The Effect of Rapid Chilling on Beef Quality

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SUMMARY: A total of 632 beef sides, ranging in fatness from 0 to 69 mm, were used to examine the effects of one form of blast chilling on carcass weight losses, pH and temperature decline and meat quality. Additionally, the effects of electrical stimulation as a means of ensuring tenderness in rapidly cooled carcasses was also examined. In lean carcasses, blast chilling reduced the amount of cooler shrink by 0.3%. The rate of temperature decline was faster and the rate of pH decline was slower as a result of blast chilling. Blast chilling resulted in slightly darker meat at the time of grading and tougher meat after 6 d aging when compared to conventionally chilled carcasses. However, the application of electrical stimulation prior to blast chilling resulted in meat quality which was as good as, or better than conventionally cooled carcasses. Hence the use of blast chilling after electrical stimulation may be a viable chilling method for lean carcasses.

INTRODUCTION: Rapid chilling of beef carcasses has several economic advantages which include reduction of cooling times, increased rate of product turnover, and decreased shrink and drip losses. Despite these economic advantages, beef carcasses are seldom subjected to rapid rates of chilling due to the accompanying reduction in meat tenderness which is thought to occur as a result of cold shortening (Locker and Hagyard, 1963). With the trend towards leaner cattle in the Canadian marketplace the introduction of rapid chilling for beef must be done carefully in order to avoid potential tenderness problems. The general rule for prevention of cold shortening is to avoid letting carcasses cool below 10 °C within 10 h post-mortem (Bendall, 1972), which negates many of the economic advantages of rapid chilling. However, electrical stimulation in the post-mortem period is known to prevent cold shortening (Locker, 1985) and could be applied prior to rapid chilling to ensure tender meat. Thus, the purpose of this study was to examine the effects of one form of rapid chilling (blast chilling) on carcass weight losses, pH and temperature decline and meat quality in beef heifers ranging in fatness from 0 to 69 mm of backfat. Additionally, the effects of electrical stimulation as a means of ensuring tenderness in rapidly cooled carcasses was also examined.

MATERIALS and METHODS: A total of 632 sides were subjected to one of three treatments: 1) Conventionally chilled for 24 hours at 2 °C (CONV); 2) Blast chilled for 3 h at -20 °C followed by conventional chilling (BL); and 3) Electrically stimulated (470 V, 1.5 A, 60 Hz, 20 pulses/min, 1 min duration at 45 minutes post-mortem) followed by 3 h blast chilling followed by conventional chilling (ES/BL). Immediately prior to and following electrical stimulation, at 4 h (just after removal from the blast chiller), at 10 h and at 24 h post-mortem pH and temperature were recorded for the longissimus (LM) and semimembranosus (SM). After 24 hours, small samples of muscle were removed from the LM and SM for determination of sarcomere length. Carcass side weights were recorded to determine cooler shrink losses. Carcass sides were split at the Canadian grade site (between the 12th and 13th rib) and the meat was allowed to bloom for 15-20 minutes. Meat color (CIE L*, a* and b* values) was measured three times using a Minolta Chroma-Meter II and the results averaged. Subjective marbling scores (using U. S. D. A. Grade Standards) were determined and loin eye area at the 12th rib was traced and the tracings were placed on a digitizing tablet for the calculation of muscle area. Portions of the LM (anterior to the grading site) and the SM (the proximal third of the muscle) were used for meat quality analysis. Twenty-four hours post-slaughter a steak was cut from each of the muscle samples and placed in a styrofoam steak tray overwrapped with O_2 permeable film for 5 days at 2 °C for determination of drip loss. The remaining portions of the muscle samples were stored in polythene bags at 2 °C for 5 days. After 5 days another steak was cut from each of the muscle samples and ultimate pH and temperature were recorded. Final objective Minolta color readings were recorded prior to cooking the steak to an internal temperature of 72 °C in a microwave oven. After chilling the steaks to 2 °C, three 19 mm cores were sheared on an Ottawa Texture Measuring System equipped with a Warner-Bratzler head.

To analyse the data, grade fat depth was treated as a class variable with every additional 5 mm increment of fat representing a new class (eg. 0≤5, >5≤10, >10≤15). Thus, the model used for analysis included the effect of treatment (3 levels), the effect of fat class (8 levels) and their interaction.

RESULTS and DISCUSSION: The only significant treatment by fat class interaction was for the 24 h cooler shrink (P=0.0001; Figure I). Normally leaner carcasses would be expected to experience greater cooler shrink than fatter carcasses as was the case for the CONV chilled carcasses. However, with increasing fat depth in the BL chilled carcasses, the amount of cooler shrink tended to increase. Similar to other studies (Bowling et al., 1987; Ortner, 1989) leaner carcasses in this study experienced approximately 0.3% less cooler shrink when BL was compared to CONV.

Temperature and pH decline curves for the LM and SM are shown in Figures II and III. For both the treatment effects (IIa vs. IIc) and the fat class effects (IIIa vs. IIIc) the rate of temperature decline in the SM was much more rapid than in the LM while the carcasses were in the blast chiller. However, upon removal from the blast chiller, the rate of temperature decline in the more superficial SM slowed more than in the LM. Hence, in the SM only the very leanest carcasses (<15 mm of backfat) reached a temperature below 10 °C in 10 h (IIIc). In the LM, carcasses with up to 25 mm of backfat reached a temperature of below 10 °C in 10 h (IIIa). Both the LM and SM reached temperatures below 10 °C in 10 h in the BL and ES/BL carcasses, whereas in CONV carcasses LM and SM temperatures remained above 10 °C (IIa and IIc). For both the SM and LM, pH decline was most rapid in the ES/BL carcasses and least rapid in the BL carcasses (IIb, IId). CONV carcasses had an intermediate rate of decline. In the LD, fatter carcasses had the most rapid rates of pH decline (IIIb), however, this did not hold true for the SM (IIId).

Neither the BL nor the ES/BL treatments had any effect on marbling scores when compared to the CONV treatment. However, BL tended to have slightly darker, and ES/BL tended to have significantly lighter meat colour (L*, a*, b*) when compared to CONV carcasses after 24 h (Table I). Rapid chilling has previously been reported to result in a darker meat colour (Bowling et al., 1987) whereas electrical stimulation is known to improve meat colour (Asghar and Henrickson, 1982). After 6 d, meat colour in the LM was similar between the ES/BL and CONV carcasses and slightly darker in the BL carcasses. As well, drip loss in the LM was significantly higher in CONV carcasses when compared to BL and ES/BL carcasses (P=0.0039), but no differences in drip loss were observed for the SM muscle.

In the LM, BL carcasses had 6% higher shear values than CONV carcasses. However, ES combined with BL resulted in shear forces that were 11% lower than CONV carcasses (despite ES/BL carcasses attaining temperatures below 10 °C within 10 h post-mortem) and 17% lower than BL carcasses. There was no evidence that these differences in tenderness resulted from cold shortening since sarcomere lengths were similar in the LM over all three treatments. In the SM, there were no differences among treatments in shear values, despite significant differences in sarcomere length. Along with evidence from other researchers (Joseph and Connolly, 1977; Lochner et al., 1980; Woltersdorf, 1988) it seems apparent that the causal mechanism for increased toughening as a result of rapid chilling in beef is not due to cold shortening. Recently, the calcium activated proteases have been implicated in the the development of tenderness during the early post-mortem period (Marsh et al., 1987; 1988) and it may be their inactivation which results in cold induced toughening.

For the most part, increasing fat depth resulted in increased marbling, increased rib eye area and improved colour in both the LM (24 h and 6d) and the SM. There were no significant differences in drip loss or shear values as a result of increasing fat depth.

CONCLUSIONS: This study indicates that blast chilling has some negative effects on objective measurements of beef quality. However, when carcasses are electrically stimulated prior to blast chilling, the resulting beef quality is similar to, or better than beef quality of

conventionally chilled carcasses. Since backfat depth within a treatment had little influence on any of the quality traits, and since leaner carcasses had less cooler shrink than fatter carcasses when blast chilled, blast chilling of lean beef carcasses may be a viable chilling method.

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Table I. The effect of blast chilling and electrical stimulation combined with blast chilling on the quality of the longissimus and semimembranosus muscles

Quality Trait	Treatment			P
	CONV	BL	ES/BL	
Grade site - 24 h				
Marbling score	6.64	6.47	6.65	0.2926
Rib-eye area, cm^2	78.16	77.25	77.81	0.6517
Minolta				
L*	34.89^a	34.53^a	35.58^b	0.0003
a*	22.23^b	21.24^a	22.94^c	0.0001
b*	9.69^b	8.98^a	10.07^c	0.0001
Longissimus - 6 d				
Drip loss, $mg.g^{-1}$	11.78^b	10.71^a	10.28^a	0.0039
Shear, kg	7.81^b	8.28^c	7.05^a	0.0001
Sarcomere length, µ	1.71	1.70	1.70	0.8399
Minolta				
L*	36.05	35.73	35.94	0.4903
a*	22.75^b	22.19^a	22.80^b	0.0122
b*	9.98^b	9.62^a	10.00^b	0.0396
Semimembranosus - 6 d				
Drip loss, $mg.g^{-1}$	20.93	19.91	20.34	0.3693
Shear, kg	9.24	9.54	9.40	0.1501
Sarcomere length, µ	1.86^a	1.90^b	1.96^c	0.0001
Minolta				
L*	39.51	39.30	39.78	0.3014
a*	27.20	27.20	27.60	0.0743
b*	13.89	13.80	14.14	0.1261

[abc] Means in the same row with different superscripts are significantly different (P≤0.05) as determined by linear contrast with a single degree of freedom.

Figure I. Cooler shrink losses with increasing fatness in the CONV, BL and ES/BL carcasses. Superscripts denote differences among fat classes within treatment.

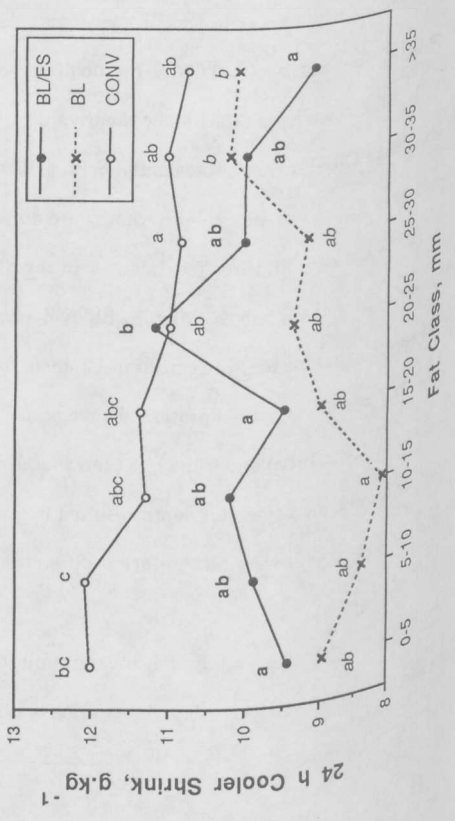

Figure II. Temperature and pH decline curves by treatment; a) temperature - LM; b) pH - LM; c) temperature - SM; d) pH - SM

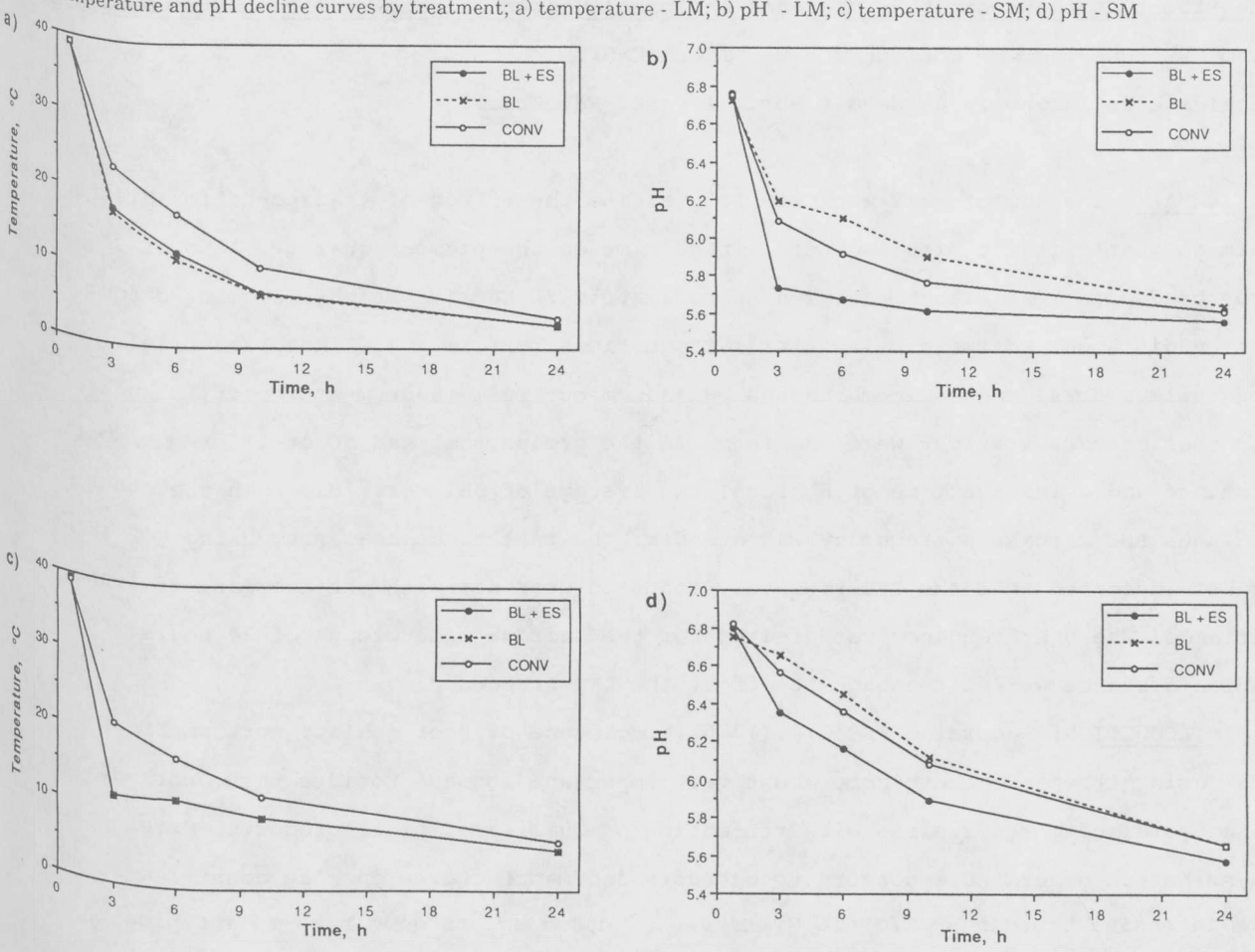

Figure III. Temperature and pH decline curves by fat class; a) temperature - LM; b) pH - LM; c) temperature - SM; d) pH - SM