Tenderness, Sensory, and Color Attributes of Two Muscles from the M. quadriceps femoris when Fabricated Using a Modified Hot-Boning Technique

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Tenderness, sensory, and color attributes of two muscles from the M. quadriceps femoris when fabricated using a modified hot-boning technique[1,2,3]

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ABSTRACT: The M. quadriceps femoris from USDA Choice (n = 12) and USDA Select (n = 12) carcasses were fabricated traditionally (COLD) or innovatively (HOT), in which the seams it shares with the top round and bottom round were separated prerigor to evaluate positional and locational effects on Warner-Bratzler shear force (WBSF), sensory attributes, and objective color. At slaughter, paired USDA Choice and USDA Select carcasses were alternately assigned either the HOT or COLD treatment. At 48 h postslaughter, subprimals were removed, vacuum-packaged, and aged for an additional 5 d. After aging, the M. quadriceps femoris was cut into 2.54-cm-thick steaks and allowed to bloom 1 h. For the M. rectus femoris (REC) and M. vastus lateralis (VAL), L* values significantly ($P < 0.050$) decreased when moving from the proximal to distal position within the muscle. Similarly, a* and b* values decreased in the VAL when moving from the proximal to the distal aspect. After color measurement, steaks were vacuum-packaged and frozen (−26°C) until shear and sensory data were collected. Significant position (proximal to distal) and location effects (cranial to caudal) were noted for both muscles. However, treatment did not affect WBSF of the VAL. Although intramuscular variation existed, WBSF and sensory panel tenderness ratings were acceptable for the REC. Although WBSF values were greater and tenderness ratings were less than the REC, the VAL were not extremely tough and therefore could be used in enhancement applications.

Key words: beef, color, knuckle, tenderness, value cut

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INTRODUCTION

The Uniform Retail Meat Identity Standards were developed in the United States to standardize meat labeling at the retail sector. Included in the labels are species, primal, and the retail cut name. According to URMIS (2003), the knuckle (IMPS no. 167; NAMP, 2007)—comprising the M. quadriceps femoris (**QUAD**)—would be labeled as a beef round sirloin tip center roast. The Institutional Meat Purchasing Specifications of the USDA classify the knuckle (IMPS no. 167; NAMP, 2007) as originating from the round (pelvic limb) under current fabrication practices utilized in the United States. However, if the knuckle was to be removed from the round before the round-sirloin separation, then the knuckle (IMPS no. 167; NAMP, 2007) would be classified as sirloin, which would be greater in value. If knuckles (IMPS no. 167; NAMP, 2007) have acceptable quality (tenderness, sensory, and color), they could justifiably be labeled as sirloin. Additionally, discrepancies in labeling could be resolved.

Hot boning is an alternative fabrication procedure that involves the disassembly of subprimals before the onset of rigor. The advantages of hot boning include reduction in time (30%) and effort (49%) by fabrication staff, smaller cooler space requirements (81%), elimination of cooler shrink, an increase in lean tissue yield (0.51%; Brasington et al., 1986), and improvements in color stability (Seyfert et al., 2004, 2005). However, others have reported distorted subprimal shapes and decreases in tenderness in various primals (Meade et al., 1992). Consequently, the industry has not readily accepted this fabrication procedure.

The beef muscle profiling study (Von Seggern et al., 2005) conducted at the University of Nebraska and the University of Florida identified muscles from the chuck and round that could be utilized as single muscle cuts,

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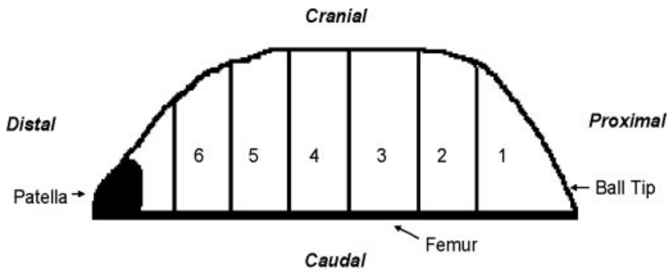

Figure 1. Anatomical directions of the M. quadriceps femoris.

which the National Cattlemen's Beef Association have marketed as beef value cuts. With the release of the beef value cuts, it is necessary to map intramuscular tenderness and color attributes of these muscles so processors and retailers can maximize product quality. Therefore, the objectives of this study were to document intramuscular differences in tenderness and objective color within the M. rectus femoris (**REC**) and M. vastus lateralis (**VAL**) and determine if prerigor separation of the natural seams shared by the QUAD and the top (IMPS no. 168; NAMP, 2007) and bottom round (IMPS no. 170; NAMP, 2007) did not compromise tenderness and color of the REC and VAL.

MATERIALS AND METHODS

No approval was obtained from the Institutional Animal Care and Use Committee, because samples were obtained from a federally inspected slaughtering facility.

Sample Procurement and Processing

Twenty-four animals were selected for this study (12 USDA Choice and 12 USDA Select) from a commercial abattoir. One side was randomly assigned to the innovative fabrication procedure (HOT), whereas the other side was traditionally fabricated (COLD). The HOT treatment was a prerigor separation of the natural seams the QUAD (knuckle, IMPS no. 167, and ball tip, IMPS no. 185B; NAMP, 2007) shares with the top (IMPS no. 168; NAMP, 2007) and bottom round (IMPS no. 170A; NAMP, 2007) while attachments to the femur were maintained. The separation occurred just after the final carcass wash. Both sides received electrical stimulation in the form of 48 V during exsanguination and 110 V during hide removal. After a 2-d chilling period, internal temperatures were taken of the intact QUAD muscles using a Precision RTD thermometer (model 2300, IMC Inc., Wittenberg, WI). After temperature recording, the QUAD muscles were removed before the sirloin-round break, vacuum-packaged, shipped to the Loeffel Meat Laboratory at the University of Nebraska, and stored at <3 C. At 7 d postmortem, knuckles were cut into 2.54-cm steaks from the proximal end of the cut (Figure 1). Steaks were then allowed to bloom for 1 h at 1°C before objective color was measured. After color measurement, steaks were vacuum-packaged and frozen until sensory and shear force measurements were conducted.

Objective Color

A Hunter Lab Mini Scan XE Plus (model 45/0-L, Reston, VA) colorimeter containing a 2.54-cm port with a 10° standard observer was used. Calibration using illuminant A with a black (X = 0.0; Y = 0.0; and Z = 0.0) tile and a white (X = 78.1; Y = 82.8; and Z = 88.5) tile was conducted before use. Three random measurements were taken on each steak, and the mean of the 3 measurements was reported.

Cooking Procedures

Before cooking, steaks were thawed overnight at 4°C. Steaks were cooked to an internal temperature of 70°C (medium degree of doneness) on an electric broiler (model FSR200, Farberware Inc., Prospect, IL). Internal temperature was monitored intermittently with a digital thermometer (model 450-ATT, Omega Engineering, Stamford, CT) with a type T thermocouple (Omega Engineering) that was less than 1 mm thick. When the internal temperature reached 35°C, the steak was turned once and cooked until the final temperature was reached.

Table 1. Eight-point hedonic scale for sensory evaluation

Scale	Tenderness	Connective tissue	Juiciness	Off-flavor intensity
8	Extremely tender	None	Extremely juicy	No off-flavor
7	Very tender	Trace amount	Very juicy	Trace off-flavor
6	Moderately tender	Slight amount	Moderately juicy	Slight off-flavor
5	Slightly tender	Small amount	Slightly juicy	Small off-flavor
4	Slightly tough	Modest amount	Slightly dry	Modest off-flavor
3	Moderately tough	Moderate amount	Moderately dry	Moderate off-flavor
2	Very tough	Slightly abundant	Very dry	Very off-flavor
1	Extremely tough	Abundant amount	Extremely dry	Extremely off-flavor

Sensory Analysis

Beginning from the proximal end of the QUAD, the 2nd, 4th, and 6th steaks (which contained both the REC and the M. vastus lateralis) were used for sensory analysis. After cooking, steaks were placed in double broilers to keep warm. The 2 muscles were cut into 1.27 cm × 1.27 cm × 2.54 cm cubes and served warm to the panelists, approximately 5 min postcooking. Panelists (n = 8) for this study were selected and trained according to the guidelines and procedures outlined by Meilgaard et al. (1991). The panelists received approximately 40 h of training. To prevent bias, panelists were seated in individual booths equipped with red fluorescent lights and partitioned to reduce collaboration between panelists and eliminate visual differences (Meilgaard et al., 1991). Each panelist was served double-distilled deionized water and unsalted, saltine crackers and given 3 min between samples to cleanse their palates. Six samples, identified using 3-digit codes, were served on each day. Eight-point descriptive attribute scales (Table 1) were used.

Figure 2. Location of cores taken for Warner-Bratzler shear force measurement. The 6 left-most X's denote cores from the M. vastus lateralis, and the remaining X's are from the M. rectus femoris.

Warner-Bratzler Shear Force

Beginning with the proximal end of each muscle, the 1st, 3rd, and 5th steaks were used for shear force measurement. After cooking, steaks were covered and allowed to cool at room temperature for 4 h. After the cooling period, 6 to 9 (1.27-cm diameter) cores were removed parallel to the muscle fibers, and core location (Figure 2) was recorded. Cores were sheared perpendicular to the fiber direction on an Instron Universal Testing Machine (model 55R1123, Canton, MA) with a Warner-Bratzler shear attachment set at a crosshead speed of 250 mm/min and equipped with a 500-kg load cell.

Statistical Analysis

An ANOVA using the GLIMMIX procedure (SAS Inst. Inc., Cary, NC) was used to analyze the data. Temperature was analyzed as a split-plot with animal within grade serving as the whole-plot error term. Color and sensory data were analyzed as a split-split plot with animal within grade and side within animal being random variables and serving as the whole-plot and split-plot error terms, respectively. Shear force data were analyzed as a split-split-split plot with animal within grade, side within animal, and side by position within animal being random variables and serving as the whole plot, split-plot, and split-split plot error terms, respectively. Additionally, day on which Warner-Bratzler Shear Force (**WBSF**) was measured was also included in the model as a random effect for shear force data. In all models, the Kenward-Roger denominator degree of freedom approximation was used. When indicated significant by ANOVA ($P \leq 0.050$), main effects (grade, treatment, location, and position) were separated using the LSMEANS, DIFF, and LINES functions, whereas simple effects of interactions were generated using the LSMEANS, SLICE, and SLICEDIFF functions, respectively.

Table 2. Treatment × position × location interaction for Warner-Bratzler shear force values (kg) of the M. rectus femoris[1,2]

	Treatment and location					
Position	Cold, cranial	Cold, middle	Cold, caudal	Hot, cranial	Hot, middle	Hot, caudal
1 (proximal)	3.12	3.45	3.57^{b}	2.85^{b}	2.94^{b}	3.22^{c}
3	3.14^{z}	3.44^{z}	$3.99^{b,y}$	$3.21^{b,z}$	$3.21^{b,z}$	$4.36^{a,y}$
5 (distal)	3.34^{z}	3.98^{y}	$4.25^{a,y}$	$4.02^{a,y}$	$4.17^{a,y}$	$3.79^{b,y}$
SEM	0.29	0.32	0.30	0.29	0.37	0.31

[a–c]Within a column, means lacking a common superscript letter differ ($P > 0.050$).

[y,z]Within a row, means lacking a common superscript letter differ ($P > 0.050$).

[1]Treatment × position × location interaction P-value = 0.026.

[2]Cold = conventional processing; hot = prefabrication.

Table 3. Grade × treatment interaction of the M. rectus femoris for the sensory attribute tender[1,2,3]

Treatment	USDA Choice	USDA Select
Hot	5.63[b]	5.84
Cold	5.91[a]	5.69
SEM	0.14	0.13

[a,b]Within a column, means lacking a common superscript letter differ ($P > 0.050$).

[1]Grade × treatment interaction P-value = 0.016.

[2]Cold = conventional processing; hot = prefabrication.

[3]1 = extremely tough; 8 = extremely tender.

Table 5. Least squares means for the position main effect on the M. rectus femoris

Effect	Connective tissue[1]	Off-flavor[2]
$P > F$	<0.001	0.001
Position		
2 (proximal)	5.91[a]	3.00[a]
4	5.41[b]	3.06[a]
6 (distal)	4.87[c]	2.81[b]
SEM	0.11	0.13

[a–c]Within a column, means lacking a common superscript letter differ ($P > 0.050$).

[1]1 = abundant amount of connective; 8 = no connective tissue.

[2]1 = No off-flavor; 8 = extreme off-flavor.

RESULTS

WBSF and Sensory Analysis

M. Rectus Femoris. Shear force values (Table 2) for all treatments were below 4.4 kg. The only difference between HOT and COLD treatments was on the cranial side of the distal end of the REC. A significant ($P = 0.026$) treatment × position × location interaction for shear force of the REC was noted. Regardless of location (cranial to caudal), there were significant ($P < 0.050$) positional (proximal to distal) differences in muscles receiving the HOT treatment. For all HOT-treated muscles (except the caudal position), tenderness decreased moving from the proximal to distal position. A similar trend was also noted for traditionally fabricated muscles at the caudal location closest to the bone. Regardless of treatment or location, there were no tenderness differences between the most proximal positions. However, within steak position 3 (regardless of treatment), the caudal location of the muscle was the toughest. Within position 5 (most distal), the cold and cranial treatment combination was the most tender. Grade had no effect on shear force values ($P = 0.340$).

Sensory analysis revealed acceptable tenderness ratings (>5.5 on an 8-point scale) for REC from USDA Choice and USDA Select for both COLD and HOT treatments (Table 3). This was true regardless of location, with the exception of the most distal region of the REC in USDA Select carcasses (Table 4). A significant ($P = 0.016$) grade × treatment interaction and grade × position ($P = 0.050$) interaction for sensory tenderness was noted. Within each treatment, there were no differences among USDA grades ($P \geq 0.286$) for sensory tenderness. Moreover, there were no differences ($P = 0.161$) between treatments among USDA Select muscles. However, within USDA Choice muscles, the COLD treatment required slightly, but significantly, more force to shear (0.28 kg) than the HOT treatment. Regardless of position, there were no significant grade effects ($P \geq 0.136$). Within each USDA grade, sensory tenderness significantly decreased proximally to distally ($P \leq 0.027$), which likely corresponds to the significant ($P < 0.001$) increase in connective tissue amount moving from the proximal to distal aspect (Table 5). Off-flavor intensity was lower in the distal aspect ($P = 0.001$), whereas juiciness was not affected by grade, treatment, position, or location.

M. Vastus Lateralis. Neither grade ($P = 0.227$) nor treatment ($P = 0.289$) had an effect on the shear force values of the VAL (data not shown). Regardless of location (cranial or caudal), WBSF significantly decreased when moving from the proximal to distal aspects of the VAL (Table 6). However, a significant ($P = 0.043$) position × location interaction was observed. Within position 1 (most proximal), the cranial portion of the VAL required less force to shear ($P = 0.003$) when compared with the caudal aspect. No location differences were observed within position 3 and 5 ($P \geq 0.508$). Within both the cranial and caudal location, shear force values increased, moving from the proxi-

Table 4. Grade × position interaction of the M. rectus femoris for the sensory attribute tender[1,2]

Position	USDA Choice	USDA Select
2 (proximal)	6.04[a]	6.26[a]
4	5.72[a]	5.84[b]
6 (distal)	5.54[b]	5.19[c]
SEM	0.14	0.13

[a–c]Within a column, means lacking a common superscript letter differ ($P > 0.050$).

[1]Grade × position interaction P-value = 0.050.

[2]1 = extremely tough; 8 = extremely tender.

Table 6. Position × location interaction for Warner-Bratzler shear force values of the M. vastus lateralis[1]

Position	Cranial	Caudal
1 (proximal)	4.33[a,y]	4.87[a,z]
3	5.18[b]	5.10[a]
5 (distal)	5.58[c]	5.69[b]
SEM	0.25	0.25

[a–c]Within a column, means lacking a common superscript letter differ ($P > 0.050$).

[y,z]Within a row, means lacking a common superscript letter differ ($P > 0.050$).

[1]Position × location interaction P-value = 0.043.

Table 7. Least squares means for the position main effect on the M. vastus lateralis

Effect	Tenderness[1]	Off-flavor[2]
$P > F$	<0.001	0.036
Position		
2 (proximal)	4.71[a]	2.85[b]
4	4.69[a]	2.86[b]
6 (distal)	3.85[b]	3.05[a]
SEM	0.16	0.12

[a,b]Within a column, means lacking a common superscript letter differ ($P > 0.050$).
[1]1 = extremely tough; 8 = extremely tender.
[2]1 = no off-flavor; 8 = extreme off-flavor.

Table 9. Treatment × position interaction for juiciness of the M. vastus lateralis[1,2,3]

Position	Cold	Hot
2 (proximal)	4.95	5.33[a]
4	4.44[z]	4.98[ab,y]
6 (distal)	4.90	4.64[b]
SEM	0.21	0.21

[a,b]Within a column, means lacking a common superscript letter differ ($P > 0.050$).
[y,z]Within a row, means lacking a common superscript letter differ ($P > 0.050$).
[1]Treatment × position interaction P-value = 0.045.
[2]Cold = conventional processing; hot = prefabrication.
[3]1 = extremely dry; 8 = extremely juicy.

mal to the distal aspect of the VAL. Sensory analysis revealed similar findings in which tenderness significantly ($P < 0.001$) decreased moving from the proximal to distal portion of the muscle (Table 7). Although the REC was more tender, the most proximal portions of the VAL were only slightly tough. A significant ($P = 0.040$) grade × treatment × position interaction for connective tissue amount was observed (Table 8). Within all treatment and grade combinations (except Choice and COLD), connective tissue amount increased, moving from the proximal to the distal aspect of the VAL. Within position 4, more connective tissue was detected in the COLD treatment (regardless of grade) when compared with the HOT treatment. Juiciness was not affected by grade ($P = 0.219$), but a significant ($P = 0.045$) treatment × position interaction was observed (Table 9). No positional differences were noted among the COLD treatment, but within the HOT treatment, juiciness decreased when moving from the proximal toward the distal aspect of the VAL. Additionally, off-flavor intensity was greatest in the distal position of the VAL.

Temperature and CIE Colorspace Values

Temperature. A significant ($P = 0.013$) treatment effect was observed for internal temperature after chilling (2 d postmortem). Quadriceps muscles that were fabricated HOT were 0.26°C lower in temperature (data not shown). The USDA Select QUAD muscles tended to have a lower final temperature when compared with USDA Choice QUAD muscles ($P = 0.082$).

M. Rectus Femoris. Grade, treatment, and position significantly ($P < 0.001$) affected L* values (Table 10). For all grade and treatment combinations, muscles were darker when moving toward the distal portion. Within positions 2, 3, and 4, USDA Select muscles that received the HOT treatment were significantly darker when compared with USDA Select muscle receiving the COLD treatment. Among USDA Choice steaks and all positions, no significant treatment differences were observed. Although a significant ($P = 0.021$) grade × treatment effect for a* values was observed (Table 11), differences were small and not likely meaningful. No grade or treatment effects were observed for b* values.

M. Vastus Lateralis. Positional effects are shown in Table 12 for CIE colorspace values. The proximal aspect of the VAL was significantly darker, redder, and more yellow in color ($P < 0.001$). The distal portion of the VAL was the lightest and least red and yellow. Grade and treatment also affected L* values as indicated by a significant ($P < 0.001$) interaction (Table 13). There were no treatment differences among USDA Choice steaks, but USDA Select steaks that received the HOT treatment were significantly darker ($P < 0.001$). Additionally, the HOT treatment tended ($P =$

Table 8. Grade × treatment × position interaction for connective tissue amount of the M. vastus lateralis[1,2,3]

	Grade and treatment			
Position	Select, cold	Select, hot	Choice, cold	Choice, hot
2 (proximal)	4.21[a]	4.10[a]	3.82	4.45[a]
4	3.62[b,z]	4.34[a,y]	4.04[yz]	4.28[a,y]
6 (distal)	2.92[c]	3.11[b]	3.46	3.26[b]
SEM	0.24	0.24	0.25	0.25

[a–c]Within a column, means lacking a common superscript letter differ ($P > 0.050$).
[y,z]Within a row, means lacking a common superscript letter differ ($P > 0.050$).
[1]Grade × treatment × position interaction P-value = 0.040.
[2]Cold = conventional processing; hot = prefabrication.
[3]1 = abundant amount of connective tissue; 8 = no connective tissue.

Table 10. Grade × treatment × position interaction for CIE L* values for the M. rectus femoris[1,2]

	Grade and treatment			
Position	Select, cold	Select, hot	Choice, cold	Choice, hot
1 (proximal)	51.02[a]	49.61[a]	49.49[a]	49.05[a]
2	48.78[b,y]	45.73[b,z]	47.45[b,y]	46.95[b,y]
3	47.00[c,y]	43.19[c,z]	44.71[c,y]	45.24[c,y]
4	44.51[d,y]	43.05[c,z]	42.99[d,z]	44.38[c,yz]
5	42.60[e]	42.80[c]	42.57[d]	42.65[d]
6 (distal)	42.31[e]	42.61[c]	43.31[d]	42.30[d]
SEM	0.93	0.93	0.99	0.97

[a–e]Within a column, means lacking a common superscript letter differ ($P > 0.050$).
[y,z]Within a row, means lacking a common superscript letter differ ($P > 0.050$).
[1]Grade × treatment × position interaction P-value <0.001.
[2]Cold = conventional processing; hot = prefabrication.

0.068) to be less red and significantly ($P = 0.001$) less yellow (Table 14).

DISCUSSION

WBSF and Sensory Analysis

Position and location effects were more pronounced than treatment effects in this study. For both the REC and VAL, objective and subjective measures of tenderness decreased when moving from the proximal to distal aspect of the muscle, which is likely due to the increase in connective tissue detected by the sensory panel. Shackelford et al. (1991) reported shear force value thresholds for retail (4.6 kg) and foodservice (3.9 kg) sectors that would be identified as slightly tender by trained panelists. Using these thresholds, all positions and locations of the REC would be considered slightly tender by the retail sector. Using the foodservice guidelines, most of the positions and locations of the REC would be considered slightly tender. For the VAL, only position 1 would be rated slightly tender by the retail sector, whereas none of the positions would be considered slightly tender by the foodservice sector. Sensory data from the present study indicates that all positions of the REC are slightly tender. For sensory analysis, a USDA Choice strip steak cooked to a medium degree of doneness was considered a 6 on the tenderness scale. Thus, the most proximal position of the REC was equivalent to a USDA Choice strip steak, whereas the distal positions rated at the lowest a 5.19. Brooks et al. (2002) noted that the sirloin portion of the REC had a significantly ($P < 0.050$) greater WBSF when compared with the round portion of the REC and that the VAL would be rated tough by consumers.

Based on the data presented here, there is evidence to indicate that the distal positions of the REC and VAL are similar in tenderness when compared with the proximal portion. Although tenderness ratings were less and WBSF values were greater in the distal portion, the values in the distal positions of the REC are still relatively tender. The current industry separation of the sirloin-round juncture bisects the QUAD, leaving a tender portion of the REC and VAL muscles on the round when they are comparable to the sirloin portion in regards to sensory panel tenderness. Because the alternative fabrication procedure presented here has minimal effects on tenderness, it could be a viable fabrication option for processors. Fabricating the QUAD before the sirloin-round separation could possibly increase profitably by not bisecting the muscle group, thus allowing processors to market portions of the muscle groups that are similar in tenderness to the sirloin portion of the muscle group, decreasing chill times, and facilitating easier postmortem fabrication.

Table 11. Grade × treatment interaction for CIE a* values for the M. rectus femoris[1,2]

Treatment	USDA Choice	USDA Select
Hot	32.90	31.88
Cold	32.45	32.35
SEM	0.52	0.50

[1]Grade × treatment interaction P-value = 0.021.
[2]Cold = conventional processing; hot = prefabrication.

Table 12. Least squares means for the position main effect on the M. vastus lateralis

Position	L*	a*	b*
$P > F$	<0.001	<0.001	<0.001
1 (proximal)	42.48[a]	34.14[a]	24.69[a]
2	41.20[b]	33.54[b]	23.85[b]
3	40.48[c]	32.96[c]	23.12[c]
4	40.12[c]	32.48[c]	22.27[d]
5	40.25[c]	31.51[d]	21.03[e]
6 (distal)	40.38[c]	30.73[e]	20.19[f]
SEM	0.49	0.28	0.62

[a–f]Within a column, means lacking a common superscript letter differ ($P > 0.050$).

Table 13. Grade × treatment interaction for CIE L* values for the M. vastus lateralis[1,2]

Treatment	USDA Choice	USDA Select
Hot	41.14	40.24[b]
Cold	40.59	41.30[a]
SEM	0.68	0.65

[a,b]Within a column, means lacking a common superscript letter differ ($P > 0.050$).
[1]Grade × treatment interaction P-value <0.001.
[2]Cold = conventional processing; hot = prefabrication.

Table 14. Least squares means for the treatment main effect on the M. vastus lateralis[1]

Treatment	a*	b*
$P > F$	0.068	0.001
Hot	32.30	21.81[b]
Cold	32.80	24.53[a]
SEM	0.47	0.60

[a,b]Within a column, means lacking a common superscript letter differ ($P > 0.050$).
[1]Cold = conventional processing; hot = prefabrication.

Temperature and Color

Although not measured in this study, previous work has documented temperature decline in subprimals that had been hot-boned (Seyfert et al., 2004). Seyfert et al. (2004) noted that hot-boned quadriceps muscles were significantly ($P < 0.05$) cooler when compared with traditionally fabricated QUAD muscles, whereas Sammel et al. (2002) reported the inner portion of the M. semimembranosus chilled significantly faster when hot-boned.

Full hot-boning has been shown to improve color and color stability of various beef round muscles due to an increase in chilling rate and a decrease in the rate of pH decline (Sammel et al., 2002; Seyfert et al., 2004, 2005) and suppressing metmyoglobin formation (Ledward, 1985). However, in this study, modified hot-boning had minimal effects on objective color.

As with tenderness, variation in color was intramuscular in nature. Sammel et al. (2002) reported that the inner portion of the M. semimembranosus that had been hot-boned was significantly ($P < 0.05$) lighter when compared with traditionally fabricated M. semimembranosus muscles, but others have shown that muscles that have been hot-boned are typically darker (Meade et al., 1992).

In conclusion, the entire REC is sufficiently tender as to merit the sirloin label, regardless of when it is separated from the round. The prefabrication procedure described herein can be applied with minimal effects on tenderness ratings.

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