THE EFFECTS OF QUALITY GRADE, AGING AND LOCATION ON SELECTED MUSCLES OF LOCOMOTION OF THE BEEF CHUCK AND ROUND

By

CHRISTY LYNN GREENHAW BRATCHER

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Abstract of Thesis Presented to the Graduate School
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By

Christy Lynn Greenhaw Bratcher

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The objective of this study was to determine the aging patterns of nine selected muscles from the chuck and round from two quality grades of beef: United States Department of Agriculture (USDA) Select and the upper 2/3 of USDA Choice grade. The International Meat Purchase Specifications (IMPS) (NAMP, 1988) 115 2-piece chuck was separated and the following muscles were selected for study: infraspinatus, triceps brachii – lateral head, triceps brachii – long head, serratus ventralis, complexus, splenius, and rhomboideus. The IMPS 167A knuckle was also separated and the vastus lateralis and rectus femoris were evaluated. These muscles were selected because of the possibility of being used as cuts where tenderness is critical due to the probability that they would be cooked with a dry cooking method, based on results from the Muscle Profiling Study conducted by the University of Florida and University of Nebraska in conjunction with the National Cattleman's Beef Association. Each muscle was divided into four portions, progressing from anterior to posterior or dorsal to ventral orientation to

the carcass. One steak was removed from each portion for evaluation. Aging was conducted at 7, 14, 21, or 28 days. After achieving their appropriate aging treatment, Warner-Bratzler Shear (WBS) force analyses were conducted on an Instron (Canton, MA) universal testing machine. Aging affected all of the muscles evaluated in this study in a similar fashion; therefore, consistent recommendations can be given for these muscles. This study revealed that USDA grade had an effect on aging, in that it would not be necessary to hold muscles from the upper 2/3 of USDA Choice grade beyond 7 days of age. For USDA Choice grade, there was in increase in thaw loss from 14 to 28 days of aging, but aging up to 7 days had no effect. Muscles from lower marbled grades (i.e., USDA Select), should be aged a minimum of 14 days postmortem. As USDA Select grade was aged from 7 to 21 days, there was an increased percentage of thaw loss. However, after 14 to 21 days of age, it seems that there is no further increase in thaw loss percentages. The muscles respond differently depending on grade; USDA Select generally had higher cooking losses than USDA Choice. Location within a muscle had an effect on WBS values in four of the nine muscles evaluated. This indicated that muscles would have to be treated on an individual basis when fabricating and merchandising individual retail cuts from these muscles. For some muscles, location within the cut can be ignored, and for others location must be considered for tenderness enhancement or product utilization.

CHAPTER 1
INTRODUCTION

In recent years, economic pressures have challenged the livestock and meat industries to seek ways of producing meat products that will enable consumers to receive maximum palatability benefits at the lowest costs (Morgan et al., 1991). Due to consumer demand for smaller portion sizes, beef retailers have been forced to fabricate steaks from cuts of meat (round and chuck subprimals) that previously were merchandised solely as roasts (Shackelford et al., 1995). As the industry begins to isolate individual muscles of the chuck and round for merchandising as steak cuts, then more knowledge about how these muscles respond to postmortem aging is required in order to assure tenderness. The round represents approximately 22% of the weight of a typical beef carcass and contains some of the least tender muscles of the carcass (Ramsbottom et al., 1945; Jones et al., 2001). Savell and Smith (2000) reported that the chuck represents about 30% of the total carcass weight. Therefore, approximately 52% of the carcass that is currently used primarily as ground beef and roasts.

The 1991 National Beef Tenderness Survey (Morgan et al., 1991) revealed problems with tenderness of beef from the chuck and round subprimals and with the top sirloin steak. The survey also found that round and chuck cuts were especially tough despite being cooked by moist-heat methods. Steaks from the round and the chuck were much tougher than their roast counterparts. The mean shear force of the top round roast was 4.06 kg while the steak counterpart had an average shear force value of 5.23 kg

(Savell and Shackelford, 1992). The industry must discover a way to utilize these cuts to provide for optimal utilization of the carcass while ensuring a tender cut of meat.

The economic incentives for the industry to improve the tenderness of beef must be established before significant improvements in the consistency and palatability of beef will occur (Miller et al., 1998). According to Miller et al. (1998), the most important factor in a tenderness study with consumers is to establish that a range in beef tenderness from tender to tough exists. The range given in Miller et al. (1995) is greater than 2.0 and less than 7.0 kg of shear force. Research has shown that consumers can detect changes in tenderness similar to those found with instrumental measurements such as Warner-Bratzler shear force (WBS) (Shackelford et al., 1991b; Miller et al., 1995; Boleman et al., 1997). Therefore, WBS values can be used as an indicator of the value relationship for tenderness.

Some possible factors that affect tenderness have been identified as postmortem storage time and temperature (aging) (Smith et al., 1978; Mitchell et al., 1991; Eilers et al., 1996;), the quality grade of the carcass (Goll et al., 1965; McBee and Wiles, 1967; Smith and Carpenter, 1974), and a possible location effect within individual muscles (Kerth et al., 2002; Reuter et al., 2002; Rhee et al., 2004). Continued work is needed on improving meat tenderness, primarily for retail cuts from the round and chuck. It is necessary to get and increased percentage of steaks from the carcass or increase the percentage of muscles that can be used for steak cuts. If consumers are willing to pay more for guaranteed tender beef products (Boleman et al., 1997; Kukowski et al., 2004), it is the industry's job to discover innovative ideas to produce guaranteed tender beef.

CHAPTER 2
REVIEW OF LITERATURE

Tenderness

Consumers have ranked tenderness as being the most important factor influencing satisfaction (Savell et al., 1987, 1989; Smith et al., 1987). The final report of the 1995 National Beef Quality Audit listed low overall palatability and inadequate tenderness among the top 10 concerns of the beef industry (Smith et al., 1995). In addition, during the National Beef Tenderness Symposium (National Cattlemen's Association, 1994) it was revealed that 1) one in every four steaks is less than desirable in tenderness and overall palatability (Smith et al., 1992), 2) one tough carcass may affect as many as 542 consumers (Harris and Savell, 1993), and 3) beef industry leadership is adamant about increasing market-share, with increasing beef tenderness being the key to this change in positioning (George et al., 1997).

The 1998 National Beef Tenderness Survey (Brooks et al., 2000) collected samples from 56 retail stores representing 15 retail chains and 14 foodservice facilities in eight U. S. cities. Steaks were divided into the following quality groups for statistical analysis: Prime, Top Choice, Choice, Select, and Lean or No Roll. Average postfabrication aging times were 32 days for foodservice subprimals and 19 days for retail cut samples. The percentages of retail top round, eye of round, and bottom round steaks with a Warner-Bratzler shear (WBS) force of greater than 3.9 kg, the 68% confidence level of Shackelford et al. (1991b), were 39.5, 55.9, and 68.0, respectively. These data indicate that improvements in the tenderness of retail cuts from the round are needed. Quality

group had little or no effect on consumer sensory evaluations and WBS values of retail and foodservice steaks used in this study.

Consumers can differentiate among steaks varying in WBS (Miller et al., 1995; Huffman et al., 1996). As WBS decreased, tenderness scores increased, indicating that consumers could detect changes in tenderness similar to those found in instrumental measurement (Miller et al., 1998). Consumers are also willing to pay more for steaks that reach a certain level of tenderness (Miller et al., 2001). If there is a possibility of increasing tenderness in these cuts of beef, the value of the total carcass can be increased. Boleman et al. (1997) also suggested that consumers can discern between categories of tenderness and are willing to pay a premium for improved tenderness. In this study, strip loins were cut into 2.54 cm-thick steaks, and the center steak from each strip loin was used to determine WBS. The remaining steaks were placed into one of the following categories based on that WBS and color-coded accordingly: 1) 2.27 to 3.58 kg (Red); 2) 4.08 to 5.40 kg (White); and 3) 5.90 to 7.21 kg (Blue). A $1.10/ kg price difference was placed between each category and randomly recruited consumers were allowed to evaluate steaks and purchase them based on their findings. Consumers gave higher tenderness ratings to Red steaks than to Blue steaks. Overall satisfaction was higher ($P<0.05$) for Red steaks than for the other two categories. The following percentages of steaks were purchased: 1) Red, 94.6%; 2) White, 3.6% and 3) Blue, 1.8%. These results suggested that consumers could discern between tenderness categories and were willing to pay a premium for improved tenderness. Therefore, the factors that affect tenderness need to be identified and studies need to be conducted to determine the best way to ensure a tender product.

Factors Affecting the Tenderness of Beef

Differences in the rate and extent of postmortem tenderization are the principle sources of variation in meat tenderness and are probably the source of inconsistency in meat tenderness at the consumer level. To solve the tenderness problem, even greater understanding of the mechanisms regulating meat tenderness and tenderization must be gained (Koohmaraie et al., 1996). Tenderness is extremely difficult to measure objectively because the chewing motions involved in mastication involve both vertical and lateral movements of the human jaw as well as various in-between modifications, which together produce the impression of tenderness (Pearson, 1963).

Before 1960, theories about meat tenderness tended to be dominated by the role of connective tissue (Locker, 1985). Locker (1960) demonstrated the importance of the myofibrillar component of tenderness and began the modern era of meat tenderness research. Tenderization begins either at slaughter or shortly after slaughter, which results from weakening of the myofibrils caused by proteolysis of proteins responsible for maintaining structural integrity of the myofibrils (Wheeler and Koohmaraie, 1994). Aging, a method for tenderization of meat by storage at above-freezing temperatures in vacuum bags, is very important to assure a tender, acceptable product (Davey et al., 1967). There are various theories about the reason for this phenomenon. Location within muscles also has been shown to play a role in tenderness variations. 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; Reuter et al., 2002). It has been established that a tenderness gradient exists within steaks obtained for the longissimus muscle (Alsmeyer et al., 1965; Sharrah et al., 1965; Smith et al., 1969). Another factor that may affect tenderness is quality

grade. Romans et al. (1965) found steaks containing moderate degrees of marbling to be juicier than steaks possessing slight marbling although marbling level did not have a significant effect on tenderness as determined by WBS. Walter et al. (1963) reported that marbling did not exert any significant effect on tenderness, flavor or juiciness scores. Research reviews (Jeremiah et al., 1970; Parrish, 1974; Smith and Carpenter, 1974) have emphasized low relationships between marbling and tenderness. Numerous investigation of the relationship between marbling and beef palatability have shown that, although there is a positive relationship between marbling degree and tenderness, this relationship is weak at best (Parrish, 1974). Wheeler et al. (1994) reported that marbling explained about 5% of the variation in palatability traits and that there was both tough and tender meat within each marbling degree. So it is important to take into account these factors when trying to determine the ideal way to create a predictability acceptable product to the consumer.

Measurement of Tenderness

Because of savings in time and money and the difficulty of maintaining a well-trained sensory panel, tenderness of cooked meat samples can be assessed much more easily via WBS than trained sensory panel analysis (Shackelford et al., 1995). Harris and Shorthose (1988) state that shear force does not accurately reflect tenderness differences among muscles, however most investigators rely upon the WBS machine for objective estimates of tenderness (Smith et al., 1978). Results of correlations between sensory panel tenderness ratings and WBS values for the same muscles have suggested that WBS is sufficiently reliable to use in lieu of taste panel results (Brady, 1937; Hay et al., 1953; Kropf and Graf, 1959; Doty and Pierce, 1961; Pearson, 1963; Alsmeyer et al., 1966).

Shackelford et al. (1995) determined the relationship between WBS and overall tenderness of 10 major beef muscles. Mean WBS differed little among muscles; however muscles differed ($P<0.05$) greatly in overall tenderness ratings (psoas major (PM) = infraspinatus (IF) > triceps brachii (TB) = longissimus dorsi (LD) = gluteus medius (GM) = supraspinatus (SS) > biceps femoris (BF) = semimembranosus (SM) = quadriceps femoris (QF)). These differences in overall tenderness among muscles were consistent with previous findings of Ramsbottom and Stradine (1948), Shorthose and Harris (1990), and Morgan et al. (1991). WBS was effective in detecting that PM and IF were more tender than the others, but failed to detect and differentiate between the other muscles studied. Differences in overall tenderness ratings among TB, LD, ST, GM, SS, BF, SM, and QF could not be explained with any of the parameters of the WBS profile. The relationship between peak load and overall tenderness within each muscle ranged from very weak for GM (r^2=0.00 to strong for LD r^2=0.73) (Shackelford et al., 1995).

Some researchers have proposed relationships between WBS and consumer perceptions of degree of tenderness. Shackelford et al. (1997a) classified a carcass as “tender,” “intermediate” or “tough” if its longissimus shear value at one or two days postmortem was < 6 kg, 6 to 9 kg, or > 9 kg, respectively. A total of 100% of the carcasses in the “tender” class had “low” WBS values at 14 days postmortem, 81% (exp 1) and 85% (exp 2) of the carcasses in the “intermediate” class had “low” WBS values at 14 days postmortem, and 74% (exp 1) and 67% (exp 2) of the carcasses in the “tough” class did not have “low” WBS values at 14 days postmortem. In correlation studies, WBS values were highly correlated with sensory tenderness (r = 0.78), which agrees with the work of Webb et al. (1964). Sensory tenderness, juiciness, and flavor were also

highly correlated with each other. Shackelford et al. (1991b) reported that 82% of samples having WBS values less than 4.6 kg were rated “slightly tender” or higher, and 66% of samples having WBS values greater than 4.6 kg were rated less than “slightly tender” by an in-home consumer panel. However, the relationship between tenderness of the longissimus and tenderness of other muscles had been reported to be weak to moderate (Slanger et al., 1985; Shackelford et al., 1995). Thus a minor muscle probably could not be used as an indicator of longissimus tenderness. There would be limited benefit to classifying the tenderness of other cuts based on tenderness of the longissimus muscle (Shackelford et al., 1999).

There would likely not be much opportunity to classify round cuts according to tenderness, on any basis, because Shackelford et al. (1997b) demonstrated that there is little animal-to-animal variation in the tenderness of round cuts from youthful grain-fed steers. Morgan et al. (1991) showed that WBS values indicate that a high percentage of retail cuts from the chuck and round would receive overall tenderness rating scores less than “slightly tender”. Tenderloin and top blade steaks, which are consistently very tender (Shackelford et al., 1995) could be guaranteed tender without product testing. However, round cuts, which have a lot of random variation within each carcass (Shackelford et al., 1997b), should not be guaranteed tender regardless of longissimus tenderness (Shackelford et al., 1997a).

Beef palatability research studies often use traits such as marbling score, WBS, and consumer or trained taste panel evaluations of tenderness, juiciness and flavor as indicators of beef palatability (Platter et al., 2003). Platter et al. (2003) revealed moderate to high correlations ($P < 0.05$) among mean marbling scores, WBS, and mean

consumer panel palatability ratings. The correlation between consumer tenderness ratings and WBS was moderately high (r = 0.63). Marbling scores were correlations with WBS, consumer tenderness ratings, consumer juiciness ratings, and consumer flavor ratings were r = -0.31, -0.27, -0.34, -0.22, respectively. High, positive correlations (r = 0.80 to 0.84) were observed among all consumer sensory ratings (Platter et al., 2003). Of the three sensory models developed by Platter et al. (2003), the most accurate was the consumer tenderness rating at r^2=0.56. The marbling and the WBS models were r^2=0.053 and 0.225, respectively, for determining whether two-thirds of consumers would have rated steaks as acceptable.

Slice force is another measurement of tenderness that has been studied. Wheeler et al. (1999) established the longissimus dorsi to be tender if the day three WBS was < 5.0 kg when cooked to 70°C. This value was equivalent to 23 kg of slice shear force that Shackelford et al. (1999) used to test the efficacy of tenderness classification.

Trained sensory panel is also a measurement of tenderness in many studies. Smith et al. (1978) demonstrated that the correlation for overall tenderness rating for 14 muscles and shear force values was r = 0.48. These data suggested that shear force and sensory panel tenderness ratings are sufficiently correlated to justify use of either measure for assessing the tenderness of muscles in a beef carcass (Smith et al., 1978). However, Lorenzen et al. (2003) reported a low correlation between trained sensory panels and consumer sensory panels. There is an inherent difficulty in predicting consumer responses from objective laboratory procedures, such as trained sensory panels and WBS. There will continue to be important future uses for trained sensory panels, WBS determination, and in home or other consumer evaluations of meat. How they can be

used to predict each other is a question that will be asked by meat science researchers for years to come (Lorenzen et al., 2003).

Aging

Aging, a method for tenderizing of meat by storage at above-freezing temperatures in vacuum bags, is very important to assure a tender, acceptable product (Davey et al., 1967). Retailers and purveyors have relied on aging as a means of controlling beef quality (Savell and Shackelford, 1992). Although aging is important in assuring tender acceptable retail products, it creates problems in merchandising and in use of storage facilities due to increased inventory of beef (Davey et al., 1967). This problem could be alleviated by identification of the minimum period of aging necessary to assure the desired level of tenderness (Smith et al., 1978).

There are two different methods of aging; wet and dry. Wet aging occurs in a vacuum bag under refrigeration. In dry aging, the product is unpackaged and exposed to air at a controlled temperature and relative humidity. Wet aging will produce acceptably tender and flavorful products without loss of yield and the necessary amount of aging space as with dry aging. For some processors, acceptable product palatability and economic savings can be accomplished by using wet aging (Parrish et al., 1991). Parrish et al. (1991) made a comparison between wet aging and dry aging and determined that little or no cooler shrink was observed with wet-aged product. No measurable purge was recorded for the wet-aged product either. Steaks for wet aging had higher scores ($P < 0.01$) for tenderness and overall palatability, although steaks from both wet and dry aging provided very palatable products.

Postmortem storage of carcasses at refrigerated temperature has been known to improve meat tenderness for many years and still remains an important procedure for

producing tender meat. Although improvement in meat tenderness is measurable both subjectively and objectively, the exact mechanism of improvement in tenderness as a result of postmortem storage still remains unclear. However there appears to be general agreement that proteolysis of myofibrillar protein is the major contributor to meat tenderization during postmortem storage (Dutson, 1983; Goll et al., 1983).

Mechanism of Aging

Tenderization begins either at slaughter or shortly after slaughter, which results from weakening of the myofibrils caused by proteolysis of proteins responsible for maintaining structural integrity of the myofibrils (Wheeler and Koohmaraie, 1994). There are some animals that go through the tenderization process rapidly and could be consumed after 1 day, whereas others could be consumed after 3, 7, or 14 days, and still others would not be acceptable even after extended post-mortem storage (Wheeler and Koohmaraie, 1994). The mechanism of postmortem aging is a very controversial issue and many researchers have made an attempt to determine the specific mode of action. Smith et al. (1978) demonstrated a characteristic improvement in beef tenderness during postmortem aging in response to myofibrillar protein degradation by endogenous proteases.

Koohmaraie (1995) suggested that calpain-mediated proteolysis of key myofibrillar proteins is responsible for improvement in meat tenderness during post-mortem storage of carcasses or cuts of meat at refrigerated temperatures. Differences in the potential proteolytic activity of the calpain system result in differences in the rate and extent of post-mortem tenderization. Koohmaraie (1995) has collected evidence indicating that, within a species, 24 hr rather than at-death, calpastain activity is related to meat tenderness. In beef, for example, calpastatin activity at 24 hr post-mortem is highly

related to beef tenderness after 14 days of postmortem storage. The estimates for the relationship between calpastatin activity and meat tenderness vary, but up to 40% of the variation in beef tenderness is explained by calpastatin activity at 1-day post-mortem (Koohmaraie, 1995). Although endogenous enzyme systems are capable of softening or degrading collagen (Dutson et al., 1980; Kopp and Valin, 1980-81; Wu et al., 1981), those enzymes have not been shown to be released in sufficient quantities postmortem to initiate such changes (Harris et al., 1992).

Calcium activated factor (CAF), also known as calcium-dependent protease (CDP), is an endogenous structural protease active in postmortem beef muscle and is responsible for myofibrillar protein degradation (disappearance of Troponin T and appearance of a 30,000 Dalton component) indicating postmortem aging (Olson et al., 1977). Of the proteases located inside skeletal muscle, CDP and lysosomal enzymes appear to be the best candidates for bringing about the tenderness changes during postmortem storage (Dutson, 1983; Goll et al., 1983). CDP was initially identified in skeletal muscle by Busch et al. (1972) and later purified by Dayton et al. (1976). Mellgren (1980) reported the existence of a second form CDP. These two forms of the protease are now referred to as CDP-I and CDP-II, according to the sequence of elution from a DEAE-cellulose column at pH 7.5. CDP-I requires only very low concentration of calcium for 50% activation, whereas CDP-II requires much higher calcium concentration (Goll et al., 1983). CDP-I has also been labeled μ-calpain, and CDP-II as m-calpain. Both of these proteases are located primarily in the cytosol.

A second group of proteases that have been implicated in postmortem tenderization are lysosomal enzymes. Of 13 reported lysosomal enzymes, only 7 have been shown to

exist in the lysosome of skeletal muscle cells (Goll et al., 1983). These enzymes have acidic pH optima and, therefore, if involved in postmortem tenderization, they are most involved once muscle approaches its ultimate pH. To explain a basis for meat tenderization during postmortem storage, it has been postulated that one class of these proteases or the synergistic action of both classes of proteases (CDP's and lysosomal enzymes) is responsible for postmortem changes (Dutson, 1983; Goll et al., 1983; Pearson et al., 1983). It is logical to assume that the class of proteases responsible for postmortem aging should have higher activity in the carcasses with a high aging response and vice versa (Koohmaraie et al., 1988). Illian et al. (2001) reported a third CDP, and stated that the primary role of CDP-I and CDP-III was associated with meat tenderness in vivo due to the high activity of these two enzymes.

Length of Aging

Another question that arises with the phenomenon of postmortem aging is how long meat should be aged to reach optimum tenderness. Smith et al. (1978) stated that aging of US Choice beef carcasses for 11 days will optimize tenderness, flavor, and overall palatability of the majority of muscles in steaks and (or) roasts from the chuck, rib, loin, and round when such cuts are ultimately broiled or roasted. Compared to shear force at 5 days, aging for 8 days, 11 days, 21 days, and 28 days decreased shear force. This was the case for sensory panel ratings also; aging for 11 days appeared to produce optimal tenderization since further aging did not accomplish further reductions in shear force (Smith et al., 1978). Doty and Pierce (1961) reported that aging of raw wholesale cuts for two weeks substantially reduced shear force, but further aging did not result in further shear force reductions.

Brooks et al. (2000) found that subprimal postfabrication times at the retail level averaged 19 days. Overall, foodservice steaks were subjected to a postfabrication time of 32 days. Interestingly, top sirloins were aged an average of 32 days with a minimum of 20 days before fabrication in an effort to maximize tenderness. However, Harris et al. (1992) reported that aging top sirloins up to 35 days postmortem had no effect on WBS values. Lorenzen et al. (1998) reported that postmortem aging times of 14 days maximized the tenderness of steaks from the chuck roll, rib, and shortloin. Reducing the number of cuts that are not sufficiently aged before consumption may help increase tenderness ratings and further reduce beef tenderness problems (Brooks et al., 2000). Harris et al. (1992) found that top sirloin steaks did not respond to aging until 28 days while top loin steaks demonstrated improvement in muscle fiber tenderness after only 7 days of postmortem aging and another increase after 28 days. Top sirloin steaks had higher ($P < 0.05$) shear force values than did top loin steaks at each aging period. The top sirloin steak demonstrated no decrease in WBS values in response to postmortem aging (Harris et al., 1992). Connective tissue concentration also plays a major role in the aging process. Connective tissue tended to remain relatively stable and intact during aging. If the top sirloin steaks were less tender due to higher concentrations of connective tissue, this lack of WBS decline would be expected (Harris et al., 1992). Overall in the study, the top loin steaks showed a relatively steady decrease in shear force values as postmortem aging time increased.

Miller et al. (1997) found that aging beef for 14 days improved the consistency of beef tenderness and should be recommended as a processing control point for the beef industry. This method would improve consumer acceptance of beef regardless of breed,

fatness, or processing variables. When steaks were aged for 7 days, WBS values of Choice steaks tended to be more tender initially (6.6 kg) than Select steaks (6.1 kg). However, aging for 14 days removed the grade effect (6.8 kg for Choice and 6.7 kg for Select). The additional 7 days of aging raised the WBS of Choice steaks 0.26 kg but raised the WBS of Select steaks twice as much (0.52 kg). Sustained tenderness scores showed a similar pattern. If aged for 7 days, Choice steaks (6.5 kg) were scored higher than Select steaks (6.0 kg). However, aging for 14 days removed the grade effect (6.7 kg vs. 6.5 kg). Choice steaks aged for 7 days were scored the same as Select steaks aged for 14 days (6.5 kg) (Miller et al., 1997).

Rate of Muscle Aging

Tenderization of different muscles during aging in an individual carcass has been shown to vary (Koohmaraie et al., 1988; Ouali and Talmant, 1990). For example, the rate of tenderization of longissimus thoracis et lumborum (LT) was different for that of the psoas major (PM) (Cridge et al., 1994). Rate of tenderization over the 14 day aging period of LT was significantly ($P < 0.05$) higher than that of PM. These observations are in accord with the results obtained by Koohmaraie et al. (1988) for the same two muscles in the bovine (Ilian et al., 2001). Therefore, the rate of tenderization within various muscles of the carcass needs to be considered when making recommendations about aging. Koohmaraie et al. (1988) demonstrated that at 24 hour postmortem longissimus (L), biceps femoris (BF), and psoas major (PM) muscles differed significantly in their shear force values, but after 14 days of aging these differences were reduced considerably. In terms of the aging response, L had the greatest response with a lesser response in BF, and no response at all in PM at day 14. In this study the activities of catheptic enzymes, B, H, L as well as the activities of CDP-I and II were examined in an

attempt to identify which protease class might be responsible for the observed differences seen in aging response. Results indicated that regardless of the differences seen in aging response, activities for cathespins (B, H, and B+L) were the same for all three muscles. However, it may be possible that these enzymes could be differentially activated in vivo by higher temperature and/or lower pH (Dutson, 1983) as seen in the PM muscle, thus causing more aging response at the same enzyme concentration. In the case of CDP, activities followed the same pattern as the aging responses; L which had the highest aging response also had the higher CDP-I activity. In turn, PM, which displayed the least aging response had the lowest CDP-I activity, and BF was intermediate in both CDP-I activity and aging response. Based on the results of this and other experiments (Koohmaraie et al., 1986, 1987) it was concluded that the initial levels of CDP-I activity determine the aging response of a given muscle. The reason PM muscle had no aging response, even though its CDP activity was about 50% of the L muscle, is not known. Koohmaraie (1987) has demonstrated that about 50% of the aging response is completed by 24 hr postmortem.

Sarcomere length may also be related to the aging response in that the muscles with shorter sarcomere lengths had a greater aging response. At present no mechanism for a relationship between sarcomere length and aging response can be proposed, however, Dutson et al. (1976) demonstrated greater ultra structural alterations of z-lines when both psoas major and sternomandibularis muscles were shortened. If CDP-I activity is responsible for postmortem changes in the muscle, then its inactivation or unfavorable conditions for its activation should prevent postmortem changes in the muscle. Also activation of CDP-I or generation of favorable conditions for its activation should

accelerate the postmortem changes. This particular point in now being addressed by attempting to manipulate animals and/or carcasses so that CDP-I would not be activated and then examining postmortem changes in these carcasses (Koohmaraie et al., 1988).

Quality Grade

Marbling has often been implicated as a contributing factor to beef palatability and is a major component in the USDA beef grading system (Jennings et al., 1978). Romans et al. (1965) found steaks containing moderate degrees of marbling to be juicier than steaks possessing slight marbling although marbling level did not have a significant effect on tenderness as determined by the WBS. Also, Walter et al. (1963) reported that marbling did not exert any significant effect on tenderness, flavor or juiciness scores. Research reviews (Jeremiah et al., 1970; Parrish, 1974; Smith and Carpenter, 1974) have emphasized low relationships between marbling and tenderness.

Numerous investigations of the relationship between marbling and beef palatability have shown that, although there is a positive relationship between marbling degree and tenderness, this relationship is weak at best (Parrish, 1974). Wheeler et al. (1994) reported that marbling explained about 5% of the variation in palatability traits and that there was both tough and tender meat within each marbling degree. Data by Wheeler et al. (1994) indicated a small, positive relationship of tenderness and juiciness with marbling score, and a variation in tenderness may be decreased slightly as marbling increases. The data also revealed a large amount of variation in sensory tenderness rating and shear force within one marbling score or another.

Various studies (Blumer, 1963; Pearson, 1966; Parrish, 1974; Jeremiah, 1978) have revealed that between 5 and 10% of the variation in tenderness can be accounted for by marbling degree. According to Smith et al. (1984), due to the USDA quality grading

standards for carcass beef and their implied segregation of meat based on palatability, the US beef industry has placed a high value on marbling at the 12th rib interface of the longissimus thoracis. The emphasis on marbling in determining carcass value is based on the slight increases in juiciness, flavor, and tenderness that are obtained as marbling is increased. There are, however, several problems with palatability estimation based solely on marbling score. An abundance of research expanding over the last 30 years has indicated that marbling/intramuscular fat has a low relationship to palatability. The variation in marbling in the longissimus thoracis has little effect on palatability of other muscles (Smith et al., 1984). The pursuit of higher amounts of marbling, however, results in more time on feed and, thus, in fatter, lower-yielding carcasses. Use of a visual assessment of the amount of fat exposed in a cross-section of the longissimus thoracis at the 12th rib as the primary determinant of the value of the entire carcass may not be justified (Wheeler et al., 1994).

Association of Level of Marbling and Quality Grade to Tenderness

Many researchers have reported that tenderness, juiciness, and flavor increase with increasing degrees of marbling in a direct, linear relationship (McBee and Wiles, 1967; Jennings et al., 1978; Dolezal et al., 1982), whereas others have reported very low or nonexistent associations (Carpenter et al., 1972; Parrish et al., 1973; Parrish 1974, Dikeman and Crouse, 1975; Davis et al., 1979; Smith et al., 1984; Brooks et al., 2000). Mean WBS differences seem to be small between chuck cuts from different quality grades. However, the frequency distribution of shear force values indicates approximately 10% more cuts from Select (24 of 58) and No-roll (36 of 87) grades having 4.0 kg of force or greater, compared with Choice chuck cuts (70 of 220) (Morgan et al., 1991). No noticeable differences in WBS or variation in tenderness were observed

between round cuts differing in quality grade (Morgan et al., 1991). Smith et al. (1984) stated that marbling is of very limited value in explaining differences in sensory panel ratings of round steaks compared to loin and rib steaks. Morgan et al. (1991) determined that USDA quality grade failed to control the variation in panel ratings or WBS values to the degree necessary to ensure consistent beef products to the consumer.

Regardless of the amount of external fat, loin steaks possessing modest or above marbling, had lower WBS values and higher tenderness and juiciness ratings ($P<0.05$) than steaks containing slight or lower marbling (Jennings et al., 1978). Wheeler et al., (1994) reported that although mean palatability scores were in the acceptable range, regression of WBS and sensory traits on marbling indicates the low association of marbling score to meat palatability, despite the fact that palatability traits generally increase as marbling level increases. Carcass characteristics and measurements are low in their relationships to tenderness attributes with marbling scores having the highest correlations. Based on these results obtained from Jennings et al. (1978) it would appear that the influence of marbling on palatability varies depending on degree of marbling.

George et al. (1997) reported that Choice rib steaks have lower ($P < 0.01$) WBS values at day 14 and day 28 than rib steaks from Select carcasses. Similarly, rib steaks for Choice carcasses had higher ratings ($P < 0.01$) for muscle fiber tenderness and overall tenderness. Quality grades in the present study were useful for segregating carcasses according to their likelihood of yielding steaks differing in palatability and should continue to be useful until a system is identified to augment or assist the current use of differences in maturity and marbling for such purpose (George et al., 1997).

The "Insurance Theory"

The "insurance theory" or the ability of marbling to maintain tender meat when cooked to high end point temperatures has been supported by some studies (Luchak et al., 1990), but not others (Parrish et al., 1973). Smith and Carpenter (1974) suggested that the "insurance theory" means that, by having higher degrees of marbling, the use of high-temperature, dry-heat methods of cookery and/or the attainment of advanced degrees of final doneness will not adversely affect the ultimate palatability of the cooked meat. Marbling would provide some insurance that the meat cooked too rapidly, too extensively, or by the wrong method of cookery would still be palatable. Fatty tissue does not conduct heat as rapidly as lean tissue, so it is possible that marbled meat can endure higher external cooking temperatures without becoming overcooked internally. This theory suggests that dry-heat cookery is suitable only for naturally tender cuts of beef such as the rib and loin from Prime, Choice, and Select carcasses and the top round, rump, and blade chuck from Prime and Choice carcasses (Smith and Carpenter, 1974).

Luchak et al. (1990) reported that Select top loin steaks were tougher at higher temperatures than Choice top loin steaks. Choice steaks were also juicier, higher in fat, cooked slower, and were more tender when compared with Select steaks (Luchak et al., 1990). Parrish et al. (1991) found that Prime and Choice steaks scored more tender ($P < 0.01$) than Select steaks when cooked to an internal temperature of 63°C. These results agreed with those reported by Smith et al. (1984), but disagreed with Goll et al. (1965) and Parrish et al. (1973) who found no statistically significant effect of quality grade on palatability of steaks when cooked to an internal temperature of 54°C.

Parrish et al. (1973) reported that internal cooking temperature of rib steaks is a much more important factor in palatability than marbling, and that degree of marbling,

and its interaction with internal cooking temperature, had essentially no effect on palatability characteristics. Parrish et al. (1991) found that although certain palatability attributes were statistically different between quality grades and cuts, all were considered palatable. WBS values were significantly influenced by USDA quality grade. Steaks that graded Choice had lower WBS values than Prime or Select steaks. Choice loin steaks also received higher sensory scores for tenderness, juiciness, and overall palatability than Select loin steaks. Prime grade loin steaks and roasts scored higher on the trained and untrained sensory panels by being more tender, juicy, and having a more intense desirable flavor. This disagreed with published data in which consumer panelists found no difference in sensory characteristics between quality grades (Francis et al., 1977; Nauman et al., 1961).

Differences Detected by Consumers

Neely et al. (1998) evaluated three kinds of beef steaks from four USDA quality grade levels in four major cities on consumer satisfaction of moderate to heavy beef users. Top Choice steaks were rated higher ($P < 0.05$) in overall like than the remainder of the grades (Low Choice, High Select, and Low Select). Ratings for High Select top loin steaks did not differ ($P > 0.05$) for those for Low Choice or Low Select steaks; however, overall like ratings for Low Choice differed for ratings for Low Select. Grade had no effect ($P > 0.05$) on overall like among the top sirloin steaks. Top Choice top round steaks were rated higher ($P < 0.05$) than the other grades of top round steaks for overall like. Across all USDA quality grades, ratings for Overall like for top loin steaks were higher ($P < 0.05$) than those for top sirloin steaks, and ratings for top sirloin steaks were higher ($P < 0.05$) than those for top round steaks. For overall like ratings, effect of

USDA quality grade was cut-specific. The cut most affected was the top loin steaks which agree with the findings of Smith et al. (1987).

The USDA quality grade has been a controversial topic for many decades. Some believe strongly that grades perform well in sorting and categorizing beef for the marketplace. Others believe that the relationship between marbling and palatability is too low to serve as any real basis for identification of products for consumers. Findings from Neely et al. (1998) and Smith et al. (1987) suggested that USDA quality grade may be limited in the sorting of products for the marketplace derived from the longissimus muscles, and that it has less effect on the remaining major muscle of the beef carcass.

Walter et al. (1965), utilized 72 carcasses that represented maturity groups A, B and E and marbling groups moderately abundant, slightly abundant, modest, small, traces, and practically devoid, as determined by USDA Official Standards for Grades of Beef Carcasses. Analysis of variance and correlation coefficients demonstrated that marbling had no effect on tenderness but that tenderness decreased with advancing carcass maturity. Nearly 85% of the variation in ether extract could be accounted for by marbling ($r = 0.92$), indicating that the subjective scoring of marbling was in close agreement with objective determinations (Walter et al., 1965). As demonstrated in numerous studies, marbling did not significantly affect tenderness (Alsmeyer et al., 1959; Blumer, 1963; Cover and Hostetler, 1960; Cover et al., 1956, 1958; Palmer et al., 1958; Tuma et al., 1962, 1963; Wellington and Stouffer, 1959). Using the same data, analysis of variance had no effect on sensory scores for tenderness, juiciness, or flavor (Goll et al., 1965).

Location

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; Reuter et al., 2002). Ginger and Weir, (1958) and Christians et al. (1961) have also conducted research to show that there is indeed definable intramuscular tenderness variation within certain beef round muscles. It has also been established that a tenderness gradient exists within steaks obtained from the longissimus muscle (Alsmeyer et al., 1965; Sharrah et al., 1965; Smith et al., 1969). The cores from the medial and dorsal portion of the longissimus dorsi muscle were more tender than those from the more lateral positions. Henrickson and Mjoseth (1964) found that longissimus dorsi steaks from the ninth thoracic vertebra were significantly ($P < 0.01$) more tender than those from the 11th thoracic vertebra when measured with WBS. Neither maturity, marbling or core location had a significant effect on tenderness as determined by WBS by these researchers.

Such variations demonstrate that meat is not a homogenous material (Walter et al., 1965). However, researchers are not in complete agreement about this gradient. Cover et al. (1962) found that there were not any differences in cores from the longissimus dorsi. Romans et al., (1965) also found no significant core location differences in WBS tenderness. When evaluated by the taste panel, steaks adjacent to the ninth thoracic vertebra were slightly more tender than those adjacent to the 11th thoracic vertebra, but these differences in taste panel tenderness were nonsignificant, however Henrickson and Mjoseth (1964) found that the longissimus dorsi steaks from the ninth thoracic vertebra were significantly ($P<0.01$) more tender than those from the 11th thoracic vertebra when measured with WBS.

Shackelford et al., (1997b) tested the effects of location and aging. Biceps femoris (BF) and semitendinosus (ST) were obtained from A maturity, grain-fed, crossbred steers (n=25) at 16 d postmortem. Steaks were removed from each muscle for determination of shear force and tenderness rating at each of three locations (A=proximal end, B=center, C=distal end). They were removed from the right round of each carcass and trimmed of all subcutaneous and intermuscular fat, vacuum packaged, and held at 2°C. Cuts were aged to 16 d postmortem because the National Beef Tenderness Survey (Morgan et al., 1991) indicated that the average aging time for beef round cut at US retail stores was 16 days. In agreement with Shackelford et al. (1995) comparison of multiple beef muscles revealed that tenderness rating was higher for BF than for ST ($P < 0.01$). Sensory tenderness ratings were more repeatable than shear force for BF ($R = 0.5$ vs. 0.3) and ST ($R = 0.6$ vs. 0.56). However, all of the estimates of repeatability were much less than values that Wheeler et al. (1997) obtained for beef longissimus using similar laboratory procedures ($R= 0.79$ vs. 0.9). Location did not affect ($P > 0.05$) BF WBS; however BF tenderness ratings were higher ($P < 0.05$) for location A than for locations B and C. WBS decreased ($P < 0.05$) from the proximal end to the distal end of the ST. Also, ST tenderness ratings were lower for location A than locations B and C. The proximal end of the ST contained heavy bands of connective tissue, which might explain the reduced tenderness rating of that location. However, the increased WBS of the proximal end of ST cannot be assigned to the presence of heavy bands of connective tissue because those bands of connective tissue were avoided when removing cores for shear force. Because of the large effect of location on ST tenderness, there might be merit to target different portions of the ST for specific uses. For example, the more tender portion (distal half) of

the ST might be suitable for use as broiled/grilled steaks, whereas the tougher portion of the ST might be more suitable for use as roasts or cubed steaks (Shackelford et al., 1997b).

In a similar study by McBee and Wiles (1967), steaks cut at the third lumbar vertebra were tested for differences in WBS values among dorsal, medial and lateral locations within steaks from the longissimus dorsi. The dorsal portion had a significantly lower mean WBS value than the other two locations. There was no significant difference in WBS values between the medial and lateral locations, although the medial location had the highest mean WBS value. These results agree with those of Alsmeyer et al. (1965) and Tuma et al. (1962).

A number of researchers have investigated potential tenderness gradients across the longissimus dorsi muscle (Hostetler and Ritchey, 1964; Alsmeyer et al., 1965; Crouse et al., 1989). Kerth et al. (2002) found that core location had a significant effect ($P < 0.01$) on WBS in both 7 and 14 days of postmortem aging. In both aging periods there were regions of WBS values that differed ($P < 0.05$) across the cross section of the longissimus dorsi producing a tenderness gradient. In general there was a lateral to medial WBS gradient across the longissimus dorsi steaks ($P < 0.05$). While a dorsal to ventral gradient was evident in both aging periods, the lateral to medial gradient was the most predominant. Cores from the center of steaks tended to have the most predictive capacity of average WBS (Kerth et al., 2002).

Location effects add difficulty in merchandising steaks from new cuts taken from the chuck and the round. The retail sector must be innovative in merchandizing techniques to maintain steak thickness and minimize portion size (Savell and

Shackelford, 1992) while taking into account the possible variations in tenderness due to location effects.

The objective of this study was to determine the aging patterns of nine selected muscles from the chuck and the round for two quality grades of beef: USDA Select and the upper 2/3 of USDA Choice. The effects of quality grade, aging, and location on tenderness were determined. Tenderness was determined by Warner-Bratzler shear force from these nine muscles of locomotion from the two different quality grades. The muscles were also divided into quadrants to test location effects.

CHAPTER 3
THE EFFECTS OF QUALITY GRADE, AGING, AND LOCATION ON WBS FORCE VALUES ON SELECTED MUSCLES OF LOCOMOTION OF THE BEEF CHUCK AND ROUND

Introduction

Recently, University of Florida and University of Nebraska Scientists characterized thirty-seven muscles of the beef chuck and round relative to size, shape, palatability, and composition (National Cattlemen's Beef Association (NCBA), 2000). This study revealed that a significant number of these muscles, when removed separately and cut across the grain, were very acceptable in sensory panel scores. The researchers concluded that there are numerous muscles that could be up-graded in value by cutting them into steaks rather than selling them as part of a roast or grinding into ground beef (NCBA, 2000). Kukowski et al. (2004) found the complexus, serratus ventralis, triceps brachii, and the infraspinatus were acceptable to consumers as steaks. By using these muscles as steaks instead of roasts, more total dollars could be generated for beef and could lead to greater profits (Kukowski et al, 2004). As the industry begins to isolate individual muscles of the chuck and round for merchandising as steak cuts, more knowledge about how these muscles respond to postmortem aging is required in order to assure tenderness.

In recent years, economic pressures have challenged the livestock and meat industries to seek ways of producing meat products that will enable consumers to receive maximum palatability benefits at the lowest costs (Morgan et. al., 1991). The increased demand for middle cuts, combined with the decreased demand for end meats, has resulted

in the average retail beef process remaining relatively unchanged during the 1990s (Kukowski et al., 2004). Due to consumer demand for smaller portion sizes, beef retailers have been forced to fabricate steaks from cuts of meat (round and chuck subprimals) that previously were merchandised solely as roasts (Shackelford et al., 1995). With traditional roasts cuts being marketed as individual muscle steaks instead of roasts, valued could be added to the beef carcass (Kukowski et al., 2004). The round represents approximately 22% of the weight of a typical beef carcass and contains some of the least tender muscles of the carcass (Ramsbottom et al., 1945; Jones et al., 2001). Rhee et al. (2004) found that the adductor, semimembranosus, gluteus medius, and semitendinosus all from the round; and the supraspinatus from the chuck had high WBS force values (WBS = 4.29 kg). Savell and Smith (2000) reported that the chuck represents about 30% of the total carcass weight. That is approximately 52% of the carcass that is currently used primarily as ground beef and roasts.

Miller et al. (2001) found that consumers were willing to pay a premium for steaks that reach certain levels of tenderness. One of the most prevalent and non-invasive methods of postmortem tenderization is “aging” meat at refrigerated temperatures (Parrish, 1997). Much of the published work to date has focused on the longissimus muscle (Jennings et al. 1978, Shackelford et al. 1991a, and Parrish, 1997). As the industry begins to isolate individual muscles of the chuck and round for merchandising as steak cuts that will be cooked commonly with a dry cooking method, then more knowledge about how these muscles respond to postmortem aging is required. Parrish (1997) stated that tenderloin and eye of round have a different aging pattern from the longissimus muscle, but other beef muscles were not mentioned in that review. Parrish et

al. (1991) also found that beef longissimus from USDA Choice aged similarly to USDA Select longissimus, but other muscles were not studied.

The economic incentives for the industry to improve the tenderness of beef must be established before significant improvements in the consistency and palatability of beef will occur (Miller et al., 1998). Kukowski et al. (2004) asked panelist to assign a price/0.45 kg (0=would not buy, 10=$10/0.45 kg). Consumers were willing to pay $5.68/0.45 kg for the infraspinatus, and $5.15/0.45 kg for the triceps brachii. This could provide a good incentive for retailers to use these individual muscles as steak cuts. Other cuts from the Kukowski et al. (2004) study that were found to be acceptable as steaks cuts were the serratus ventralis ($4.78/0.45 kg), and the complexus ($4.75/0.45 kg). According to Miller et al. (1998), the most important factor in a tenderness study with consumers was to establish that a range in beef tenderness from tender to tough exists. The range given in this study was greater than 2.0 and less than 7.0 kg of shear force. Research has shown that consumers can detect changes in tenderness similar to those found with instrumental measurements such as WBS force (Miller et al., 1995; Shackelford et al., 1991b; Boleman et al., 1997). Therefore, WBS values can be used as an indicator of the value relationship for tenderness.

Some possible factors that affect tenderness have been identified as postmortem storage time and temperature (aging) (Smith et al., 1978; Eilers et al., 1996; Mitchell et al., 1991), the quality grade of the carcass (Goll et al, 1965; McBee and Wiles, 1967, Smith and Carpenter, 1974), and a possible location effect within individual muscles (Kerth et al., 2002; Reuter et al., 2002; Rhee et al., 2004). Continued work is needed on improving meat tenderness, primarily for retail cuts from the round and chuck. If

consumers are willing to pay more for guaranteed tender beef products (Boleman et al., 1997), additional work needs to be conducted to investigate aging patterns of other muscles of the chuck and round so that the highest and best use for each muscle can be determined. If certain muscles do not respond to aging then it seems a waste of resources to do so, and other methods of ensuring tenderness need to be explored. If muscles from the chuck and round do respond to aging, then targeting or customizing aging time to individual muscles and desired level of tenderness would seem appropriate.

Materials and Methods

Institutional Meat Purchase Specifications (IMPS) (North American Meat Processors, 1988) 115 2-piece boneless chucks and IMPS 167A peeled knuckles were purchased from a major packer of known USDA grade and slaughter date. Two grades of cuts were studied: USDA Select and the upper 2/3 of the USDA Choice grade. Eight subprimals of each grade were immediately shipped to the University of Florida Meats Laboratory for muscle separation. The IMPS 115 2-piece chuck was separated and the following muscles were selected for study: infraspinatus, triceps brachii – lateral head, triceps brachii – long head, serratus ventralis, complexus, splenius, and rhomboideus. The IMPS 167A knuckle was also separated and the vastus lateralis and rectus femoris were evaluated. These nine muscles were selected because of the possibility that these could be used as steak cuts where tenderness is critical due to the probability that they would be cooked with a dry cooking method, based on results from the Muscle Profiling Study conducted by University of Florida and University of Nebraska in conjunction with National Cattleman's Beef Association (NCBA, 2000).

Each muscle was divided into four portions, progressing from anterior to posterior orientation to the carcass, or from dorsal to ventral orientation to the carcass depending

on muscle fiber orientation: A was the 1st 25% portion of the muscle, B was the 2nd 25% portion of the muscle, C was the 3rd 25% portion of the muscle, and D was the 4th 25% portion of the muscle. One steak was removed for evaluation from each portion of the muscle to be studied. For small muscles the entire portion may have been used as the steak. Postmortem aging was conducted for 7, 14, 21, or 28 days at 2 ± 2°C. Individual steaks were vacuum sealed in Cryovac B550T (Sealed Air Corp., Duncan, SC) bags and subsequently heat shrunk in 82°C water as per manufacturers recommendation. A Latin square was used to assign each steak into one of four postmortem aging treatments. There were eight 2 piece chucks from the USDA Select grade numbered one through eight, and eight knuckles from the USDA Select grade numbered one though eight. The same numbering system was used for the subprimals from the USDA Choice grade. For pieces one through four, the postmortem aging period was rotated clockwise for each location. For pieces five through eight, the positions for postmortem aging period was rotated counter-clockwise. This was done to remove muscle location effect on WBS values. Also, this treatment allocation method allowed for location effect to be tested and determined statistically.

After achieving the appropriate postmortem aging treatment, steaks were frozen at -40° C then transferred to a -20° C holding freezer until WBS could be conducted. Eight of each of the subprimals for each grade were sampled and replicated twice for a total of 32 subprimals boned to generate 288 muscles. Four steaks per muscle produced 1152 observations for this trial.

Steaks were thawed for 18 hours at 2 to 4° C then broiled on Farberware (Farberware, Bronx, NY) open-hearth broilers to an internal temperature of 71°C

(American Meat Science Association, 1995). The housing and drip pans of each broiler were covered with aluminum foil and preheated for 15 min. Copper-constantan thermocouples attached to a potentiometer were placed in the approximate geometric center of each steak and used to record internal temperature. Steaks were turned when the internal temperature of 35° C was reached and removed from the broiler when the internal temperature reached 71°C. Samples were allowed to cool at 2 to 4° C for approximately 18 hours and then 4 to 6 1.27-cm cores were removed from each steak, parallel to fiber orientation, for shear force determination. Shear force determinations were conducted on an Instron (Canton, MA) universal testing machine equipped with a WBS head, with a crosshead speed of 200 mm/min.

Least squares, fixed model procedures of SAS (2001) were used to analyze these data. This study was analyzed as a split-plot design where quality grade and muscle was the main-plot and postmortem aging and location were the sub-plots which were assigned using a Latin square design.

Results and Discussion

Mean values and other descriptive statistics are presented in Table 3-1 for the nine muscles evaluated in this study. The results of the current study agree with that of Rhee et al. (2004). For the muscles that were evaluated in both studies, the infraspinatus the most tender muscle, followed by the rectus femoris. Rhee et al. (2004) showed a higher WBS for the triceps brachii than the rectus femoris, where as in the current study, the triceps brachii-lateral head and the triceps brachii-long head were equivalent in WBS to the rectus femoris. For consumer panel ratings, Kukowski et al. (2004) also found the infraspinatus to be the most tender muscle followed by the triceps brachii, the serratus

ventralis, and the complexus, which are comparable to the WBS results obtained in the current study.

Table 3-2 gives the mean and standard deviation for the nine muscles used in this study. The rhomboideus, vastus lateralis, and splenius muscles were the least tender tier of the muscle groups and the infraspinatus muscle was by far the most tender of the nine muscles. The intermediate group of muscles that were very similar in WBS included the triceps-lateral and long head, complexus, serratus ventralis, and rectus femoris. Variation in shear values appeared to be directly related to average shear value. For instance, the rhomboideus had the highest standard deviation and the highest average WBS value. In comparison, the infraspinatus had the lowest standard deviation and average shear value.

The analysis of variance revealed a significant grade by postmortem aging interaction effect; Table 3-3 gives interaction mean values for these two factors. The USDA Select Grade steaks had a significant reduction in shear force values between 7 and 14 days of about 10 percent. There was no significant reduction of shear values after 14 days. Doty and Pierce (1961) reported that beef from all carcass grades had substantially reduced shear force requirements after two weeks of aging, but further aging did not reduce shear force values. For steaks from the upper two-thirds of the Choice grade, no significant improvement in WBS values was noted after 7 days postmortem aging. This is similar to results from Smith et al. (1978) which reported that aging beyond 11 days did not accomplish further reductions in shear force requirements, and Mitchell et al. (1991) reported little advantage in extending aging beyond 10 days. The effect of grade was only significant at day 7 and day 21 of postmortem aging (Table 3). If an end-user has the ability or can afford to hold steaks for 28 days postmortem, then

according to these data, USDA Select would be equivalent to the upper two-thirds of the Choice grade for WBS force values.

There was a significant main effect for USDA Grade and for postmortem aging; these values are also presented in Table 3-3. When averaged across all postmortem aging periods, grade only influenced WBS values by about 5 percent. The grade effect was greatest at 7 days postmortem and lessened as postmortem aging increased. If grade is ignored and only postmortem aging considered, it appeared that there was a significant decrease in WBS values between 7 and 14 days aging and 21 and 28 days aging. These data would suggest that 14 days aging would be an appropriate recommendation if end users could not hold product an entire 28 days aging period. This 14 day aging recommendation agrees with that of other researchers (Doty and Pierce, 1961; Eilers et al., 1996; Miller et al., 1997). Miller et al. (1997) suggested that aging beef for 14 days would improve the consistency of beef tenderness and should be recommended as a processing control point for the beef industry to improve consumer acceptance of beef regardless of breed, fatness, or processing variables.

Table 3-4 presents the effect of muscle location on WBS force values by muscle. Only four of the nine muscles were significantly impacted by anatomical location on shear force values, those included the complexus, rhomboideus, vastus lateralis, and rectus femoris. Both the complexus and rhomboideus muscles had higher shear force values going from the anterior to the posterior portion of the muscle. Both of these muscles run along the top of the shoulder and neck in close proximity. For the complexus, the anterior 25-percentile muscle portion had higher shear value than the center 50 percent of the muscle. The quartile closest to the wholesale rib was the lowest

in shear value and about 26 percent lower in shear value than the quartile found closest to the head. Similar results were noted for the rhomboideus, except not as extreme as noted for the complexus. The anterior one-half of the muscle was approximately nine percent higher in shear value than the posterior quartile of the muscle.

The two muscles evaluated from the knuckle were opposite in location effect when compared to the two previously mentioned muscles. Both the vastus lateralis and rectus femoris had increasing shear value when going from the anterior to posterior portion of the muscle. The anterior one-half of the vastus lateralis was approximately 10 percent more tender than the posterior quadrant of the muscle from the chuck. The rectus femoris was similar in its aging pattern to the vastus lateralis muscle in that the anterior 25 percent was more tender than the posterior 25 percent of the muscle. The middle 50 percent of the muscle was intermediate in shear values to the two end quadrants and not statistically different. Reuter et al. (2002) found a tenderness variation within the biceps femoris and the semimembranosus, but not within the adductor and the semitendinosus. For the biceps femoris and the semimembranosus the lowest shear force values were at the anterior end, highest shear force values at the posterior end and intermediate shear values in the middle (Reuter et al. 2002), which is similar to the rectus femoris in the current study. These data would suggest that for at least some individual muscles of the chuck and round, location should be considered when fabricating and merchandizing these muscles. For other muscles, location within the muscle need not be considered when merchandizing decisions are made.

Postmortem aging affects by muscle interaction was tested within subprimals and found to be not significant ($P = 0.53$). This suggests that postmortem aging affects all

muscles in a similar manner for WBS force values. Therefore, aging recommendations for the nine muscles studied in this project can be identical but USDA grade or intramuscular fat content would need to be considered. In contrast, Parrish et al. (1991) reported that there was no difference between the aging rates of USDA Choice versus USDA Select longissimus, but aging rates were significantly influenced by USDA quality grade. Steaks that graded Choice had lower WBS values than Prime or Select steaks (Parrish et al. 1991). It is important to note that there was a greater difference in grade or intramuscular fat in the present study because the Select grade was compared to the upper two-thirds of the Choice grade. Parrish (1997) noted that tenderloin and eye of round had different aging patterns from the longissimus muscle whereas muscles in the present study appeared to age in a similar fashion. It is important to note also that in the Parrish study, muscles of locomotion were compared to muscles of support where in the present study all muscles would be considered locomotive muscles. Miller et al. (1997) reported that sensory scores for USDA Choice steaks were higher than USDA Select, but USDA quality grade did not affect WBS. Kukowski et al. (2004) also reported USDA Choice steaks to have higher sensory panel scores than USDA Select steaks, but did not test WBS.

Implications

Postmortem aging affects all of the muscles evaluated in this study in a similar fashion. Therefore, consistent recommendations about postmortem aging can be given for these muscles. This study revealed that USDA grade would have an effect on postmortem aging, in that for muscles from the upper two-thirds of USDA Choice grade was not significantly improved after seven days postmortem aging. Muscles from the

USDA Select grade should be aged a minimum of 14 days postmortem to achieve optimum tenderness.

Location within a muscle was found to have an effect on WBS values in four of the nine muscles evaluated. This would indicate that muscles would have to be treated on an individual basis when fabrication and merchandising individual retail cuts or portions from muscles of the chuck and round. For some muscles, location within the cut can be ignored and for others location must be considered for tenderness enhancement or product utilization.

Table 3-1. Means, standard deviations, minimum, and maximum values for WBS at 14 days postmortem aging by muscle

Subprimal	Muscle	Mean, kg	SD	Minimum, kg	Maximum, kg
Chuck	Triceps-lateral	3.8	0.66	2.1	5.2
	Triceps-long	3.8	0.67	2.5	5.3
	Splenius	4.5	0.97	3.0	6.4
	Complexus	3.7	0.97	2.3	7.2
	Rhomboideus	5.2	1.13	3.3	7.3
	Serratus ventralis	3.7	0.78	2.1	5.2
	Infraspinatus	2.8	0.58	1.8	4.5
Knuckle	Vastus lateralis	4.5	0.96	3.1	7.2
	Rectus femoris	3.8	0.78	2.4	5.5

Each muscles mean represents an average of 768 measurements.

Table 3-2. WBS values for muscles of the chuck and knuckle averaged across all aging periods

Subprimal	Muscle	Mean, kg	SD
Chuck	Triceps – lateral head	3.9[d]	0.79
	Triceps – long head	3.8[de]	0.76
	Splenius	4.4[c]	1.07
	Complexus	3.6[e]	0.85
	Rhomboideus	5.0[a]	1.27
	Serratus ventralis	3.6[e]	0.84
	Infraspinatus	2.8[f]	0.75
Knuckle	Vastus lateralis	4.7b	0.97
	Rectus femoris	3.8[de]	0.97

[abcdef] Means with the same superscript in the same column are not significantly different at $P<0.05$ according to LSD=0.225. Each muscles mean represents an average of 768 measurements.

Table 3-3. WBS values by grade and aging treatment

	Postmortem aging (days)									
Grade	7		14		21		28		Average	
	Mean, kg	SD	Mean, kg	SD	Mean, kg	SD	Mean, kg	SD	Mean, kg	SD
Select	4.4^{ax}	1.32	4.0^{bx}	1.01	4.1^{bx}	1.15	3.9^{bx}	0.91	4.1^{x}	1.12
Top Choice	3.9^{ay}	1.23	3.9^{ax}	1.09	3.8^{ay}	1.05	3.8^{ax}	1.11	3.9^{y}	1.12
Average	4.2^{a}	1.30	4.0^{b}	1.05	4.0^{bc}	1.11	3.8^{c}	1.01	4.0	

^{abc} Means with same superscript on same row are not significantly different at P<0.05 according to LSD=0.21 for the individual grades, and LSD=0.15 for the average of the grades. ^{xy} Means with same superscript on same column are not significantly different at P<0.05 according to LSD=0.22 for the individual age groups, and LSD=0.18 for the average of all age groups. Each grade mean represents an average of 432 measurements.

Table 3-4. WBS values by location

		Location							
		A		B		C		D	
Subprimal		Mean, kg	SD	Mean, kg	SD	Mean, kg	SD	Mean, kg	SD
Chuck	Triceps-lateral	3.7[a]	0.72	3.9[a]	0.88	4.0[a]	0.74	4.1[a]	0.79
	Triceps-long	3.8[a]	0.86	3.8[a]	0.78	3.8[a]	0.66	4.0[a]	0.74
	Splenius	4.3[a]	1.00	4.5[a]	1.07	4.3[a]	0.86	4.7[a]	1.29
	Complexus	4.2[a]	1.02	3.7[b]	0.75	3.7[b]	0.74	3.1[c]	0.51
	Rhomboideus	5.3[a]	1.20	5.2[a]	1.37	5.1[ab]	1.28	4.8[b]	1.21
	Serratus ventralis	3.6[a]	0.70	3.6[a]	0.96	3.5[a]	0.64	3.7[a]	1.05
	Infraspinatus	2.9[a]	0.75	2.8[a]	0.73	2.7[a]	0.82	2.7[a]	0.68
Knuckle	Vastus lateralis	4.5[b]	0.85	4.5[b]	0.89	4.8[ab]	1.1	5.0[a]	1.04
	Rectus femoris	3.4[c]	0.83	3.8[abc]	0.88	3.9[ab]	1.12	4.1[a]	0.92

[abc] Means with same superscript in same row are not significantly different at $P<0.05$ according to LSD=0.45. Each muscle mean is an average of 1,728 measurements.

CHAPTER 4
EFFECTS OF QUALITY GRADE, AGING, AND LOCATION ON COOK AND THAW LOSS OF SELECTED MUSCLES OF LOCOMOTION OF THE BEEF CHUCK AND ROUND

Introduction

Recently, University of Florida and University of Nebraska Scientists characterized thirty-seven muscles of the beef chuck and round relative to size, shape, palatability, and composition (NCBA, 2000). This study revealed that a significant number of these muscles, when removed separately and cut across the grain, were very acceptable in sensory panel scores. Their conclusions were that there are numerous muscles that could be up-graded in value by cutting them into steaks rather than selling them as part of a roast or grinding into ground beef (NCBA, 2000). Kukowski et al. (2004) found the complexus, serratus ventralis, triceps brachii, and the infraspinatus were acceptable to consumers as steaks.

In recent years, economic pressures have challenged the livestock and meat industries to seek ways of producing meat products that will enable consumers to receive maximum palatability benefits at the lowest costs (Morgan et. al., 1991). With traditional roasts cuts being marketed as individual muscle steaks instead of roasts, valued could be added to the beef carcass (Kukowski et al., 2004). The round represents approximately 22% of the weight of a typical beef carcass and contains some of the least tender muscles of the carcass (Ramsbottom et al., 1945; Jones et al., 2001). Rhee et al. (2004) found that the adductor, semimembranosus, gluteus medius, and semitendinosus all from the round; and the supraspinatus from the chuck had high Warner-Bratzler shear force values (WBS

= 4.29 kg). Savell and Smith (2000) reported that the chuck represents about 30% of the total carcass weight. That is approximately 52% of the carcass that is currently used primarily as ground beef and roasts.

Miller et al. (2001) found that consumers were willing to pay a premium for steaks that reach certain levels of tenderness. One of the most prevalent and non-invasive methods of postmortem tenderization is “aging” meat at refrigerated temperatures (Parrish, 1997). Thaw loss and cook loss could be of concern when aging meat though (Mitchell et al., 1991). However, that study did not report significant differences in thawing or cooking losses among aging periods. Rhee et al. (2004) found a lower cooking loss for the biceps femoris in the round than any chuck muscles studied when aged to 14 days. As the industry begins to isolate individual muscles of the chuck and round for merchandising as steak cuts that will be cooked commonly with a dry cooking method, then more knowledge about how these muscles respond to postmortem aging is required.

The economic incentives for the industry to improve the tenderness of beef must be established before significant improvements in the consistency and palatability of beef will occur (Miller et al., 1998). Kukowski et al. (2004) asked panelist to assign a price/0.45 kg (0=would not buy, 10=$10/0.45 kg). Consumers were willing to pay $5.68/0.45 kg for the infraspinatus, and $5.15/0.45 kg for the triceps brachii. This could provide an incentive for retailers to use these individual muscles as steak cuts. Other cuts from the Kukowski et al. (2004) study that were found to be acceptable as steaks cuts were the serratus ventralis ($4.78/0.45 kg), and the complexus ($4.75/0.45 kg).

According to Miller et al. (1998), the most important factor in a tenderness study with consumers was to establish that a range in beef tenderness from tender to tough exists.

Continued work is needed on improving meat tenderness, primarily for retail cuts from the round and chuck. If consumers are willing to pay more for guaranteed tender beef products (Boleman et al., 1997), additional work needs to be conducted to investigate aging patterns of other muscles of the chuck and round so that the highest and best use for each muscle can be determined. And if thaw loss and cook loss is a concern with aging, the cost and benefit of aging versus loss needs to be explored. If certain muscles do not respond to aging then it seems a waste of resources to do so, and other methods of ensuring tenderness need to be explored. If muscles from the chuck and round do respond differently to aging, then targeting or customizing aging time to individual muscles and desired level of tenderness would seem appropriate.

Materials and Methods

Institutional Meat Purchase Specifications (IMPS) (North American Meat Processors, 1988) 115 2-piece boneless chucks and IMPS 167A peeled knuckles were purchased from a major packer of known USDA grade and slaughter date. Two grades of cuts were studied: USDA Select and the upper 2/3 of the USDA Choice grade. Eight subprimals of each grade were immediately shipped to the University of Florida Meats Laboratory for muscle separation. The IMPS 115 2-piece chuck was separated and the following muscles were selected for study: infraspinatus, triceps brachii – lateral head, triceps brachii – long head, serratus ventralis, complexus, splenius, and rhomboideus. The IMPS 167A knuckle was also separated and the vastus lateralis and rectus femoris were evaluated. These nine muscles were selected because of the possibility that these could be used as steak cuts where tenderness is critical due to the probability that they

would be cooked with a dry cooking method, based on results from the Muscle Profiling Study conducted by University of Florida and University of Nebraska in conjunction with National Cattleman's Beef Association (NCBA, 2000).

Each muscle was divided into four portions, progressing from anterior to posterior orientation to the carcass, or from dorsal to ventral orientation to the carcass depending on muscle fiber orientation: A was the 1st 25% portion of the muscle, B was the 2nd 25% portion of the muscle, C was the 3rd 25% portion of the muscle, and D was the 4th 25% portion of the muscle. One steak was removed for evaluation from each portion of the muscle to be studied. For small muscles the entire portion may have been used as the steak. Postmortem aging was conducted for 7, 14, 21, or 28 days at 2 ± 2°C cooler temperature. Individual steaks were vacuum sealed in Cryovac B550T (Sealed Air Corp., Duncan, SC) bags and subsequently heat shrunk in 82°C water as per manufactures recommendation. A Latin square was used to assign each steak into one of four postmortem aging treatments. There were eight 2 piece chucks from the USDA Select grade numbered one through eight, and eight knuckles from the USDA Select grade numbered one though eight. The same numbering system was used for the subprimals from the USDA Choice grade. For pieces one through four, the postmortem aging period was rotated clockwise for each location. For pieces five through eight, the positions for postmortem aging period was rotated counter-clockwise. This was done to remove muscle location effect. Also, this treatment allocation method allowed for location effect to be tested and determined statistically.

After achieving the appropriate postmortem aging treatment, steaks were frozen at -40° C then transferred to a -20° C holding freezer until analysis could be conducted.

Eight of each of the subprimals for each grade were sampled and replicated twice for a total of 32 subprimals boned to generate 288 muscles. Four steaks per muscle produced 1152 observations for this trial.

Steaks were thawed for 18 hours at 2 to 4° C then broiled on Farberware (Farberware, Bronx, NY) open-hearth broilers to an internal temperature of 71°C (American Meat Science Association, 1995). The housing and drip pans of each broiler were covered with aluminum foil and preheated for 15 min. Copper-constantan thermocouples attached to a potentiometer were placed in the approximate geometric center of each steak and used to record internal temperature. Steaks were turned when the internal temperature of 35° C was reached and removed from the broiler when the internal temperature reached 71°C. Weight in grams was taken while the steaks were frozen, after thawing, and after cooking for calculation of cook loss and thaw loss.

Least squares, fixed model procedures of SAS (2001) were used to analyze these data. This study was analyzed as a split-plot design where quality grade and muscle was the main-plot and postmortem aging and location were the sub-plots which were assigned using a Latin square design.

Results and Discussion

Thaw loss mean values and standard error means (SEM) are shown in Table 4-1 for the nine muscles averaged across all aging periods. The infraspinatus had the lowest amount of thaw loss, followed by the rectus femoris, splenius. The rhomboideus and the complexus had by far the most thaw loss, with the vastus lateralis and the triceps both lateral and long head being similar. The serratus was intermediate for thaw loss. Compared to Warner-Bratzler (WBS) shear force for the same nine muscles, from the previous chapter, the rhomboideus and the vastus lateralis were in the least tender tier of

muscles also. The infraspinatus had both the lowest amount of thaw loss and the lowest WBS. The thaw loss percentage could have an effect on the endpoint tenderness. The aging treatment did not have an effect on thaw loss.

The interaction of grade by age is shown in Figure 4-1. As USDA Select grade was aged from 7 to 21 days, there was an increased percentage of thaw loss. However, after 14 to 21 days of age, it seems that there is not further increase in thaw loss percentages. For USDA Choice grade, there was in increase from 14 to 28 days of aging. There is not a difference in thaw loss for steaks from the USDA Choice grade aged from 7 to 14 days. It seems also that by 28 days of aging, there were no significant differences in steaks from either the USDA Choice or the USDA Select grades

The splenius and vastus lateralis and triceps brachii lateral head had the largest amount of cook loss as shown in Table 4-2. The triceps brachii long head, the rectus femoris and the infraspinatus followed these muscles. The muscles with the least amount of loss were the serratus ventralis, rhomboideus and the complexus. The splenius, complexus and rhomboideus had low thaw losses and subsequently higher cook losses as compared to other muscles. Rhee et al. (2004) reported that the infraspinatus and the triceps brachii had low cook losses after 14 days of age. This is consistent with the findings of the current study with the exception of the higher cook loss for the triceps brachii lateral head.

The analysis of variance revealed a grade by muscle interaction effect (Figure 4-2). The muscles responded differently depending on grade. The most significant cook loss was observed for the triceps brachii- lateral head and the serratus ventralis. The explanation of this is not clearly obvious but could be due to the amount of exposed

muscle fibers during the cooking process. The muscle fibers from these steaks run in a fan shaped pattern allowing for more detrimental effects of heat to the fibers. Another possibility is the amount of connective tissue that is located within these muscles. There could be a great cook loss with a higher amount of connective tissue although Mitchell et al. (1991) and Jones et al. (1992) did not observe this difference. This difference may have been seen in the infraspinatus also if the connective tissue had not been trimmed from the muscle prior to steak separation.

All other muscles had less observable losses for both the USDA Select and USDA Choice steaks. The triceps brachii long head and to a less extent, the rhomboideus had a slightly higher cook loss for USDA Choice, but it was not significant. Berry and Leddy (1990) observed a lower cooking loss for USDA Select steaks than USDA Choice steaks when the steaks were broiled. This does not agree with the current study where USDA Select had a higher amount of cooking loss than did USDA Choice.

The interaction effect of age by subprimal approached a level of significance with P=0.071). This interaction is shown in Figure 4-3. As the chuck was aged from 7 to 28 days, the cook loss tended to increased. With the knuckle, the cook loss tended to decrease from 7 to 14 days of aging and from 21 to 28 days of aging. Cook loss remained consistent from 14 to 21 days of aging. There are more detrimental effects to steaks from the knuckle when they are aged from 14 to 21 days. Rhee et al. (2004) reported that low biceps femoris cook losses were unique among muscles from the round. It seems that in the current study, there is a larger cook loss associated with muscles from the knuckle.

The majority of researchers have not reported a significant difference in cook losses and thaw losses among grade or muscle (Mitchell et al., 1991; Jones et al., 1992; Shackelford et al., 1997) with the exception of higher cook losses when steaks are cooked with a belt grill.

Implications

There is a greater amount of thaw loss and cook loss for steaks from USDA Select than for steaks from USDA Choice grades. Further research needs to be conducted to discover why. Aging USDA Select grade from 14 to 21 days seems to reduce the likelihood that further increases in thaw loss percentages will occur. For USDA Choice grade there is no differences in thaw loss until after 14 days of postmortem aging. After 28 days of aging there is no difference in thaw loss steaks between the USDA Choice or the USDA Select grades. It is suggested that aging past 14 days will increase thaw loss, but cook loss is possibly only affected by cooking method as suggested by Shackelford et al. 1997).

Table 4-1. Thaw loss for muscles of the chuck and knuckle averaged across all aging periods

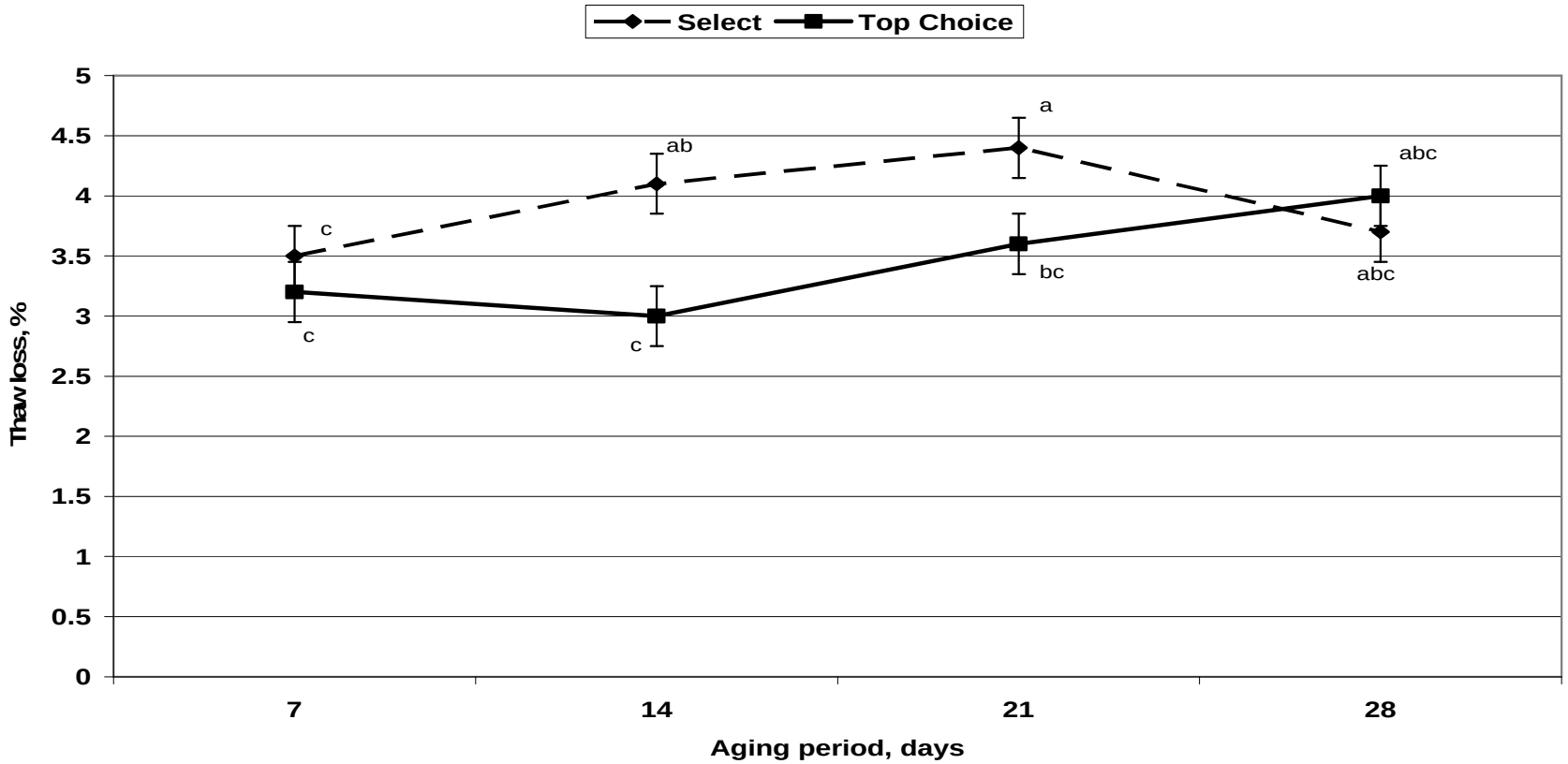
Subprimal	Muscle	Mean, %	SEM
Chuck	Triceps – lateral head	3.8[cd]	0.23
	Triceps – long head	3.8[bcd]	0.23
	Splenius	3.2[de]	0.23
	Complexus	4.9[a]	0.23
	Rhomboideus	4.5[a]	0.23
	Serratus ventralis	3.5[cd]	0.23
	Infraspinatus	2.2[f]	0.23
Knuckle	Vastus lateralis	4.2[ac]	0.23
	Rectus femoris	3.1[e]	0.23

[abcdef] Means with the same superscript in the same column are not significantly different at $P<0.05$. Each muscle mean is an average of 768 measurements.

Table 4-2. Cook loss for muscles of the chuck and knuckle averaged across all aging periods

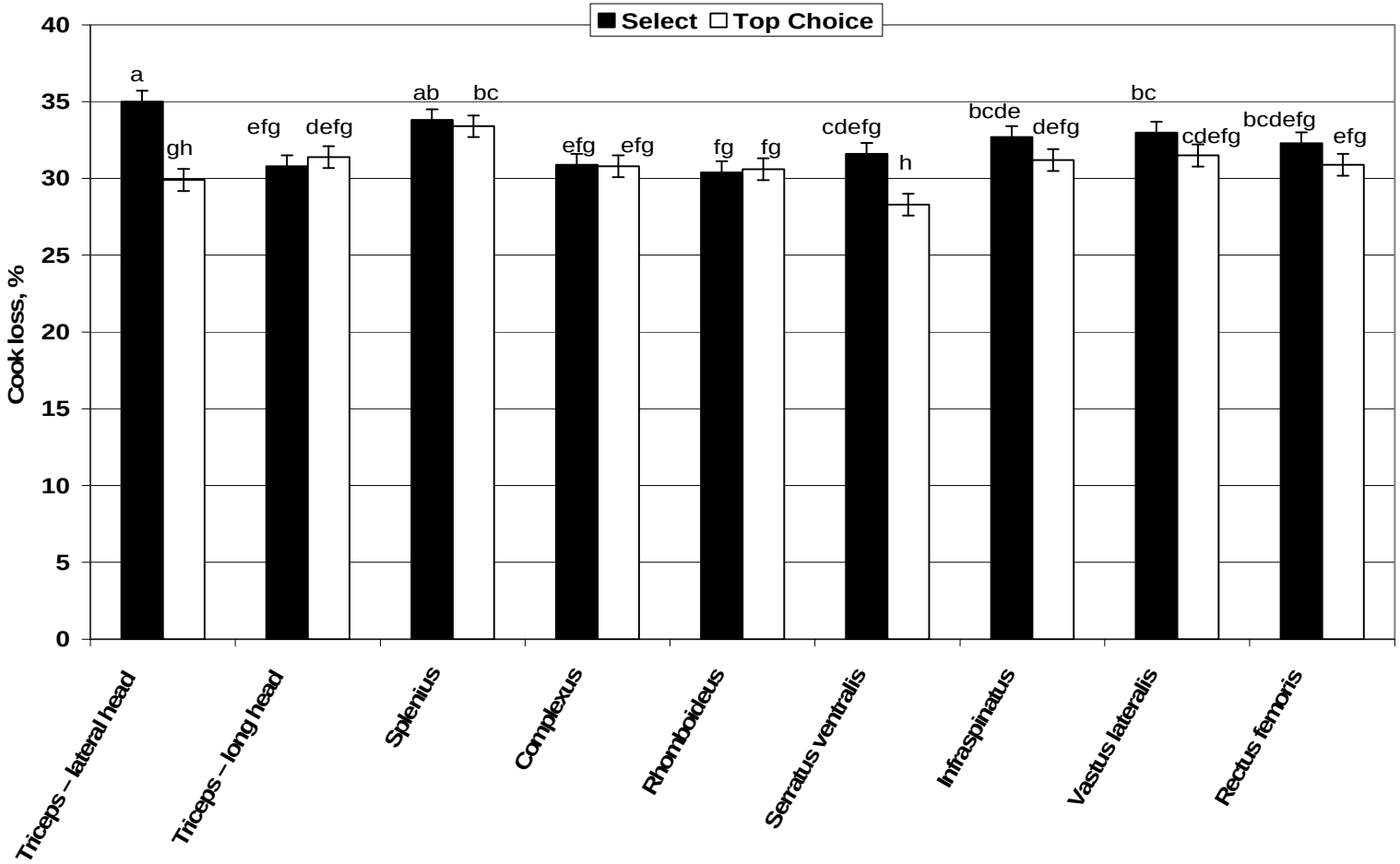
Subprimal	Muscle	Mean, %	SEM
Chuck	Triceps – lateral head	32.4[ab]	0.50
	Triceps – long head	31.1[bcde]	0.50
	Splenius	33.6[a]	0.51
	Complexus	30.8[cde]	0.51
	Rhomboideus	30.5[de]	0.51
	Serratus ventralis	30.0[e]	0.50
	Infraspinatus	30.9[bcd]	0.50
Knuckle	Vastus lateralis	32.3a[b]	0.50
	Rectus femoris	31.6[bcd]	0.50

[abcde] Means with the same superscript in the same column are not significantly different at $P<0.05$. Each muscle mean is an average of 768 measurements.



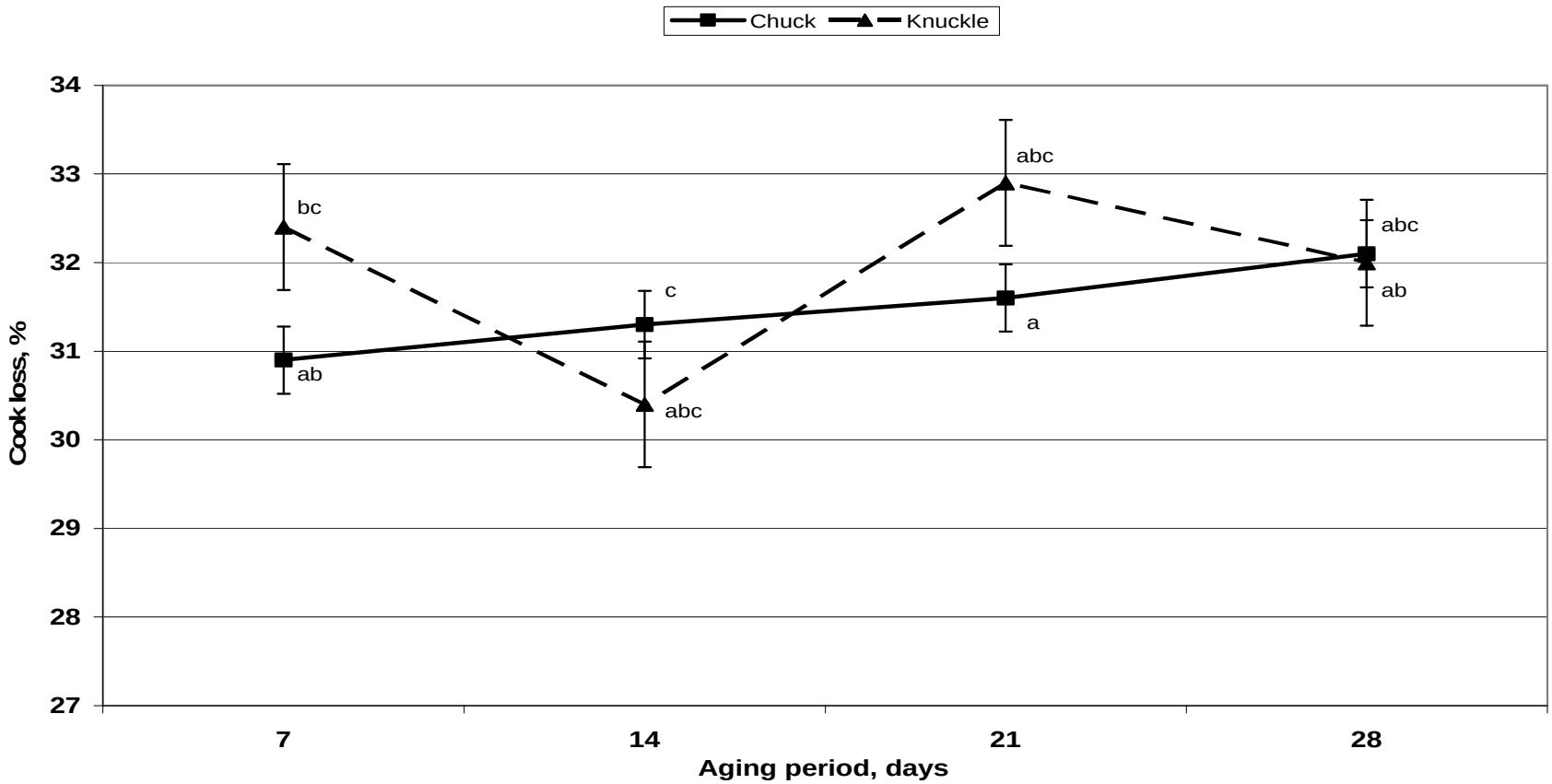
[abc]Means with the same superscript are not significantly different at P<0.05. Each grade mean is an average of 864 measurements.

Figure 4-1. Thaw loss average for grades across aging periods.



[abcdegfh]Means with the same superscript in the are not significantly different at P<0.05. Each muscle mean at each grade is an average of 384 measurements.

Figure 4-2. Cook loss for muscles by grade.



[abc]Means with the same superscript are not significantly different at P<0.05. Each chuck mean is an average of 1,344 measurements. Each knuckle mean is an average of 384 measurements.

Figure 4-3. Cook loss of subprimals averaged across grade by aging period.

CHAPTER 5
CONCLUSIONS

Postmortem aging affects all of the muscles evaluated in this study in a similar fashion. Therefore, consistent recommendations about postmortem aging can be given for these muscles of locomotion. This study revealed that USDA grade would have an effect on postmortem aging, in that for muscles from the upper two-thirds of USDA Choice grade were not significantly improved after seven days postmortem aging. Muscles from the USDA Select grade should be aged a minimum of 14 days postmortem to achieve optimum tenderness.

Location within a muscle was found to have an effect on Warner-Bratzler shear values in four of the nine muscles evaluated. This indicated that muscles would have to be treated on an individual basis when fabricating and merchandising individual retail cuts or portions from muscles of the chuck and round. For some muscles, location within the cut can be ignored and for others location must be considered for tenderness enhancement or product utilization.

There was a greater amount of thaw loss and cook loss for steaks from USDA Select than for USDA Choice grades. It was not entirely obvious as to why, so further research needs to be conducted. Aging USDA Select grades from 14 to 21 days seems to reduce the likelihood that further increases in thaw loss percentages will occur. For USDA Choice grades, there was no difference in thaw loss until 14 days. After 28 days of aging there was no difference in thaw loss of steaks between the USDA Choice and the

USDA Select grades. Aging past 14 days postmortem will increase thaw loss, but cook loss is possibly only affected by cooking method.

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BIOGRAPHICAL SKETCH

Christy Lynn Greenhaw Bratcher was born in Huntsville, Alabama on October 23, 1979. She spent the first 11 years of life in a small town in North Alabama called Arab. In 1991, she moved to Daytona Beach, Florida, with her parents and brother. After high school, Christy attended the University of Florida pursuing a degree in animal sciences to ultimately become a large animal veterinarian. During the first two years of college, she became interested in meat sciences and specialized her animal sciences degree by pursuing the option of food safety and meats processing. During her undergraduate program, Christy was involved with Gator Collegiate Cattlewomen and Alpha Zeta, as well as holding a job as a veterinarian technician and then an assistant at the University of Florida Meat Processing Center, and did an internship with Buckhead Beef in Atlanta, Georgia, for 3 months. This internship became a part-time position for her as she finished her Bachelor of Science degree. She also became the teaching assistant for ANS 2002, The Meat We Eat, from Fall 2001 to Spring 2002. These experiences guided Christy to pursue a Master of Science degree in animal sciences, after graduating with a Bachelor of Science degree in Spring of 2002.

Also, while pursuing her undergraduate degree, Christy was married to Michael Bratcher in May of 1999. Michael was pursuing a degree at the University of Florida in exercise and sport sciences with the goal of becoming a physical education teacher and football coach.

In August 2002, Christy was accepted to a graduate research and teaching program at the University of Florida Department of Animal Sciences under the direction of Dr. W. Dwain Johnson. Her major responsibility during the program was to teach ANS 2002, The Meat We Eat, and to assist with other meat science undergraduate courses. In the 2003-2004 school year Christy was the recipient of the Jack Fry Graduate Teaching Award for the College of Agricultural and Life Sciences. As a graduate student she was involved with the Animal Sciences Graduate Student Association and the Graduate Student Council.