CHARACTERIZATION OF CERTIFIED ANGUS BEEF™ STEAKS FROM THE ROUND, LOIN AND CHUCK

By

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NOMENCLATURE

AOAC	Association of Official Analytical Chemists
^{o}C	degree (s) Celsius
cm	centimeter (s)
d	day (s)
g	gram (s)
hr	hour (s)
IMPS	Institutional Meat Purchase Specifications
kg	kilogram (s)
mm	millimeter (s)
USDA	Unites States Department of Agriculture
WBS	Warner-Bratzler shear force
YG	USDA yield grade
QG	USDA quality grade

CHAPTER I

INTRODUCTION

For nearly 25 years it has been repeatedly established that consumers place strong emphasis on tenderness when determining the "quality" of a cooked beef steak (Forbes et al., 1974; Savell et al., 1987, 1989). More recently, it was documented that consumers are willing to pay a premium for beef that is "guaranteed tender" (Boleman et al., 1997). Data from the National Beef Quality Audit (National Cattlemens Association [NCA], 1996) indicated that carcasses in the U.S. have become heavier, more muscular and have less marbling than those surveyed in 1974, which has resulted in leaner, and potentially less palatable products. Excluding various changes in genetics and management practices, the new target for producing leaner beef has been partially attributed to the demands of a more health-conscious society. The beef industry fears that increasing leanness will contribute to decreases in palatability; eliminating "waste" while sacrificing "taste". Yet it has been reported that far more consumers of beef (nearly three fold) are concerned with the tenderness rather than the taste of cooked beef (McDonell, 1990). Hence, to remain competitive with other food protein sources, an objective of the beef industry must be to provide a uniform, tender product to consumers that will result in pleasant eating experiences. The need for this objective was substantiated by the inconsistency associated with beef palatability noted by purveyors, restaurateurs, retailers and packers surveyed during the 1995 National Beef Quality Audit (NCA, 1996). Previously, the National Beef Tenderness Conference (NCA, 1994) revealed: 1) One in every four beef steaks is less than desirable in tenderness and overall palatability; 2) One tough carcass may affect as many as 542 consumers; 3) Tenderness within as well as among cuts differs greatly; 4) Beef industry leadership is adamant about increasing market-share. Increasing beef tenderness was the key component to this plan.

Extensive research has focused on identifying factors that influence palatability, with particular emphasis placed on increasing tenderness and reducing the variation in beef palatability. Results of the National Beef Tenderness Survey (Morgan et al., 1991) concluded that palatability hurdles such as breed type, U.S. quality grade, minimum postmortem aging and geographical source of cattle were identified as contributing sources of beef tenderness variation. This survey (Morgan et al., 1991) also indicated that the transition from thick roast to thin steak cuts of the chuck and round – to provide convenience – could increase toughness and decrease consumer satisfaction. Over one-half (58%) of all U.S. beef consumers prepare beef steaks to an internal cooking endpoint of "medium well" (77°C) or greater (National Livestock and Meat Board, 1995). Data from the National Livestock and Meat Board study also indicated that steaks from carcasses with U.S. quality grades of at least Average Choice generally were more desirable than steaks from lower quality grading carcasses.

These data combined with the evidence that increased marbling degrees provide beef with "insurance" against drying out or being less tender when cooked to higher degrees of doneness (Smith and Carpenter, 1974) provides part of the basis for the Certified Angus Beef Program™.

The Certified Angus Beef™ Program was created in 1978 by the American Angus Association to provide consumers with a "premium quality" product in terms of consistency, palatability and overall eating satisfaction. This development came at a time when "premium quality" beef appeared to be declining (Hildebrand and Ward, 1994).

The value of wholesale beef rounds and chucks decreased 20 and 23%, respectively, from 1993 to 1997 (Dolezal, 1998). Boneless, closely trimmed (0.6 cm fat) beef subprimals from the round (inside round, gooseneck round and knuckle) and chuck (clod) account for 21.4% of carcass weight (Dolezal, 1998). More importantly, these same subprimals represent 26.6% of the total carcass value (Dolezal, 1998). The potential exists to increase value of beef carcasses by identifying carcass characteristics that yield more palatable end cuts. The current research was designed to 1) Determine base-line tenderness values and sensory panel ratings, 2) Assess variation in tenderness, and 3) Compare the mean values and variation for tenderness and sensory characteristics among Certified Angus Beef™, U.S. Choice (commodity) and U.S. Select steaks from the round, loin and chuck.

CHAPTER II

REVIEW OF LITERATURE

Factors affecting tenderness

The determination of cooked meat palatability (tenderness, juiciness and flavor) involves structural and compositional differences of muscle components (sarcomeres, myofibrils, muscle fibers and muscle bundles) and multiple animal and carcass factors (physiological age, fatness, marbling, biological type and ante- and postmortem management practices). These factors may individually or collectively influence overall palatability. Of the three palatability attributes, tenderness seems to be the most perplexing, while juiciness and flavor can be readily controlled by management, selection and cooking criteria (Smith et al., 1998).

Marbling. Fat deposition in animals, particularly marbling, undoubtedly influences both the actual and perceived value of fresh meat. As mentioned by Smith and Carpenter (1974), references made to the value of fattened animals date to Biblical times. The idea that presence of fat in animal carcasses influences palatability, and thus value, supported the development of the U.S. Standards for Grades of Carcass Beef. Emerging in 1916, these standards were developed to provide uniform reporting of dressed beef markets according to various grades, and eventually became the Official United States Standards for the Grades of Carcass Beef which served as the basis for carcass grading when the beef grading and stamping service began in May 1927 (USDA, 1997). These grades are arranged in a hierarchical system and are intended to segment carcasses based upon their market value and expected desirability or cooked palatability. Presently, the quality grades range from U.S. Prime (expected to be most desirable) to U.S. Canner (expected to be least desirable) and are determined by: 1) physiological maturity of the carcass, 2) marbling level within the *longissimus dorsi* at the $12^{th}/13^{th}$ rib interface, and 3) meat firmness (USDA, 1997). Once carcasses are segmented into maturity groups based upon physiological indicators, marbling becomes the primary determinant when assigning the final USDA quality grade. According to the National Beef Quality Audit (NCA, 1996), 95% of cattle harvested in the United States qualify for the "A" (most youthful) maturity group. Thus, for the current meat supply in the food service and retail sectors, marbling rather than physiological maturity has a greater effect on ultimate quality grade.

Some researchers have reported poor relationships between marbling and cooked beef tenderness (Tuma, 1963; Romans et al., 1965; Parrish, 1973; Parrish, 1974; Dikeman and Crouse, 1975; Wheeler, et al., 1994). But an extensive review by Jeremiah (1978) identifies considerable other research which indicates that marbling has a positive effect on beef palatability. McBee and Wiles (1967) found that shear force, sensory panel tenderness, juiciness and flavor improved as marbling increased. Dolezal et al. (1982a) concluded sensory panel ratings increased and shear force values decreased as marbling increased. Steaks from carcasses with at least a "modest" degree of marbling received the highest ratings for juiciness and overall palatability and had lower shear force values than steaks from carcasses with a "slight" degree of marbling (Dolezal, et al., 1982a). Similarly, steaks with at least a "small" degree of marbling (Jones and Tatum, 1994) and steaks with at least a "modest" degree of marbling (Jennings, 1978) were reported to have lower shear force values than steaks with "slight" or lower marbling scores. Previously, Romans et al. (1965) reported that steaks with at least a "moderate" amount of marbling had higher juiciness ratings than steaks with a "slight" degree of marbling. Breidenstein et al. (1968) found as marbling scores increased from "slight" to "abundant" sensory panel juiciness scores significantly ($P<.01$) increased. Moreover, it has been demonstrated with consumers that the effect of marbling on palatability has some regional implications; consumers in different regions of the country respond differently to steaks varying in their amounts of marbling (Savell et al., 1987; Neely et al., 1998).

Based upon the standards set forth by the USDA, marbling is a subjective measure of the total amount of intramuscular fat and is obtained by viewing only one cross-section of the *longissimus dorsi.* As a more objective approach, researchers have sampled, measured and used chemical fat percentages to represent total intramuscular fat. When loin steaks were evaluated, Davis et al. (1979) found that the most tender steaks had higher intramuscular fat percentages and expectedly, lower moisture percentages. However, in the Davis study, tenderness differences disappeared as the range of visible marbling decreased, as reflected by no detectable tenderness differences within the U.S. Good (Select) grade. Savell and Cross (1989) concluded that 3% *longissimus dorsi* fat was sufficient for acceptable palatability, which supports earlier research conducted by Campion and Crouse (1975); these reserearchers suggested that 2.9% chemical fat was adequate to assure acceptable palatability of *longissimus* steaks. Savell et al. (1986) studied the relationship between USDA marbling score and ether extractable fat content of the *longissimus* muscle. The marbling score and fat percentage relationships for the Savell study were: Moderately Abundant (10.42%), Slightly Abundant (8.56%), Moderate (7.34%), Modest (5.97%), Small (4.99%), Slight (3.43%), Traces (2.48%) and Practically Devoid (1.77%) (Savell et al., 1986).

In a celebrated review, Smith and Carpenter (1974) defined four theorized mechanisms in which marbling may contribute to increases in real or apparent tenderness: 1) The *bite theory* proposes that within a given size of meat, marbling decreases the muscle mass per unit of volume (reduces bulk density) because protein is replaced by lipid; 2) The *strain theory* states as marbling is deposited, perimysial and/or endomysial walls (connective tissue walls) are stretched, thinned and therefore weakened; 3) *Lubrication theory* says the deposited fat within the muscle fibers serves to lubricate the mastication process, thus creating a perception of increased tenderness – which lends to the belief that tenderness is closely associated with juiciness; 4) The *insurance theory* suggests the presence of higher levels of marbling provides "insurance" – beef can be cooked to higher endpoint temperatures without having as detremental effect on palatability as would be expected from meat with lower levels of marbling. Luchak et al. (1991) found U.S. Choice top loin steaks to have lower shear force values than U.S. Select steaks, but tenderness differences between quality grades were even more pronounced as cooking endpoint temperature increased.

Inconsistencies in beef palatability have been identified as a major concern of purveyors, restaurateurs and retailers in the United States (NCA, 1996), and researchers have studied the effect of marbling on beef palatability variation. Campion et al. (1975) concluded that marbling had little or no effect on the palatability variation of beef; less than 10% of the variation in cooked beef palatability was explained by marbling. Crouse and Smith (1978) reported marbling accounted for 3% of variability in taste panel tenderness. Likewise, Armbruster et al. (1983) stated that marbling was a poor predictor of tenderness and only accounted for 1.2% of the variation in beef tenderness, while Jones and Tatum (1994) reported that marbling score was the best single carcass trait predictor of Warner-Bratzler shear and sensory panel tenderness; marbling alone accounted for 9.0% of Warner-Bratzler shear and 5.1% of sensory panel tenderness variaability, respectively. Conversely, Smith et al. (1984, 1987) reported that marbling accounted for 33% of loin steak palatability variation, and steaks from carcasses with "traces" or "practically devoid" degrees of marbling had more variable Warner-Bratzler shear values than steaks from carcasses with higher marbling degrees. May et al. (1992) also reported a moderately strong relationship between marbling and palatability attributes; marbling accounted for 37 and 26% of Warner-Bratzler shear and sensory panel tenderness variation, respectively.

Time-on-feed. The primary cause of fat deposition and marbling accretion is the practice of maintaining animals on a high plane of nutrition prior to slaughter. Thus, the most common method to enhance quality grade is to extend the time that animals are fed a high concentrate diet (Gardner, 1997). As time-on-feed increases, marbling scores and U.S. quality grades are improved (Zinn, 1970; Tatum et al., 1980; Dolezal et al., 1982). When comparing grain-finished versus forage-finished beef, Bowling et al. (1977) summarized that grain-finished beef was more tender, more desirable in flavor and more satisfactory in overall palatability. Van Koevering et al. (1995) determined that overall tenderness of steaks from "A" maturity carcasses improved with increased time-on-feed. This was exhibited by a decrease in the percentage of steaks with Warner-Bratzler shear values in the "tough" category (greater than 4.5 kg). Much of the palatibility improvements associated with increased time-on-feed is simply attributed to increases in marbling. However, Tatum et al. (1980) determined that the percentage of steaks qualifying for the "very desirable" category increased from 37.5 to 47.7 percent for steaks from cattle fed 100 and 160 days, respectively, despite minimal differnce in mean marbling score (Slight 83 versus Small 20 for 100 and 160 days on feed, respectively). Similarly, and using sensory panel attributes as an indicator, Dolezal et al. (1982b) suggested the minimum degree of marbling required to achieve the U.S. Choice quality grade could be lowered to the "slight" category, provided that cattle were maintained on a high-energy diet for at least 90 days. Huffman et al. (1990) concluded that calves immediately placed on a high concentrate diet and fed longer in the cool season (November to May) had more intramuscular fat and more favorable sensory panel tenderness scores than yearling calves assigned to a winter stocker program and then placed on a high concentrate for a shorter period during the warm season (June to October), despite the fact that calves from both groups were fed to the same 12^{th} rib adjusted fat thickness. Conversely, Burson et al. (1980) concluded that U.S. quality grade and time-on-feed had little effect on juiciness, muscle fiber tenderness, overall tenderness or flavor attributes during sensory panel evaluation. Interestingly, in the Burson study, U.S. quality grades ranged from U.S. Standard to U.S. Choice, and time-on-feed ranged from 0 to 175 days.

Similar to marbling, external fat has been shown to influence tenderness. Interests in changing the standards for USDA quality grades based upon subcutaneous fat thicknesses used in addition to or in place of marbling have been exhibited (Riley et al., 1983). When studying lamb carcasses, Smith (1976) concluded that increases in external fat thickness improved tenderness by decreasing the carcass temperature rate of decline during postmortem chilling, which inhibited cold shortening, which is a decrease in sarcomere length due to rapid temperature decline. Bowling et al. (1977) found similar tenderness results when comparing grain-finished versus forage-finished beef; grain-finished beef had significantly higher fat thickness values with no difference in mean marbling scores. May et al. (1992) further demonstrated the "insulation effect" of subcutaneous fat on carcass temperature decline. Dolezal et al. (1982) and Tatum et al. (1982) both studied the effects of marbling and subcutaneous fat thickness on cooked beef palatability and found that steaks from carcasses with less than 5.08 mm subcutaneous fat over the *longissimus dorsi* at the 12^{th} rib had the highest (P<.05) shear force values and had generally lower sensory panel ratings for overall tenderness and overall palatability. Riley et al. (1983) found that steaks from steers within the U.S. Good grade and with less than 7.6 mm subcutaneous fat were less palatable than steaks from steers with at least 7.6 mm of fat. As stated earlier, possible changes to the USDA grading standards have been examined in the past. Shackelford et al. (1994) tested the efficacy of applying a minimum subcutaneous fat thickness requirement to the grading standards and found that varying subcutaneous fat thicknesses minimally yet statistically affected meat tenderness. However, within the U.S. Select grade, sensory panel attributes did not differ among subcutaneous fat groupings, which may imply difficulties in acceptance of this type change in the standards (Shackelford, 1994). Some research has indicated that subcutaneous fat may effect tenderness during cooking. Berry (1993) found that external fat may provide an insulation effect when cooking top loin steaks. Tenderness scores in the Berry study, though minimal (6.0 versus 5.6), were more desirable for steaks that had a uniform subcutaneous fat thickness versus those steaks from which the subcutaneous fat was removed, but tenderness differneces were noted for only those steaks with a "small" degree of marbling.

P*roteolysis.* It is generally accepted that postmortem refrigerated storage of meat (aging) improves tenderness (Hedrick et al., 1994). Smith et al. (1978) investigated the aging process and proposed that 11 days postmortem storage of meat from U.S. Choice carcasses was sufficient to produce a palatable product. Fifty percent of the aging response occurs within the first 24 hours postmortem (Koohmaraie et al., 1988) and 65 to 80% is achieved within 3-4 days postmortem (Taylor et al., 1995). Natural enzymes or calpains within the muscle were believed historically to improve tenderness by degrading sarcomere boundaries or Z-lines, resulting in disruption in the myofibrillar structure. However, Taylor et al. (1995) challanged this belief and indicated that most Z-disk structure in postmortem muscle remains nearly unchanged. Taylor et al. (1995) concluded postmortem tenderization due to calpains involves at least three other interrelated events including: 1) weakening of the myofilament structure (actin/myosin interaction), 2) weakening of thin filament/Z-disk connections and 3) degradation of intermyofibrillar linkages. In the Taylor study, Z-disk degradation did not occur to any significant extent during the time in which postmortem tenderization is first noticed (3 to 4 days) and Z-disks nearly maintained their ultrastructure up to 16 days postmortem. Irregardless of the actual process by which calpains enhance postmortem tenderization (Z-disk degradation or other mechanisms), calpains are regulated by the presence or absence of calcium ions. Thus, increased levels of calcium enhance proteolysis. Numerous researchers have investigated the efficacy of calcium chloride infusion as a postmortem tenderization technique for meat. (Koohmaraie and Shackelford, 1991; Morgan et al., 1991; Diles et al., 1994; McFarlane and Unruh, 1996; Wulf et al., 1996; Clare et al., 1997).

Physiological age. The USDA recognizes five maturity groups for beef carcasses. The maturity groups are based upon physiological indicators of carcasses and presumably describe the approximate chronolgoical age of the animal at time of slaughter. As animals increase in age, meat tenderness decreases as a result of changes in the amount and/or structure of connective tissue within muscle. However, carcass physiological indicators are not always consistently associated with chronological age. In a review of factors affecting carcass maturity, Gardner and Dolezal (1997) summarized that certain management practices including harvest of pregnant or once-pregnant heifers and use of anabolic implants in beef may impact carcass physiological maturity. Romans et al. (1965) found that rib steaks from "D" maturity carcasses had higher sensory panel ratings than steaks from "A", "B" or "C" maturity carcasses. Shackelford et al. (1995) studied the effects of animal age on meat tenderness using animals with known history, similar breed type and that were fed similar diets. The Shackelford study found no differences in Warner-Bratzler shear among "A" and "B" maturity carcasses, but a tendency towards lower sensory ratings was exhibited for B-maturity cows versus A-maturity heifers. Previous research by Tuma et al., (1962) showed that Warner-Bratzler shear values of *longissimus dorsi* steaks increased significantly with advanced animal age; most notably when the age of the animals ranged from 18-24 months. Jeremiah (1978) reported it was once believed that the positive effects of carcass fatness on palatability could compensate for the negative effects of advancing maturity. However, Smith et al. (1982) reported a low relationship between marbling and overall palatability variation for "C" maturity or older carcasses. When a high marbling degree (moderately abundant) was held constant, percentages of steaks with overall palatability ratings above 6.0 (8=extremely desirable, 1=extremely undesirable) decreased as maturity scores progressed from "A" to "E"; 69% of steaks from "A" maturity carcasses versus 53% of steaks from "A" through "E" carcasses (Smith et al., 1982). Earlier research (Tuma, 1962) indicated that increases in marbling did not necessarily compensate for advanced maturities, but that tenderness differences due to marbling were more pronounced as animals increased in chronological age at the time of slaughter. Increased time-on-feed generally improves tenderness; however, Zinn (1970) reported that the benefits of extended time-on-feed can be suppressed by increased animal age. Time-on feed up to 150 days had a beneficial effect on tenderness, but after 180 days-on-feed, animal age exerted a greater negative effect on tenderness (Zinn, 1970). Data showing the negative effects of increased maturity on palatability provided the rational for the most recent change to the Official United States Standards for the Grades of Carcass Beef. This change involved carcasses of "B" maturity with "small" or "slight" marbling, which are all graded U.S. Standard rather than U.S. Choice or Select, respectively (USDA, 1997).

Breed type. Since marbling is currently the primary determinant of U.S. quality grade, knowing the effect of breed on carcass traits could be valuable. The Angus breed is well known for its ability to deposit higher degrees of marbling within the ribeye (Huffman et al., 1990; Gregory et al., 1994; Marshall, 1994). However, differences in tenderness due to breed are most evident upon comparison of cattle types or species rather than breeds (i.e., *Bos taurus* versus *Bos indicus*). Tenderness differences between these species is largely due to increased levels of calpastatin in *Bos indicus* species, which inhibits the activity of calpains and thus reduces postmortem proteolysis (Wheeler, et al., 1994). Koch et al. (1988) determined that sensory tenderness scores for steaks from *Bos taurus* breeds were higher than steaks from *Bos indicus* breeds, even at equivalent marbling levels. When studying palatability traits of Hereford and Hereford by Brahman crossbreds, Sherbeck et al. (1995) found that crossbred cattle with at least 25% Brahman yielded steaks with higher Warner-Bratzler shear values and lower sensory panel tenderness scores than steaks from straightbred Hereford cattle. Similarly, Johnson et al. (1990) studied Angus and Brahman crossbreds and discovered that sensory panel tenderness decreased slightly but statistically ($P<.05$) as percentage Brahman reached 50%, and Warner-Bratzler shear improved statistically as percentage Angus reached 75%.

Subprimal or muscle type. Ramsbottom and Strandine (1948) recognized that tenderness varied between beef muscles and established tenderness ratings for 50 different beef muscles by collecting Warner-Bratzler shear values. Perhaps the most common explanation for tenderness differences among muscles is the amount and structure of connective tissue. Collagen is the most abundant protein in the animal body and significantly influences meat tenderness. Moreover, collagen is not equally distributed among muscles, but collagen amount is related to individual muscle activity; muscles that are more active have greater amounts of connective tissue (Hedrick et al., 1994). Sensory panel scores have been reported to decrease as the cuts evaluated moved from the anterior to the posterior regions of carcasses (Shackelford et al., 1995). In the same study, overall tenderness varied much more between muscles than any other attribute such as juiciness or beef flavor Tenderness showed twice the variation of juiciness and four times the variation of beef flavor (Shackelford et al., 1995). The idea that tenderness is the most variable palatability attribute has been recognized for some time (Ramsbottom and Strandine, 1948).

In a study conducted by Morgan et al. (1991), Warner-Bratzler shear values indicated a high percentage of chuck and round cuts would receive panel tenderness scores less than "slightly tender". Swatland (1984) reported that muscles used more frequently, such as muscles used for locomotion, have higher myoglobin concentrations due to increased oxygen demand as compared to support muscles. This coupled with the findings of Quali (1990) which indicated that the degradation of myofibrillar structure was greater for muscles with increased contraction speed (white fibers) and lower for muscles with increased levels of heme iron (red fibers), may relate to possible differences in postmortem proteolysis. Smith et al. (1984) found that marbling was much more influential on the palatability of loin steaks than round steaks. Carcasses utilized by Smith et al. (1984) that had a "moderately abundant" degree of marbling yielded loin steaks that had superior palatability ratings in 60% of all comparisons, while round steaks from the same carcasses were superior in only 37% of comparisons. When studying Limousin steers, Wulf et al. (1996) reported that tenderness decreased, especially in high-collagen cuts, as the steers matured within a narrow range of 15 to 18 months. In the Wulf study, end cuts (round) were overall tougher than middle meat cuts (strip loin); however round cuts exhibited a quadratic response to increases in internal temperature (i.e., increased in tenderness followed by toughening), while strip loin steaks toughened linearly as internal temperature increased. This non-linear response in the round cuts was due to collagen solubility up to a point to where muscle fiber shrinkage exceeded any benefits from collagen solubility (Wulf et al., 1996).

Warner-Bratzler Shear Force

K. F. Warner invented an apparatus (Wheeler, 1996) to objectively measure and determine differences in meat tenderness, commonly known as Warner-Bratzler shear or shear force. Since then, numerous researchers have utilized this approach to objectively determine differences among various factors that may affect tenderness. Likewise, researchers have used individuals, either as trained evaluators or lay consumers, to evaluate meat palatability differences. To obtain a 50 or 68% confidence level of having slightly tender top loin steaks (as determined by trained sensory panel), Shackelford (1991) concluded that Warner-Bratzler shear should not exceed 4.6 or 3.9 kg, respectively. However, these values were obtained using top loin steaks only and should not be applied to other muscles groups or cuts. Subsequent to those findings, Shackelford et al. (1995) compared the values of Warner-Bratzler shear against the values reported by a trained sensory panel across ten beef muscles. Those results indicated that Warner-Bratzler shear was not able to detect the same statistical differences among muscles as the sensory panel did for overall tenderness; thus if muscles are to be ranked according to tenderness values, the ranking procedure is highly dependant upon the method employed to assess tenderness. Other research has explored the accuracy of methods utilized when evaluating meat tenderness using Warner-Bratzler shear, trained sensory panels or both (Shackelford et al., 1997; Wheeler, et al., 1996, 1997; Otremba, 1997).

Methods to predict tenderness of beef shortly after harvest have been investigated to further segment carcasses based upon expected palatability. Shackelford et al. (1997) concluded that *longissimus dorsi* tenderness after aging 14 days could be predicted by first assessing tenderness of the same muscle 1 or 2 days postmortem. Previously though, Shackelford et al. (1995) explained the *longissimus dorsi* had the highest variation for Warner-Bratzler shear and sensory panel tenderness, which implies that systems to predict tenderness of the *longissimus dorsi* may not accurately reflect tenderness of other muscles.

CHAPTER III

CHARACTERIZATION OF CERTIFIED ANGUS BEEF™ STEAKS FROM THE ROUND, LOIN AND CHUCK

ABSTRACT

Beef steer carcasses (n=150) of "A" maturity were selected randomly to determine baseline shear force and sensory panel ratings, assess variation in tenderness, and evaluate mean value differences between Certified Angus Beef™ (CAB), U.S. Choice, commodity (Choice) and U.S. Select (Select) steaks. Three steaks were removed from the clod or *triceps brachii*, strip loin or *longissimus dorsi*, top sirloin butt or *gluteus medius*, inside round or *semitendinosus*, round flat or *biceps femoris*, and knuckle or *quadriceps femoris* complex, and assigned to Warner-Bratzler shear (WBS), sensory panel and to serve as a spare. Marbling score and intramuscular fat percentage were highest (P<.05) for CAB, intermediate (P<.05) for Choice and lowest (P<.05) for Select carcasses. A significant (P<.05) subprimal by quality level interaction was observed for WBS and sensory panel tenderness ratings. CAB clod, strip loin, top sirloin butt and round flat steaks had significantly lower shear force values than Select steaks from the same subprimals. No differences (P<.05) in WBS were evident for CAB and Choice steaks, except CAB strip loin and top sirloin butt steaks were more tender than Choice steaks. When grouped by subprimal, Select steaks had the highest WBS variation, and when grouped by quality level, strip loin steaks had the most variable WBS values. Trained sensory panelists rated CAB strip loin steaks more tender than all other steaks, followed by Choice and Select strip loin steaks, which differed (P<.05). Select clod steaks were less (P<.05) tender than Choice or CAB, but sensory panel ratings indicated that quality level showed little consistency among the top sirloin butt, inside round, round flat and knuckle. No benefit from additional marbling was noted for steaks from the chuck of at least commodity Choice quality, and marbling was a better indicator of tenderness in steaks from the loin than steaks from the round.

(Key Words): Quality Grade, Tenderness, Certified Angus Beef™

INTRODUCTION

Low overall consistency, inadequate tenderness and low overall palatability were the top three "quality" concerns noted by beef purveyors, restaurateurs, retailers and packers in the 1995 National Beef Quality Audit (NCA, 1996). This coupled with the fact that consumers are able to discern differnces in beef tenderness and are willing to pay a premium for "guaranteed tender" beef (Boleman et al., 1997) creates a challenge for beef industry leadership. One approach to solving the beef palatability dilemna has been the development of branded beef programs. The beef industry is experiencing a gradual transition from commodity-based to value-based marketing, and branded beef programs attempt to add value to a raw commodity.

One of the first branded beef programs introduced was Certified Angus Beef™. The American Angus Association established the Certified Angus Beef™ program at a time when "premium quality" beef appeared to be declining (Hildebrand and Ward, 1994). Originally, the American Angus Association wished to establish a guaranteed product for the demanding specifications of the food service industry (Hildebrand and Ward, 1994), but Certified Angus Beef™ has since expanded to the retail segment. Since 1978, the Certified Angus Beef™ Program has established itself as a successful branded beef program; promoting middle meat cuts through the foodservice and retail sectors and establishing and maintaining tenderness hurdles during the selection process.

Even though it has been reported that consumers recognize Certified Angus Beef™ steaks to be more tender, juicy and flavorful than U.S. Choice (commodity) and U.S. Select strip loin steaks (Claborn, 1996), there is currently limited data relative to palatability of end cuts (i.e., cuts from the round, sirloin and chuck). The current research was conducted to 1) Determine base-line tenderness values and sensory panel ratings, 2) Assess variation in tenderness and 3) compare the mean values and variation for tenderness and sensory characteristics among Certified Angus Beef™, U.S. Choice (commodity) and U.S. Select steaks from the round, loin and chuck.

MATERIALS AND METHODS

Sample collection. Carcasses (n=150) from steers of unknown origin were selected randomly over a six month period at a commercial meat processing facility to fit pre-determined USDA yield and quality grade criteria. Fifty Certified Angus Beef™ (CAB), U.S. Choice (Choice) and U.S. Select (Select) carcasses were selected to follow the marbling score by yield grade criteria defined in Table 1. The basis for the carcass selection criteria was the yield grade by quality grade distribution reported in the National Beef Quality Audit (NCA, 1996) and hot carcass weights were maintained between 272 and 408 kg. Carcass data were collected by two trained Oklahoma State University personnel, and the average score for each trait was recorded. Factors used to determine quality grade were monitored so as to remain consistent with the onsite USDA grading personnel. After carcass data were collected, six subprimals comprised of the clod or *triceps brachii*, (IMPS 114), strip loin or *longissimus dorsi* (IMPS 180); top sirloin butt or *gluteus medius* (IMPS 184); inside round or *semitendinosus* (IMPS 168); round flat or *biceps femoris* (IMPS 171a); and knuckle or *quadriceps femoris complex* (IMPS 167a) (USDA, 1996) from the left carcass side were removed, vacuum packaged, and aged 14 d postmortem at approximately 2°C.

Subsequent to the aging period, three 2.54 cm steaks were removed from each subprimal and assigned to Warner-Bratzler shear force determination, sensory panel evaluation or to serve as a spare. Prior to the removal of strip loin steaks, a section (1.27 cm thick) free of external fat and connective tissue was removed from the anterior end of the strip loin for proximate analysis. After fabrication, steaks were vacuum packaged, proximate analysis samples were placed in whirlpack bags and samples were subsequently stored at –28°C.

Warner-Bratzler shear force. Steaks were assigned randomly to a cooking order within subprimal. Seventy-five steaks were allowed to temper daily at 4°C 24 h prior to cooking. Steaks were broiled in an impingement oven (Lincoln Impinger, Model 1132-000-A) at 180°C to an internal temperature of 70°C; temperatures were monitored with copper constantan thermocouples (Model OM-202, Omega Engineering, Inc., Stamford, Conn.). Individual steak weights were recorded prior to and following cooking to determine cook loss percentages. After steaks were cooled for at least 2 h to 25°C, a minimum of six cores (1.27 cm diameter) were removed parallel to the muscle fiber orientation and sheared once using a Warner-Bratzler head attached to an Instron Universal Testing Machine (Model 4502, Instron, Canton, MS) moving at a crosshead speed of 200 mm/minute. The peak load (kg) of the cores was recorded by an IBM PS2 (Model 55 SX) using software provided by the Instron Corporation; the mean peak load of the cores was analyzed.

Sensory analysis. Seventeen potential panel members were trained for sensory analysis as outlined by American Meat Science Association, (1995). Following training, at least ten panelists were identified. Subprimal sensory ratings were obtained in the order of strip loin, clod, inside round, knuckle, round flat and top sirloin butt. Steaks were assigned randomly to a cooking order within subprimal. No more than 16 steaks per day were tempered at 4°C 24 h prior to cooking. Steaks were broiled in an impingement oven (Lincoln Impinger, Model 1132-000-A) at 180°C to an internal temperature of 70°C and immediately placed into a foil pouch. Two cubed sections (1.3cm x 1.3cm x cooked steak thickness) from each steak were served warm to the panelists and the average for each section was recorded. Samples from eight steaks were served consecutively after which panelists were allowed to rest for at least ten minutes before serving the remaining steak samples.

Proximate analysis. Proximate analyses of *longissimus dorsi* samples were performed in duplicate and averaged according to procedures outlined by AOAC (1990). Each sample was frozen individually in liquid nitrogen and pulverized to a powder in a Waring® Commercial Blender. Three grams of the powdered sample were placed in glass thimbles, dried at 100°C for 24 h, desiccated for 1 h and re-weighed to determine moisture. Following moisture determination, each sample was placed in a soxhlet for 24 h for ether extraction of lipid followed by drying at 100°C for no more than 12 h. Each sample was then desiccated and re-weighed to calculate lipid content. Using a Leco Nitrogen

Determinator (Model FP-428) protein content was determined and recorded from a separate .5 g pulverized sample.

Statistical analysis. Data were analyzed by least squares analysis of variance as a split-plot design. Quality level served as the main plot with ID within quality level as the appropriate error term. Subprimal and quality level by subprimal served as the subplot with residual error as the appropriate error term. Shear force variances not homogeneous for quality level or subprimal effects were identified using the Levenes test and analyzed using least squares analysis of variance. Regression analysis was performed to determine the accuracy at which one muscle predicts the tenderness of other muscles, as well as to determine confidence levels for Warner-Bratzler shear at a constant sensory panel overall tenderness rating.

RESULTS AND DISCUSSION

Carcass characteristics and meat traits. Carcass data are presented in Tables 2 and 3. By design, marbling score differed ($P<.05$) among quality levels. CAB carcasses were slightly fatter and consequently had a higher ($P<.05$) numeric yield grade than Select carcasses. CAB and Choice carcasses had more youthful lean maturity scores than Select carcasses, however overall maturity was similar ($P>.05$) among quality levels. No differences ($P>.05$) in carcass weight, ribeye area or percentage kidney, pelvic and heart fat were observed when stratified by quality level. Percentage protein and ether extractable fat differed (*P*<.05) across all quality levels; CAB carcasses exhibited the highest intramuscular fat and lowest protein percentages followed by Choice and Select (Table 3). The relationship between mean marbling score and mean percentage intramuscular fat for CAB, Choice and Select carcasses was comparable to data summarized by Savell et al. (1986). Select carcasses had the highest (*P*<.05) percentage moisture, but no differences (*P*<.05) in percentage moisture were noted between CAB and Choice carcasses. Weight loss during cooking was not affected (*P*>.05) by quality level (Table 3), but differed among four of the six subprimals. Steaks from the knuckle had the highest (*P*<.05) percentage cook loss (29.0%) followed by steaks from the top sirloin butt (27.8%), inside round (26.8%) and clod (26.0%). Steaks from the strip loin and round flat had the lowest percentage cook loss (25.3 and 25.0%, respectively) but were not different (*P*>.05). When comparing cooking properties of various subprimals, Nick (1993) reported that percentage weight loss due to cooking increased as total surface area of the steak increased.

Warner-Bratzler shear force. Least squares means and standard deviations for quality level and subprimal are reported in Tables 4 and 5, respectively. A significant (*P*<.05) quality level by subprimal interaction was observed for WBS (Figure 1). With the exception of one quality level and subprimal combination (Choice clod), the strip loin was the most tender subprimal. Within the strip loin, all quality levels differed ($P<.05$); CAB was the most tender, Select was the least tender, and Choice was intermediate. In a similar study, Claborn (1996) reported Certified Angus Beef™ strip loin steaks to be more tender than U.S. Choice and U.S. Select strip loin steaks. Steaks from Select carcasses in the present study were more variable in shear force ($P<.05$) than either CAB or Choice steaks (Table 4), which agrees with previous data where Warner-Bratzler shear values increased in variability as marbling score decreased (Smith et al., 1984). Within the top sirloin butt, CAB steaks had lower ($P<.05$) shear force values than either Choice or Select which were similar ($P>.05$). Select steaks from the clod and flat had higher ($P<.05$) shear force values than steaks from either CAB or Choice carcasses; no differences ($P>.05$) were noted between CAB and Choice for these two subprimals. Knuckle steaks of Choice quality were more tender than those from Select; CAB knuckle steaks were intermediate and did not differ ($P>.05$) from either Choice or Select. No differences ($P>.05$) were observed in shear force for inside round steaks regardless of quality level. Among the six subprimals, the strip loin was the most variable and the knuckle was the most consistent in shear force. The inside round, round flat, top sirloin butt and clod were intermediate and did not differ ($P>.05$) in WBS variability.

Researchers have identified tenderness thresholds which represent a given level of confidence of a steak being rated at least "slightly tender". Based upon sensory panel ratings compared to WBS values of the same samples, steaks having a WBS value less than 4.6 and 3.9 kg should have a 50 and 68%

chance of being rated "slightly tender" (Shackelford et al., 1991). Tables 6, 7 and 8 summarize the percentage distribution of steaks within the pre-determined tenderness thresholds for quality level, subprimal and quality level by subprimal, respectively. Ninety percent of CAB strip loin steaks had WBS values less than 3.9 kg; a six and twenty percent improvement over Choice and Select strip loin steaks, respectively. When all subprimals were pooled, CAB steaks had the lowest percentage of steaks with a shear force of greater than 4.6 kg and the highest percentage of steaks with a shear force of less than 3.9 kg. Among subprimals, the top butt and round flat subprimals produced the highest percentage of steaks with shear force values of 4.6 kg or greater, the knuckle, inside round and clod were intermediate, and the strip loin produced the lowest percentage. Subprimal differences between CAB and Choice were most notable within the top butt and inside round. CAB top butt steaks produced 16% fewer shear force values of 4.6 kg or more and CAB inside round steaks had 16% more shear force values of less than 3.9 kg. Compared to Select, CAB carcasses had lower percentage frequencies in the 4.6 kg or more category for round flat (-24%), top butt (-18%), clod (-18%), strip loin (-16%), knuckle (-12%) and inside round (-8%) steaks. Moreover, compared to Select, CAB had substantially higher percentages of steaks in the most tender category (less than 3.9 kg) for strip loin (+20%), knuckle (+12%) and inside round (+10%) steaks.

Sensory analysis. Least squares means for sensory panel attributes within quality level and subprimal are listed in tables 9 and 10, respectively. A significant (P<.05) quality level by subprimal interaction was also observed for overall tenderness (Figure 2). Strip loin steaks were rated more (P<.05) tender than all other subprimals. Within the strip loin subprimal, CAB steaks were the most tender (P<.05), Select steaks were the least tender (P<.05) and Choice steaks were intermediate (P<.05), yet means for all quality levels were within the "slightly tender" category. Claborn (1996) found Certified Angus Beef™ strip loin steaks to be superior in sensory panel tenderness when compared to U.S. Choice and U.S. Select strip loin steaks. CAB and Choice clod steaks did not differ (P<.05) but, were more tender than all other steaks from the top sirloin butt, inside round, and flat, and were more tender than CAB and Select knuckle steaks. CAB and Choice knuckle steaks had higher (P<.05) tenderness scores than Select knuckle steaks, and CAB and Choice knuckle steaks were more tender than top butt, inside round and flat steaks across all quality levels. Overall tenderness differences for the top butt and inside round subprimals were minimal. No differences (P>.05) were noted among quality levels within the top butt subprimal, although numerically, CAB steaks superceded Choice steaks which superceded Select steaks. Within the inside round subprimal, CAB and Select steaks did not differ (P>.05) and Select and Choice steaks did not differ (P>.05), but CAB inside round steaks were more (P<.05) tender than Choice inside round steaks. Steaks from the round flat were the least tender (P<.05) of all subprimals. Within the round flat subprimal, quality level did not statistically affect sensory panel overall tenderness scores, although the mean rating for Select flat steaks was in the "moderately tough" category while the mean ratings for CAB and Choice round flat steaks were rated in the "slightly tough" category.

Unlike WBS, the sensory panel did not detect differences in tenderness variation due to quality level or subprimal. Shackelford et al. (1995) reported that among 10 major beef muscles, Warner-Bratzler shear was not able to detect the same statistical differences as a trained sensory panel.

Juiciness, beef fat flavor and beef flavor intensity scores were all affected ($P<.05$) by quality level. CAB and Choice steaks had higher ($P<.05$) juiciness, beef fat flavor and beef flavor intensity scores than Select steaks, though no differences were noted between CAB and Choice for these attributes. No differences ($P>.05$) were apparent across quality level for connective tissue amount or off flavors. When all quality levels were pooled, sensory panel attribute differences were most noticeable relative to connective tissue amount; all subprimals differed in the amount of detectable connective tissue. The round flat had the highest connective tissue amount followed by the inside round, top sirloin butt, knuckle, clod and strip loin. Subprimal effects on juiciness scores were slightly varied from that of tenderness and connective tissue; strip loin steaks had the highest juiciness scores while inside round and top sirloin butt steaks were the driest. Juiciness scores for clod, knuckle and flat steaks were intermediate, but all differed ($P<.05$) in a decreasing manner, respectively.

Simple correlation coefficients for marbling score, Warner-Bratzler shear force and sensory panel overall tenderness ratings are presented in Table 11. Marbling score had a significant ($P<.05$) negative correlation with shear force for all subprimals but the inside round. Marbling score and shear force were most highly correlated within the strip loin subprimal, while the inside round had the lowest coefficient. Sensory panel overall tenderness scores exhibited a generally weaker relationship when comparing these ratings against marbling score. Coefficients for this comparison (marbling score by sensory panel overall tenderness ratings) for all six subprimals were numerically lower than the marbling score by shear force coefficients. Similar to WBS, the strip loin subprimal showed the strongest relationship between marbling score and sensory panel tenderness ratings. The sensory panel detected no significant relationship between marbling score and tenderness for two of the three round cuts (inside round and flat). Smith et al. (1984) reported that marbling was much more influential on the palatability of loin steaks than that of round steaks. Even though the relationship between marbling and tenderness was generally less recognized by the sensory panel, sensory panel scores were moderately consistent with WBS values, which may be explained by the effect of connective tissue amount among different subprimals. Across all subprimals, sensory panel connective tissue amount and overall tenderness were highly related ($r=.85$, $P<.05$, data not in tabular form). The relationship between shear force and sensory panel ratings was strongest within the strip loin subprimal, followed by the clod, inside round, round flat and knuckle, and lowest for the top sirloin butt. Interestingly, these relationships follow the same numerical rankings as shear force values (i.e., as shear force values increased due to subprimal, sensory panel ratings were less likely to reflect shear force value differences).

For the present study, the coefficient of determination (R^2 x 100) revealed that marbling accounted for 3.6 and 1.4% of the observed shear force and sensory panel tenderness variability, respectively. This agrees with previous research which states that marbling explains less than 10% of cooked beef tenderness and palatability variation (Campion et al., 1975; Crouse and Smith, 1978; Armbruster, 1983; Jones and Tatum, 1994), while other researchers have reported marbling to account for nearly 30% of beef palatability variation (Smith et al., 1984; May et al., 1992). Marbling explained 4.0, 2.4 and1.7% of the variability in beef fat flavor, juiciness and flavor intensity, respectively.

Similar to the method described by Shackelford et al. (1991), confidence levels (50, 68 and 95%) were calculated to determine WBS thresholds for strip loin steaks with a sensory panel rating of "slightly tender". Shackelford et al. (1991) reported thresholds to be 4.60, 3.90 and 3.20 kg for 50, 68 and 95% confidence levels, respectively (e.g., steaks having a WBS value of less than 4.6 kg should have a 50% chance of being rated "slightly tender", etc.). The thresholds for the present data were 4.45, 4.01 and 3.57 kg for 50, 68 and 95% confidence levels, respectively (Figures 3 through 5). The distance between confidence levels (0.44 kg of WBS) is a result of the standard deviation of the slope of the regression equation. The data utilized in the Shackelford study was more variable in WBS (0.7 kg) for a given sensory panel rating, and those researchers indicate that decreases in tenderness variation will result in higher confidence levels associated with a given WBS value.

To determine if WBS values of strip loin steaks were a reliable tenderness predictor for other muscles, regression analyses were performed for each quality level within a subprimal (Figures 6 through 10). In general, the strip loin was a poor predictor of WBS values for the remaining five steak cuts. The best linear predictive model by the strip loin was exhibited in the Select knuckle steaks (R^2= .4527, *P*= .0001). A significant (*P*<.05) curvilinear response was observed for Choice clod (Figure 6), Choice top sirloin butt (Figure 7) and Select inside round (Figure 8) steaks, indicating that these cuts did not respond similarly to strip loin steaks at the lower end of the strip loin WBS values. However, as strip loin WBS values exceeded approximately 4 kg, predicted values for the Choice clod, Choice top sirloin butt and Select inside round steaks increased at an increasing rate. Excluding the top sirloin butt subprimal, the strip loin was consistently the best predictor of tenderness for the remaining subprimals within the Select quality level. Since the strip loin served as the tenderness predictor, and it was the only "middle meat" cut utilized in the study, these data seem to suggest that marbling plays a larger role in improving the tenderness of "middle meat" cuts than on the tenderness of "end meat" cuts.

IMPLICATIONS

Branded beef programs exist to provide consumers with a favorable product that is consistent. The present study indicates that steaks from carcasses qualifying for the Certified Angus Beef™ program generally have improved tenderness and palatability ratings when cooked to a medium degree of doneness (70°C). Based upon pre-determined tenderness thresholds, the likelihood of receiving steaks rated at least "slightly tender" is greater for CAB carcasses and lowest for Select carcasses.

Irregardless of tenderness classification, steaks of at least U.S. Choice quality are more consistent in tenderness, even though marbling accounted for a minimal amount of Warner-Bratzler shear and sensory panel tenderness variation. The effect of marbling on tenderness was more evident in middle meat cuts than in end cuts, particularly in the round. Methods alternative to the current quality grading system that identify differences in the tenderness and palatability of end cuts should be explored further.

Table 1. Marbling score by yield grade consist of carcasses

Quality level[a]	Marbling score	Yield grade	Number of sides
Certified Angus Beef™ (N=50)	Moderate	1	1
		2	5
		3	6
	Modest	1	2
		2	18
		3	18
U.S. Choice (N=50)	Moderate	1	1
		2	2
		3	0
	Modest	1	1
		2	4
		3	4
	Small	1	3
		2	17
		3	18
U.S. Select (N=50)	Slight +	1	3
		2	9
		3	5
	Slight o	1	3
		2	7
		3	4
	Slight -	1	4
		2	10
		3	5

[a]Selected U.S. Choice and U.S. Select carcasses were "A" overall maturity, displayed no *Bos indicus* characteristics and did not qualify for the Certified Angus Beef™ program on a live animal specification basis.

Table 2. Selected carcass and meat traits

Trait	Mean	Minimum	Maximum	SD
Carcass maturity[a]				
Skeletal	156.6	110.0	200.0	21.21
Lean	149.7	110.0	205.0	15.56
Overall	153.15	120.0	187.5	15.30
Marbling score[b]	466.7	305.0	670.0	100.55
Fat thickness, cm	1.04	.25	2.08	.42
Adjusted fat thickness, cm	1.25	.51	1.88	.37
Ribeye area, cm^2	86.3	64.8	111.9	9.32
KPH, %	2.3	1.1	4.8	.48
Hot carcass weight, kg	347.3	273.5	403.7	29.80
Yield grade	2.8	1.0	3.9	.63
Warner-Bratzler shear, kg	4.15	1.85	7.28	.82
Cook loss, %	26.7	5.1	51.9	3.1

[a]Carcass maturity: 100-199 = approximately 9-30 months chronological age at time of slaughter (USDA, 1997).

[b]Marbling score: 300-399 = "Slight", the amount required for U.S. Select; 400-499 = "Small", the amount required for U.S. Low Choice; 600-699 = "Moderate", the amount required for U.S. High Choice (USDA, 1997).

Table 3. Carcass and meat traits stratified by quality level

Trait	CAB	Choice	Select	SE
	Quality level			
Number of carcasses	50	50	50	
Carcass maturity[a]				
Skeletal	160.4	155.9	153.3	2.99
Lean	146.9[d]	148.1[d]	154.2[c]	2.17
Overall	153.7	152.0	153.8	2.17
Marbling score	570.3[c]	480.9[d]	348.8[e]	6.00
Quality grade, %				
High Choice	24.0	6.0	--	
Average Choice	76.0	18.0	--	
Low Choice	--	76.0	--	
High Select	--	--	34.0	
Average Select	--	--	28.0	
Low Select	--	--	38.0	
Fat thickness, cm	1.14[c]	1.07[c]	.90[d]	.06
Adjusted fat thickness, cm	1.35[c]	1.27[cd]	1.14[d]	.06
Ribeye area, cm^2	84.2[c]	87.2[cd]	87.5[d]	1.31
KPH, %	2.3	2.2	2.3	.07
Hot carcass weight, kg	343.7	355.1	343.1	4.17
Yield Grade	2.99[c]	2.84[cd]	2.62[d]	.09
1, %	6.0	10.0	20.0	
2, %	46.0	46.0	52.0	
3, %	48.0	44.0	28.0	
Lipid, %	6.2[c]	4.9[d]	3.0[e]	.22
Protein, %	21.2[e]	21.9[d]	22.4[c]	.13
Moisture, %	71.4[d]	71.9[d]	73.6[c]	.20
Cook loss, %	26.5	26.7	26.8	.16

[a] Carcass maturity scores: 100-199 = approximately 9 to 30 months chronological age at time of slaughter (USDA, 1997).

[b] Marbling score: 300-399 = "Slight", the amount required for U.S. Select; 400-499 = "Small", the amount required for U.S. Low Choice; 500-599 = "Modest", the amount required for U.S. Average Choice (USDA, 1997).

[cde] Means with a common superscript letter in a row do not differ (P>.05).

Table 4. Least squares means and standard deviations for Warner-Bratzler shear averaged for six subprimals stratified by quality level

	Quality level			
Trait	CAB	Choice	Select	SE
Shear force, kg[a]	4.00	4.12	4.35	.03
SD, kg	.74[c]	.79[c]	.88[b]	

[a]Superscripts are not presented due to a significant quality level by subprimal interaction (P<.05).

[bc]Values with a common superscript in a row do not differ (P>.05).

Table 5. Least squares means and standard deviations for Warner-Bratzler shear stratified by subprimal

	Subprimal						
Trait	Clod	Strip loin	Top sirloin butt	Inside Round	Round Flat	Knuckle	SE
Shear force, kg[a]	3.98	3.35	4.83	4.09	4.51	4.17	.04
SD, kg	.63^{c}	.90^{b}	.63^{c}	.68^{c}	.64^{c}	.54^{d}	

[a]Superscripts are not presented due to a significant quality level by subprimal interaction (*P*<.05).

[bcd]Values with a common superscript in a row do not differ (*P*>.05).

Table 6. Percentage distribution of steaks within tenderness thresholds stratified by quality level

	Quality level		
Tenderness threshold	Certified Angus Beef™	U.S. Choice	U.S. Select
Less than 3.9 kg, %	38.7	36.7	30.0
3.9 to 4.5 kg, %	38.7	35.7	31.3
Greater than or equal to 4.6 kg, %	22.7	27.7	38.7

Table 7. Percentage distribution of steaks within tenderness thresholds stratified by subprimal

Tenderness threshold	Subprimal					
	Clod	Strip loin	Top butt	Inside round	Round Flat	Knuckle
Less than 3.9 kg, %	46.0	81.3	4.7	37.3	10.7	30.7
3.9 to 4.5 kg, %	36.7	9.3	30.0	43.3	47.3	44.7
Greater than or equal to 4.6 kg, %	17.3	9.3	65.3	19.3	42.0	24.7

Table 8. Percentage distribution of steaks within tenderness thresholds stratified by quality level and subprimal.

	Quality level		
Shear Force	Certified Angus Beef™	U.S. Choice	U.S. Select
Clod			
Less than 3.9 kg	44	54	40
3.9 to 4.5 kg	46	32	32
4.6 kg or greater	10	14	28
Strip loin			
Less than 3.9 kg	90	84	70
3.9 to 4.5 kg	8	8	12
4.6 kg or greater	2	8	18
Top sirloin butt			
Less than 3.9 kg	8	2	4
3.9 to 4.5 kg	38	28	24
4.6 kg or greater	54	70	72
Inside round			
Less than 3.9 kg	46	30	36
3.9 to 4.5 kg	38	52	40
4.6 kg or greater	16	18	24
Flat			
Less than 3.9 kg	10	14	8
3.9 to 4.5 kg	56	52	34
4.6 kg or greater	34	34	58
Knuckle			
Less than 3.9 kg	34	36	22
3.9 to 4.5 kg	46	42	46
4.6 kg or greater	20	22	32

Table 9. Least squares means of sensory attributes averaged for six subprimals stratified by quality level

	Quality level			
Trait[d]	CAB	Choice	Select	SE
Juiciness	4.92[a]	4.91[a]	4.68[b]	.03
Beef fat flavor	.5[a]	.5[a]	.41[b]	.01
Overall tenderness[e]	4.87	4.79	4.65	.03
Connective tissue amount	5.06	5.07	5.01	.03
Flavor intensity	5.12[a]	5.12[a]	5.01[b]	.02
Off flavors	3.94	3.94	3.94	.006

[abc]Means with a common superscript in a row do not differ (P>.05).

[d]Juiciness: 1=extremely dry, 8=extremely juicy; Beef fat flavor: 0=none detectable, 2=very strong; Overall tenderness: 1=extremely tough, 8=extremely tender; Connective tissue amount: 1=abundant, 8=none; Flavor intensity: 1=extremely bland, 8=extremely intense; Off flavor: 1=intense, 4=none.

[e]Overall tenderness: Superscripts are not presented due to a significant quality level by subprimal interaction (P<.05).

Table 10. Least squares means and standard deviations of sensory attributes stratified by subprimal.

	Subprimal						
Trait[g]	Clod	Strip loin	Top sirloin butt	Inside round	Round flat	Knuckle	SE
Juiciness	5.17^{b}	5.39^{a}	4.37^{e}	4.39^{e}	4.78^{d}	4.91^{c}	.05
Beef fat flavor	.48^{b}	.68^{a}	.38^{d}	.35^{d}	.50^{b}	.43^{c}	.02
Overall tenderness[h]	5.06	5.70	4.51	4.44	4.02	4.88	.04
Connective tissue	5.44^{b}	5.78^{a}	5.00^{d}	4.88^{e}	4.01^{f}	5.15^{c}	.04
Flavor intensity	5.26^{a}	5.32^{a}	4.99^{c}	4.81^{d}	4.98^{c}	5.16^{b}	.03
Off flavors	3.94^{ab}	3.95^{ab}	3.95^{ab}	3.96^{a}	3.89^{c}	3.93^{b}	.009

[abcdef]Means with a common superscript in a row do not differ (*P*>.05).

[g]Juiciness: 1=extremely dry, 8=extremely juicy; Beef fat flavor: 0=none detectable, 2=very strong; Overall tenderness: 1=extremely tough, 8=extremely tender; Connective tissue: 1=abundant, 8=none; Flavor intensity: 1=extremely bland, 8=extremely intense; Off flavor: 1=intense, 4=none.

[h]Overall tenderness: Superscripts are not presented due to a significant quality level by subprimal interaction (*P*<.05).

Table 11. Selected Pearson Correlation Coefficients (r) across and within subprimals

	Comparisons[a]		
Subprimal	Marbling x WBS	Marbling x Sensory	WBS x Sensory
Overall	-.19*	.12*	-.67*
Clod	-.19*	.17*	-.61*
Strip loin	-.33*	.30*	-.82*
Top butt	-.24*	.18*	-.35*
Inside round	-.13	.03	-.52*
Flat	-.23*	.09	-.49*
Knuckle	-.21*	.17*	-.49*

[a]*Marbling* = carcass marbling degree; WBS = Warner-Bratzler shear force; *Sensory* = sensory panel overall tenderness rating.

*$P<.05$

Figure 1. Warner-Bratzler shear force by quality level and subprimal

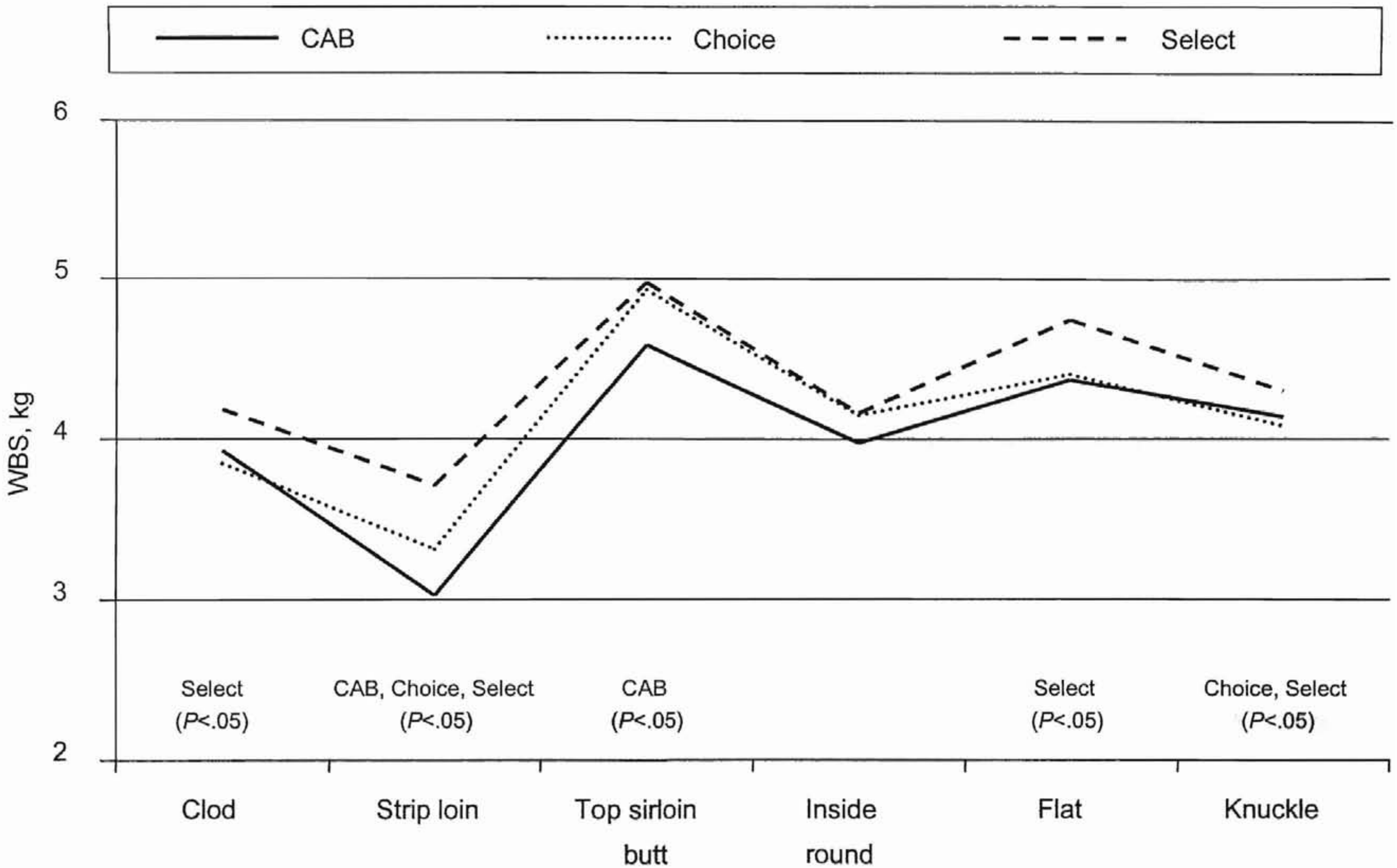


Figure 2. Sensory panel overall tenderness rating by quality level and subprimal

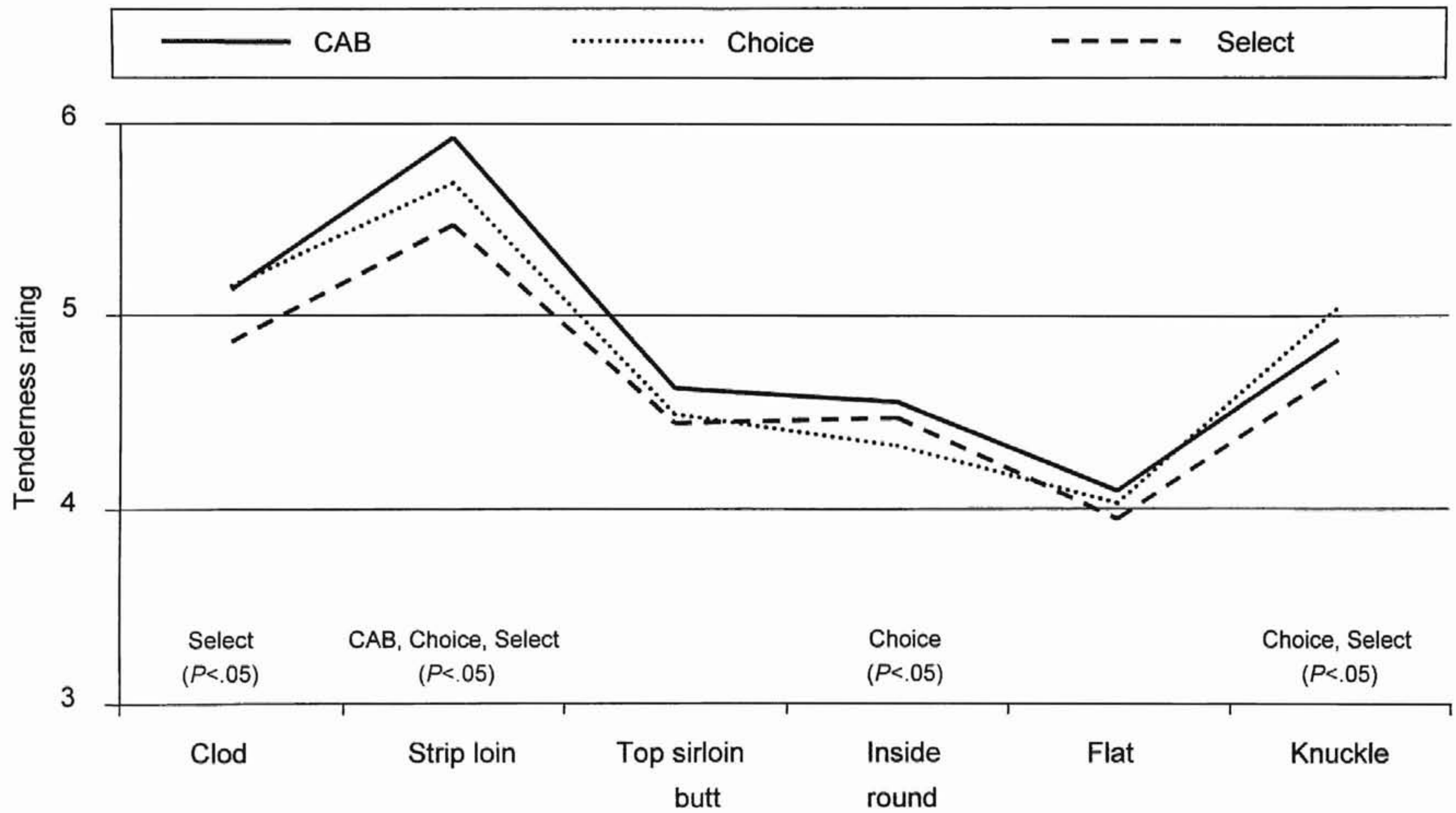


Figure 3. Fifty percent confidence level for strip loin steaks receiving a sensory panel rating of at least "slightly tender"

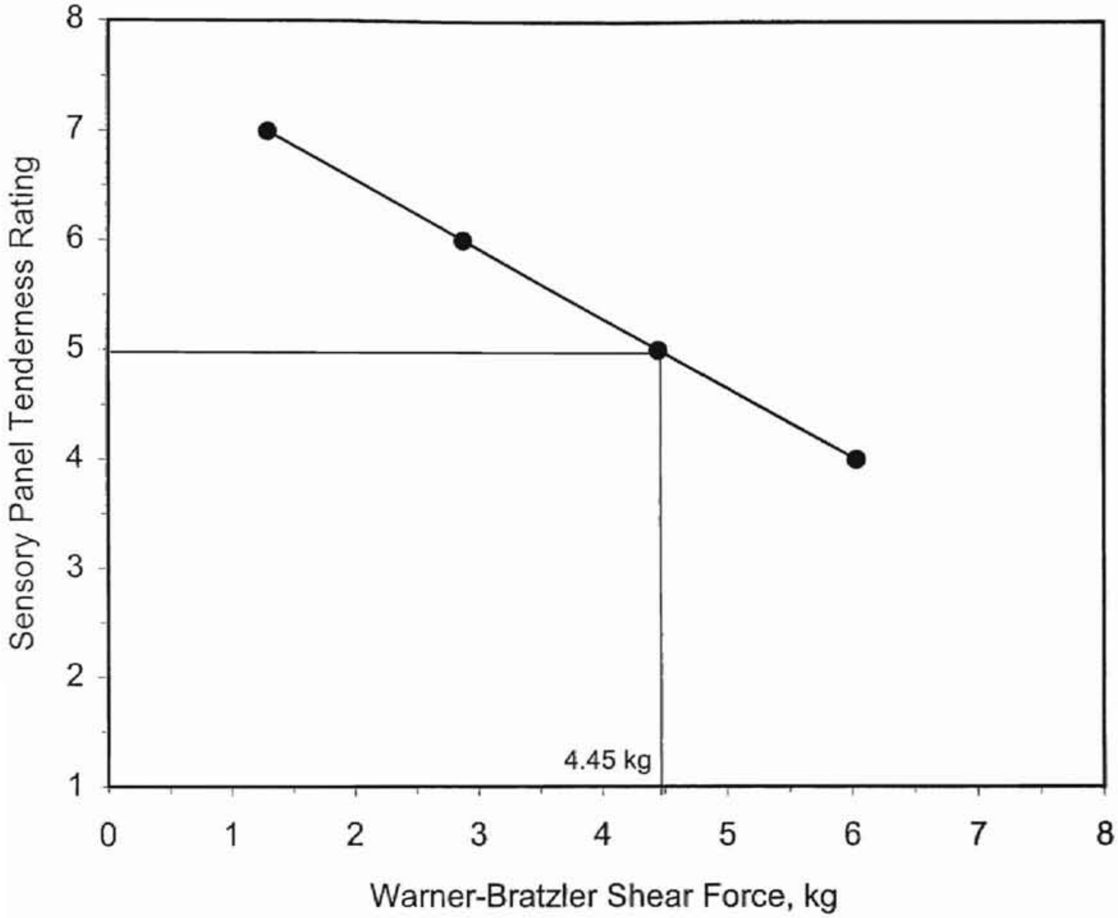


Figure 4. Sixty-eight percent confidence level for strip loin steaks receiving a sensory panel rating of at least "slightly tender"

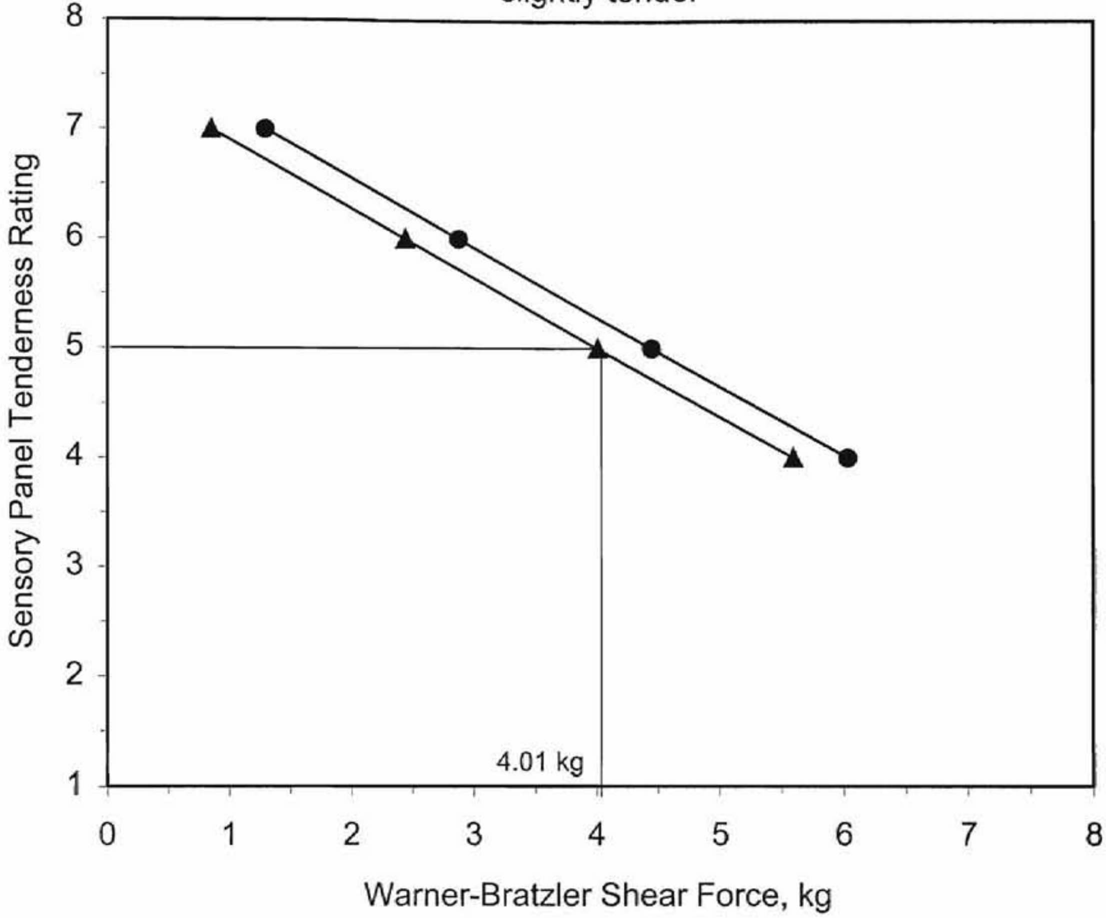


Figure 5. Ninety-five percent confidence level for strip loin steaks receiving a sensory panel rating of at least "slightly tender"

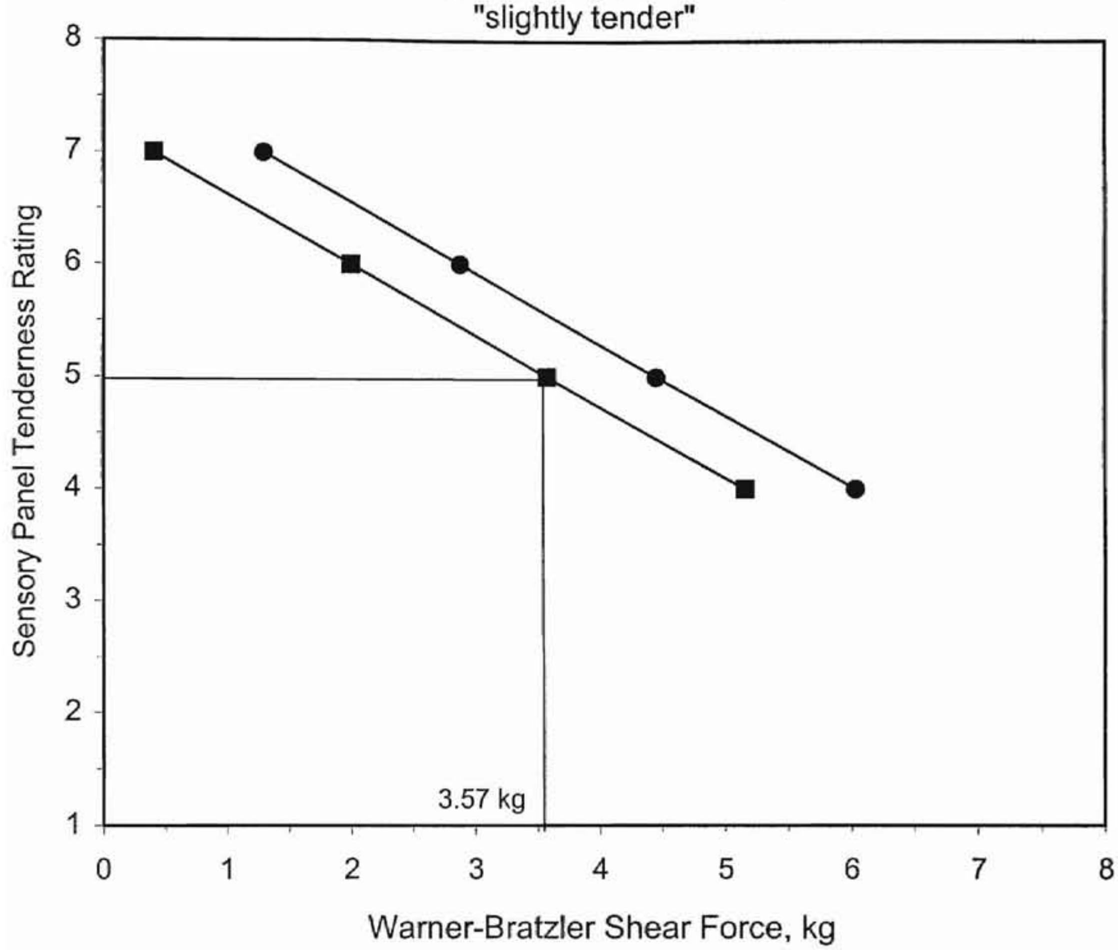


Figure 6. Predicted Warner-Bratzler shear values for the clod derived from the strip loin stratified by quality level

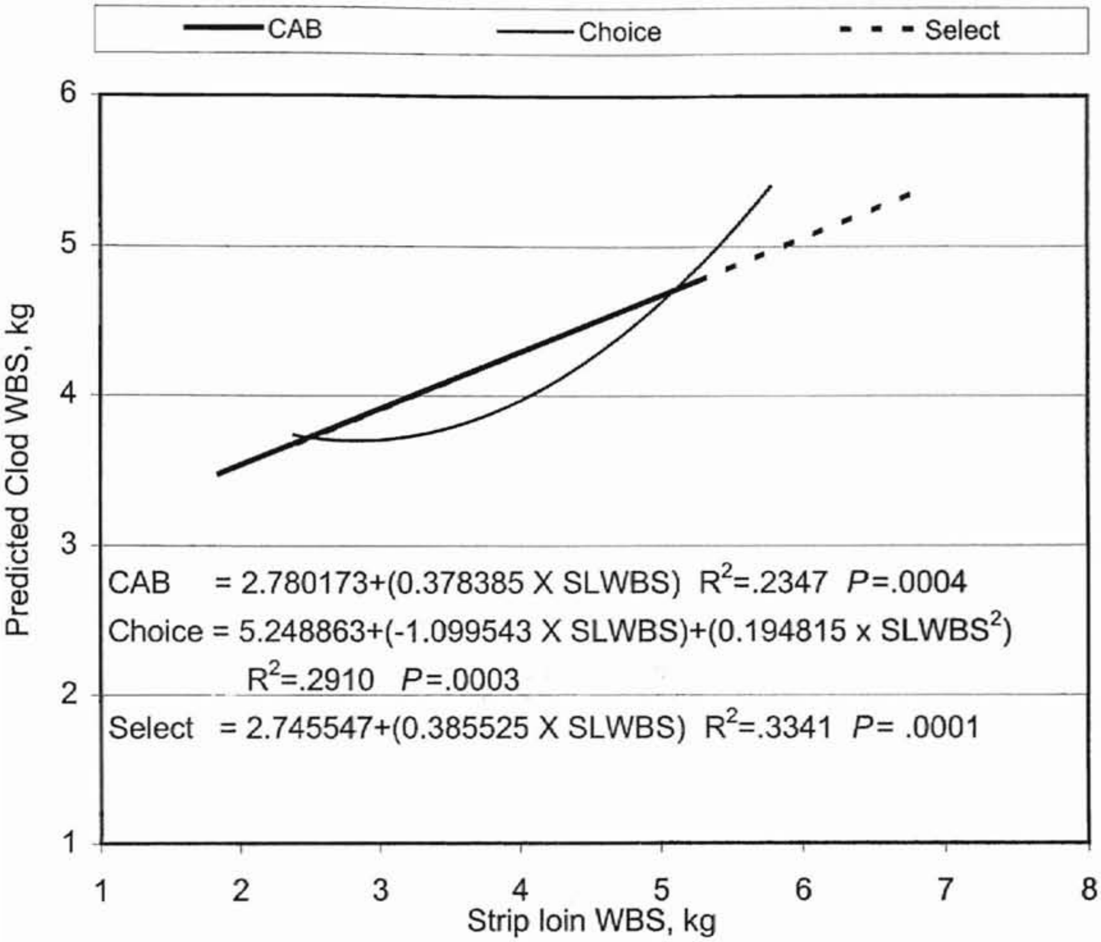


Figure 7. Predicted Warner-Bratzler shear values for the top sirloin butt derived from the strip loin stratified by quality level

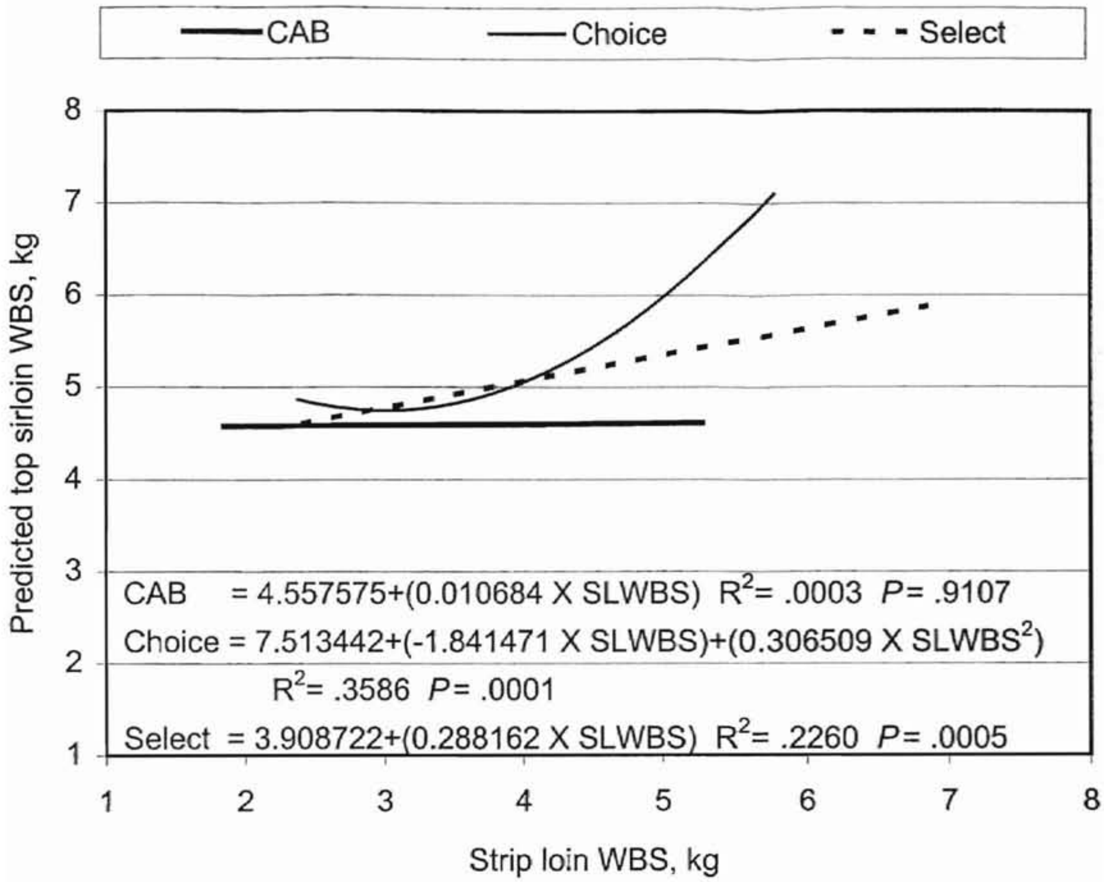


Figure 9. Predicted Warner-Bratzler shear values for the round flat derived from the strip loin stratified by quality level

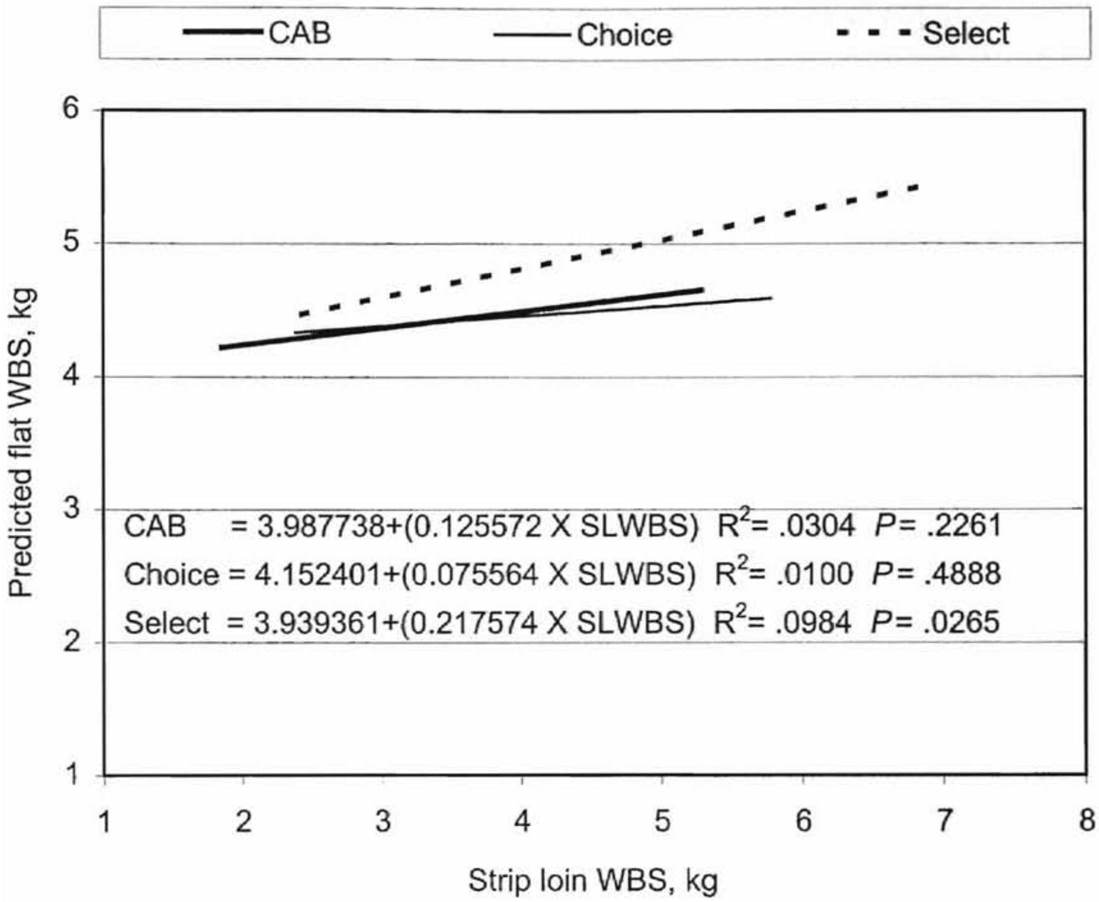
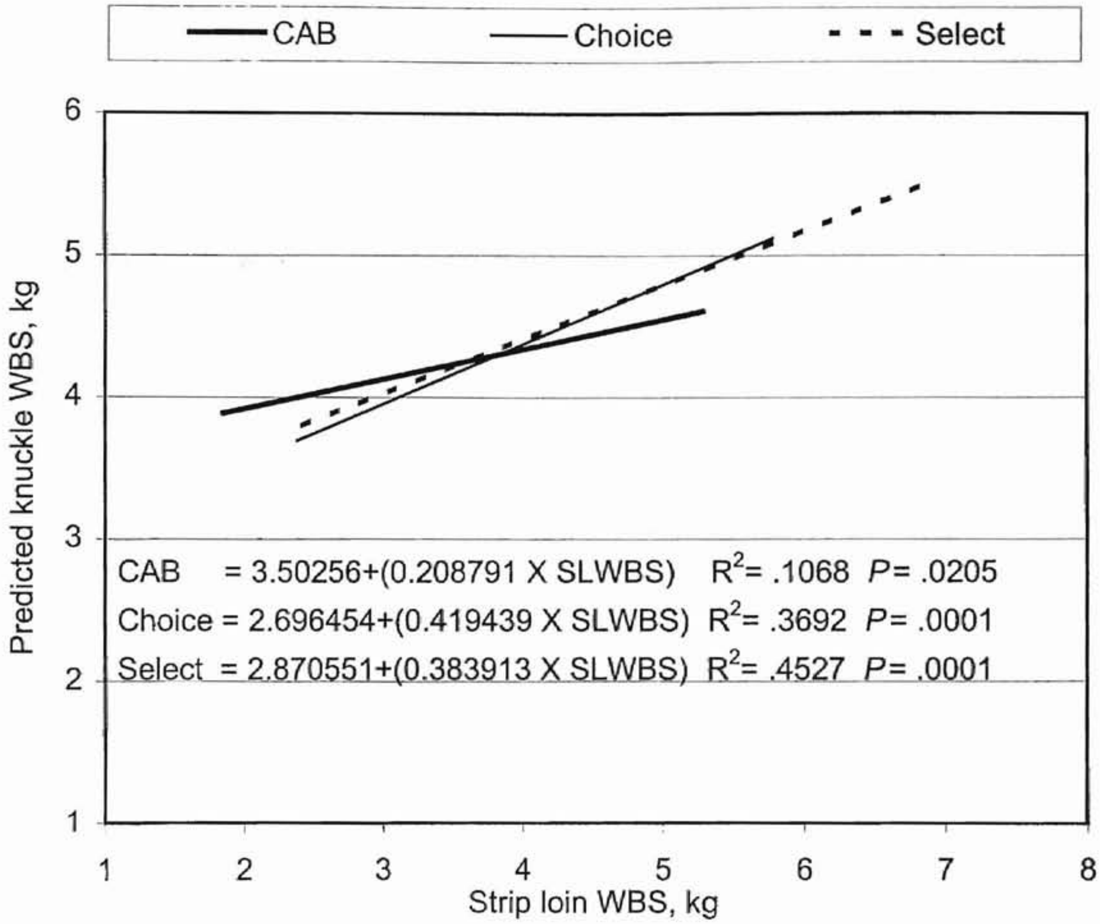


Figure 10. Predicted Warner-Bratzler shear values for the knuckle derived from the strip loin stratified by quality level



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APPENDIX

APPENDIX A

FREQUENCY PERCENTAGES FOR MARBLING SCORE AND U.S. YIELD GRADE DISTRIBUTION STRATIFIED BY U.S. QUALITY GRADE AS REPORTED IN THE 1995 NATIONAL BEEF QUALITY AUDIT

	Quality grade	
Carcass trait	U.S. Choice	U.S. Select
Marbling score, %		
Moderate	6	--
Modest	18	--
Small	76	--
Slight+	--	33
Slighto	--	29
Slight-	--	38
Yield grade, %		
1	6	19
2	46	53
3	48	28

APPENDIX B

LEAST SQUARES MEANS AND STANDARD DEVIATIONS FOR WARNER-BRATZLER SHEAR STRATIFIED BY QUALITY LEVEL AND SUBPRIMAL

	Quality level		
Subprimal	Certified Angus Beef™	U.S. Choice	U.S. Select
Clod	3.92[ij] (.55)	3.84[jk] (.56)	4.18[fg] (.74)
Strip loin	3.02[m] (.70)	3.31[l] (.73)	3.71[k] (1.10)
Top Butt	4.59[cd] (.46)	4.93[ab] (.68)	4.98[a] (.67)
Inside Round	3.97[hij] (.64)	4.15[fgh] (.66)	4.16[fgh] (.73)
Flat	4.37[ef] (.50)	4.40[de] (.55)	4.75[bc] (.76)
Knuckle	4.13[fgh] (.45)	4.08[ghi] (.50)	4.30[ef] (.63)

[abcdefghijklm]Means with a common superscript do not differ (P>.05).

APPENDIX C

LEAST SQUARES MEANS AND STANDARD DEVIATION FOR SENSORY PANEL TENDERNESS RATINGS STRATIFIED BY QUALITY LEVEL AND SUBPRIMAL

	Quality Level		
Subprimal	Certified Angus Beef™	U.S. Choice	U.S. Select
Clod	5.14^{d} (.63)	5.16^{d} (.57)	4.87^{ef} (.59)
Strip loin	5.93^{a} (.55)	5.69^{b} (.69)	5.47^{c} (.76)
Top butt	4.62^{gh} (.44)	4.49^{hi} (.49)	4.44^{hi} (.52)
Inside round	4.55^{gh} (.53)	4.32^{i} (.59)	4.47^{hi} (.65)
Flat	4.09^{j} (.61)	4.02^{j} (.51)	3.94^{j} (.62)
Knuckle	4.88^{ef} (.56)	5.05^{de} (.45)	4.70^{fg} (.52)

^{abcdefghij}Means with a common superscript do not differ (P>.05).

APPENDIX D

STATISTICAL ANALYSIS SYSTEM (SAS) COMMANDS USED TO TEST FOR NON-HOMOGENEITY OF VARIANCES FOR WARNER-BRATZLER SHEAR FORCE VALUES AND SENSORY PANEL OVERALL TENDERNESS RATINGS

For Warner-Bratzler shear values:

```
PROC GLM; CLASSES QLEVEL SUBPRMAL ID;
MODEL WBSKG WBSLB = QLEVEL|SUBPRMAL ID(QLEVEL);
TEST H=QLEVEL E=ID(QLEVEL);
LSMEANS QLEVEL|SUBPRMAL / PDIFF STDERR;

OUTPUT OUT = LEVENES2 R=RWBS;
DATA LEVENES3; SET LEVENES2;
Z=ABS(RWBS);

PROC GLM; CLASSES QLEVEL SUBPRMAL; MODEL Z =
QLEVEL|SUBPRMAL;
LSMEANS QLEVEL|SUBPRMAL / PDIFF STDERR;
```

For sensory panel overall tenderness ratings:

```
PROC GLM; CLASSES QLEVEL SUBPRMAL ID;
MODEL TENDER = QLEVEL|SUBPRMAL ID(QLEVEL);
TEST H=QLEVEL E=ID(QLEVEL);

OUTPUT OUT = LEVENES2 R=RTENDER;
DATA LEVENES3; SET LEVENES2;
Z=ABS(RTENDER);

PROC GLM; CLASSES QLEVEL SUBPRMAL; MODEL Z =
QLEVEL|SUBPRMAL;
LSMEANS QLEVEL|SUBPRMAL / PDIFF STDERR;
```

APPENDIX E

LIVE ANIMAL AND CARCASS CRITERIA REQUIRED TO QUALIFY FOR THE CERTIFIED ANGUS BEEF™ PROGRAM

1. Carcasses from steers or heifers that are predominantly solid black (i.e., 51% black) can only be certified.

2. Splenius muscle (neck crest) should not exceed 5 cm (i.e., no significant *Bos indicus* influence).

3. Carcasses must exhibit physiological characteristics representative of "A" maturity.

4. Carcasses must possess a marbling degree of Modest or greater.

5. Marbling must have medium or fine texture.

6. Carcasses must not possess a U.S. yield grade greater than 3.9.

7. Carcasses must display "moderately thick" or thicker muscling characteristics.

8. Carcasses must not exhibit any evidence of internal muscle hemorrages.

9. Carcasses must not exhibit any evidence of the dark cutting condition.

VITA

Jacob L. Nelson

Candidate for the Degree of

Mater of Science

Thesis: CHARACTERIZATION OF CERTIFIED ANGUS BEEF™ STEAKS FROM THE ROUND, LOIN AND CHUCK

Major Field: Food Science

Biographical:

Personal Data: Born in El Paso, Texas, On October 31, 1972, the son of Gary and Mary Nelson.

Education: Graduated from Charles Page High School, Sand Springs, Oklahoma in May 1990; received Associate of Applied Science degree in Meat Science from Eastern Oklahoma State College, Wilburton, Oklahoma and a Bachelor of Science degree in Animal Science from Oklahoma State University, Stillwater, Oklahoma in May 1992 and December 1994, respectively. Completed the requirements for the Master of Science degree with a major in Food Science at Oklahoma State University in December, 1998.

Experience: Raised in rural Osage county, Oklahoma; employed by Eastern Oklahoma State College meat laboratory, Wilburton, Oklahoma, 1990-1992; employed by Noble's Town and Country Meats, Skiatook, Oklahoma, summers 1991-1993; employed by Country Cut Meats, Stillwater, Oklahoma, fall 1993; employed by Excel Corp., Dodge City, Kansas, summer 1994; employed by Oklahoma State University, Department of Animal Science as an undergraduate and as a graduate research assistant; Oklahoma State University, Department of Animal Science,1993-1997; employed by the Oklahoma Food and Agricultural Products Research and Technology Center as the Meat Pilot Plant Manager; Oklahoma State University, Oklahoma Food and Ag. Products Center, 1997 to present.

Professional Memberships: American Meat Science Association