

The influence of beef quadriceps hot-processing on carcass chilling and beef round quality

Christina A. Hayes¹, Robert J. Maddock¹, Wanda L. Keller¹ and Kasey R. Maddock-Carlin¹

This project evaluated the impact of hot-carcass boning on beef round meat quality attributes in a small processor setting. Temperature and pH declines were monitored on chilling beef carcasses that had one carcass side where the beef knuckle was separated from the femur within 1.5 hours of stunning. Beef quality tenderness and shelf-life attributes were evaluated after aging. Our research indicates that hot-boning techniques applied in a small processing setting may not create added value to the beef round.

Summary

The objective of the present study was to determine the effects of partial hot-boning on meat quality attributes in deep and superficial portions of the beef *semimembranosus* (SM). At the entrance of the carcass-chilling cooler during slaughter (60 to 90 minutes postmortem), the beef knuckle (quadriceps) was partially hot-boned on one side of each beef carcass (n = 15), whereas the opposite side remained intact throughout the 48-hour chilling period. Randomized treatments were deep SM hot-boned (DH) or cold-boned (DC), and superficial SM hot-boned (SH) or cold-boned (SC). Post-mortem temperature decline was monitored every 10 minutes for 24 hours and post-mortem pH decline was recorded at 45 minutes, three hours, and 24 hours. Samples were collected after 24 hours (protein degradation and protease activity measurements) and 10 days (tenderness and display life evaluation) of aging in an air-chilled cooler. The deep portion of the SM had a slower chill rate and a sharper pH decline when compared with the superficial SM, regardless of hot-boning treat-

ment. No treatment differences were observed for beef color L* and b* values ($P > 0.05$). By day 4 of display life, both deep muscle treatments were less red ($P < 0.001$) when compared with superficial SM locations. Modified hot-boning did not ($P > 0.49$) influence tenderness in deep or superficial portions of the SM.

Introduction

Compared with traditional boning of refrigerated carcasses, partial hot-boning (limited separation of meat from the skeleton pre-rigor) is a well-established technique used to optimize meat processing parameters, including processing time, chilling costs and contamination reduction (Kastner, 1977; Røtterud et al., 2006). Inconsistent meat quality attributes of the SM are possibly due to variations in pH and temperature decline between the deep and superficial muscle locations (Tarrant and Mothersil, 1977; Seyfert et al., 2005; Sawyer et al., 2007).

Generally, the deep portion of the SM is a larger, thicker muscle, exhibiting a slower chill rate and more rapid pH decline than its superficial counterpart. As a result, meat from the inner SM tends to

have inconsistent color stability and protein functionality.

Tenderness differences within the beef round muscle are well-documented (Johnson et al., 1988; Kim et al., 2010). Limited studies have investigated how partial hot-boning of the SM might affect post-mortem determinants of meat quality in view of differences in chilling and pH conditions of the superficial and deep SM.

Therefore, the objective of this study was to examine the effects of partial hot-boning on pre-rigor temperature and pH decline and subsequent proteolysis of the superficial and deep portions of the SM in relation to beef palatability traits.

Experimental Procedures

Fifteen market-weight beef heifers were purchased from area commercial feedlots and harvested at the U.S. Department of Agriculture-inspected meat laboratory at North Dakota State University during a period of six months. The carcasses were split and one half of each carcass was assigned randomly to a hot-boning technique conducted 60 to 90 minutes after stunning, where the quadriceps complex, along with the patella, was separated from the insertion at the distal end of the femur, whereas the other half of each carcass remained as a control.

Following the hot-boning procedure, temperature and pH were monitored in the deep and superficial portions of the SM for 24 hours. At 24 hours post-mortem, muscle biopsies were taken within the SM. Samples collected at 24 hours post-mortem were frozen immediately for measurement of troponin-T

¹Department of Animal Sciences, NDSU

degradation by Western blot, as well as for calpain 1 and calpain 2 activity by casein zymograms (Melody et al., 2004).

Hanging carcasses were air-chilled in a dark cooler for 10 days at 36 F, upon which steaks were cut from deep and superficial portions of the SM for immediate display life assessment and Warner-Bratzler shear force measurement for tenderness.

Results and Discussion

The pH declined from an average value of 6.66 at one hour post-mortem to 5.68 at 24 hours post-mortem in the four muscle locations and their corresponding treatments (n = 15 per treatment; Figure 1). Treatments DH and DC had similar ($P > 0.05$) pH decline, indicating that hot-boning was not enough to slow pH decline in the deep portion of the SM.

SC and SH pH decline values were similar ($P > 0.05$). Differences between superficial and deep for either boning treatment were significant ($P < 0.05$) at 45 minutes and three hours post-mortem; however, all treatments had similar pH values 24 hours post-mortem.

Temperature decline was similar (Figure 2) among all muscle locations monitored. As expected, the superficial muscles investigated (SC and SH) had a faster rate of decline than those locations from the deep SM. Treatments DH and DC had similar temperature decline rates, indicating that partial hot-boning was not enough to hasten temperature decline in the deep portion of the SM.

The temperature of the cooling chamber during the SM treatment oscillated around 41 F during the first 12 hours and reached 36 F at the end of chilling. While 36 F is consistent with similar studies investigating beef hot-boning treatments

(Seyfert et al., 2005; Pivotto et al., 2014), the warmer temperature observed during the first 12 hours may have adversely influenced the speed at which the SM muscle temperature dropped.

No treatment differences ($P > 0.05$) were observed for beef color L* and b* values. By day 4 of display life, both deep muscle treatments

were less red ($P < 0.001$) when compared with superficial SM locations. However, by day 10 of display life, only the SC-treated SM had a greater a* value ($P < 0.01$), compared with all other treatments.

Shear force values did not differ ($P > 0.49$) between hot- and cold-boned SM muscle locations (Table 1). However, at 24 hours post-mortem

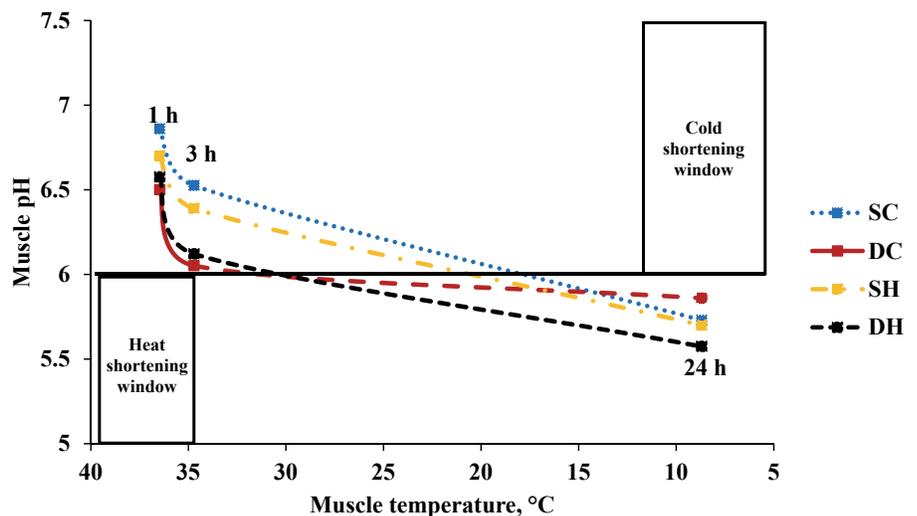


Figure 1. Means of decline in pH at one, three and 24 hours post-mortem relative to the temperature of the SM muscle location. Heat and cold shortening windows adapted from Thompson, J. 2002. Meat Sci. 62:295-308. Treatments on beef semimembranosus muscle were deep hot-boned (DH) or cold-boned (DC), and superficial SM hot-boned (SH) or cold-boned (SC).

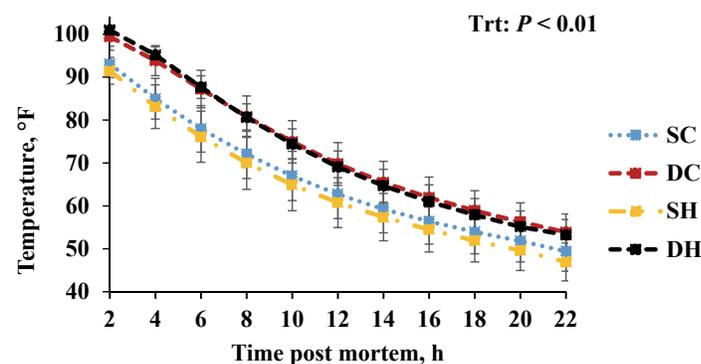


Figure 2. Mean temperature fall [\pm standard deviation] of bovine semimembranosus muscle with modified processing conditions up to 22 hours post-mortem (n = 15 per treatment). Treatments were deep SM hot-boned (DH) or cold-boned (DC), and superficial SM hot-boned (SH) or cold-boned (SC).

tem, SC- and SH-treated sides had greater ($P < 0.01$) calpain 1 activity when compared with both deep SM treatments, whereas the activity of calpain 2 was similar for all treatments.

However, the troponin-T degradation products were less in the DC ($P < 0.01$), compared with SH-treated sides, with DH and SC treatments being intermediate. The degradation of troponin-T has been linked to early post-mortem impacts on meat tenderness. In the present study, while we did see differences in troponin-T degradation, we did not observe differences in tenderness.

Results indicate that differences in meat quality across deep and superficial locations of the SM were not altered by partial hot-boning in the conditions of the NDSU Meat Science Laboratory chilling cooler. Because the treatment did not alter temperature decline or pH in the DH-treated carcasses, meat tenderness or color attributes also were not impacted.

Results from this study did reveal location differences within the muscle regarding meat quality and

protein degradation, demonstrating the need for future investigations to consider variation between the inner and outer SM when developing strategies to improve overall quality of the beef round muscle.

Literature Cited

- Johnson, R.C., C.M. Chen, T.S. Muller, W.J. Costello, J.R. Romans and K.W. Jones. 1988. Characterization of the muscles within the beef forequarter. *J. Food Sci.* 53:1247-1250.
- Kastner, C.I. 1977. Hot processing: Update on potential energy and related economics. *Proceedings of the Meat Industry Research Conference* (pp. 43). Chicago: American Meat Institute Foundation.
- Kim, Y.H., S.M. Lonergan and E. Huff-Lonergan. 2010. Protein denaturing condition in beef deep semimembranosus muscle results in limited μ -calpain activation and protein degradation. *Meat Sci.* 86:883-887.
- Melody, J.L., S.M. Lonergan, L.J. Rowe, T.W. Huiatt, M.S. Mayes and E. Huff-Lonergan. 2004. Early postmortem biochemical factors influence tenderness and water-holding capacity of three porcine muscles. *J. Anim. Sci.* 82:1195-1205.
- Pivotto, L.M., C.P. Campbell, K. Swanson and I.B. Mandell. 2014. Effects of hot boning and moisture enhancement on the eating quality of cull cow beef. *Meat Sci.* 96:237-246.
- Røtterud, O.J., C.R. Helps, T.J. Hillman, A.V. Fisher, D. Harbour, H. Anil and T. Nesbakken. 2006. Hot boning of intact carcasses: a procedure to avoid central nervous system self-contamination in beef and beef products. *J. Food Prot.* 69:405-411.
- Sawyer, J.T., R.T. Baublits, J.K. Apple, J.F. Meullenet, Z.B. Johnson and T.K. Alpers. 2007. Lateral and longitudinal characterization of color stability, instrumental tenderness, and sensory characteristics in the beef semimembranosus. *Meat Sci.* 75:575-584.
- Seyfert, M., M.C. Hunt, R.A. Mancini, K.A. Hachmeister, D.H. Kropf, J.A. Unruh and T.M. Loughin. 2005. Beef quadriceps hot boning and modified-atmosphere packaging influence properties of injection-enhanced beef round muscles. *J. Anim. Sci.* 83:686-693.
- Tarrant, P.V., and C. Mothersil. 1977. Glycolysis and associated changes in beef carcasses. *J. Sci. Food Agric.* 28(8):739-749.
- Thompson, J. 2002. Managing meat tenderness. *Meat Sci.* 62:295-308.

Acknowledgments

The authors express their appreciation to the North Dakota State Board of Agricultural Research and Education for partial funding for this study and to the staff at the NDSU Meat Science Laboratory for assistance with carcass fabrication and sampling.

Table 1. Least squares means and standard errors for tenderness measurements from semimembranosus muscle of beef heifers with modified processing conditions.

Variable ^A	SH	DH	SC	DC	SEM	P-value
WBSF ^B , lb.	9.1	9.1	8.5	4.0	0.58	> 0.49
calpain 1 activity ^C	0.33 ^a	0.10 ^b	0.29 ^a	0.15 ^b	0.04	< 0.01
Autolyzed calpain 1 activity ^C	0.01 ^a	0.07 ^b	0.02 ^a	0.06 ^b	0.01	< 0.01
calpain 2 activity ^C	0.40	0.40	0.42	0.43	0.03	> 0.80
Troponin-T, 30-kDa band ^D	1.16 ^a	0.82 ^{ac}	0.83 ^{ac}	0.50 ^{bc}	0.15	< 0.01

^ATreatment abbreviations: SH = superficial hot-boned, DH = deep hot-boned, SC = superficial cold-boned, DC = deep cold-boned.

^BWarner-Bratzler shear force.

^CCalpain activity was assessed in SM collected at 24 hours post-mortem by casein zymography. Values are relative to the activity of a control of partially purified calpain 2, which was set to 1.

^DTroponin-T degradation in SM collected at 24 hours post-mortem was assessed by Western immunoblotting and values are relative to the 30-kDa band of a pooled-control loin sample.

^{abc}Within rows, mean values without a common superscript differ ($P < 0.05$).