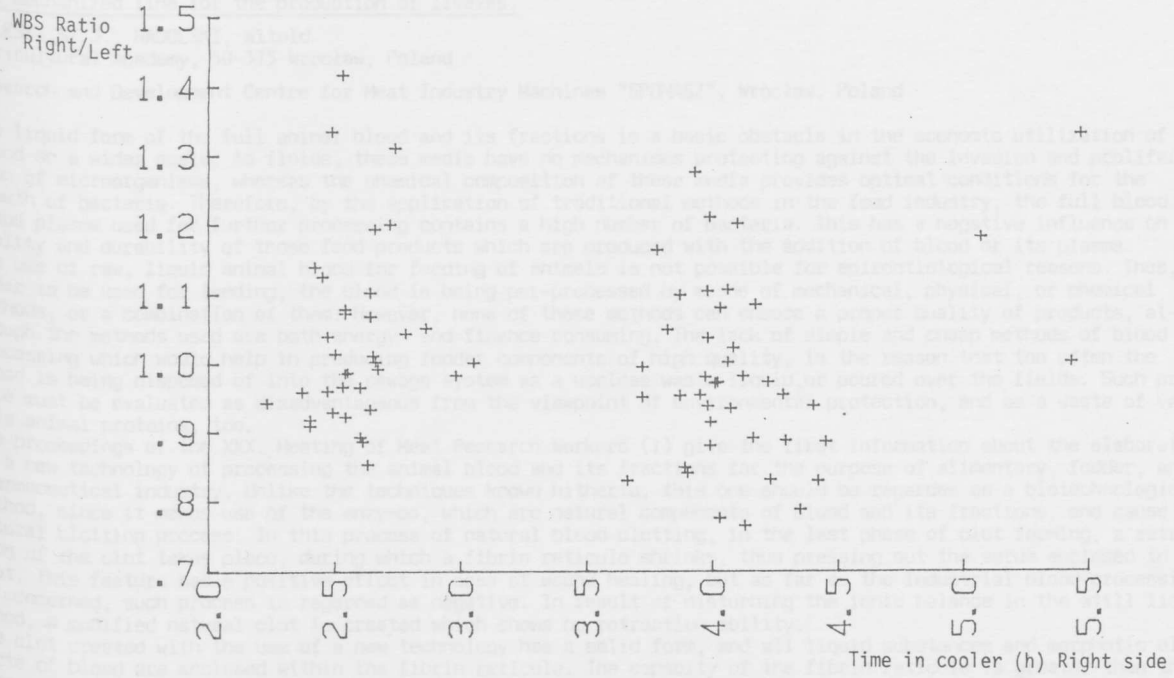

Figure 1 : Warner-Bratzler shear Ratios Right over Left (control) in relation to the delay (h p.m.) before transport of the right side in the cooler.

importance of temperature not merely in the VEP period, but until the installation of rigor.
WBS is slightly positively correlated with pH at 1, 2.5, 4h p.m. (data not shown). These correlations indicate that at a lower pH at these times p.m. the meat is more tender 8 days p.m. This is in contradiction with the theory of Marsh (1983) that a relativelly high pH in combination with a high temperature in the VEP period is necessary for optimal tenderization.
As could be expected temperature and pH are significantly correlated both for left (r = -0.593 and -0.510 at 2.5 and 4h p.m. respectively) and right (r = -0.338 and -0.411 respectively) carcass sides. This means that post mortal glycolysis is hastened when temperature is higher. This illustrates another controversial aspect of the VEP-period theory of Marsh (1983) : when temperature is higher in the VEP-period, pH will fall faster and so the period with a high temperature and relatively high pH will be much shorter.
It must be noted that although cooling conditions were very moderate, Warner-Bratzler shear force was negatively correlated (p < 0.05) with sarcomere length (-0.311 and -0.421 for left and right carcass halves, respectively).
As WBS is only measured 8 days p.m. (when ageing is completed) whe were not able to study an eventual acceleration of tenderization at the beginning of the ageing period by high VEP period temperatures.
Although our experiment did not allow a complete test of the VEP period theory, our results serve arguments that contradict important aspects of this theory. On the other hand, the work of Marsh will continue to stimulate further research on meat tenderness.

Acknowledgement

This research was supported by the I.W.O.N.L., Brussels.

References

Bouton, P.E., Ford, A.L., Harris, P.V., Shorthose, W.R., Ratcliff, D. and Morgan, J.H.L. (1978). Meat Sci. 2, 301.
Buts, B., Claeys, E. and Demeyer, D. (1984). Proc. 30 th Europ. Meet Meat Res. Workers, 55.
Dransfield, E., Rhodes, D.N., Nute, G.R. Roberts, T.A., Boccard, R., Touraille, C., Buchter, L., Hood, D.E., Joseph, R.L., Schön, I., Casteels, M., Cosentino, E. and Tinbergen, B.J. (1983). Meat Sci. 6, 163.
Lochner, J.V., Kauffman, R.G. and Marsh, B.B. (1980). Meat Sci., 4, 227.
Marsh, B.B. (1983) Reciprocal Meat Conf. (AMSA), 36, 131.
Marsh, B.B., Lochner, J.V., Takahashi, G. and Kragness, D.D. (1981). Meat Sci. 5, 479.
Vandendriessche, F., Buts, B., Claeys, E., Dendooven, R. and Demeyer, D. (1984). Proc. 30th Europ. Meet of

Table 1 : Mean temperatures (± SD) and temperature range 7.5 cm deep in the L.D. at different times p.m.

	1h p.m.		2.5h		4h		6h	
	Mean(SD)	range min-max	Mean(SD)	range min-max	Mean(SD)	range min-max	Mean(SD)	range min-max
L	39.8±0.8	37.4-42.4	34.0±1.6	29.6-37.9	27.7±2.0	22.9-35.6	21.4±1.6	17.0-28.8
R	39.7±0.9	37.7-41.9	34.9±1.5	31.1-39.6	29.0±1.9	25.2-33.2	22.7±2.0	19.3-29.0
Level of significance	N.S.		*		*		*	

Level of significance : * : at least p ≤ 0.05, N.S. = not significant : p > 0.05 (paired t-test)

Table 2 : Mean (SD) meat quality characteristics for both left and right sides.

	Left		Right	
	mean(SD)	range min-max	mean(SD)	range min-max
WS (N)	49.6 (12.6)	25.9-87.6	49.2 (14.0)	31.3-98.8
SL (µ)	1.87 (0.18)	1.45-2.47	1.90 (0.17)	1.48-2.52
80Fo	76.5 (5.0)	59 -86.9	73.3 (5.2)	62.5-86
Drip (%)	3.10 (1.2)	1.45-7.79	3.09 (1.1)	1.24-7.57
Cooking loss (%)	22.6 (2.9)	16.8-28.2	21.9 (3.0)	13.4-30.6