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Does artificially raising the ultimate pH produce similar effects on tenderness to those observed previously in Dark-Cutting (DC) beef.

Beverley C. Thomson and Graham R. Trout
School of Life Sciences and Technology, Victoria University of Technology, Werribee Campus, PO Box 14428, Melbourne City MC, Victoria 8001, Australia.

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Introduction:

Post-mortem pH in muscle affects meat tenderness. When the living animal is at rest, the regulation of pH depends on Na^+/H^+ exchanges as well as Na^+-dependent and Na^+-independent Cl^- bicarbonate transport systems (Juel, 1998). When an animal is killed these regulatory processes break down and in muscles where glycogen levels are adequate, the muscle pH falls from 7.20 to a pH of approximately 5.5. If the level of glycogen is limiting then the ultimate pH will be raised. The reported effects of differences in ultimate pH on tenderness vary. For example, Silva et al (1998) found that meat with an ultimate pH between 5.8 and 6.2 was more tender than meat with a pH of 5.5 while Purchas (1990) found that meat in this region was tougher than meat with pHs greater or less than this.

Objectives:

This experiment aimed to artificially raise the ultimate pH in beef strip loins to between 5.8 and 6.1 in order to determine the direct effect of ultimate pH in this region on tenderness as determined using Warner Bratzler shear force (WBSF).

Materials and Methods:

Strip loins (Longissimus dorsi) from the carcasses of four commercially produced grass fed steers (carcass weight around 200 kg) were collected. All samples were collected and treated within two hours of slaughter. Each strip loin was divided into two pieces and each piece was allocated to one of two treatments which were: a) Control (non-injected) and b) Bicarbonate (10 % injected with 0.8M sodium bicarbonate). Sodium bicarbonate was injected by inserting a 18 G needle halfway through the sample and injecting approximately 2 mls while slowly withdrawing the syringe. The injection sites were approximately 1 cm apart in a grid pattern.

Temperature, pH and weight were determined pre- and post-injection. The samples were then further sub-sampled into four, each piece was weighed prior to being randomly allocated to a storage period. Temperature and pH were measured in one sub-sample every 15 minutes for two hours post treatment, then every 30 minutes for one hour and then hourly until the pH values stabilised. Five hours post-slaughter the rest of the samples were vacuum packed prior to being placed in a controlled temperature cabinet set to 10 °C; 24 hours post-slaughter the temperature in the cabinet was reduced to 0 °C. WBSF was determined in cooked samples 1, 2, 7 and 14 days post-slaughter. Samples were cooked in a waterbath at 70 °C for 1 hour, cooled in iced water and then stored overnight in a 4 °C chiller. The samples were then cut into ten 0.6 cm by 1.5 cm strips following the direction of the fibres (Bouton and Harris, 1978) for WBSF measurement using an Instron Texture Analyser (Model 4465, Instron Incorp., England).

Data analysis was carried out using the Generalised Linear Model procedure in SAS (SAS for Windows, Version 6.12, SAS Institute Inc., Cary, NC, USA).

Results:

The weight of fluid injected and retained was 9.3 % (SE 0.21 %). The bicarbonate injection had no effect on pH immediately post injection but the ultimate pH of 6.1 (SE 0.20 %) in the bicarbonate treated samples was significantly higher than the control samples where the ultimate pH was 5.6 (SE 0.03). The sodium bicarbonate and control samples reached ultimate pH levels 24 hours post-slaughter (Figure 1).

The bicarbonate treated samples were more tender than the control samples with the difference being greatest 24 hours post-slaughter (Table 1). Although the mean within-sample variation for tenderness was larger in the treated samples, it was not significant.

Table 1. Effects of pH treatment on WB shear force (kg) and the within-sample variation for the determination of shear force during the storage period.

Storage	Shear force (kgN)[a]		WBSF (kg)				Within-sample variation			
Day	High	Normal	Bicarbonate	Control	SE	P	Bicarbonate	Control	SE	P
1	12.2	11.2	6.8	10.1	0.46	0.0001	2.02	1.02	0.741	0.11
2			6.8	9.1	1.63	0.09	1.92	1.33	0.756	0.30
7	9.6	6.5	4.7	6.0	0.97	0.31	1.50	1.79	0.446	0.58
14	11.8	5.4	3.6	4.9	0.55	0.02	0.89	0.73	0.298	0.49

[a] Strip loins from pasture fed bull beef (with storage day adjusted for ageing temperature) from Thomson et al (1999)

Discussion:

The aim of this study was to mimic as closely as possible the pH changes recorded in DC meat in other studies by artificially raising the ultimate pH to between 5.8 and 6.1. The bicarbonate treatment decreased the rate of pH decline without altering the time taken to reach ultimate pH. This resulted in an elevated ultimate pH of 6.1. It produced a similar pH decline curve to that observed by Thomson et al (1999) in bull strip loins with high ultimate pH values.

Sodium bicarbonate treatment resulted in more tender meat and reduced the length of the ageing period required for tender meat. This increase in tenderness with an ultimate pH of 6.1 is inconsistent with Purchas (1990) and Thomson et al (1999) who found that strip loins with a similar pH to this were tougher than those with a normal ultimate pH (5.5) (Table 1). Therefore from these results, it would appear that ultimate pH does not appear to cause the increased toughness associated with a moderately high ultimate pH.
One possible explanation for the increase in tenderness in this experiment may be the increased sodium ion concentration in the tissue as Thomson et al (1997) and Koohmaraie et al (1989) found that sodium chloride injection increased the rate of tenderisation early in the ageing period. However, both these groups found no significant treatment effect at the end of ageing, while in the present experiment, there was still a significant difference between the treated and the non-treated samples after 14 days suggesting that the increased tenderness was not totally due to the increased sodium ion concentration.
Another possibility is that the tenderisation is due to an increased activity of the components of the calpain system, since this system appears to play a major role in tenderisation. The calpains are most active at neutral pHs and their activity declines with decreasing pH (Dransfield, 1994). When the pH decline rate is slow the calpains are active longer, thereby increasing the rate of tenderisation, which may be what is happening in the sodium bicarbonate treated samples in this experiment. In contrast, in bull beef strip loins with a moderately high ultimate pH due to pre-slaughter factors, the higher pH is associated with an increase in toughness (Table 1) and a decrease in the level of μ-calpain at slaughter (Thomson et al, 1999). Therefore, in that experiment the effect of any increase in percentage activity due to the higher pH on overall proteolytic activity would be small due to the reduced initial level of μ-calpain. This would result in tough meat because the actual μ-calpain proteolytic activity in the high ultimate pH strip loins would be low relative to that in a strip loin with a normal ultimate pH.

Conclusion:

The ultimate pH in the bicarbonate samples was 6.1 which is similar to that observed with DC meat. The bicarbonate treated samples were more tender 24 hours post-slaughter than the control samples. The effects of sodium bicarbonate treatment on shear force did not mimic the results found previously in beef samples with ultimate pH values between 5.8 and 6.2. Therefore, pH by itself does not appear to be the cause of tough meat in beef strip loins with moderately high ultimate pH values.

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Figure 1 The change in pH post slaughter in sodium bicarbonate treated and control LD samples