

Mapping intramuscular tenderness variation in four major muscles of the beef round¹

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ABSTRACT: The objective of this study was to quantify intramuscular tenderness variation within four muscles from the beef round: biceps femoris (BF), semitendinosus (ST), semimembranosus (SM), and adductor (AD). At 48 h postmortem, the BF, ST, SM, and AD were dissected from either the left or right side of ten carcasses, vacuum packaged, and aged for an additional 8 d. Each muscle was then frozen and cut into 2.54-cm-thick steaks perpendicular to the long axis of the muscle. Steaks were broiled on electric broilers to an internal temperature of 71°C. Location-specific cores were obtained from each cooked steak, and Warner-Bratzler shear force was evaluated. Definable intramuscular shear force variation (SD = 0.56 kg) was almost twice as large as between-animal shear force variation (SD = 0.29 kg) and 2.8 times as large as between-muscle variation (SD = 0.20 kg). The ranking of muscles from greatest to least definable intramuscular shear force variation was BF, SM, ST, and AD (SD = 1.09, 0.72, 0.29, and 0.15 kg, respectively). The BF had its

lowest shear force values at the origin (sirloin end), intermediate shear force values at the insertion, and its highest shear force values in a middle region 7 to 10 cm posterior to the sirloin-round break point ($P < 0.05$). The BF had lower shear force values toward the ST side than toward the vastus lateralis side ($P < 0.05$). The ST had its lowest shear force values in a 10-cm region in the middle, and its highest shear force values toward each end ($P < 0.05$). The SM had its lowest shear force values in the first 10-cm from the ischial end (origin), and its highest shear force values in a 13-cm region at the insertion end ($P < 0.05$). Generally, shear force was lower toward the superficial (medial) side than toward the deep side of the SM ($P < 0.05$). There were no intramuscular differences in shear force values within the AD ($P > 0.05$). These data indicate that definable intramuscular tenderness variation is substantial and could be used to develop alternative fabrication and/or merchandising methods for beef round muscles.

Key Words: Beef, Muscles, Tenderness

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Introduction

The National Beef Tenderness Survey (Morgan et al., 1991) identified significant tenderness variation in beef offered at retail. A follow-up study, the National Beef Tenderness Survey-1998 (Brooks et al., 2000), revealed

that improvements in tenderness of retail cuts from the round were still needed.

There are tenderness differences among muscles within the beef wholesale round, and these differences are well documented (Ramsbottom et al., 1945; McKeith et al., 1985; Johnson et al., 1988; Jones et al., 2001). However, research on intramuscular tenderness variation is quite limited. Studies that have been conducted show that there is indeed definable intramuscular tenderness variation within certain beef round muscles (Ginger and Weir, 1958; Christians et al., 1961).

The round represents approximately 22% of the weight of a typical beef carcass and contains some of the largest muscles; however, these muscles are some of the least tender muscles of the carcass (Ramsbottom et al., 1945; Jones et al., 2001). Because of the large size of the muscles of the round, tenderness evaluation on a single steak may not necessarily represent the tenderness of the entire muscle. Furthermore, if intramuscular tender-

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ness variation was well defined, alternative fabrication and merchandising methods could be developed to increase total carcass value. Therefore, this study was undertaken to define intramuscular tenderness variation within four muscles of the beef round, including biceps femoris (BF), semitendinosus (ST), semimembranosus (SM), and adductor (AD).

Materials and Methods

Ten Limousin-Angus and Angus steers were harvested in four groups at the South Dakota State University Meat Laboratory. After a 48-h dry chill at 1°C, carcasses were ribbed between the 12th and 13th ribs, and USDA quality and yield grade data (USDA, 1997) were collected by experienced evaluators. At 48 h postmortem, the BF, ST, SM, and AD were dissected from a randomly selected left or right side of each carcass, vacuum packaged, and aged for an additional eight days at 2°C. Each muscle was then frozen (-18°C) and cut on a bandsaw into 2.54-cm-thick steaks perpendicular to the long axis of the muscle. Round and sirloin sections of the BF were separated at the wholesale sirloin/wholesale round point of separation, and then steaks were sawed perpendicular to the long axis of each section (Figure 1). Each SM/AD steak was sliced perpendicular to the fiber direction of the muscles from the top round as one steak (Figure 2). An identification tag was placed in the vacuum package bag along with the steak showing animal identification number, muscle identification number, steak number, and orientation of the steak. Steaks were then vacuum packaged and stored at -17°C.

Shear Force Determination

Steaks were thawed at 2°C for 24 h, and a fishhook was then inserted in a constant identifiable location on each steak to maintain orientation throughout cooking and shearing. Steaks were then broiled on Farberware Open Hearth electric broilers (Farberware, Bronx, NY). Steaks were turned every 4 min until an internal temperature of 71°C was reached (AMSA, 1995). Internal temperature was monitored by inserting a thermocouple probe (Model 31901-K, Atkins Technical, Inc., Gainesville, FL) into the geometrical center of each steak. Steaks were allowed to cool to room temperature (approximately 21°C), and then BF and SM steaks were divided into zones (Figures 1 and 2). Zones were allotted according to the size of the steaks from each location. Positioning a 5.3 cm wide area at the horizontal center of each steak designated the middle zone. The remaining area on either side of the middle zone was designated the outside zones. For the larger steaks, three zones were bisected horizontally to get six zones per steak (Figure 1 and 2). The ischiatic head of the BF was designated as a separate zone for BF steaks #15 through #18 (Figure 1). As many 1.27-cm-diameter cores as possible were removed from each zone (with a goal of six good cores) parallel to the muscle fiber orientation. A single

peak shear force value was obtained for each core using a Warner-Bratzler shear machine (G-R Manufacturing Co., Manhattan, KS) and the shear force values were averaged for each experimental unit (each zone by steak by animal combination).

Statistical Analysis

Warner-Bratzler shear force values were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC) with a model that included steak and zone within steak as independent variables and animal as a random effect. Least squares means were calculated for each steak and for each zone within steak and separated using pairwise *t*-tests (PDIF option of SAS).

Results and Discussion

Mean carcass trait values (Table 1) were generally representative of the population sampled in the 1995 National Beef Quality Audit (Boleman et al., 1998). However, much less variation existed among carcasses in this project than in the 1995 audit.

Definable intramuscular shear force variation, that which was consistent across animals, averaged across all four muscles (SD = 0.56 kg) was almost twice as large as between-animal shear force variation (SD = 0.29 kg) and 2.8 times as large as between-muscle variation (SD = 0.20 kg) (data not shown in tabular form). While most previous round tenderness research has focused on factors affecting among-animal variation and between-muscle variation, these results indicate that within-muscle variation may be more important. Ranking of muscles from greatest to least definable intramuscular shear force variation was BF, SM, ST, and AD (SD = 1.09, 0.72, 0.29, and 0.15 kg, respectively). In other words, shear force varied greatly depending on location within the BF and SM, whereas ST and AD were relatively uniform in shear force values.

The BF had its lowest shear force values at the origin (sirloin end), intermediate shear force values at the insertion, and its highest shear force values in a middle region 7 to 10 cm posterior to the separation point between the sirloin and round ($P < 0.05$; Figure 1). The BF also had lower shear force values toward the ST side than toward the vastus lateralis side ($P < 0.05$). There were no consistent shear force differences from the superficial side to the deep side of the BF. In a study utilizing one carcass, Ramsbottom et al. (1945) reported the BF to be most tender at the origin, intermediate in the middle, and least tender at the insertion. Ginger and Weir (1958) also found tenderness variation within the BF, but did not report the location of steaks sampled. Shackelford et al. (1997) found there to be little shear force variation in a 15-cm portion from the thickest region of the BF.

Under normal U.S. carcass fabrication procedures, the point of separation of the sirloin from the round results in a portion of the BF remaining on the sirloin; however,

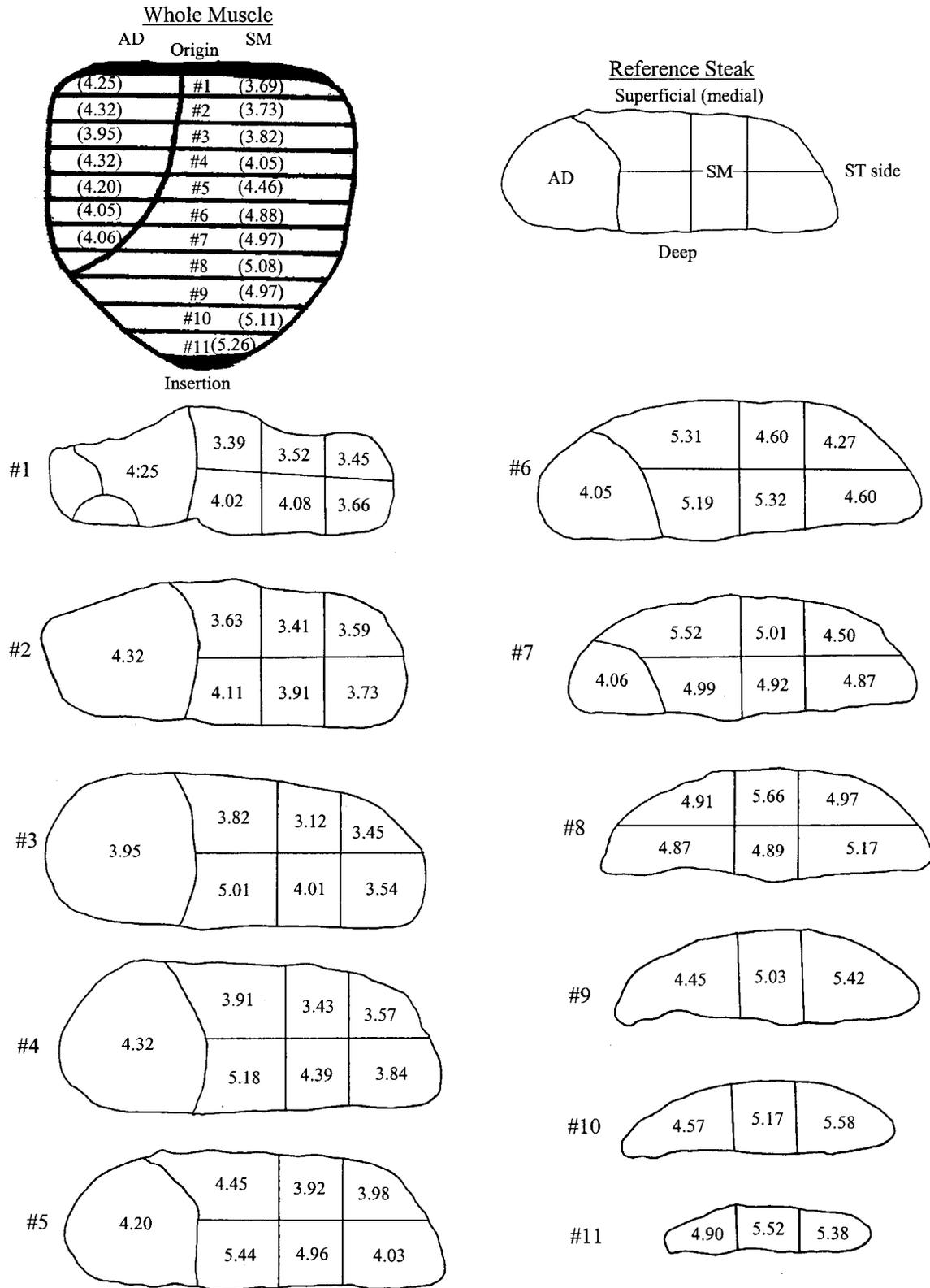


Figure 2. Schematic of the adductor (AD)/semimembranosus (SM) and representative steaks from 2.5 cm increments along the longitudinal axis of the muscle and least squares means for shear force values expressed in kg. Parenthetical data represents steak average shear force (SE = 0.14 for SM steaks 1–8; SE = 0.16 for SM steaks 9–11; SE = 0.19 for all AD steaks). Location within steak shear force is indicated within each location (SE = 0.19 for all AD locations; SE = 0.23 for all SM locations). The LSD for semimembranosus locations = 0.57 kg. ST = semitendinosus.

Table 1. Means, standard deviations, and minimum and maximum values for live weight and carcass traits (n = 10)

Item	Mean	SD	Minimum	Maximum
Live weight, kg	559	11	540	579
Carcass wt, kg	341	8	329	356
Adjusted fat thickness, cm	1.19	0.17	0.89	1.40
Longissimus muscle area, cm ²	78.5	4.5	72.9	87.1
Actual kidney, pelvic, and heart fat, %	3.6	0.8	2.5	5.1
USDA yield grade	3.4	0.4	2.6	3.9
Overall maturity ^a	152	8	140	160
Marbling score ^b	418	56	340	530

^a100 = A⁰⁰, 200 = B⁰⁰, etc.

^b300 = slight⁰⁰, 400 = small⁰⁰, etc.

there remains an equally tender portion of the BF in the round. A slight rotation (clockwise on Figure 1) of the point of separation between the sirloin and round on its midpoint axis would allocate more of the tender portion of the BF to the sirloin, thereby utilizing the tender region of the BF more effectively and yielding more sirloin steaks. With current U.S. fabrication procedures, the sirloin/round separation bisects the quadriceps muscle group and results in two separate subprimal cuts: the knuckle (IMPS 167) from the round and the ball tip (IMPS 185B) from the sirloin (USDA, 1975). This proposed modification to beef carcass fabrication (rotation of the sirloin/round separation) would eliminate the ball tip, leaving the whole quadriceps muscle group intact, but would require that the tri-tip (IMPS 185C; USDA, 1975) be removed prior to separating the round from the sirloin in order to prevent cutting the tri-tip into two pieces.

The SM had its lowest shear force values in the first 10 cm from the ischial end (origin), and its highest shear force values in a 13-cm region at the distal end (insertion) ($P < 0.05$; Figure 2). Furthermore, shear force was generally lower toward the superficial (medial) side than toward the deep side of the SM ($P < 0.05$). In agreement with our findings, Paul and Bratzler (1955) found that the anterior portion of the SM was more tender than the center portion, while the posterior portion was less tender. Ginger and Weir (1958) reported a similar pattern of tenderness from end to end of the SM.

Tenderness information revealed in the present study and previous experiments would suggest that steaks from the anterior half of the SM will be more tender than steaks from the posterior half and could be marketed as "premium" top round steaks. The posterior half of the SM would be more suited for roasts.

There were no intramuscular differences in shear force values within the AD ($P > 0.05$; Figure 3). Paul and Bratzler (1955) also found the AD to be quite uniform in shear force regardless of position of the steak within the muscle.

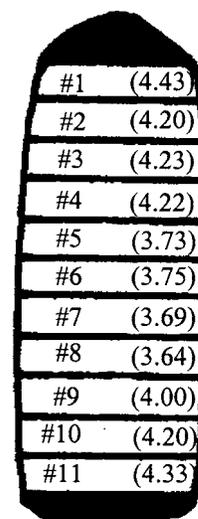
The ST had its lowest shear force values in a 10 cm region in the middle, and its highest shear force values toward each end ($P < 0.05$) (Figure 3). Henrickson and Mjoseth (1964) also found the ST to be more tender in

the middle than at either end. Shackelford et al. (1997) reported the ST to have higher shear force values at the proximal end than at the center and distal end; however, shear force measurements termed distal end were taken approximately 7 to 10 cm from the actual distal end of the muscle.

With case-ready products becoming more prevalent in the retail market, processors will be able to market more tender portions of a muscle differently than less tender portions of a muscle. Because the center region of the ST was found to be more tender than either end, center-cut ST could be marketed as "premium" eye of the round steaks and roasts, whereas end-cut ST steaks could be mechanically tenderized (i.e., cubed).

Intramuscular differences in tenderness found in this study probably resulted from a combination of several factors including intramuscular variation in the amount,

Origin (ischial end)



Insertion (distal end)

Figure 3. Schematic of the semitendinosus and least squares means for steak average shear force expressed in kg (SE = 0.11). The LSD for semitendinosus locations = 0.31 kg.

type, and solubility of collagen (Dutson et al., 1976; Bailey, 1985; Burson and Hunt, 1986), muscle fiber type (Ashmore, 1974; Calkins et al., 1981; Klont et al., 1998) and postmortem temperature decline (Hunt and Hedrick, 1977; Marsh, 1977); however, we did not measure any of these factors in the present study. Hunt and Hedrick (1977) found differences in fiber type, pH, and temperature decline between the inner and outer portions of the SM muscle, which could possibly explain the tenderness differences between the deep and superficial sides of the SM found in the present study.

Much of the beef round is currently merchandised as roasts rather than steaks, and roasts are often cooked with moist heat cookery, such as braising, as opposed to the dry heat cooking methods used in this study. The results of this study may have been different if moist heat cooking methods were used, and it seems logical to hypothesize that the large tenderness differences observed in this study may be lessened if greater amounts of collagen were solubilized through moist heat cooking. However, the dry heat cooking methods used in this study are more appropriate if the objective is to identify those portions of the round muscles that could be utilized as steaks. During the decade of the 90s, the retail price spread between middle meats (loin and rib) and end meats (round and chuck) increased dramatically in the United States (AMI, 1999), indicating that relative demand for beef roasts has decreased while relative demand for beef steaks has increased. This research could be used to address this shift in consumer demand by identifying those portions of beef round muscles, which may be suitable for steaks.

Implications

Definable intramuscular tenderness variation within the biceps femoris, semitendinosus, and semimembranosus muscles exceeded intermuscular tenderness variation and therefore warrants serious consideration from researchers and industry. Researchers examining tenderness in beef round muscles must be aware of intramuscular differences and obtain samples for assays from consistent within-muscle locations across treatments. The information presented in this study provides relatively detailed mapping of the tenderness regions within the biceps femoris, semitendinosus, semimembranosus, and adductor muscles and proposes several alternative fabrication and marketing practices. This information could be used to develop alternative marketing strategies for beef round steaks and roasts and for developing new food products from the large muscles of the beef round.

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