TENDERISATION OF BEEF MUSCLE BY INJECTION OF SALTS

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BACKGROUND

There is need to more rapidly and efficiently process meat. Conventional practices involve the holding of entire carcasses for 24 to 48 h at chilled temperatures before boning out cuts. This is very inefficient since there are parts of the carcass that contain bones and fat which will be discarded after boning and are hence chilled needlessly. Removing the muscles very early postmortem (PM), while the carcass is still hot(hot-boning), accelerates processing, and reductions in energy of up to 50% have been reported for refrigeration of hot-boned beef compared to beef processed by conventional procedures. Utilization of hot-boning also conserves chiller space since less space is needed to store cartons of meat than for whole carcasses. The major disadvantage of hot-boning is believed to be a decrease in tenderness caused by rapid pre-rigor cooling resulting in cold-shortening (Marsh et al., 1972; Hinnergardt et al., 1973). The organoleptic trait most affecting consumer acceptance of beef is inconsistent tenderness (Morgan et al., 1991). Therefore, a commercially applicable method that conserves energy yet is able to ensure a consistently tender product is critical for improved consumer acceptance. Cold-shortening (CS) occurs when pre-rigor muscle is removed from the skeleton and chilled rapidly, causing the muscle to contract, resulting in shortened sarcomeres. Shortening has a profound effect on meat tenderness: a length change of 30-40% toughens meat to the point of inedibility (Marsh and Leet, 1966). The extent of shortening and toughening is less for pork than for beef and lamb (Marsh et al., 1972). The tenderness problems associated with hot-boning can be overcome, minimized or limited by conditioning the carcass for 3-8 h at elevated temperatures (16°C or higher) before boning or by holding the excised cuts at 10-15°C for 12-48 h (Taylor et al., 1980-81). However, it is questionable whether regulatory authorities would permit the holding of meat at elevated temperatures due to microbiological concerns, therefore a process is needed which overcomes or prevents the cold-induced-toughening associated with rapid chilling, but which also ensures desirable flavour and appearance (particularly colour and minimal purge).

OBJECTIVES

Investigate the effects of distilled water, sodium chloride and sodium pyrophosphate injected into muscle pre- and post-rigor to determine whether the effects were solely due to pre-rigor actions (i.e. preventing contraction) and to ensure that any prevention of toughening resulted in muscles of similar tenderness to conventionally boned controls.

METHODS

In three experiments six (~30 month old) heifers were slaughtered in a random order (2 per day for 3 days). In expt. 1 the semimembranosus (SM) and biceps femoris (BF) muscles were removed from the carcasses within 60 min PM (hot-boned). In expt. 2 the carcasses were chilled under conventional conditions and the SM and BF muscles were excised at 48 h PM (cold-boned). In expt's 1 and 2 the BF muscles were kept whole but the SM muscles were halved, the right and left BF muscles were randomly assigned to be either injected with 0.1125 M $Na_4P_2O_7$ + 0.1125 M $Na_2H_2P_2O_7$ + 0.2 M NaCl (PPi) or non-injected controls (C) and the four SM muscle halves were randomly assigned to be either injected with distilled water (H_2O), 0.875 M NaCl (NaCl), PPi or C. In expt. 3 the right and left sides of the carcass were randomly assigned to be either hot-boned or cold-boned and both muscles were halved and each half was randomly assigned to be either PPi or C. All muscles and muscle halves were weighed and solutions were injected at 10% w/w using a multi-needle hand-held brine pump (Hantover, Kansas City, MO 64120). Muscles were weighed after injection and actual % fluid injected and retained was recorded. Immediately after processing, muscles were placed in plastic bags in a cooler at 2°C with rapid air movement, with the aim of producing CS in the hot-boned muscles. Temperature, pH, ATP, sarcomere length, protein solubility, gel electrophoresis, western blot analysis, composition, colour, drip loss and cooking loss traits were all measured but only tenderness will be reported on in this paper. Steaks at 3, 7 and 14 d PM were broiled to an internal temperature of 73°C in a conventional oven then allowed to cool at room temperature for 1 h before being cut into 1 cm^2 cores and sheared using a Warner-Bratzler shear device.

RESULTS AND DISCUSSION

The control steaks from HB muscles had high Warner-Bratzler shear values (table 1) and where direct statistical comparisons could be made between hot-and cold-boned treatments (expt 3 only), the HB controls had significantly higher ($P < 0.05$) shear values than the CB controls at all evaluation times indicating that CS or cold-induced toughening had occurred in the HB control muscles as desired for this work. The muscles that were cut in half (the SM's in expt. 1 and all muscles in expt 3) had higher shear values than the whole BF muscles in expt 1 and where direct statistical comparisons could be made between the halved and whole HB muscles (it was assumed that direct statistical comparisons could be made across the two different muscles since when both muscles were cut in half (expt 3 only), there was no significant difference between the muscles) the muscles cut in half did not have-significantly higher ($P > 0.05$) shear values than the whole muscles due to large variations in the degree of toughening in individual muscles.

In expt. 1 where a number of treatments were compared in the HB muscles, there was a significant time effect, a significant treatment effect and a significant treatment x time interaction. It was found that injecting distilled water (H_2O) had only a slight tenderising effect and did not appear to have prevented toughening as indicated by the lack of significant difference ($P > 0.05$) between the H_2O-injected muscles and the control muscles overall and at 3 d PM. There was a significant difference ($P < 0.05$) between the H_2O-injected muscles and the control muscles at 7 and 14 d PM and, unlike the controls, the H_2O-injected muscles had significantly ($P < 0.05$) lower shear values at 7 and 14 d than at 3 d PM, but the H_2O-injected muscles were still considered to have unacceptably high shear values even at 14 d PM. The lack of PM tenderisation observed in the controls is indicative of considerable CS (Davey et al., 1967). Meat which is cold-shortened to the point of maximum toughness is little influenced by even prolonged ageing according to Davey et al., (1967), and, if the length change has not exceeded about 20%, tenderising will take place quite rapidly, and to an appreciable extent, but beyond this shortening the ageing process becomes progressively less, no matter how prolonged, and is negligible if the earlier length change was 40% or greater.

The NaCl treatment of HB muscles resulted in significantly lower ($P < 0.05$) shear values than the controls at all times and resulted in significant postmortem tenderisation such that the 14 d shear values were significantly lower ($P < 0.05$) than the 3d values for this treatment

and were considered to be acceptably tender. However, the PPi treatment of HB muscles resulted in the most tender steaks of all of the HB treatments investigated in this study. The HB PPi-treated steaks were significantly lower ($P < 0.05$) in shear values than the controls at all times and resulted in very tender steaks at 3 d PM in expt 1, with no significant postmortem tenderisation observed for this treatment in expt 1, i.e. there was no significant difference between the 3, 7 and 14 d shear values ($P > 0.05$). In expt 3 there was also a large and significant difference between the HB controls and PPi-treated steaks at each evaluation time ($P < 0.05$), but the 3d shear values were significantly higher than the 14 d shear values ($P < 0.05$) and the 3d values were not considered to be acceptably tender. The control muscles in expt 3 also showed significant tenderness differences between 3 and 14 d PM and considering that these muscles had very high shear values at 3 d indicating CS, it is unclear why they showed considerable postmortem tenderisation. However, these steaks were still considered to be very tough even at 14 d PM.

Where direct statistical comparisons could be made between HB and CB treatments (expt 3 only), the HB PPi-treated steaks were not significantly different ($P > 0.05$) from the CB controls, but the CB PPi-treated steaks were more tender than the HB PPi-treated steaks at 3 and 7 d PM ($P < 0.05$). The PPi-treatment also showed evidence of tenderisation even in CB muscles, though this was only significant ($P < 0.05$) in the BF muscles in expt 2. It is worth noting that all of the CB control muscles in this study were of quite low shear force and it is possible that the PPi-treatment would have had greater effects in the CB muscles if they had not already been so tender. The PPi treatment has also been compared to injecting 0.3 M $CaCl_2$ in HB muscles (Stevenson-Barry and Kauffman, 1995) and was found to produce steaks of similar tenderness ($P > 0.05$) to steaks from muscles injected with $CaCl_2$.

CONCLUSIONS

These results indicate that PPi-treatment has beneficial effects on tenderness and completely overcomes toughening induced by very rapid chilling, resulting in beef of similar tenderness to conventionally boned muscles, and, it may have beneficial effects on tenderness in CB muscles also. The PPi treatment had minimal effects on steak colour, drip and cooking losses, indicating that there would not be problems with consumer acceptance. For muscles that are chilled rapidly, PPi-treatment could possibly be a cost-effective treatment that would ensure consistently tender product. Pork muscles treated with polyphosphate to enhance juiciness and tenderness have been available in certain US supermarkets for several years and appear to be well-received by consumers (these are apparently injected post-rigor).

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TABLE 1: Warner-Bratzler shear values of hot- and cold-boned muscles at various times after postmortem chilling.

Expt's 1 & 2[1]	Biceps femoris		Semimembranosus					Expt 3[3]	Hot-boned		Cold-boned		Overall
	Control	PPi[2]	Control	H_2O[2]	NaCl[2]	PPi[2]	Overall mean		Control	PPi[2]	Control	PPi[2]	mean
Hot-boned								Time					
3 d	7.9	5.6	9.6	9.3	7.2	5.9	7.6^{a}	3 d	10.3	7.1	6.1	5.5	7.3^{a}
7 d	7.9	5.3	9.5	7.4	5.9	5.2	6.9^{ab}	7 d	8.5	6.5	6.1	4.9	6.5^{b}
14 d	7.7	5.8	8.3	6.2	5.3	5.0	6.4^{b}	14 d	7.4	5.8	5.7	4.9	6.0^{c}
Overall mean	7.8^{ab}	5.6^{c}	9.2^{ab}	7.6^{ab}	6.2^{bc}	5.3^{c}	↑LSD = 0.5						↑LSD = 0.3
Cold-boned								Overall					
Overall mean		5.1^{a}	4.4^{b}		5.3^{a}	5.7^{a}	5.6^{a} 5.1^{a}	mean[4]	8.7	6.5	6.0	5.1	

[abc]Overall means with differing superscripts either within a column or within a row differ ($P < 0.05$); LSD for Expt's 1 & 2 = 1.9 and 0.7 for hot-and cold-boned respectively. For expt 2 cold-boned muscles there was no significant treatment x time interaction, but there was a significant, but non-meaningful, time effect with overall means 3 d = 5.1^{b}, 7 d = 5.2^{ab}, 14 d = 5.4^{a} (LSD = 0.3).

[1]Note the hot-boned muscles were not from the same animals as the cold-boned muscles so no direct statistical comparison can be made between the hot-and cold-boned treatments. For hot-boned muscle x treatment x time interaction least squares means without superscripts: LSD for comparing means across time for fixed muscle and treatment = 1.3; LSD for comparing means across treatment for fixed muscle = 1.8; LSD for comparing control and PPi treatments across muscle for fixed treatment and time = 2.1. N = 6 animals for each boning x muscle x treatment cell, n = 18 observations for each muscle x treatment overall mean, and n = 36 observations for each time effect overall mean. Each observation consisted of 10 sheared cores per steak. Units are kgF/cm^2. [2]H_2O = distilled water, NaCl = 0.875 M NaCl, PPi = 0.1125 M $Na_4P_2O_7$ + 0.1125 M $Na_2H_2P_2O_7$ + 0.2 M NaCl. All treatments injected at 10% (w/w). [3]Note the hot- and cold-boned muscles were from the same animals so direct statistical comparison can be made between the hot-and cold-boned treatments. For boning x treatment x time interaction least squares means comparisons: LSD for comparing means across time with fixed boning and treatment = 0.7; LSD for comparing means across treatment with fixed boning, or for comparing means across boning = 1.2. N = 6 animals, n = 12 observations for each boning x treatment x time cell, n = 36 observations for each boning x treatment overall mean, and n = 48 for each time effect overall mean. Each observation consisted of 10 sheared cores per steak. [4]For boning x treatment interaction least squares means comparisons: LSD for comparing means across treatment with fixed boning = 0.4; LSD for comparing means across treatment or boning = 0.7.