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Intramuscular tenderness variation within four muscles of the beef chuck¹

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ABSTRACT: The i.m. tenderness variation was examined within four beef chuck muscles, the infraspinatus (IF), supraspinatus (SS), triceps brachii (TB), and serratus ventralis (SV). The IF, SS, TB, and SV muscles were cut into 2.5 cm thick steaks perpendicular to the long axis of the muscle. An identification tag was placed on each steak, consisting of a muscle identification number, steak number, and orientation of the steak. Steaks were vacuum-packaged and stored at -22°C until subsequent analysis. Steaks were thawed at 1°C and cooked on electric broilers to an internal temperature of 71°C . One core was removed from each 2.5-cm \times 2.5-cm section parallel to the muscle fiber and sheared once to determine Warner-Bratzler shear force (WBSF). The SS had an overall WBSF mean of 5.43 kg (SD = 2.20

kg) with no tenderness difference ($P = 0.43$) among steak locations. The IF had an overall WBSF mean of 3.16 kg (SD = 1.01 kg) with no tenderness difference ($P = 0.51$) among steak locations. The SV had a mean WBSF value of 4.37 kg (SD = 1.27 kg) with tenderness variation ($P < 0.05$) among steak locations; however, tenderness variations were not dispersed in a discernible pattern. The TB had a mean WBSF value of 4.12 kg (SD = 1.26 kg) with lower ($P < 0.05$) shear force in the middle region of the TB, and the distal and proximal ends were tougher ($P < 0.05$). Results of this study provided a reasonably detailed mapping of the tenderness regions within the IF, SS, TB, and SV muscles, and this information could be used to add value to the beef chuck by cutting and marketing consistently tender regions.

Key Words: Beef, Chuck, Tenderness

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Introduction

Tenderness has been identified as the most important palatability attribute of meat and, thus, the primary determinant of meat quality (Huffman et al., 1996). Tenderness is a characteristic that has large variation among animals, carcasses, muscles, and cuts of meat. A cut of meat also can vary in tenderness within its own boundaries (Reuter et al., 2002).

Traditionally, the beef chuck has been merchandised in the form of low-priced roasts and steaks consisting of a number of different muscles and various quantities of i.m. fat (Kukowski, 2003). The size, shape, and composition of muscles located in the chuck vary greatly. Various studies (Paterson and Parrish, 1986; Johnson et al., 1988; NCBA, 2000) have been conducted to determine the physical and chemical composition of a few muscles from the beef chuck to gain a better under-

standing of their eating potential. Because of the various sizes and shapes of chuck muscles, measuring tenderness of a single steak might not adequately represent the entire muscle. It is possible for different regions of a muscle to have different tenderness ratings. Reuter et al. (2002) conducted a study to define i.m. tenderness variation within four muscles from the beef round. Results from that study indicated shear force values varied greatly depending on location within the biceps femoris and semimembranosus, whereas the semitendinosus and adductor were relatively uniform in shear force values. Therefore, the current study was conducted to define i.m. tenderness variation within four muscles of the beef chuck: infraspinatus (**IF**), supraspinatus (**SS**), triceps brachii (**TB**), and serratus ventralis (**SV**).

Materials and Methods

Ten of each of the IF, SS, TB, and SV muscles were obtained from USDA Choice boxed beef subprimals and aged at 2°C for 14 d from box date and frozen at -26°C . Muscles were obtained from various Institutional Meat Purchasing Specifications (**IMPS**; USDA, 1996). The IF and TB were from IMPS #114, the SS was from IMPS #116B, and the SV was from IMPS #116A. The frozen IF, SS, TB, and SV muscles were cut into 2.5 cm

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thick steaks on a band saw across the length of the muscle (perpendicular to the long axis of the muscle fibers). The SS and TB steaks were cut from the distal end of each muscle to the proximal end, IF steaks were cut from the proximal end of the muscle to the distal end, and the SV steaks were cut from the dorsal-cranial end of each muscle to the ventral-caudal end. All steaks were numbered, beginning at the distal, proximal, or cranial ends through the number of steaks obtained and ending at the proximal, distal, or caudal ends of each muscle group. An identification tag was placed on each steak consisting of a muscle identification number, steak number, and orientation of the steak. Steaks were vacuum-packaged and stored (-22°C) until shear force determination.

Shear Force Determination

Steaks were thawed at approximately 1°C for 24 h (approximately 4°C before cooking), and raw steak weights were obtained using a balance (Model TR-2102; Denver Instrument Company, Denver, CO). Steaks were broiled on Farberware Open Hearth electric broilers (Farberware, Bronx, NY) and turned every 4 min until an internal temperature of 71.1°C was reached. During cooking, steaks were turned in a specific way relative to their identification tag to maintain orientation throughout cooking and shearing. Internal temperature was monitored by inserting a thermocouple probe (Model 31308-KF; Atkins Technical, Inc., Gainesville, FL) into the geometrical center of each steak. Cooked weights were obtained for each steak. Steaks were cooled at 1°C for 2 h and then allowed to equilibrate to room temperature (approximately 45 min). Once the steaks reached room temperature, a ruler was used to divide each steak into $2.5\text{-cm} \times 2.5\text{-cm}$ sections. First, the steak was bisected horizontally into 2.5-cm sections. Then, vertical coordinates were determined, each arranged 2.5 cm from one another. The number of sections within each steak depended on the size of the steak and varied from steaks that originated at the cranial and distal end of the muscle to the caudal and proximal end and from one muscle group to the next. One 1.27 cm diameter core was removed from each $2.5\text{-cm} \times 2.5\text{-cm}$ section 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 Electric Manufacturing Co., Manhattan, KS).

Statistical Analyses

To determine tenderness variation across the length of a muscle, the whole muscle was analyzed for Warner-Bratzler shear force (WBSF) values using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC) with a model that included WBSF value and the main effect of steak. Least squares means and pooled SE were calculated for each steak and separated using the PDIF option of SAS. To determine tenderness variation

within each steak (side-to-side variation), WBSF values were analyzed using the GLM procedure of SAS with a model that included the independent variables of row, column, and the intersection of each row and column within steak as the independent variables. Within each steak, row was defined as a 2.5-cm section located across the steak, and column was defined as a 2.5-cm vertical section on each steak. The intersection of row and column was defined as the section within a steak that was the intersection of each 2.5-cm row \times 2.5-cm column. Least squares means were calculated for each row, column, and intersection of row and column within steak. Row and column were only significant for the SV and were removed from the model for the IF, SS, and TB, leaving only the intersection means. As before, least squares means were separated using the PDIF option of SAS.

Results and Discussion

Supraspinatus

The SS mean WBSF value was 5.43 kg with a SD of 2.20 kg (Figure 1). There was no difference ($P = 0.43$) among WBSF values within or between steaks when evaluating the SS. According to Miller et al. (2001), practical WBSF/tenderness levels for "tender," "slightly tender/slightly tough," and "tough" are <3.0 , 3.0 to 4.6 , and $>4.6\text{ kg}$, respectively. In the case of the SS, the whole muscle was classified as tough using dry cookery methods; thus, the SS might not be an ideal muscle to market as single-muscle steak. Johnson et al. (1988) found that total collagen present in a muscle was positively correlated with WBSF values. Moreover, Jones et al. (2000) reported that the collagen content of the SS was 17.77 mg/g , which is comparable with other muscles considered to be tough. High levels of collagen greatly affect WBSF values because muscle fiber networks become more durable as they connect to collagen. In addition, collagen does not solubilize well under dry cooking conditions, which were used in the current study. The high WBSF values of the SS may be a result of location and function; the SS is located along the juncture of the humerus and scapula, lying on top of the blade bone (NCBA, 2000), and it functions to extend the shoulder joint, while preventing shoulder dislocation (Jones et al., 2000). Muscle fibers that connect with multiple bones are more resilient and have more detailed cross-linking patterns to aid in proper attachment. Muscle fibers taper slightly at the ends, resulting in muscle banding patterns becoming less obvious and myofibrils becoming continuous with strands of noncontractile fibers (connective tissue; Lawrie, 1998). This narrowing of muscle fibers and increased strength effectively forms a network that attaches muscles to another component and can cause meat to be tougher. Both functions of the SS require strong networks of muscle fibers, which can result in greater WBSF values.

Cooking method also affects WBSF values. In the current study, all muscles were cooked using a dry cook-

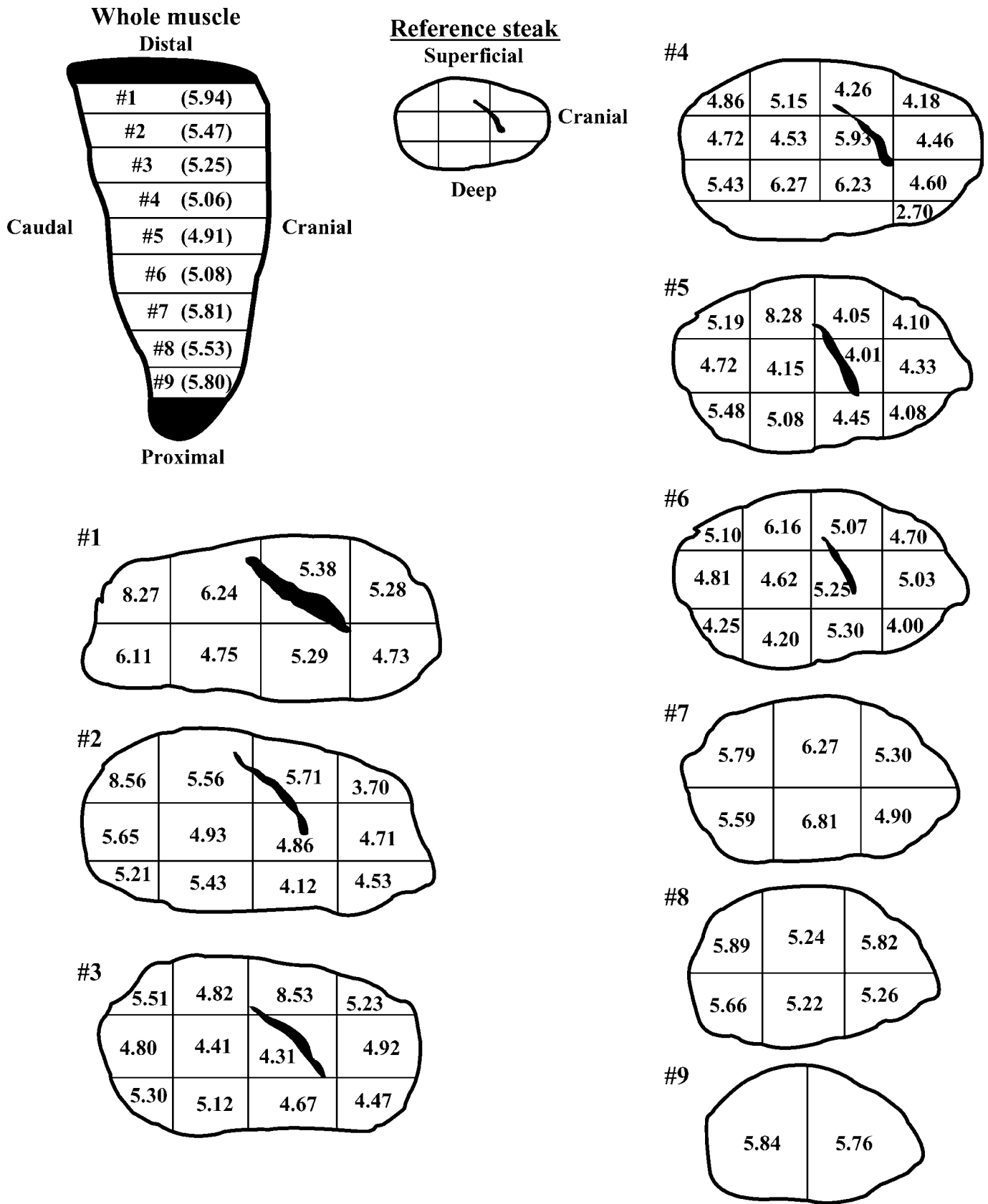


Figure 1. Schematics of the supraspinatus and representative steaks from 2.5-cm increments along the long axis of the muscle. Least squares means for shear force values (kg) are also displayed. Parenthetical data represent steak average shear force values (SE = 0.30, 0.25, 0.24, 0.23, 0.25, 0.28, 0.32, 0.37, and 0.75 for steaks 1, 2, 3, 4, 5, 6, 7, 8, and 9, respectively). No differences ($P = 0.43$) were found when evaluating Warner-Bratzler shear force values between or within steaks.

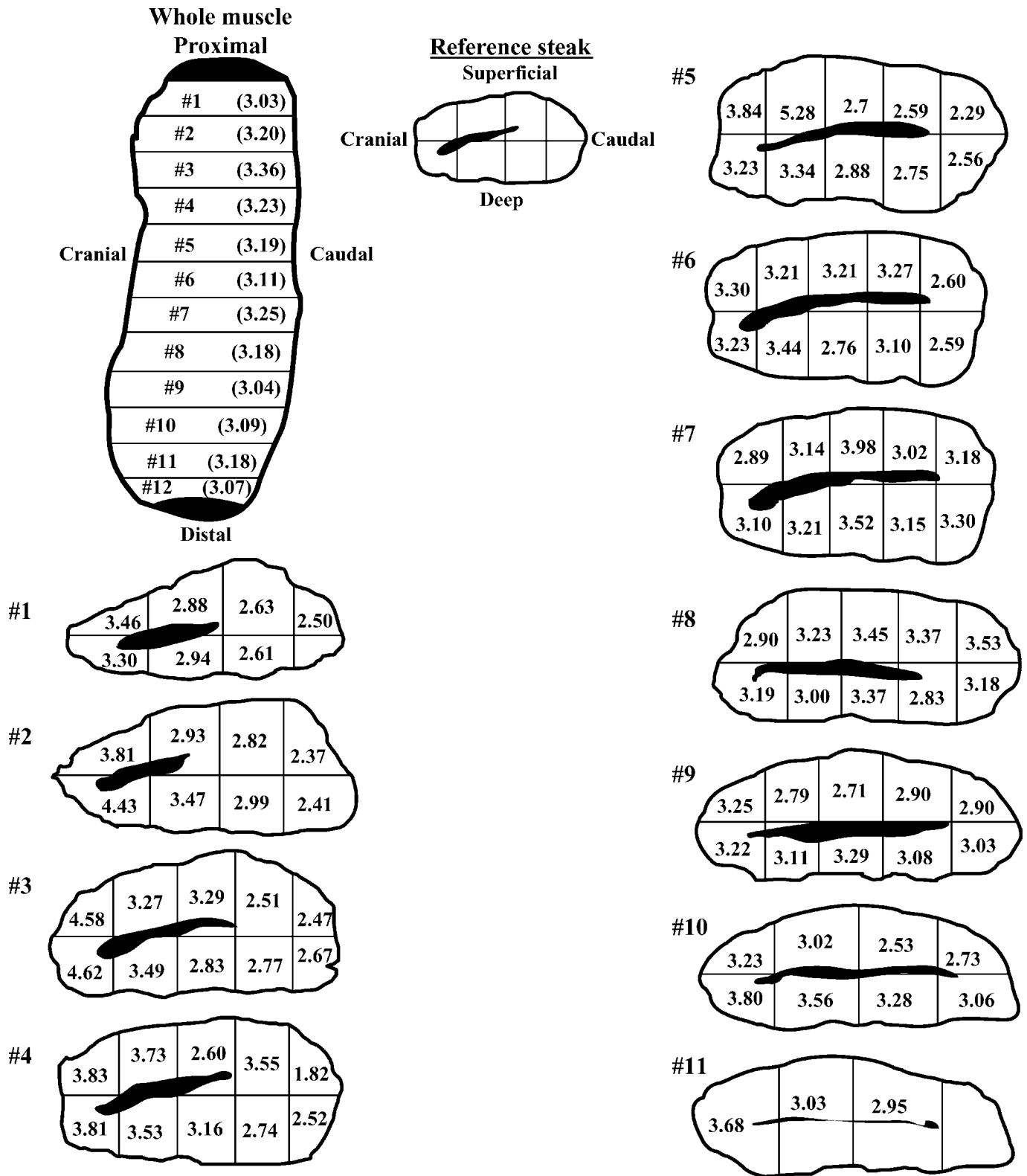


Figure 2. Schematic of the infraspinatus and representative steaks from 2.5-cm increments along the long axis of the muscle. Least squares means for shear force values (kg) are also displayed. Parenthetical data represent steak average shear force (SE = 0.16, 0.13, 0.12, 0.12, 0.11, 0.12, 0.12, 0.12, 0.12, 0.15, 0.28, and 0.64 for steaks 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, and 12, respectively). No differences ($P = 0.51$) were found when evaluating Warner-Bratzler shear force values between or within steaks.

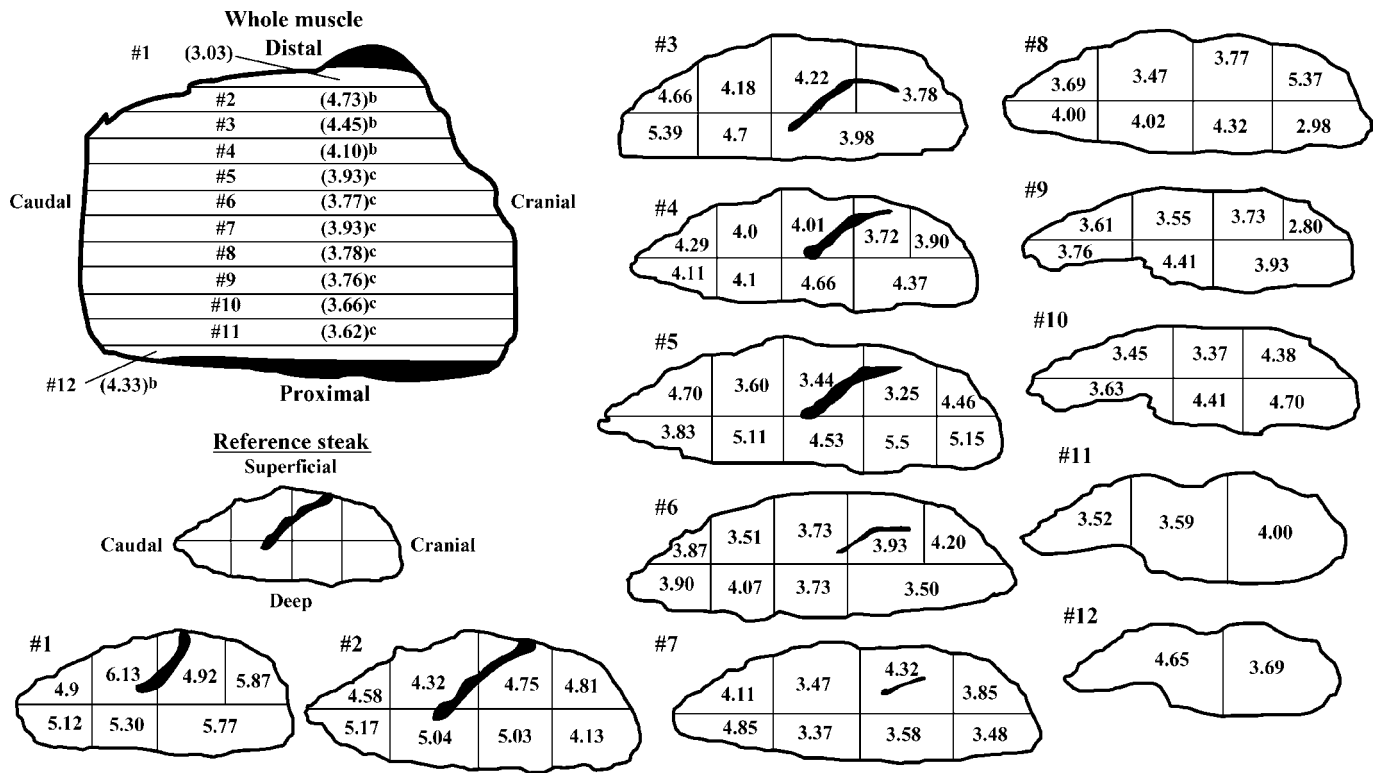


Figure 3. Schematics of the triceps brachii and representative steaks from 2.5-cm increments along the long axis of the muscle. Least squares means for shear force values (kg) are also displayed. Parenthetical data represent steak average shear force (SE = 0.26, 0.18, 0.12, 0.11, 0.10, 0.09, 0.08, 0.08, 0.08, 0.08, 0.09, and 0.11 for steaks 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, and 12. Within the muscle, least squares means that do not have a common superscript letter differ, $P < 0.05$.

ing method, a typical preparation for tender cuts of meat. The SS may perform differently when prepared using a moist cooking method, which is suitable for less tender cuts of meat. When preparing cuts from the beef chuck, moist cooking methods are typically implemented. Under moist cooking conditions, greater amounts of existing connective tissue (collagen) can be solubilized, resulting in an increase in overall tenderness. According to the results of the National Cattlemen’s Beef Association’s Muscle Profiling Study (NCBA, 2000), moist cooking methods for the SS resulted in lower WBSF values than dry cooking methods; however, in the current study, using a dry cooking method was more appropriate in determining the regions of the studied muscles that would be suitable to market as single-muscle steaks. Using the Miller et al. (2001) tenderness threshold levels, the SS can be considered “slightly tender” when prepared using moist cooking methods.

Infraspinatus

There were no ($P = 0.51$) differences in WBSF values within and among steaks when evaluating the IF; however, unlike the SS, the IF was consistently tender throughout the muscle with average steak shear of 3.16 kg and a SD of 1.01 kg (Figure 2). This consistency in

tenderness indicates that the IF would be suitable to market as single-muscle steak. Paterson and Parrish (1986) evaluated nine muscles from the square-cut beef chuck and reported that the IF scored highest in sensory panel scores for tenderness and overall palatability, and the SS scored low for all sensory attributes. Paterson and Parrish (1986) also discovered significant correlations between myofibrillar fragmentation index (MFI) values, sensory panel tenderness scores, and WBSF values; the IF had significantly greater MFI values than intermediate (deep pectoral) and tough (rhomboides) muscles. One reason the IF is consistently tender might be muscle function and collagen content. The IF abducts the arm of an animal, rotating it outward (Jones et al., 2000). In terms of general movement, cattle do not extend their front limbs outward to any great extent. Instead, the front limbs mainly move in a forward/backward movement; therefore, the IF is not used extensively in locomotion. The IF has been reported to have a collagen content of 8.72 mg/g (Jones et al., 2000), which is a much lower content than that of the SS; this low collagen content may be another factor contributing to the consistently tender quality of IF. Generalities such as this are, however, less applicable when a wide array of individual muscles is evaluated for tenderness (Belew et al., 2002).

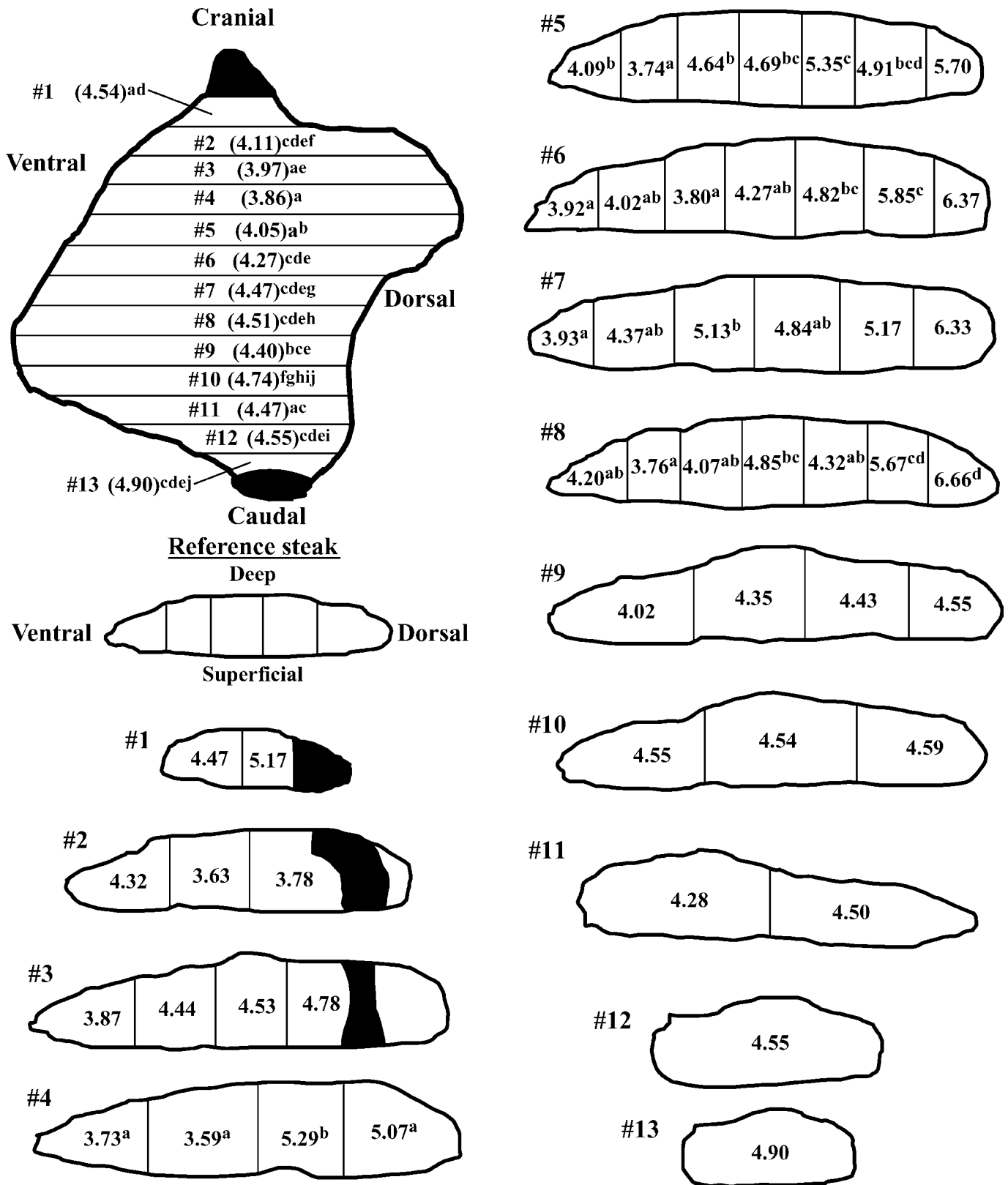


Figure 4. Schematics of the serratus ventralis and representative steaks from 2.5-cm increments along the long axis of the muscle. Least squares means for shear force values (kg) are also displayed. Parenthetical data represent steak average shear force (SE = 0.34, 0.22, 0.18, 0.16, 0.15, 0.13, 0.13, 0.14, 0.17, 0.24, 0.52, 0.64, and 0.74 for steaks 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, and 13, respectively). Within a muscle and specific steak, least squares means that do not have a common superscript letter differ, $P < 0.05$.

Triceps Brachii

To construct simplified TB steak figures (Figure 3), least squares means from adjoining cores were averaged to give a single shear value for a given area of approximately 5 cm². The TB had different ($P < 0.05$) WBSF values among steaks. The mean steak WBSF value was 4.12 kg with a SD of 1.26 kg. The first four steaks originating at the distal end of the muscle and the last steak located at the proximal end of the muscle were tougher ($P < 0.05$) than the middle steaks and had WBSF values >4.1 kg, characterizing them as slightly tough or tough according to the tenderness ranges used by Miller et al. (2001). A tenderness gradient (lack of tenderness consistency) similar to the pattern observed here for TB has been reported in the beef LM (Crouse et al., 1989; Zuckerman et al., 2001; Kerth et al., 2002). The specific cause of the tenderness gradient of the beef LM has not been defined. Possible factors causing shear force differences among TB steaks may be the rate of temperature increase during cooking experienced by the ends of the smaller steaks compared with the middle steaks. In addition, the basic physiological tapering of muscle fibers as they reach their points of attachment also may be important. The TB functions to extend the elbow joint, and it flexes the shoulder joint. Extending the elbow and flexing the shoulder joint may account for the fact that steaks located at the distal and proximal ends of the TB have greater WBSF values than the remaining middle steaks. The outer portions of the TB are used in attachment, whereas the middle section may only be used for stability, which may explain the tenderer middle steaks. When evaluating an objective technique for tenderness determination according to location within a steak, Zuckerman et al. (2001) observed greater shear force values at the edges of steaks. These greater shear force values were possibly due to an increased rate of chilling on the most external portions of the muscle, differences in skeletal attachment, cooling gradient effects, or inconsistent cooking (Dugan and Aalhus, 1998). Koohmaraie et al. (1996) reported that rigor-related toughening only occurs if muscles are allowed to shorten. Tough sections of a steak may be related to rigor shortening, and tender sections of the same steak may be due to lack of rigor shortening and/or an accelerated rate of tenderization (Dugan and Aalhus, 1998).

Serratus Ventralis

The SV steak figures (Figure 4) were constructed to illustrate column effects within each steak. There were differences ($P < 0.001$) in tenderness values throughout the SV; however, the SV did not have a consistent pattern of tenderness. The mean steak WBSF value was 4.37 kg with a SD of 1.27 kg. The SV contained locations with intermediate WBSF values intermixed with high WBSF values. The middle five steaks produced signifi-

cant column effects; the ventral sides of those steaks were tenderer ($P < 0.05$) than the dorsal sides. This variation in tenderness could be a result of the physical construction of the muscle as a whole and its function. The SV is a large, fan-shaped muscle lying from the dorsal region just over the ribs ventral toward the sternum or brisket (NCBA, 2000). Although the SV is not used in true locomotion, it functions to protract and retract the shoulder, and it flexes the neck when acting unilaterally (Jones et al., 2000). The muscle fibers run parallel to the long axis of the SV with heavy sheets of surface connective tissue (NCBA, 2000). Some of the tender regions found in the SV may be a result of it not functioning as a motility muscle, allowing some muscle fibers to be tenderer. As mentioned previously, muscle fibers become stronger and more concentrated when they connect with connective tissue; therefore, with a large amount of connective tissue dispersed throughout the SV, it is clear why there would be no true mapping pattern of tenderness. Because the ventral sides of the SV steaks are tenderer than the dorsal sides and because of the size of these steaks, it may be possible to fabricate and market those regions as single-muscle steaks. However, further tenderness mapping of this muscle is needed to determine whether the tenderer region of these steaks is large enough to validate single-muscle fabrication.

Implications

This study is a reasonably detailed mapping of the tenderness regions within the infraspinatus, supraspinatus, triceps brachii, and serratus ventralis. Tenderness levels were acceptable for the entire infraspinatus, unacceptable for the supraspinatus, and variable for the serratus ventralis. The distal end of the triceps brachii was unacceptable for tenderness, and the remainder of the muscle was acceptable. Results of the current study could be used to add value to the beef chuck by using those muscles with consistently tender regions for fabrication and marketing them as single-muscle steaks.

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