Alternative Fabrication and Muscle Profiling of the Beef Top Sirloin Butt

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ABSTRACT

Muscle profiling improves value and optimization of beef carcasses by expanding knowledge of physical, compositional, and marketable attributes of single-muscle cuts. Traditional fabrication of the beef top sirloin butt (NAMI #184) incorporates several muscles into a single steak, leading to tenderness variation and inconsistent portion sizing compared to steaks consisting of a single muscle. The objective of the study was to isolate and discern yield and intrinsic characteristics of individual muscles and muscle subunits of top sirloin butts (N = 70) collected from carcasses ranging in quality grade (QG: USDA Select and Top Choice), hot carcass weight (HCW: light ≤ 362 kg, medium = 363 - 453 kg, heavy ≥ 454 kg), and ribeye area (REA: small ≤ 27.8 cm^2, medium = 27.9 - 40.6 cm^2, large ≥ 40.7 cm^2). Weight and dimension (length, width, height) were obtained for the whole top sirloin, *Biceps femoris* (BF), *Gluteus accessorius* (GA), and *Gluteus medius* [whole, dorsal (GMD), ventral (GMV)]. From each muscle and muscle subunit, a 2.54cm steak was obtained and analyzed for fluid loss, color, pH, and tenderness. Results show USDA Select carcasses yielded heavier top sirloin butts than Top Choice carcasses ($P = 0.001$), with Select products having less yield loss compared to Top Choice (35.5% vs. 41.4%). Weights of top sirloin butts increased as HCW increased from light to heavy ($P < 0.001$), and REA increased from small to large ($P < 0.001$). For all individual muscles, weights were found to be heavier in Select carcasses compared to Top Choice: BF ($P < 0.001$), GA ($P < 0.001$), GM whole ($P < 0.001$). Three-way interactions between QG, HCW, and REA were observed for weight of the GM whole ($P = 0.036$), width of GMD ($P = 0.004$), and length of GMV ($P = 0.039$), confirming the GM muscle was the primary source of muscle size variation in the beef top sirloin butt. For individual muscles (BF, GA, GMD, GMV), USDA Top Choice muscles were more tender than Select ($P < 0.001$). Objective tenderness, measured using averaged Warner-Bratzler shear force values, were the lowest for the GA and BF ($P < 0.001$) and were statistically different than the GMD and GMV. A two-way interaction for a^* color score ($P = 0.046$) between individual sirloin muscle and quality grade indicated BF and GA muscles within either quality grade were more red than GM muscles, and USDA Select GM muscles were redder than Top Choice GM muscles. The BF presented the lowest L^* value ($P < 0.001$), thus the darkest color. The GA reported the highest pH value ($P < 0.001$), with the lowest percentage of fluid loss ($P < 0.001$). *Gluteus medius* muscle subunits manifested the highest shear force values ($P < 0.001$), lightest color ($P < 0.001$), lowest pH ($P < 0.001$), and most fluid loss ($P < 0.001$). All four top sirloin muscles and muscle subunits averaged peak shear force values below 3.9 kg, thus, all within the threshold for USDA “very tender.” The resulting muscle profiling data will benefit in identifying new beef value cuts from the top sirloin butt and assessing acceptability of sirloin cuts for further retail and foodservice merchandising opportunities.

Keywords: beef, top sirloin, muscle profiling, *Gluteus accessorius*

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DEDICATION

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LIST OF ABREVIATIONS

BF	*Biceps femoris*
C	Celsius
GA	*Gluteus accessorius*
GM	*Gluteus medius*
GMD	*Gluteus medius*, dorsal
GMV	*Gluteus medius*, ventral
GP	*Gluteus profundus*
HCW	Hot carcass weight
IF	*Infraspinatus*
NAMI	North American Meat Institute
PM	*Psoas major*
PSO	Purchaser Specified Option
QG	Quality grade
REA	Ribeye area
SAS	Statistical Analysis System
SEM	Standard Error of the Mean
SR	USDA National Nutrient Database for Standard Reference
USDA	United States Department of Agriculture
WBSF	Warner-Bratzler shear force

CHAPTER 1

Review of Literature

Introduction

The top sirloin butt has long been recognized as an economical and versatile beef subprimal (Hosch, 2012). Therefore, top sirloin cuts are offered on a variety of menus, with diverse utilization as steaks, grind, and value-added products, all offered at affordable, consumer friendly prices (NCBA, 2001). King et al. (2009) found that consumers consider top sirloin steaks to be of comparable eating experience to steaks from the beef knuckle in the round. This is good news for food service wanting to enhance profitability of the round; however, it is unfortunate for the value of the sirloin and for consumers purchasing sirloin steaks expecting an elevated eating experience. Muscle profiling has proven to be an effective means of increasing consumer awareness and purchase interest for cuts fabricated from locomotive primals (Calkins, 2009). Research has been conducted for yield and palatability properties of traditional cuts from the top sirloin (Beyer et al., 2021; King et al., 2021; Olson et al., 2019; Colle et al., 2016 & 2015; Apple et al., 2014; Smith et al., 2014; Hosch et al., 2013; Machete et al., 2013; King et al., 2009; Machete, 2009); however, full muscle profiling of the top sirloin subprimal utilizing modern fabrication methods remains understudied. Additionally, beef hot carcass weights (HCW) and ribeye areas (REA) continue to rise (Boykin et al., 2017), thus further understanding is necessary to evaluate how various carcass characteristics impact individual top sirloin muscle yield and palatability. The review of this literature outlines the importance of comprehensive muscle profiling for the beef top sirloin butt, which contains the *Gluteus medius* (GM)*, Biceps femoris* (BF)*, Gluteus accessorius* (GA)*,* and *Gluteus profundus* (GP). Expanding knowledge of muscles that comprise the top sirloin subprimal will aid wholesalers, retailers, and branded meat programs in selection of carcasses that will achieve consistent portion cutting and eating quality of top sirloin cuts, in turn, adding value to the beef commodity.

Gluteus medius

The function of the GM is to extend the hip joint and abduct the limb (Jones et al., 2004). The GM center-cut may be further fabricated into dorsal and ventral muscle subunits, yet comparisons between the two subunits are understudied (Apple et al., 2014). To date, Machete (2009) is the most complete muscle profile of the GM. Morgan et al. (1991) declared that top sirloin steaks are the most unpredictable retail steak offering for tenderness, with Machete (2009) proving that a tenderness gradient exists within the GM, becoming less tender from anterior to posterior locations. When compared to the *Infraspinatus* (IF), *Subscapularis,* and *Rectus femoris*, the GM was reported to be the least tender, least juicy, and have the most connective tissue, with a mild off-flavor (Yeh et al., 2018). Shackleford et al. (1995) found the GM was above average for other muscles studied for intensity of beef flavor, yet average for tenderness and juiciness. It has been reported that the GM possess a more intense beefy flavor and greater off flavors than the *Psoas major* (Rhee et al., 2004; Shackleford et al.,1995). When an off flavor is detected in the GM, it is described as sour (Yeh et. al., 2018).

Biceps femoris

The function of the BF is to extend the hip and hock joints, while flexing the stifle when the foot is off the ground (Jones et al., 2004). NCBA (2001) was one of the first publications to suggest innovatively merchandising the BF as the Coulotte. Although the BF residing within the top sirloin subprimal has become a popular retail item due to flavor and tenderness, Paul and Bratzler (1955) categorized the BF as "moderately tough," ranking similarly alongside neck and shank meat, flank steak, and mock tender. Various researchers have confirmed that there is a strong variation of tenderness as the BF extends posterior into the round (Colle et al., 2016; Gruber et al., 2006; Rhee et al., 2004; Prost et al., 1975; Ramsbottom et al., 1945). Ramsbottom et al. (1945) discovered that size, weight, pH, and tenderness differed between muscles, and on occasion, even within the muscle. This was one of the earliest studies to demonstrate the BF progressively becomes less tender from anterior to posterior, with Apple et al. (2014) and Senaratne et al. (2010) confirming that the more tender portion of the BF is within the anterior (sirloin) portion, opposed to the portion residing in the bottom round.

Gluteus accessorius & Gluteus profundus

The function of the GA is to extend the hip joint and abduct the limb; the function of the GP is to abduct and rotate the thigh inward (Jones et al., 2004). Limited academic discussion exists for the GA and GP, only being mentioned as removed prior to conducting yield trials or palatability profiling of top sirloin steaks (King et al., 2021; Apple et al., 2014; Smith et al., 2014; Desimone et al., 2013). As discussed by Clark (2019), the GA and GP may be merchandised together as the "Mouse"; however, experts explain that processors have not experienced great success with this combination of muscles being sold in U.S. retail. This is likely due to the fan-like shape of muscle fibers comprising the GP and presence of connective tissue (Jones et al., 2004). Instead, both GA and GP muscles are commonly incorporated into lean beef trimmings or old-fashioned multi-muscle sirloin steaks (Smith et al., 2014; Jones et al., 2004). It has been postulated that further value may be added to the top sirloin butt and the entire beef commodity if the GA were fabricated individually and sold as a single-muscle steak.

Muscle Profiling

Muscle profiling is an essential tool for studying physical, compositional, and marketable attributes of meat products (Jung et al., 2016). A major muscle profiling study (Von Seggern et al., 2005) conducted comprehensive muscle profiling research on the beef chuck and round, evaluating individual muscle cuts for weight, dimension, color variability, pH, composition, cook loss, and tenderness. Individual muscle profiling found unique differences in the muscles of the round and chuck, making it worthwhile to conduct muscle profiling as a means of increasing commodity value (Calkins, 2009). As a result of this initial muscle profiling study, the Bovine Myology online resource was created (Jones et al., 2004). Bovine Myology has become a highly used and greatly beneficial tool in characterization of individual muscles for size, location, orientation, and standardization of nomenclature, while also being a catalyst for alternative fabrication and processing techniques. Through use of these carcass mapping resources, further understanding and value has been added to beef carcasses, shifting trends towards marketing individual whole-muscle cuts opposed to traditional multi-muscle steaks and roasts (Jung et al., 2016).

Beef Value Cuts

As a result of the muscle profiling study by Von Seggern et al. (2005), beef value cuts such as the flat iron steak, petite shoulder tender, and ranch steaks were introduced to consumers, increasing the worth of the beef chuck primal by 60% (Calkins, 2009). Three years after the introduction of these innovative cuts, the flat iron steak, alone, exceeded an annual volume of 37 million kgs of steakable product added to retail (Hosch, 2012). This study also revealed that beef carcass value increased between \$70 - \$90 from 1998 to 2009; a period that captured beef prices before the introduction of these value cuts and nine years following their availability to consumers, which also demonstrates the steady increase in valuation of beef over the span of a decade. Seeing the economic benefits to the beef industry, further value cuts have been developed from the chuck such as the country-style chuck ribs, Sierra cut steak, and the Denver cut steak (Calkins, 2009). These alternatively fabricated cuts are comprised of single muscles rather than cutting steaks across multiple muscle groups that may vary in tenderness, texture, connective tissue content, color stability, and fluid retention. Researchers found that these new beef value cuts ranked similar to the ribeye for tenderness, juiciness, flavor, and overall likeness, outperforming top sirloin and bottom round steaks (Lepper-Blilie et al., 2014). This study reflected praise from the National Cattlemen's Beef Association for the potential of these innovative steaks and roasts to be highly accepted at retail, referring to them as "next generation value cuts."

Carcass Characteristics in Relation to Palatability

The 1991 National Beef Quality Audit (Smith et al., 1992) published a list of the Top 15 quality concerns for beef palatability, finding 11 of the top concerns to be related to carcass yield characteristics (Savell and Shackelford, 1992). The number one concern was low overall uniformity of beef. Lusk et al. (1999) found that beef consumers base purchasing decisions on consistency of products and will pay more for a guaranteed tender steak. Palatability remains the highest precedence for consumer acceptability of beef, however, individual muscles are not consistent in their attributes of tenderness, juiciness, or flavor (Jung et al., 2016).

The past five National Beef Quality Audits have identified increasing HCW as a top 10 concern for beef quality (Boykin et al., 2017; Garcia et al., 2008; McKenna et al., 2000;

Boleman et al.,1998; Lorenzen et al., 1993), with average HCW increasing at a pace of approximately 2 kg per year (USDA – NASS, 2021). As HCW continues to rise, so does the variability of muscle sizing. Previous research has proposed sorting carcasses by REA to achieve consistent portion sizing of custom cuts (Steele et al., 2020). This research is combatted by Bass et al. (2009), which shows REA was not sufficient in predicting muscle size in other subprimals throughout the carcass. As REA is not a reliable indicator of portion size for other muscles, this method of sorting carcasses may cause for misrepresentation of beef carcass value.

With increasing HCW and REA, steaks are being cut thinner to remain equivocal in servings sizes portioned to consumers (Sweeter et al., 2005). Sweeter et al. (2005) found that consumers did not have a preference between light and heavy weight carcasses when assessing eating quality of beef. In fact, in that particular study consumers were willing to pay a premium for larger ribeyes. Consumers were less favorable of smaller portions being achieved by cutting ribeye steaks in half. As this research confirmed large carcasses were not a detriment to consumer purchasing decisions at retail, the beef industry has continued charging forward with cattle breeding, feeding, and management strategies that focus on increasing gains and finishing weight of beef cattle (Boykin et al., 2017; Aberle et al., 1981).

Traditional vs. Alternative Fabrication

Early methods of cutting meat were strongly influenced by cultural heritage and religious affiliation of butchers and community members in cities along the East Coast of the United States (Hosch, 2012). Although standard methods of fabricating beef carcasses did not exist until the 1940's (National Provisioner, 1942), these practices have remained relatively unchanged. Early methods of meat cutting are referred to as "traditional" or "conventional" fabrication methods. Following the Von Seggern et al. (2005) muscle profiling study, "alternative" and "innovative" cutting styles were quickly adopted in many large processing facilities to add value to beef carcasses by isolating high value, single muscle cuts from the chuck and round. Smaller family-owned processors, however, are more hesitant to adopt new cutting techniques due to ease of cutting bone-in multi-muscle steaks on the bandsaw, and customer recognition of traditional cuts (Calkins, 2009). Separation of individual muscle cuts require additional understanding of beef carcass anatomy to keep muscles intact and remove connective tissue that may inhibit tenderness (Ramsbottom et al.,1945). Appropriately adjusting fabrication methods to shift from multi-muscle steaks and roasts to singular muscle cuts may not only provide consumers with more desirable portion sizing, but also improve consistency and palatability of beef (Jung et al., 2016).

Studies have been conducted to explore optimization of beef value through innovative fabrication, comparing traditional and alternative fabrication methods of the beef chuck and round (Jung et al., 2016; West et al., 2011; Pfeiffer et al., 2005; Jeremiah and Gibson, 2003). Pfeiffer et al. (2005) found innovative fabrication increased saleable yield of the beef chuck, yet hindquarter cut yields were unchanged compared to conventional styles of fabrication. This study also reported that innovatively processing chucks and rounds added $14 of total value to the beef carcass compared to conventional processing, with innovative two-piece beef top sirloins adding $1.99 per carcass. Inversely, West et al. (2011) found that yields were lower for innovatively fabricated top sirloin butts and ribeyes opposed to conventional cutting methods. This study also found that carcasses with heavy HCWs yielded more saleable product for the striploin and ribeye, but not the top sirloin. Finally, heavy HCWs took longer to fabricate than average weights, and innovative styles took longer to fabricate than conventional.

Innovative fabrication has also aided in reducing connective tissue within beef (Jung et al., 2016). Ramsbottom et al. (1945) reported that connective tissues found within the IF and BF were so tough, they required more force to shear than the Warner-Bratzler shear force (WBSF) machine would allow (54.43 kgs of force), even being greater than uncooked ligamentum nuchae at 36.79 kgs of force. Today with innovative fabrication, the IF is recognized as the second most tender muscle in the entire carcass (Calkins and Sullivan, 2007), next only to the tenderloin. Through the years, alternative fabrication methods of individual muscles have expanded our understanding of these single muscle cuts, changing fabrication styles to exclude connective tissue, thus improving tenderness and allowing for substantial value to be added to the beef commodity.

Traditional-style top sirloin steaks are cut end-to-end with all four muscles present – GM, BF, GA, GP (West et al., 2011). Some methods of fabricating the top sirloin butt include separating the BF from the GM center-cut, with each being merchandised separately. Additional methods of fabricating top sirloin butts refer to the GM dorsal and ventral subunits also being divided. However, even these boneless cutting styles exclude the GA and GP, discarding both into lean beef trimmings (West et al., 2011). True innovative fabrication of the top sirloin butt should separate all four muscles individually, utilizing the GM, BF, and GA as retail cuts, with only the GP being incorporated into lean trimmings. It is anticipated that innovative fabrication of top sirloin butts would result in lower or unchanged yield percentage compared to traditional fabrication methods. Nevertheless, it is foreseen for value of the top sirloin to increase by $1.99 (Pfeiffer et al., 2005) or 11.6% (West et al., 2011) as tenderness, marketability, and consumer awareness improve with introduction of single-muscle top sirloin steaks.

Tenderness

Muscle tenderness is influenced by functional use in the live animal, degree of muscle contraction upon onset of rigor mortis, enzyme activity, and amount of connective tissue (Montgomery and Leheska, 2008). Tenderness is easily evaluated by consumers and often is the primary determinant of retail value for beef cuts (Lusk et al., 1999). The two most widely accepted methods of evaluating tenderness of meat are WBSF and sensory analysis (Montgomery and Leheska, 2008). Warner-Bratzler shear force evaluates objective mechanical tenderness, measuring the peak strength (kg of force or Newtons) required to "bite" through a muscle sample. Subjective tenderness utilizes sensory analysis data, collected either through a consumer taste panel assessing acceptability or trained taste panel assessing a ranking based on calibrated samples. Consumers recognize meat as tender at a WBSF value of 4.1 kg or less (Huffman et al., 1996). The USDA has set the parameter for certified "tender" at a WBSF value of 4.4 kg, and certified "very tender" at 3.9 kg or less (ASTM, 2008). Over the years, it is noticeable that WBSF values of beef products have continued to decrease (Boykin et al., 2017; Voges et al., 2007) This is likely due to improvements in cattle genetics, nutrition, and beef production practices, as well as improved chilling rates, electrical stimulation, and advancements in product aging management (Nair et al., 2019; Gruber et al., 2010; Hwang et al., 2003; King et al., 2003; Marshall, 1994; Aberle et al., 1981). As continuous focus is placed upon quality of the end product, it may be necessary for the USDA to reassign values for certified "tender" and "very tender" classifications.

Caution must be exercised when strictly ranking muscles based on WBSF values, as mechanical means of evaluating objective tenderness may not reflect results as a consumer would (Jung et al., 2016). Attempts have even been made in scientific literature to rank muscles based on tenderness (Calkins and Sullivan, 2007), however, such lists may be misleading due to a variety of factors used in each study, such as breed of cattle, location of cut, and cookery method. For example, Calkins and Sullivan (2007) did not find the *Longissimus dorsi* to be ranked in the top 10 muscles for tenderness, or the GM to be ranked in the top 30. Paul and Bratzler (1955) even ranked the eye of round over the striploin and ribeye for tenderness when strictly utilizing WBSF values.

Paul and Bratzler (1955) determined that middle meats were more tender than end meats, with Prost et al. (1975) finding the tenderloin to be the most tender muscle in the carcass and the BF as the least tender. These studies were important in demonstrating how tenderness may change within a muscle from anterior to posterior dependent on the muscle's positioning and orientation towards the middle of the body and away from locomotive regions. Quality grade (QG) of beef and aging time postmortem also play a role in improving qualities of tenderness (Beyer et al., 2021; Colle et al., 2016 & 2015). A variety of QGs should be used when making determinations about tenderness in individual muscles to ensure differences are being observed due to muscle components and function rather than marbling. It has been recommended that beef cuts should be aged at least 21 days before evaluating tenderness to ensure data is not simply reflecting differences from QG (Gruber et al., 2006). During one postmortem aging study, it took the GM four to six days longer for USDA Select steaks to reach the same tenderness levels of Top Choice steaks; beyond 21 days, tenderness of USDA Select and Top Choice muscles became similar (Gruber et al., 2006).

Color

Consumers use meat color as a measurement, or gauge, of freshness (Insani et al., 2008). Beef color at retail impacts the likelihood a consumer will purchase a product, as consumers often associate bright, cherry red color with freshness (Troy and Kerry, 2010). Even though consumer perceptions of color do not impact eating experience or perceived palatability (Carpenter et al., 2001), color remains one of the most influential factors in aiding a sale of beef at the meat counter. Smith et al. (2000) calculated that 15% of retail meats were discounted due to discoloration, resulting in an approximate net loss of $1 billion. Likewise, Ramanathan et al. (2022), found that 2.55% of beef is discarded each year due to discoloration, resulting in a loss of 194.70 million kg of product each year, equaling $3.73 billion dollars of lost revenue.

Myoglobin is the iron containing, oxygen binding compound in muscle that gives meat a distinguishable red color (Faustman and Cassens, 1990). Myoglobin serves both functions of storing and freeing oxygen in the cell and is also water soluble (Livingston, 1983). Mancini and Hunt (2005) confirmed that color dynamics are influenced by how closely heme iron is bound. Fernandez et al. (1994) found that darker color is due to less light scatter. Heme iron may occur in ferrous (Fe^{2+}) or ferric (Fe^{3+}) states (Machete, 2009). Ferrous states give meat a traditionally recognized, desirable color, either being purplish-red when vacuum packaged or bright cherry-red color when exposed to oxygen or packaged beneath oxygen permeable film. Oxidation of ferrous myoglobin results in the ferric state, referred to as metmyoglobin. A brown-green hue becomes present on the surface of meat which is considered as discolored (Livingston and Brown, 1981). Partial pressure of oxygen, decline of metmyoglobin reductase, pH, temperature, and growth of microbes all influence the rate of meat discoloration (Machete, 2009).

Color is assessed using colorimetric measurements *L**, *a**, and *b**, measuring dark to light (black = 0, white = 100), green to red (-50 to 50), and blue to yellow (-50 to 50), respectively (Page et al., 2001). McKenna et al. (2005) found that *L** values of the BF decrease after day 1 of retail display but remain fairly consistent throughout the remainder of display. This was different to other muscles, which steadily decreased in *L** values over time. This research concluded that “lightness” of a muscle played no role in color stability. The BF had lower oxygen penetration depths than the GM across a 5-day retail study. Additionally, *L** values for the BF increased over retail display time. The study found that muscles can be categorized based on color stability, with the GM having intermediate color stability and the BF having low color stability. *Psoas major* and IF were in the category “very low” color stability. This research found higher myoglobin content within muscles relates to lower color stability. McKenna et al. (2005) found the GM to have statistically similar myoglobin content (5.62 mg/g) as the BF (5.41mg/g), with statistically similar metmyoglobin reductase activity, corroborating that the GM has potential for extended color stability.

Muscle pH

During postmortem metabolism, lactic acid builds in muscle tissues due to the stoppage of circulating blood, thus becoming more acidic (Montgomery and Leheska, 2008). Faustman and Cassens (1990) determined normal muscle tissue possesses a pH between 5.4 and 5.8. This research explored the impact of glycogen content in muscle and temperature of muscle on ultimate pH of muscle tissue, finding ultimate pH to be a key determinant of meat color and water holding capacity. Thus, pH is a valuable assessment for overall meat quality. Higher pH creates greater water binding affinity, therefore, a firmer, less oxygen permeable meat product (Machete, 2009). Zhu and Brewer (1998) determined that low pH is a clear indication that product color will be more unstable compared to meat products with a higher pH.

Jeong et al. (2009) found that color stability is influenced by pH of muscle given the association of pH with performance ability of metmyoglobin reductase, oxygen consumption rate, and lipid oxidation. The effect of pH on color stability is impacted by post-mortem conditions, primarily pre-rigor pH decline and ultimate pH post-rigor (Machete, 2009). This research also determined steak cut location does not change muscle pH of the GM. Additionally, pH was not impacted by quality or yield grade.

Ground Beef Valuation

Ground beef is a highly versatile product of the beef commodity, generating $12.42 billion in retail sales annually (Ground Beef at Retail and Foodservice, 2021). In fact, the volume of beef products being consumed annually in ground form has jumped from 42% (Davis and Lin, 2005) to 61.6% (Ground Beef at Retail and Foodservice, 2021). The National Beef Checkoff reports 60% of consumers utilize ground beef as an ingredient, with 50% eating at least one hamburger each week (Ground Beef at Retail and Foodservice, 2021). Within this report, purchase data shows that consumers prefer to purchase ground beef that is 80-89% lean. Variation in beef price is found to be the ultimate factor that drives consumers to purchase ground beef products instead of steaks or roasts (Close, 2014).

Additionally, ground beef is served in similar forms in restaurants as at home, thus always presenting a recognizable and predictable eating experience. As most consumers do not put significant foresight into planning meals ahead of time, ground beef serves as a fast, simple meal-time solution. Majority of ground beef sold at retail (71 – 72%) is comprised of beef trimmings not being derived or categorized as a specific primal or subprimal; however, ground sirloin, ground chuck, and ground round are sold at a higher premium than nondescript ground beef (Wholesale Price Update, 2022). The most popular primal grind is ground chuck, with ground round and ground sirloin comprising only 4% of retail ground beef, yet still garnering $500 - $600 million in annual sales.

While ground sirloin currently holds the highest grind value above chuck, round, and assorted beef trimmings (Wholesale Price Update, 2022; Ground Beef at Retail and Foodservice, 2021), it is anticipated that further value may be added if the GA were fabricated individually and sold as a single-muscle steak being that consumers are willing to pay premiums for grillable meat options (Lusk et al., 1999). Questions remain if ground sirloin holds equal or higher value than what could be achieved by alternatively fabricating top sirloin butts in order to sell the GA as a single-muscle steak. Sirloin subprimals are significantly smaller than chuck and round primals, yielding less available product to incorporate into grind. A downfall of the muscle profiling project was finding less product was available for valuable grinds after alternative fabrication (Davis and Lin, 2005). To transition the GA from a muscle cut that is traditionally ground to one that is sold as a steakable item, no additional fabrication or retraining of butchery methods would be necessary for processors given the muscles anatomical location and natural dimensions (Jepsen et al., 2022). Processors would simply shift this whole muscle from the grind bin to the line-up of steaks ready to be packaged and sold at a premium.

Cookery

Despite efforts by the livestock and meat industries to raise, cut, and deliver high quality meat products for consumers, final preparation of meat is a key determinant of a product’s palatability. Overcooking is a high risk for reducing the tenderness, flavor, and juiciness of meat, ranking “high,” “high,” and “very very high,” respectively, for significant impact on overall palatability of meat (Montgomery and Leheska, 2008). In fact, degree of doneness is the most crucial influence of juiciness within a meat product in relation to all production or meat science interventions. Previous research has shown cookery, pH, and connective tissue attributes may differ substantially between muscles and muscle groups within the same subprimal (Jerimiah et al., 2003a; 2003b; 2003c), consequently influencing palatability and tenderness. Knowing that cookery method influences palatability and yield of the end product due to fluid loss, a study was conducted on beef retail cuts to measure beef fat, moisture and cooking yields (Roseland et al., 2015). Yet again, the top sirloin subprimal was excluded from the study, thus no conducive information could be gathered for this subprimal. Further research should be conducted to expand understanding of cooking times and fluid retention of sirloin steaks during cooking to aid consumers in having a consistent dining experience with top sirloin cuts, regardless if their meal is being prepared at home or in a restaurant.

USDA National Nutrient Database

Future research should be conducted to evaluate nutrient and lean attributes of the BF and GA, with updates being submitted to the USDA National Nutrient Database for Standard Reference (SR) (Acheson et al., 2015; USDA – ARS, 2015). Currently, only the GM is listed in the data base as "top sirloin steak." Performing proximate analysis on the BF and GA to assess percent fat, moisture, protein, and ash would achieve the desired analysis to include these whole muscle cuts into the database, providing valuable labeling transparency and marketability.

As three sirloin cuts are currently recognized as part of the 28 lean cuts of beef (NCBA, 2022), it is theorized that the GA would also qualify for this listing. Updates within the SR may allow for the GA to be labeled and categorized as "lean" or "extra lean," providing an additional healthful beef option to consumers. As beef cattle production practices continue to evolve, improvements are made to meat fabrication, storage, and cookery, and new retail value cuts are added, it is essential for regular updates to be made to the SR to ensure comprehensive and accurate profiling of beef nutritional information (Acheson et al. 2015).

The most recent update of the SR (13, pg. 69) features the addition of Beef Value Cuts from muscle profiling research (Acheson et al., 2015; Calkins, 2009; Von Seggern et al., 2005). The SR states that analysis was conducted on the newly introduced single muscle steaks and roasts from the chuck and round, identifying five of the six as USDA lean or extra lean. Within the SR, 24 retail cuts of beef have been profiled, with only one cut deriving from the sirloin: top sirloin steak (USDA – ARS, 2015). This is an exceptionally useful resource for wholesalers, retailers, restaurants, and consumers as the SR identifies muscles through species, primal, subprimal, scientific name, common name, and URMIS number. For each of the cuts provided, nutrient content is listed for raw and cooked forms. A greater percentage of restaurants are providing calorie and nutritional information on menus (Bleich et al., 2015), thus additional updates for the BF and GA may be increasingly valuable as marketability of these steaks are explored. This resource validates the need for muscle profiling specific data to be tracked and updated regularly to account for the everchanging variation within muscle fabrication, palatability, and cookery.

Conclusion

Muscle profiling improves utilization and value of beef carcasses through expansion of knowledge regarding yield, palatability, and salability of individual muscles. Exploring the implication of beef carcass characteristics such as QG, HCW, and REA on dimensional and compositional make-up of top sirloin steaks may provide solutions of addressing inconsistency within this subprimal. Additionally, alternative fabrication of beef top sirloin butts has potential to reduce variability in steak portion sizing, while increasing market value. This review of literature capitalizes the need for comprehensive muscle profiling to provide valuable purchasing, packaging, and marketing information to beef wholesalers, retailers, and branded meats programs. Furthermore, value may be added to the carcass and provide a more desirable, and predictable eating experience to the consumer.

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CHAPTER 2

Alternative fabrication, dimensional profiling, and yield analysis of the beef top sirloin butt

ABSTRACT

Traditional fabrication of the beef top sirloin butt (NAMI #184) incorporates several muscles into a single steak, leading to decreased tenderness and inconsistent portion sizing compared to steaks consisting of a single muscle. The objective was to isolate and discern yield and dimension of individual muscles and muscle subunits of top sirloin butts (N = 70) collected from carcasses ranging in quality grade (USDA Select and Top Choice), hot carcass weight (light ≤ 362 kg, medium = 363 - 453 kg, heavy ≥ 454 kg), and ribeye area (small ≤ 27.8 cm^2, medium = 27.9-40.6 cm^2, large ≥ 40.7 cm^2). Weight and dimension (length, width, height) were obtained for the whole top sirloin, *Biceps femoris* (BF), *Gluteus accessorius* (GA), and *Gluteus medius* [whole, dorsal (GMD), ventral (GMV)]. Results show USDA Select carcasses yielded heavier top sirloin butts than Top Choice carcasses ($P = 0.001$), with Top Choice products having higher yield loss compared to Select (41.4% vs. 35.5%). Weights of top sirloin butts increased as HCW increased from light to heavy ($P < 0.001$), and REA increased from small to large ($P < 0.001$). For all individual muscles, weights were found to be heavier in Select carcasses compared to Top Choice: BF ($P < 0.001$), GA ($P < 0.001$), GM whole ($P < 0.001$). Dimensional measurements of the GA were not significant (Length: $P = 0.565$, Width: $P = 0.311$, Height: $P = 0.819$). Three-way interactions were shown for weight of the GM whole ($P = 0.036$), width of GMD ($P = 0.004$), and length of GMV ($P = 0.039$), confirming GM muscles are the primary source of muscle size variation in the beef top sirloin butt. The yield and dimensional analysis generated from this study will be a useful resource to wholesalers, retailers, and branded meat programs for portion sizing and added value.

Keywords: beef, dimensions, yield, sirloin, *Gluteus accessorius*

INTRODUCTION

The beef top sirloin butt (NAMI #184) is comprised of four muscles: *Gluteus medius* (GM)*, Biceps femoris* (BF)*, Gluteus accessorius* (GA)*,* and *Gluteus profundus* (GP). Traditional methods of fabricating the top sirloin butt (NAMI #184) incorporate multiple, if not all, of these muscles and muscle subunits into a single steak or roast. Recognizing that consumers base purchasing decisions on tenderness and consistency of products (Bonny et al., 2018; Lyford et al., 2010; Lusk et al., 1999; Savell and Shackelford, 1992; Smith et al., 1992), this information presents challenges to beef processors, wholesalers, and branded meat programs who aim to deliver consistent and recognizable products to consumers with every sale.

Previous research exploring the significance of tenderness in beef purchasing decisions published a list of the "Top Fifteen Quality Concerns of the Beef Industry," (Savell and Shackelford, 1992; Smith et al., 1992). As this list intended to focus on concerns that impact beef palatability, it is interesting to note 11 of the 15 concerns related to carcass yield characteristics. As early as the beginning years of the 1990's, the beef industry recognized the overarching importance of uniformity in beef cattle, consistency of product size, and the role that increasing hot carcass weights (HCW) and ribeye area (REA) play in perceived tenderness and acceptability by consumers. Unfortunately, carcass variability continues to increase with rising HCW (USDA – NASS, 2021; Steele et al., 2020; USDA – ERS, 2020; Boykin et al., 2017).

Muscle profiling research was first conducted on the beef chuck and round, evaluating individual muscles for physical, compositional, and marketable attributes in attempt to add value to underutilized subprimals (Calkins, 2009; Von Seggern et al., 2005; Jones et al., 2004; Johnson et al., 1988). Following the publication of results in the early 2000's, beef value cuts such as the flat iron steak and petite shoulder tender were introduced to consumers, increasing the value of the beef chuck primal by 60% in just three years (Roybal, 2009). Seeing the economic benefits to the beef industry, commercial beef processors have sought to capitalize on beef value cuts by shifting from traditional, bone-in, multi-muscle cuts, to boneless, single-muscle steaks (Calkins, 2009; Carr et al., 2009; Roybal, 2009; Pfeiffer et al., 2005).

It has been hypothesized by the authors that differences will be observed between muscles and muscle subunits, thus, innovative fabrication will improve understanding of muscle size variability of the beef top sirloin butt subprimal. Limited academic discussion exists for smaller muscle portions, GA and GP, leaving researchers to ponder if further value may be added to the top sirloin butt if the GA were fabricated as a single-muscle steak. The primary objective of the current study was to isolate individual top sirloin muscles from carcasses ranging in quality grade (QG), HCW, and REA to assess yield and dimensional characteristics.

MATERIALS & METHODS

Product Procurement

Beef carcasses (N = 70) were selected from a commercial beef processing facility (Toppenish, WA) based on a 2x3x3 factorial matrix of QG, HCW, and REA (Table 2.1). Carcasses were sourced from youthful (determined to be less than 30 months of age physiologically by United States Department of Agriculture [USDA] grading protocol), concentrate fed, *Bos taurus*, beef cattle. Due to the postmortem opportunistic means of choosing the beef carcasses at the commercial beef processing facility the specific cattle rations, breeds, and other management practices were unknown to the researchers. Left sides of beef carcasses were evaluated on a USDA grading line using an E + V Vision Grading camera (VBG_{2000}, E + V Technology, Oranienburg, Germany) to measure marbling score and REA. Carcasses with marbling score of $Slight^{00-99}$ (USDA Select) and $Modest^{00}$ – $Moderate^{99}$ (Top Choice) were the parameters of the first factor. Within each QG, carcasses were selected for HCW; light (≤ 362 kg), medium (363 – 453 kg) and heavy (≥ 454 kg). The third factor was REA; small (≤ 27.8 cm^2), medium (27.9 – 40.6 cm^2), and large (≥ 40.7 cm^2). Of carcasses selected, the left-sided top sirloin butts were purchased boneless, not trimmed.

Product Preparation

Subprimals were transported under refrigeration (2°C) in vacuum packaging to the University of Idaho Meat Laboratory and aged for 21 d post-mortem at 4°C. Subsequently, top sirloin butts were weighed initially inside vacuum packaging. Once removed from packaging, top sirloins were trimmed to approximately 0.64 cm of subcutaneous fat to achieve industry standards.

Top Sirloin Butt, Whole

Whole top sirloin butts were weighed to account for yield loss, being measured as purge lost and excess fat removed from top sirloin butts during fabrication.

$$\begin{gathered} Yield\ loss = Whole\ weight, in\ bag - bag\ weight - weight\ BF, fat\ off - weight\ GA \\ - weight\ GP - weight\ GM, dorsal - weight\ GM, ventral \end{gathered}$$

Dimensional measurements (length, width, height) were measured using a 61 cm L x 40 cm H aluminum framing square for length and width, and a 16 cm L x 9 cm H combination square for height (ACE hardware, Product #27096 & #27097, Johnson Level & Tool MFG Co. Inc., Mequon, WI). Whole top sirloin butt subprimals were further fabricated, separating each individual muscle and muscle subunit independently to capture weight and dimensional data.

Biceps femoris

The BF (Top Sirloin Butt Cap; NAMI #184D) was removed from the top sirloin subprimal and weighed with fat-on. Dimensional measurements were recorded. The BF was then denuded of fat, weighed, and dimensional measurements were recorded again as “BF trimmed” to allow for BF trim yield analysis.

Gluteus accessorius & Gluteus profundus

The GA and GP were removed from the top sirloin subprimal as an intact subunit. Both muscles were weighed together as a single subunit, but dimensional measurements were not recorded as this combination of muscles holds little value in U.S. retail markets (Clark, 2019).

The GA was then separated from the GP, with silverskin left on. Weight and dimensional measurements for the GA were recorded. Weight of GP was calculated by subtracting the individual weight of the GA from the combined weight. The GP was excluded from the remainder of the study and incorporated into lean beef trimmings.

Gluteus medius, center-cut*: *Whole, Dorsal, & Ventral

The remaining portion of the top sirloin subprimal was the whole GM center-cut. The GM center-cut was weighed, and dimensional measurements were recorded. From the whole GM center-cut, the Dorsal Side (GMD; NAMI #184F) and Ventral Side (GMV; NAMI #184B PSO 1) were separated from each other. For the GMV, PSO 1 indicates that the dorsal portion of the GM was separated from the main portion by cutting through the natural seam (NAMA, 2014). The GMD was weighed individually, and dimensional measurements were recorded. The final remaining GMV portion was weighed individually, and dimensional measurements were recorded.

Statistical Analysis

Data were analyzed using a general linear model procedure of SAS V 9.4. (SAS Inc., Cary, NC), with significance being determined at $P < 0.05$. Simple statistics were generated through Microsoft Excel V. 16.60. Prior to full analysis, normality of each data set was ensured utilizing boxplots and regression models of the residuals to evaluate for skewness or outliers. A 2x3x3 factorial was evaluated for treatment effects. Quality grade, HCW, REA, and their interactions were assumed as fixed effects. Treatment least square means differences were assessed through pair-wise comparisons for significant effects.

The original research design intended to utilize a total of 72 top sirloin subprimals. For each treatment, four carcasses were to be selected. As depicted in Table 2.1, only two carcasses were found during the selection phase for the carcass combination of Top Choice QG, light HCW, and large REA due to the extreme rarity of this carcass parameter combination. This resulted in a total of 70 top sirloin butts being collected. To account for inconsistent sample size, LS Means was evaluated in data output.

RESULTS & DISCUSSION

Top Sirloin Butt, Whole

Simple weight descriptive statistics were presented in Table 2.2. The present study found a wide variation exists for the untrimmed whole weight of beef top sirloin butts from a variety of carcass sizes; a range of 3.72 kg from largest to smallest. Pearson correlation coefficients (Appendix A) and stepwise regression (Appendix B) found HCW to be a highly influential factor on weight and dimensionality of whole top sirloin butts and individual muscles. USDA Select carcasses yielded heavier top sirloin butts and individual muscles than Top Choice carcasses (whole: $P = 0.001$; BF, fat-on: $P = 0.002$; BF, fat-off: $P = 0.006$; Mouse: $P = 0.008$; GA: $P < 0.001$; GMV: $P = 0.017$; Table 2.3). As predicted, weights of top sirloin butts increased as HCW increased from light to heavy ($P < 0.001$), and REA increased from small to large ($P < 0.001$). The statistical models for length ($P = 0.111$; Table 2.4), and height ($P = 0.207$; Table 2.5) were insignificant in discerning dimensional variability. Width, however, was significant (Table 2.6), being wider in USDA Select carcasses compared to Top Choice ($P = 0.004$) and becoming wider as hot carcass weight increased from light to heavy ($P < 0.001$), and ribeye area increased from small to large ($P = 0.005$). Yield of the top sirloin butt is increasingly important, as sirloin steaks and roasts ranked second in 2020 market share of beef products sold in foodservice, with ground beef ranking first (Ground Beef at Retail and Foodservice, 2021). Simple statistics indicate Top Choice subprimals had a higher yield loss percentage than Select when fabricated using the full muscle fabrication (41.1% vs. 35.3%; Table 2.7); a 2-way interaction for yield loss was found between QG and HCW ($P = 0.005$; Figure 2.1), showing heavy weight carcasses had the highest yield loss of both Select and Top Choice products. The current study did not fabricate top sirloin butts in a traditional vs. innovative fashion to calculate comparative yield differences (West et al., 2011; Pfeiffer et al., 2005). While previous research has found marbling score has a minimal impact on eating quality of top sirloin steaks (King et al., 2021; Olson et al., 2019), wholesalers and branded meat programs may still need to consider QG a key selection criterion for sirloin products due to the sizing differences and variability observed between Select and Top Choice products.

Biceps femoris

An average of 23.02% yield loss from fat-on to fat-off BF retail cuts were observed (Table 2.2). Less than 1% difference in yield loss was observed between Select and Top Choice BF cuts (Table 2.7). As demonstrated in Table 2.3, BF muscles with fat-on and fat-off proved to increase in weight as HCW increased from light to heavy ($P < 0.001$ and $P < 0.001$, respectively) and REA increased from small to large ($P = 0.008$ and $P = 0.003$, respectively). Weights of BF muscles in USDA Select carcasses were observed to be heavier than Top Choice carcasses, both with fat-on and fat-off ($P = 0.002$ and $P = 0.006$, respectively). The BF, fat-on, had a 3-way interaction for length ($P = 0.039$; Figure 2.2), indicating Select carcasses yielded longer BF muscles, with heavy carcass weights and large REAs also increasing the length of the cut. Height of the BF, fat-on, was impacted by HCW ($P < 0.001$; Table 2.5). The BF, fat-off, showed that even as fat was trimmed away, Select carcasses ($P = 0.031$), heavy HCW ($P < 0.001$), and large REA ($P = 0.003$)] increased length of the BF (Table 2.4). Width of BF, fat-off, was also impacted by QG ($P < 0.001$), HCW ($P = 0.005$), and REA ($P = 0.023$; Table 2.6). In today's beef retail markets, the BF is sold fat-on and fat-off, as some suppliers prefer the fat cap to retain moisture when cooking (Costco Business Center, 2022; Smith et. al., 2014).

Gluteus accessorius & Gluteus profundus

When intact, the GA and GP are commonly called the "Mouse" (Clark, 2019); however, little retail value currently exists due inconsistent muscle fiber direction and presence of connective tissue in the GP (Jones et al., 2004). All relationships between treatment parameters and dimensional characteristic of the GA were insignificant [length, $P = 0.565$, Table 2.4; width, $P = 0.311$, Table 2.6; height, $P = 0.819$, Table 2.5). These insignificant comparisons imply the GA remains consistent in sizing regardless of carcass QG, HCW, or REA. Table 2.8 demonstrates that the GA averages 2.50 cm. in height, expanding potential for this muscle to be marketed as an individual, whole muscle steak with no further cutting needed from processors to achieve steak thickness.

Similar to findings from muscle profiling research of underutilized muscles in the beef chuck and round, (Calkins, 2009; Von Seggern et al., 2005; Jones et al., 2004; Johnson et al., 1988), the GA is an excellent candidate to be added to the list of alternatively fabricated beef value cuts. Weight and dimensional consistency of this muscle would be of immense value to restaurants and consumers seeking a reliable portion size and eating experience with minimal further fabrication. Furthermore, alternatively fabricating the GA as an individual steak without the presence of the GP will nearly eliminate undesirable connective tissue and boost palatability (Clark, 2019; Carr et al., 2009). The size and dimension of the GA would allow the GA to be merchandised similarly to the Beef Chuck, Shoulder Tender (NAMI #114F), of which over 21 million kg were purchased in a single year after the cut's introduction to consumers (Roybal, 2009).

Gluteus medius

Within individual muscles of the top sirloin butt, the GM center-cut, whole exhibited the widest range of weight variation within the top sirloin butt (Table 2.2); particularly, the GMV. A 3-way interaction of the GM center-cut, whole ($P = 0.036$; Figure 2.3), revealed that Select carcasses yielded heavier GM muscles than Top Choice, with heavier HCW and larger REAs also increasing the weight of the center-cut. Of the individual subunits, weights from the GM center-cut, the GMD exhibited a 2-way interaction ($P = 0.014$; Figure 2.4) between QG and HCW for weight of the cut, being heavier for Select products and increasing in weight as HCW increased. Figure 2.3 and Figure 2.4 confirm Select carcasses yielded heavier GM muscles than Top Choice, and the weight of GM muscles increased as HCW increased from light to heavy while REA increased from small to large. The GMV corroborated this data (Table 2.3). The GM center-cut, whole also exhibited extensive dimensional variability. A 2-way interaction for height of the center-cut, whole ($P = 0.009$; Figure 2.5) was observed between QG and HCW, while a 3-way interaction was observed for GMD width ($P = 0.004$; Figure 2.6), and GMV length ($P = 0.039$; Figure 2.7), confirming GM muscles are longer, wider, and taller in Select carcasses, and become larger as HCW becomes heavier and REA increases in size.

As the GM is the primary muscle within the top sirloin butt subprimal that yields traditional top sirloin steaks and roasts, the current research provides evidence as to why retail consumers are not experiencing consistency when purchasing top sirloin, given the GM was found to vary most significantly in weight and dimensionality. The GM center-cut, whole is also popular in foodservice as an alternative to higher-valued middle meats (King et al., 2009). As the GM is the most prevalent top sirloin muscle being sold to consumers, this research may be a valuable training resource for meat purchasers to consider in order to secure consistent portion sizing and eating experience of top sirloin cuts.

CONCLUSION

Quality grade, HCW, and REA are common specification parameters for branded meat programs to consider when attempting to control variability of fresh beef products. Understanding how these three parameters impact consistency of muscle sizing in the beef top sirloin butt will aid in greater assurance for predictable product size and quality as meat purchasers choose top sirloins for merchandising. This study demonstrates that USDA Select carcasses presented higher yields for beef top sirloin butts than Top Choice carcasses. The greatest weight and dimensional variability within the top sirloin butt was attributed to the GM. Regardless of varying carcass traits, the GA showed the most consistency in muscle weight and dimension, with dimensionality not being dependent upon QG, HCW, or REA, allowing for more merchandising flexibility. Additional muscle profiling research should be conducted to evaluate nutrient and lean attributes of the BF and GA, with updates being submitted to the USDA National Nutrient Database for Standard Reference (SR) (Acheson et al., 2015; USDA – ARS, 2015), providing valuable labeling transparency and further marketability.

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TABLES & FIGURES

Table 2.1. Factorial matrix for product selection utilizing marbling score and ribeye area data generated from USDA grading camera. Hot carcass weight was displayed on carcass identification tags.

		REA[3]		
QG[1]	HCW[2]	Small	Medium	Large
Select				
	Light	n = 4	n = 4	n = 4
	Medium	n = 4	n = 4	n = 4
	Heavy	n = 4	n = 4	n = 4
Top Choice				
	Light	n = 4	n = 4	n = 2[a]
	Medium	n = 4	n = 4	n = 4
	Heavy	n = 4	n = 4	n = 4

[1] Quality Grade: USDA Select = Slight^{00} – Slight^{99}; Top Choice = Modest^{00} – Moderate^{99}

[2] Hot Carcass Weight: Light ≤ 362 kg; Medium = 363 – 453 kg; Heavy = ≥454 kg

[3] Ribeye Area: Small ≤ 27.8 cm^2; Medium = 27.9 – 40.6 cm^2; Large ≥ 40.7 cm^2

[a] Two carcasses were never found during product selection phase due to the rare nature of this combination of carcass traits.

Table 2.2. Simple statistics for pooled weight (kg) of whole top sirloin and individual muscles.

	Weight (kg)			
	Min	Max	Mean	SEM
Top sirloin butt, whole, in bag	5.51	9.83	7.86	0.13
Top sirloin butt, whole, trimmed	4.63	8.35	6.75	0.11
Biceps femoris, fat-on	0.97	2.03	1.52	0.03
Biceps femoris, fat-off	0.69	1.60	1.17	0.02
Mouse[1]	0.50	0.93	0.71	0.01
Gluteus accessorius	0.19	0.44	0.29	0.01
Gluteus profundus	0.29	0.61	0.42	0.01
Gluteus medius, center-cut, whole	2.14	4.85	3.39	0.06
Gluteus medius, center-cut, dorsal	0.71	1.66	1.21	0.02
Gluteus medius, center-cut, ventral	1.43	2.88	2.13	0.04
Top sirloin butt, yield loss[2]	0.36	3.86	2.58	0.08

[1] Mouse = *Gluteus accessorius* + *Gluteus profundus*

[2] Loss calculated from whole, in bag weight – weight of bag – weight of individual muscles after trim and purge loss

Table 2.3. Least square means dependent upon quality grade, hot carcass weight, and ribeye area, impacting weight (kg) of whole top sirloin and individual muscles.

	QG[1]			HCW[2]				REA[3]			
	SE	TC	SEM	Light	Med.	Heavy	SEM	Small	Med.	Large	SEM
Whole[4]	6.93^{a}	6.56^{b}	0.08	5.95^{c}	6.76^{b}	7.52^{a}	0.11	6.37^{c}	6.75^{b}	7.11^{a}	0.11
BF[5], fat-on	1.58^{a}	1.45^{b}	0.03	1.34^{c}	1.52^{b}	1.69^{a}	0.04	1.45^{b}	1.49^{b}	1.62^{a}	0.04
BF[5], fat-off	1.22^{a}	1.10^{b}	0.02	0.98^{c}	1.21^{b}	1.30^{a}	0.03	1.08^{b}	1.15^{b}	1.25^{a}	0.03
Mouse[6]	0.74^{a}	0.68^{b}	0.01	0.62^{c}	0.71^{b}	0.79^{a}	0.02	0.69	0.73	0.71	0.02
GA[7]	0.31^{a}	0.26^{b}	0.01	0.25^{b}	0.29^{a}	0.31^{a}	0.01	0.28	0.30	0.28	0.01
GMV[8]	2.20^{a}	2.06^{b}	0.04	1.90^{c}	2.17^{b}	2.32^{a}	0.05	1.95^{b}	2.16^{a}	2.28^{a}	0.05

[1] Quality Grade: USDA Select (SE) = Slight^{00} – Slight^{99}; Top Choice (TC) = Modest^{00} – Moderate^{99}

[2] Hot Carcass Weight: Light ≤ 362 kg; Medium = 363 – 453 kg; Heavy = ≥ 454 kg

[3] Ribeye Area: Small ≤ 27.8 cm^2; Medium = 27.9 – 40.6 cm^2; Large ≥ 40.7 cm^2

[4] Top sirloin butt, whole, trimmed

[5] *Biceps femoris*

[6] *Gluteus accessorius* + *Gluteus profundus*

[7] *Gluteus accessorius*

[8] *Gluteus medius*, center-cut, ventral

[abc] Within a row, means without a common superscript differ ($P < 0.05$)

Table 2.4. Least square means dependent upon quality grade, hot carcass weight and ribeye area, impacting length (cm) of whole top sirloin and individual muscles.

	QG[1]			HCW[2]				REA[3]			
	SE	TC	SEM	Light	Med.	Heavy	SEM	Small	Med.	Large	SEM
Whole[4]	26.1	26.1	0.34	24.9	26.4	27.1	0.42	25.9	26.1	26.5	0.42
BF[5]	23.6^{a}	22.7^{b}	0.29	22.3^{b}	22.9^{b}	24.3^{a}	0.37	22.4^{b}	22.8^{b}	24.2^{a}	0.37
GA[6]	22.8	22.1	0.42	21.9	22.3	23.2	0.53	22.5	22.1	22.8	0.53
GM[7]	23.8	23.5	0.39	22.5	23.9	24.4	0.49	23.5	23.6	23.7	0.49
GMD[8]	23.9	23.0	0.36	22.3	23.4	24.8	0.45	23.2	23.6	23.8	0.45

[1] Quality Grade: USDA Select (SE) = Slight^{00} – Slight^{99}; Top Choice (TC) = Modest^{00} – Moderate^{99}
[2] Hot Carcass Weight: Light ≤ 362 kg; Medium = 363 - 453 kg; Heavy = ≥ 454 kg
[3] Ribeye Area: Small ≤ 27.8 cm^2; Medium = 27.9 - 40.6 cm^2; Large ≥ 40.7 cm^2
[4] Top sirloin butt, whole, trimmed
[5] *Biceps femoris*, fat-off
[6] *Gluteus accessorius*
[7] *Gluteus medius,* center-cut, whole
[8] *Gluteus medius*, center-cut, dorsal
[abc] Within a row, means without a common superscript differ ($P < 0.05$)

Table 2.5. Least square means dependent upon quality grade, hot carcass weight and ribeye area, impacting height (cm) of whole top sirloin and individual muscles.

	QG[1]			HCW[2]				REA[3]			
	SE	TC	SEM	Light	Med.	Heavy	SEM	Small	Med.	Large	SEM
Whole[4]	13.14	13.34	0.19	13.02	13.02	13.68	0.24	12.86	13.34	13.52	0.24
BF[5], fat-on	5.91	5.91	0.16	5.56^{b}	5.66^{b}	6.51^{a}	0.20	5.85	5.77	6.11	0.20
BF[5], fat-off	4.51	4.66	0.13	4.58	4.45	4.74	0.16	4.34	4.71	4.71	0.16
GA[6]	2.52	2.48	0.10	2.46	2.54	2.51	0.13	2.43	2.62	2.46	0.13
GMD[7]	6.77	6.40	0.14	6.48	6.43	6.85	0.17	6.32	6.85	6.59	0.17
GMV[8]	7.73	7.78	0.17	7.81	7.59	7.86	0.22	7.43	7.73	8.10	0.22

[1] Quality Grade: USDA Select (SE) = Slight^{00} – Slight^{99}; Top Choice (TC) = Modest^{00} – Moderate^{99}

[2] Hot Carcass Weight: Light ≤ 362 kg; Medium = 363 - 453 kg; Heavy = ≥ 454 kg

[3] Ribeye Area: Small ≤ 27.8 cm^2; Medium = 27.9 - 40.6 cm^2; Large ≥ 40.7 cm^2

[4] Top sirloin butt, whole, trimmed

[5] *Biceps femoris*

[6] *Gluteus accessorius*

[7] *Gluteus medius*, center-cut, dorsal

[8] *Gluteus medius*, center-cut, ventral

[abc] Within a row, means without a common superscript differ ($P < 0.05$)

Table 2.6. Least square means dependent upon quality grade, hot carcass weight and ribeye area, impacting width (cm) of whole top sirloin and individual muscles.

	QG[1]			HCW[2]				REA[3]			
	SE	TC	SEM	Light	Med.	Heavy	SEM	Small	Med.	Large	SEM
Whole[4]	33.1^a	32.2^b	0.22	31.5^c	32.6^b	33.8^a	0.27	32.0^b	32.5^b	33.3^a	0.27
BF[5], fat-on	22.7	21.3	0.33	21.1	22.6	22.2	0.42	22.1	21.6	22.2	0.42
BF[5], fat-off	21.7^a	19.9^b	0.33	19.7^b	21.4^a	21.3^a	0.41	20.5^b	20.3^b	21.6^a	0.41
GA[6]	8.9	8.0	0.19	8.2	8.5	8.7	0.23	8.8	8.4	8.3	0.23
GM[7]	28.1^a	26.2^b	0.27	26.1^c	27.1^b	28.2^a	0.33	26.3^b	27.3^a	27.9^a	0.33
GMV[8]	20.3^a	19.6^a	0.29	19.1^b	20.2^a	20.6^a	0.37	19.0^b	20.4^a	20.5^a	0.37

[1] Quality Grade: USDA Select (SE) = Slight^{00} – Slight^{99}; Top Choice (TC) = Modest^{00} – Moderate^{99}

[2] Hot Carcass Weight: Light ≤ 362 kg; Medium = 363 - 453 kg; Heavy = ≥ 454 kg

[3] Ribeye Area: Small ≤ 27.8 cm^2; Medium = 27.9 - 40.6 cm^2; Large ≥ 40.7 cm^2

[4] Top sirloin butt, whole, trimmed

[5] *Biceps femoris*

[6] *Gluteus accessorius*

[7] *Gluteus medius,* center-cut

[8] *Gluteus medius,* center-cut, ventral

[abc] Within a row, means without a common superscript differ ($P < 0.05$)

Table 2.7. Simple statistics pooled from USDA Select and Top Choice top sirloin butts to compare weight ranges (kg) impacted by quality grade differences.

	Weight (kg)							
	Min	Max	Min	Max	Mean		SEM	
	SE[1]		TC[1]		SE[1]	TC[1]	SE[1]	TC[1]
Top sirloin butt, whole trimmed	5.37	8.35	4.63	8.19	6.94	6.57	0.14	0.16
Biceps femoris, fat-on	1.24	2.03	0.97	1.91	1.58	1.45	0.04	0.04
Biceps femoris, fat-off	0.93	1.60	0.69	1.58	1.22	1.11	0.03	0.04
Mouse[2]	0.50	0.93	0.53	0.89	0.74	0.69	0.02	0.02
Gluteus accessorius	0.21	0.44	0.19	0.37	0.31	0.27	0.01	0.01
Gluteus profundus	0.29	0.61	0.29	0.55	0.43	0.42	0.01	0.01
Gluteus medius, center-cut, whole	2.74	4.85	2.14	4.30	3.59	3.19	0.08	0.09
Gluteus medius, center-cut, dorsal	1.00	1.66	0.71	1.55	1.31	1.12	0.03	0.03
Gluteus medius, center-cut, ventral	1.52	2.85	1.43	2.88	2.20	2.06	0.05	0.06
Top sirloin butt, yield loss[3]					2.45	2.72	0.13	0.09

[1] Quality Grade: USDA Select (SE) = Slight^{00} – Slight^{99}; Top Choice (TC) = Modest^{00} – Moderate^{99}

[2] Mouse = *Gluteus accessorius* + *Gluteus profundus*

[3] Loss calculated from whole, in bag weight – weight of bag – weight of individual muscles after trim and purge loss

Table 2.8. Simple statistics for pooled dimensional measurements of whole top sirloins and individual muscles.

	Length (cm)				Width (cm)				Height (cm)			
	Min	Max	Mean	SEM	Min	Max	Mean	SEM	Min	Max	Mean	SEM
Whole[1]	15.9	30.5	26.1	0.25	27.9	35.6	32.6	0.20	10.8	15.9	13.2	0.13
BF[2], fat-on	20.3	31.1	25.9	0.26	15.2	26.7	22.0	0.24	3.8	8.3	5.9	0.12
BF[2], fat-off	19.1	29.9	23.1	0.24	15.2	24.8	20.9	0.26	2.5	5.7	4.6	0.09
GA[3]	15.2	24.4	22.5	0.28	6.4	10.8	8.5	0.13	1.9	3.8	2.5	0.07
GM[4]	15.9	29.9	23.6	0.26	21.6	31.1	27.2	0.26	6.4	12.1	8.1	0.13
GMD[5]	15.2	27.3	23.5	0.27	9.5	15.9	12.3	0.16	5.1	8.9	6.6	0.1
GMV[6]	16.5	26.7	23.2	0.21	15.9	24.8	19.9	0.23	5.1	9.5	7.3	0.11

[1] Top sirloin butt, whole, trimmed
[2] *Biceps femoris*
[3] *Gluteus accessorius*
[4] *Gluteus medius,* center-cut, whole
[5] *Gluteus medius,* center-cut, dorsal
[6] *Gluteus medius,* center-cut, ventral

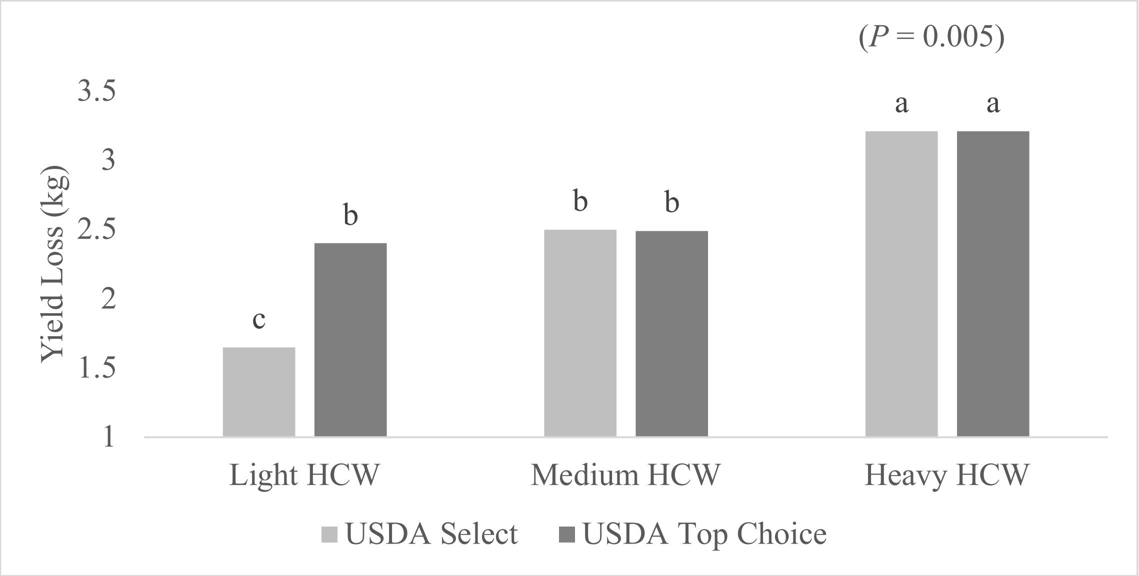

Figure 2.1. Least square means for 2-way interaction of quality grade and hot carcass weight (HCW) impacting weight (kg) of yield loss of top sirloin butts. Quality grade was characterized as USDA Select (Slight^{00} – Slight^{99}) and Top Choice (Modest^{00} – Moderate^{99}). Carcass weights were categorized as light (≤ 362 kg), medium (= 363 - 453 kg), and heavy (≥ 454 kg). ^{abc} Within a row, means without a common superscript differ ($P < 0.05$). Yield loss was calculated as whole, in bag weight – weight of bag – weight of individual muscles after trim and purge loss.

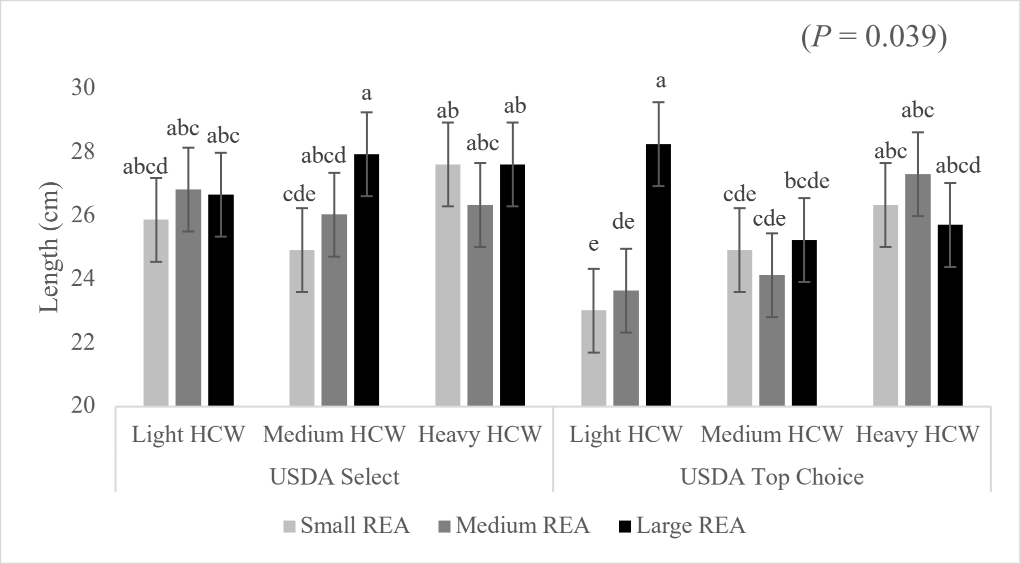

Figure 2.2. Least square means for 3-way interaction of quality grade, hot carcass weight (HCW), and ribeye area (REA) impacting length (cm) of *Biceps femoris*, fat-on. Quality grade was characterized as USDA Select (Slight^{00} – Slight^{99}) and Top Choice (Modest^{00} – Moderate^{99}). Carcass weights were categorized as light (≤ 362 kg), medium (= 363 - 453 kg), and heavy (≥ 454 kg). Ribeye area was categorized as small (≤ 27.8 cm^2), medium (= 27.9 - 40.6 cm^2), and large (≥ 40.7 cm^2). ^{abc} Within a row, means without a common superscript differ ($P < 0.05$).

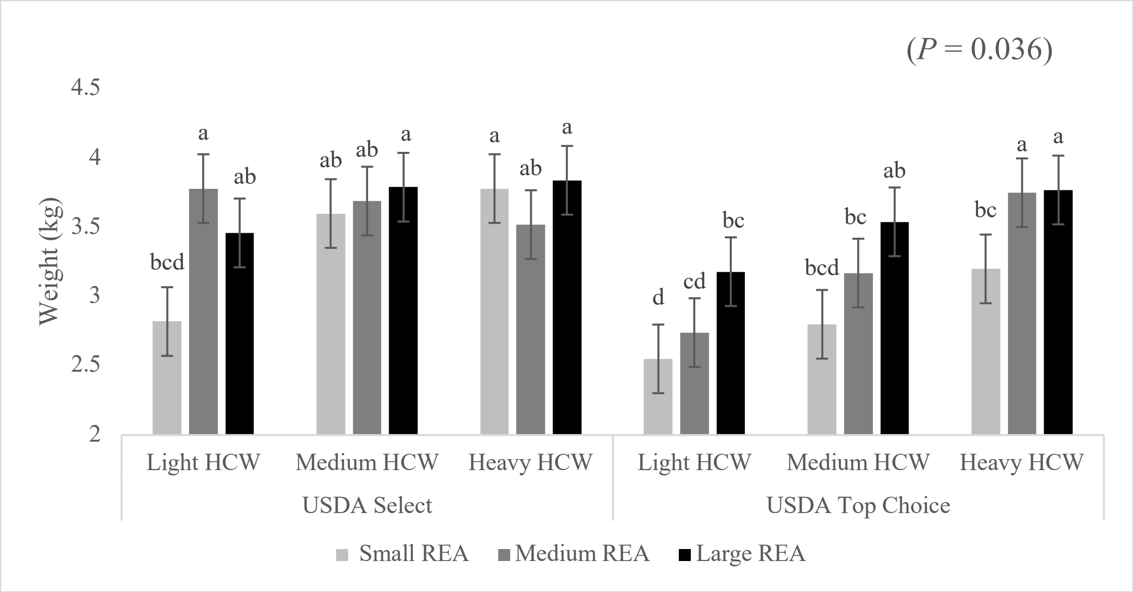

Figure 2.3. Least square means for 3-way interaction of quality grade, hot carcass weight (HCW), and ribeye area (REA) impacting weight (kg) of *Gluteus medius*, center-cut, whole. Quality grade was characterized as USDA Select (Slight^{00} – Slight^{99}) and Top Choice (Modest^{00} – Moderate^{99}). Carcass weights were categorized as light (≤ 362 kg), medium (= 363 - 453 kg), and heavy (≥ 454 kg). Ribeye area was categorized as small (≤ 27.8 cm^2), medium (= 27.9 - 40.6 cm^2), and large (≥ 40.7 cm^2). ^{abc} Within a row, means without a common superscript differ ($P < 0.05$).

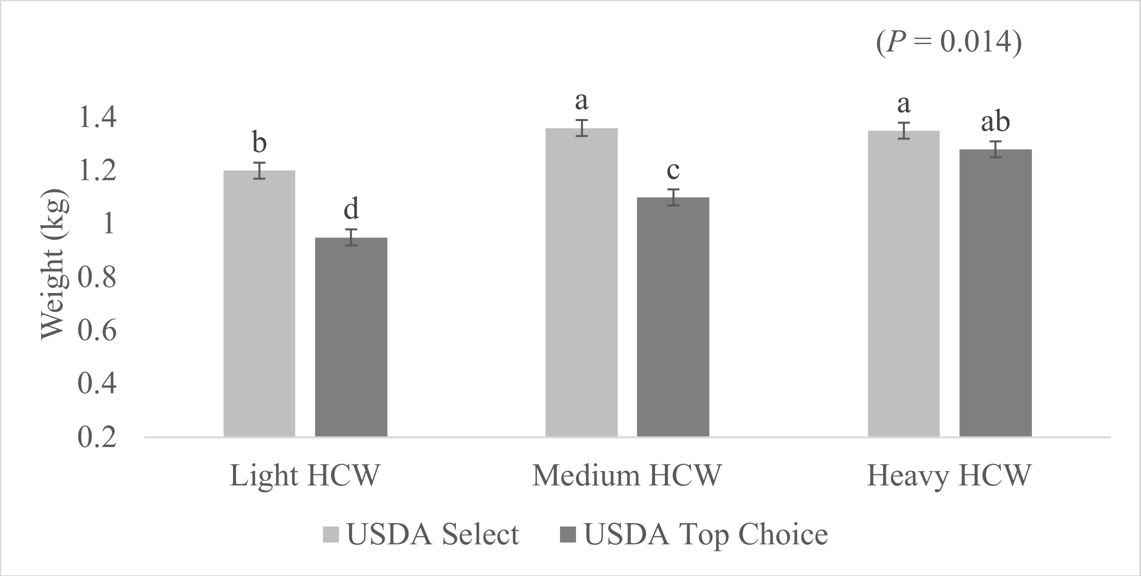

Figure 2.4. Least square means for 2-way interaction of quality grade and hot carcass weight (HCW) impacting weight (kg) of *Gluteus medius*, center-cut, dorsal. Quality grade was characterized as USDA Select (Slight^{00} – Slight^{99}) and Top Choice (Modest^{00} – Moderate^{99}). Carcass weights were categorized as light (≤ 362 kg), medium (= 363 - 453 kg), and heavy (≥ 454 kg). ^{abc} Within a row, means without a common superscript differ ($P < 0.05$).

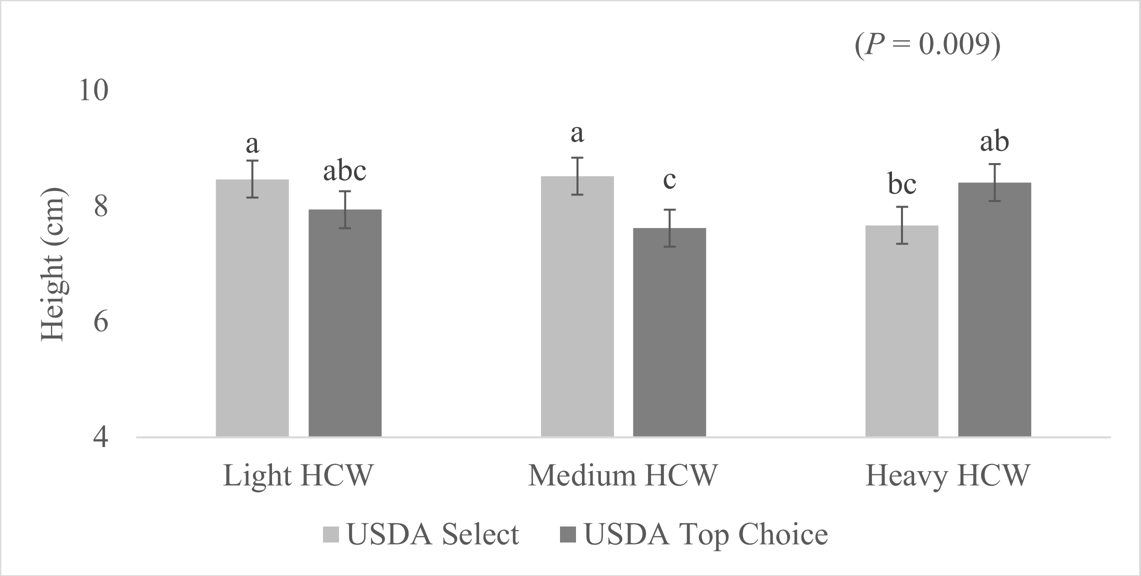

Figure 2.5. Least square means for 2-way interaction of quality grade and hot carcass weight (HCW) impacting height (cm) of *Gluteus medius*, center-cut, whole. Quality grade was characterized as USDA Select (Slight^{00} – Slight^{99}) and Top Choice (Modest^{00} – Moderate^{99}). Carcass weights were categorized as light (≤ 362 kg), medium (= 363 - 453 kg), and heavy (≥ 454 kg). ^{abc} Within a row, means without a common superscript differ ($P < 0.05$).

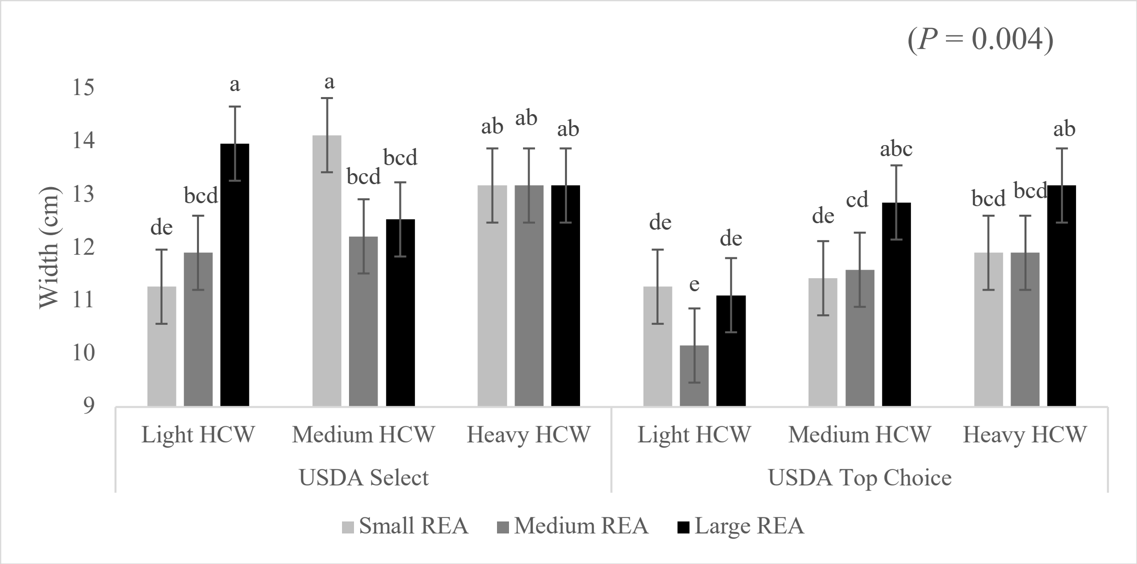

Figure 2.6. Least square means for 3-way interaction of quality grade, hot carcass weight (HCW), and ribeye area (REA) impacting width (cm) of *Gluteus medius*, center-cut, dorsal. Quality grade was characterized as USDA Select (Slight^{00} – Slight^{99}) and Top Choice (Modest^{00} – Moderate^{99}). Carcass weights were categorized as light (≤ 362 kg), medium (= 363 - 453 kg), and heavy (≥ 454 kg). Ribeye area was categorized as small (≤ 27.8 cm^2), medium (= 27.9 - 40.6 cm^2), and large (≥ 40.7 cm^2). ^{abc} Within a row, means without a common superscript differ ($P < 0.05$).

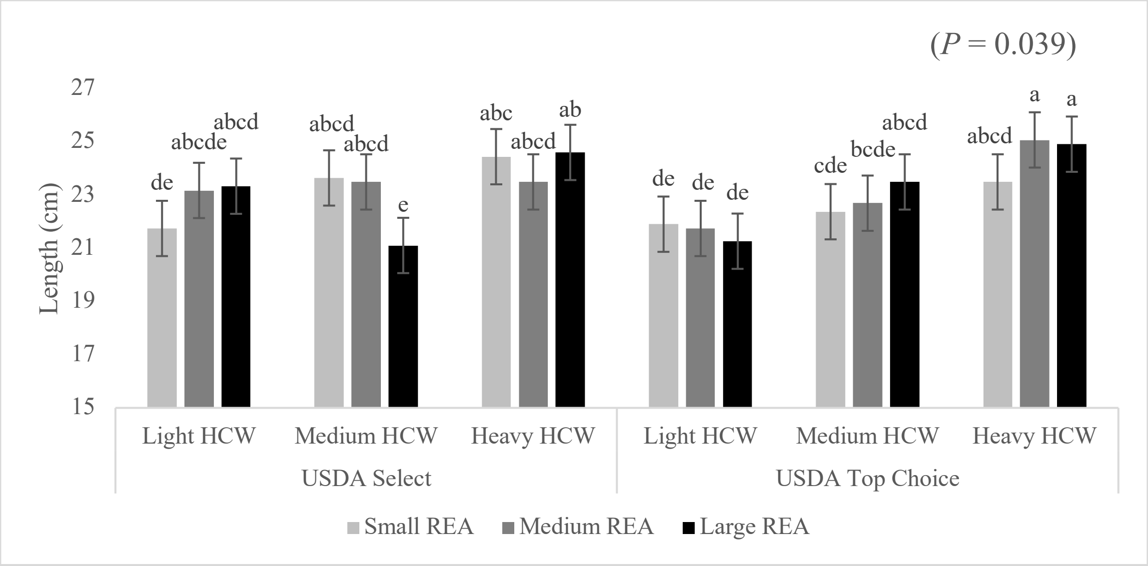

Figure 2.7. Least square means for 3-way interaction of quality grade, hot carcass weight (HCW), and ribeye area (REA) impacting length (cm) of *Gluteus medius*, center-cut, ventral. Quality grade was characterized as USDA Select (Slight^{00} – Slight^{99}) and Top Choice (Modest^{00} – Moderate^{99}). Carcass weights were categorized as light (≤ 362 kg), medium (= 363 - 453 kg), and heavy (≥ 454 kg). Ribeye area was categorized as small (≤ 27.8 cm^2), medium (= 27.9 - 40.6 cm^2), and large (≥ 40.7 cm^2). ^{abc} Within a row, means without a common superscript differ ($P < 0.05$).

CHAPTER 3

Muscle profiling of the Biceps femoris, Gluteus accessorius, and Gluteus medius comprising the beef top sirloin butt

ABSTRACT

Muscle profiling improves value and optimization of beef carcasses by expanding knowledge of physical, compositional, and marketable attributes of single-muscle cuts. Extensive profiling for individual muscle portions of the NAMI #184 beef top sirloin butt remains understudied. The objective of the study was to compare fluid loss, color score, pH, and objective tenderness of the *Biceps femoris* (BF), *Gluteus accessorius* (GA), *Gluteus medius,* dorsal (GMD), and *Gluteus medius*, ventral (GMV) throughout the beef top sirloin butt subprimal. Beef top sirloin butts (N = 70) from two quality grades (USDA Select and Top Choice) were utilized to evaluate differences between muscles previously mentioned and quality grades. Average Warner-Bratzler shear force values were the lowest for the GA and BF ($P < 0.001$) and were significantly different than the GMD and GMV. The GA reported the highest pH value ($P < 0.001$), with the lowest percentage of fluid loss ($P < 0.001$). *Gluteus medius* muscle subunits, GMD and GMV, exhibited the highest mean shear force values ($P < 0.001$), lightest color ($P < 0.001$), lowest pH ($P < 0.001$), and most fluid loss ($P < 0.001$). USDA Top Choice muscles were more tender than Select ($P < 0.001$), and lighter in color ($P < 0.001$). All four top sirloin muscles and muscle subunits averaged peak shear force values below 3.9 kg, thus, all within the threshold for USDA “very tender.” This muscle profiling data will aid in identifying new beef value cuts from the top sirloin butt and assess acceptability of sirloin cuts for further retail and foodservice merchandising opportunities.

Keywords: beef, alternative merchandising, top sirloin, muscle profiling

INTRODUCTION

Maximizing carcass utilization while optimizing consumer preference continues to be a key focus of the beef industry (West et al., 2011). By expanding knowledge of individual muscle yield and palatability traits, muscle profiling is an effective means of increasing value of less tender subprimals at a rate comparative to middle meats (Jung et al., 2016). Despite being a subprimal of the highly valued beef loin, previous research has found top sirloin steaks to be the most unpredictable steak offering at retail for eating quality (Morgan et al., 1991). Even with this knowledge, the NAMI #184 beef top sirloin butt and its individual muscles [*Gluteus medius* (GM), *Biceps femoris* (BF), *Gluteus accessorius* (GA), and *Gluteus profundus* (GP)] remain understudied and some are underutilized as individual cuts.

Von Seggern et al. (2005) conducted comprehensive muscle profiling research of the beef chuck and round. This study evaluated individual muscle cuts and muscle subunits from traditionally less tender primals for weight, dimension, color variability, pH, composition, cook loss, and tenderness. Following the publication of results, beef value cuts such as the flat iron steak, petite shoulder tender, and ranch steaks were introduced to consumers, increasing the value of the beef chuck primal by 60% in just three years (Calkins, 2009). The National Cattlemen's Beef Association has praised the numerous innovative steaks and roasts that emerged from this study, referring to them as "next generation value cuts" (Lepper-Blilie et al., 2014).

While research has indeed been conducted on muscle characteristics of the beef top sirloin butt (Beyer et al., 2021; King et al., 2021; Olson et al., 2019; Colle et al., 2016 & 2015; Apple et al., 2014; Smith et al., 2014; Hosch et al., 2013; Machete et al., 2013; King et al., 2009; Machete, 2009), smaller muscle portions such as the GA remain understudied and underutilized (Clark, 2019). Instead, both GA and GP muscles are most commonly incorporated into lean beef trimmings or traditionally fabricated, multi-muscle steaks (Smith et al., 2014; Jones et al., 2004). It is pondered that further value may be added to the top sirloin butt, and the entire beef commodity, were the GA fabricated individually and sold as a single-muscle steak.

The objective of the study was to compare fluid loss, color score, pH, and objective tenderness of individual top sirloin butt muscles and muscle subunits that have been incomplete up to the present time. It is hypothesized that differences will be observed between individual muscles and muscle subunits that may suggest higher market value and consumer appeal. This data will preface greater value opportunities for the beef top sirloin butt and new beef value cuts derived from individual sirloin muscles.

MATERIALS & METHODS

Product Procurement

Beef carcasses (N = 70) were selected from a commercial beef processing facility (Toppenish, WA) based on a 2x3x3 factorial matrix of quality grade (QG), hot carcass weight (HCW), and ribeye area (REA) (Table 3.1). Beef carcasses were collected by opportunistic means thereby no breed, management, or specific ration information were not known. Carcasses selected were sourced from youthful (determined to be physiologically less than 30 months of age according to United States Department of Agriculture [USDA] protocol for grading. Left sides of beef carcasses were evaluated on a USDA grading line using an E + V Vision Grading camera (VBG_{2000}, E + V Technology, Oranienburg, Germany) to measure marbling score and REA. Carcasses with marbling score of $Slight^{00-99}$ (USDA Select) and $Modest^{00}$ – $Moderate^{99}$ (Top Choice) were the parameters of the first factor. Within each QG, carcasses were selected for HCW; light (≤ 362 kg), medium (363 – 453 kg) and heavy (≥ 454 kg). The third factor was REA; small (≤ 27.8 cm^2), medium (27.9 – 40.6 cm^2), and large (≥ 40.7 cm^2). Of carcasses selected, left-sided top sirloin butts were purchased boneless, not trimmed.

Product Preparation

Subprimals were transported under refrigeration (2°C) in vacuum packaging to the University of Idaho Meat Laboratory and aged for 21 d post-mortem at 4°C. Once removed from vacuum packaging, top sirloins butts were fabricated into individual muscles and muscle subunits: BF (Top Sirloin Butt Cap, NAMI #184D), GA, GMD (*Gluteus medius* center-cut Dorsal Side, NAMI #184F), and GMV (*Gluteus medius* center-cut Ventral Side, NAMI #184B PSO 1). For the GMV, PSO 1 indicates that the dorsal portion of the GM was separated from the main portion by cutting through the natural seam (NAMA, 2014). Muscle profiling characteristics were not analyzed for the GP due to inconsistent muscle fiber orientation and presence of connective tissue (Jones et al., 2004). The GP was excluded from further quality analyses.

Steak samples were acquired from the BF, GA, GMD, and GMV muscles and muscle subunits. An individual steak measuring 2.54 cm in thickness was cut from the BF, GMD, and GMV from the anterior end and longitudinal center perpendicular to the longitudinal axis of the muscle cut. The GA was approximately 2.54 cm in natural height when measured from the table (steak thickness), thus no additional portioning was necessary. Individual steaks were vacuum packaged and placed in frozen storage (-20◦C) to await further muscle profiling analysis.

Steak Purge

Steaks were weighed in a frozen state prior to thawing at 4°C. After a 24-hour period, steaks were removed from packaging and weighed in the raw state. A percentage of fluid loss was calculated:

$$Purge = Steak\ weight, frozen - steak\ weight, thawed - \ bag\ weight \\ - \ label\ weight$$

$$Purge\ Percentage = \frac{Purge}{Steak\ weight, frozen - bag\ weight - label\ weight}\ x\ 100$$

Color

Steaks were allowed to bloom for one hour prior to assessing colorimetric measurements L* (lightness), a* (redness), and b* (yellowness). Measurements were collected using a Nix Pro Color Sensor (Nix Sensor Ltd., Hamilton, Ontario, Canada; V 2.6.4). The color sensor was equipped with a 14 mm-diameter measuring area and a 10° standard observer. The instrument was set to Illuminant A and Commission Internationale de l'Eclairage, measuring L* (dark to light; black = 0, white = 100), a* (green to red; -50 to

50, respectively), and $b*$ (blue to yellow; -50 to 50, respectively). Colorimetric measurements were taken in duplicate and averaged to obtain a mean $L*$, $a*$, and $b*$ color score for each steak.

Muscle pH

A portable puncture-type pH meter (Apera Instruments SX811-SS, Columbus, OH) was utilized to probe each steak to measure pH. Prior to use, the probe was calibrated for pH 4.0, 7.0, and 10.0 (Hanna Instruments, Woonsocket, RI). The probe was then inserted approximately 1.27 cm into the side of each thawed steak, being cognizant to target lean while avoiding heavy seam fat and connective tissue.

Cooking

Steaks were thawed for 24 hours at 4°C, then brought to room temperature for 20 minutes prior to cooking. Two-sided electric grills were preheated to 232◦C and steaks were probed with Type K thermocouple (Copper-Atkins 93230-K EconoTemp) to monitor internal temperature during cooking. Steaks were cooked on direct heat until internal temperature reached 71◦C. Cook time, removal temperature, and peak temperature were recorded for each steak. After cooling to room temperature, cooked steaks were weighed to measure cooking loss.

$$Cooking\ Loss = Steak\ weight, thawed - steak\ weight, cooked$$

$$Cooking\ Loss\ Percentage = \frac{Cooking\ Loss}{Steak\ weight, thawed}\ x\ 100$$

Objective Tenderness

Warner-Bratzler shear force (WBSF) was used to determine objective tenderness of top sirloin muscles. From each steak, a minimum of six cores (1.27 cm diameter) were removed parallel to the muscle fiber orientation. Each core was sheared once perpendicular to the muscle fiber using a WBSF machine (G-R Manufacturing, Manhattan, KS) at a crosshead speed of 225 mm/sec. Peak shear force values for individual cores were averaged to compute a mean shear force value for each steak.

Statistical Analysis

Data were analyzed using a general linear model procedure of SAS V 9.4. (SAS Inc., Cary, NC), with significance being determined at $P < 0.05$. Prior to full analysis, normality of each data set was ensured utilizing boxplots and regression models of the residuals to evaluate for skewness or outliers. Quality grade, individual muscle, and their interaction were assumed as fixed effects. Treatment least square means differences were assessed through pair-wise comparisons for significant effects. Peak temperature was used as a covariate when significant for cook loss and objective tenderness. Shear force data was analyzed for acceptability at USDA tenderness thresholds of 4.4 and 3.9 kgs of shear force, which are representative of USDA "tender" and "very tender," respectively (ASTM, 2008).

The original research design intended to utilize a total of 72 top sirloin subprimals. For each treatment, four carcasses were to be selected. Only two carcasses were found during the selection phase for the carcass combination of Top Choice, light HCW, and large REA. This resulted in a total of 70 top sirloin butts being collected. To account for inconsistent sample size, LS Means was evaluated in data output.

RESULTS & DISCUSSION

Fluid Loss & Cookery

The GA retained more water than all other muscles in the top sirloin butt, having the least purge (Table 3.2) and cooking loss ($P < 0.001$, Table 3.2). The GMD manifested the highest percentage of moisture loss in both the raw and cooked state (Table 3.2). Quality grade (Table 3.3) did not impact raw purge ($P = 0.189$) or cook loss ($P = 0.125$) of top sirloin muscles, which is different than what was observed by Machete (2009) who reported Select GM steaks having higher cook loss percentages than Top Choice. Freezing and thawing of steaks used in the present study may have increased purge of raw sirloin muscles compared to fresh sirloin steaks as were used by Colle et al. (2015). Colle et al. (2015) found GM purge to be 3.51% on day 21 of aging, as compared to the current study that found 9.73% and 8.26% purge from the GMD and GMV, respectively. However, in the previous research (Colle et al., 2015), fluid loss during cooking was higher than the present study, perhaps as a result of the GM losing less free water in the raw state, thus, having more fluid to release during cooking. In a comparison of total moisture loss percentage between the GMD in the current study (37.24%) and day 21 of previous research (37.65%; Colle et al., 2015), total fluid loss appears to be consistent between these two studies, regardless if steaks were frozen prior to analysis. Neely et al. (1998) showed that consumers have traditionally cooked top sirloin steaks on the grill, and regardless of cookery method, tend to prepare sirloin steaks to well-done. The GA would be an advantageous steak alternative for traditionally cut top sirloin steaks, given the ability to retain moisture in both raw and cooked form better than GM muscle subunits, thus being more likely to deliver a juicy eating experience.

Color

The BF averaged the lowest L^* value ($P < 0.001$), thus being the darkest muscle evaluated (Table 3.2). Assessing a^* values for redness, a two-way interaction was observed between individual sirloin muscle and QG ($P = 0.046$, Figure 3.1). The BF and GA muscles of either QG were redder than GM muscles, while GM Select muscles were redder than GM Top Choice. The GA had the highest average b^* value (Table 3.2). Of all top sirloin muscles evaluated, the GMD subunit displayed the highest average L^* value, with lowest a^* and b^* values. McKenna et al. (2005) found that muscles can be categorized based on color stability, with the GM being labeled as having “intermediate” color stability and the BF having “low” color stability. The previous research (McKenna et al., 2005) analyzed BF muscles from the round, thus, color stability of the BF sirloin portion had yet to be classified. The likelihood that a consumer will purchase a product at retail is greatly impacted by color, as consumers often associate bright cherry red color with freshness of beef (Troy and Kerry, 2010). Even though consumer perception of color does not impact eating experience or perceived palatability (Carpenter et al., 2001), color remains one of the most influential factors in aiding a beef sale at the meat counter.

Chuck and round profiling from Von Seggern and Calkins (2005) found variation in physical and chemical properties of muscles were most evident across QG. Our results corroborated this data, showing lower L^* values (darker in color) within USDA Select carcasses than sirloin muscles from Top Choice carcasses ($P < 0.001$, Table 3.3).

Muscle pH

The GA possessed the highest pH ($P < 0.001$), possibly confirming why this muscle also displayed the lowest fluid loss percentages, with darker, more red coloring than the other top sirloin muscles (Table 3.2). Muscle pH is highly correlated with water holding capacity as well as color intensity of meat (Montgomery and Leheska, 2008). As pH nears the isoelectric point of meat (5.1 – 5.2), water is less tightly bound to myofibrillar proteins, creating more space between water molecules for light reflectivity and more water to purge (Machete, 2009; Mancini and Hunt, 2005). The GMD and GMV muscle subunits displayed lower mean pH values than both the BF and GA ($P < 0.05$; Table 3.2), corroborating lower water holding capacity and lighter color. Zhu and Brewer (1998) determined that low pH is indicative of definitively more unstable color than higher pH. It is reasonable to conclude that lower ultimate pH for GM muscle subunits is a key indication as to why GM muscles displayed lower color scores than GA and BF muscles. Average muscle pH for the GA (5.75) in the current study was similar to that of the *Teres major* (5.72) reported by Von Seggern and Calkins (2005). Compositional parallels between the GA and *Teres major* may suggest similar marketability and consumer acceptability of the GA as a single muscle steak. McKenna et al. (2005) found pH of the BF to be 5.69, and Von Seggern et al. (2005) found GM pH to be 5.45. The previously published data closely confirm the present study's findings (Table 3.2). Quality grade did not influence ultimate pH of sirloin muscles ($P = 0.481$, Table 3.3).

Objective Tenderness

The GA and BF had lower average peak WBSF values than both of the GM subunits ($P < 0.05$, Table 3.2). Although not significant in all circumstances, numerically the GA was observed to be the most tender muscle in the top sirloin butt. Within the GM, the dorsal subunit was less tender than the ventral subunit ($P < 0.05$), manifesting the highest average peak shear force value of all muscles evaluated. Quality grade was found to impact objective tenderness ($P = 0.008$) within top sirloin muscles (Table 3.3), which contradicts previous findings from the 2015 National Beef Tenderness Survey (Martinez et al., 2017) and 2006 National Beef Quality Audit (Voges et al., 2007). These previous studies report that consumer perceptions of muscle tenderness were not related to QG, but rather, more greatly influenced by unique properties of muscle fiber composition and function of the muscle in the live animal.

Regardless of muscle or QG differences, all top sirloin muscles would qualify for USDA "very tender," as each reported peak WBSF values below 3.9 kg of force needed to shear through the sample (ASTM, 2008). Destefanis et al. (2008) found consumers can detect differences in tenderness within 0.5 kg of force. This information signifies that consumers would likely be able to detect tenderness differences between the GA and GMD, as well as the BF and GMD (Figure 3.2). Even as GM muscle subunits recorded the highest peak shear force values for this study, sirloin steaks from the GM are still considered tender and comparable in eating experience to high dollar beef cuts such as the *Longisimus lumborum* (Hunt et al., 2014).

CONCLUSION

Muscle profiling is of high importance to continue mapping palatability characteristics of individual beef muscles. Through alternative fabrication, individual muscles comprising the beef top sirloin butt have been further explored for intrinsic characteristics, thus potentially increasing the salability and availability of tender, single muscle steaks to consumers at retail. The present study found GA and BF muscles to be superior to the GM in fluid retention, color, pH, and tenderness, suggesting higher market value potential and consumer appeal for these alternatively fabricated cuts compared to traditional top sirloin steaks. The present data suggests the GA possesses intrinsic qualities that may lead to favorable edibility, making this cut a high contender for addition as a new beef value cut. Further research should be conducted to determine consumer preference of the GA compared to other highly favored cuts of beef.

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TABLES & FIGURES

Table 3.1. Factorial matrix for product selection utilizing marbling score and ribeye area data generated from USDA grading camera. Hot carcass weight was displayed on carcass identification tags.

		REA[3]		
QG[1]	HCW[2]	Small	Medium	Large
Select				
	Light	n = 4	n = 4	n = 4
	Medium	n = 4	n = 4	n = 4
	Heavy	n = 4	n = 4	n = 4
Top Choice				
	Light	n = 4	n = 4	n = 2[a]
	Medium	n = 4	n = 4	n = 4
	Heavy	n = 4	n = 4	n = 4

[1] Quality Grade: USDA Select = Slight^{00} – Slight^{99}; Top Choice = Modest^{00} – Moderate^{99}
[2] Hot Carcass Weight: Light ≤ 362 kg; Medium = 363 – 453 kg; Heavy = ≥454 kg
[3] Ribeye Area: Small ≤ 27.8 cm^2; Medium = 27.9 – 40.6 cm^2; Large ≥ 40.7 cm^2
[a] Only two carcasses were found during product selection phase due to the rare nature of this combination of carcass traits.

Table 3.2. Least square means for fluid loss, color score, pH, and objective tenderness of individual sirloin muscles.

	BF[1]	GA[2]	GMD[3]	GMV[4]	SEM	Model p-value
Purge[4] (%)	8.88^{b}	4.95^{c}	9.73^{a}	8.26^{b}	0.25	< 0.001
Cook loss[5] (%)	28.89^{b}	25.75^{d}	27.51^{c}	30.19^{a}	0.37	< 0.001
*L**	30.13^{c}	31.85^{b}	35.38^{a}	32.87^{b}	0.42	< 0.001
*b**	16.15^{b}	17.16^{a}	15.75^{c}	15.87^{bc}	0.30	< 0.001
pH	5.62^{b}	5.75^{a}	5.55^{c}	5.52^{c}	0.01	< 0.001
WBSF[6] (kg)	2.83^{c}	2.79^{c}	3.55^{a}	3.09^{b}	0.08	< 0.001

[1] *Biceps femoris*
[2] *Gluteus accessorius*
[3] *Gluteus Medius*, center-cut, dorsal
[4] *Gluteus Medius*, center-cut, ventral
[4] Purge percentage = [(steak weight, frozen – steak weight, thawed – bag weight – label weight) / (steak weight, frozen – bag weight – label weight)] x 100
[5] Cooking loss percentage = [(Steak weight, thawed – steak weight, cooked) / (steak weight, thawed)] x 100
[6] Warner-Bratzler shear force
[abcd] Within a row, means without a common superscript differ ($P < 0.05$)

Table 3.3. Least square means for quality grade treatment effects on fluid loss, color score, pH, and objective tenderness of individual sirloin muscles.

	USDA Quality Grade			
	Select	Top Choice	SEM	*P*
Purge[1] (%)	8.12	7.79	0.19	0.189
Cook loss[2] (%)	28.33	27.83	0.29	0.125
*L**	31.61^{b}	33.50^{a}	0.30	< 0.001
*b**	16.26	16.20	0.22	0.858
pH	5.61	5.62	0.01	0.481
WBSF[3] (kg)	3.16^{a}	2.97^{b}	0.06	0.008

USDA Select = Slight^{00} – Slight^{99}; Top Choice = Modest^{00} – Moderate^{99}

[1] Purge percentage = [(steak weight, frozen – steak weight, thawed – bag weight – label weight) / (steak weight, frozen – bag weight – label weight)] x 100

[2] Cooking loss percentage = [(Steak weight, thawed – steak weight, cooked) / (steak weight, thawed)] x 100

[3] Warner-Bratzler shear force

[ab] Within a row, means without a common superscript differ ($P < 0.05$)

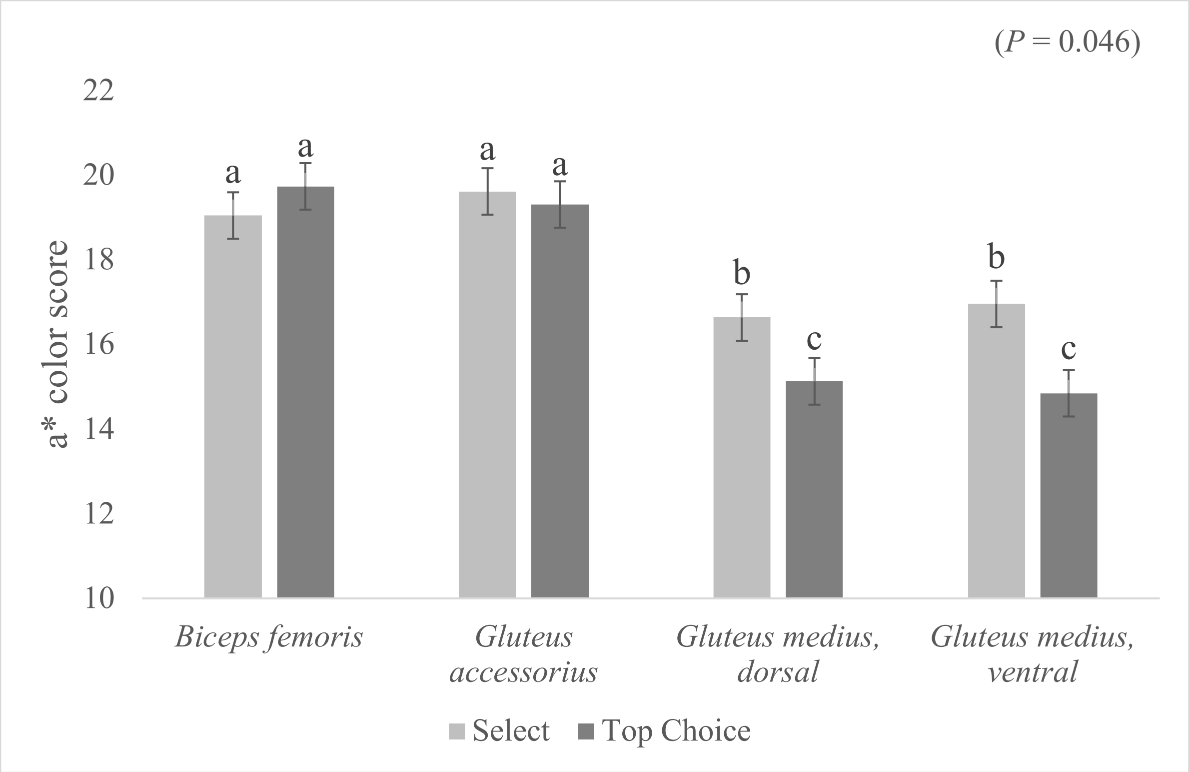

Figure 3.1. Two-way interaction between individual beef sirloin muscle and quality grade (USDA Select and Top Choice) for *a** color score of the *Biceps femoris, Gluteus accessorius*, *Gluteus medius* dorsal, and *Gluteus medius* ventral. Steaks were thawed 24 hours at 4°C, then allowed to bloom for one hour prior to assessing colorimetric measurements using a Nix Pro Color Sensor. The instrument was equipped with a 14 mm-diameter measuring area and a 10° standard observer set to Illuminant A. Values for *a** hues are represented as green to red (-50 to 50, respectively). Values are shown as least square means ± SE. ^{abc}Means without a common superscript differ ($P < 0.05$).

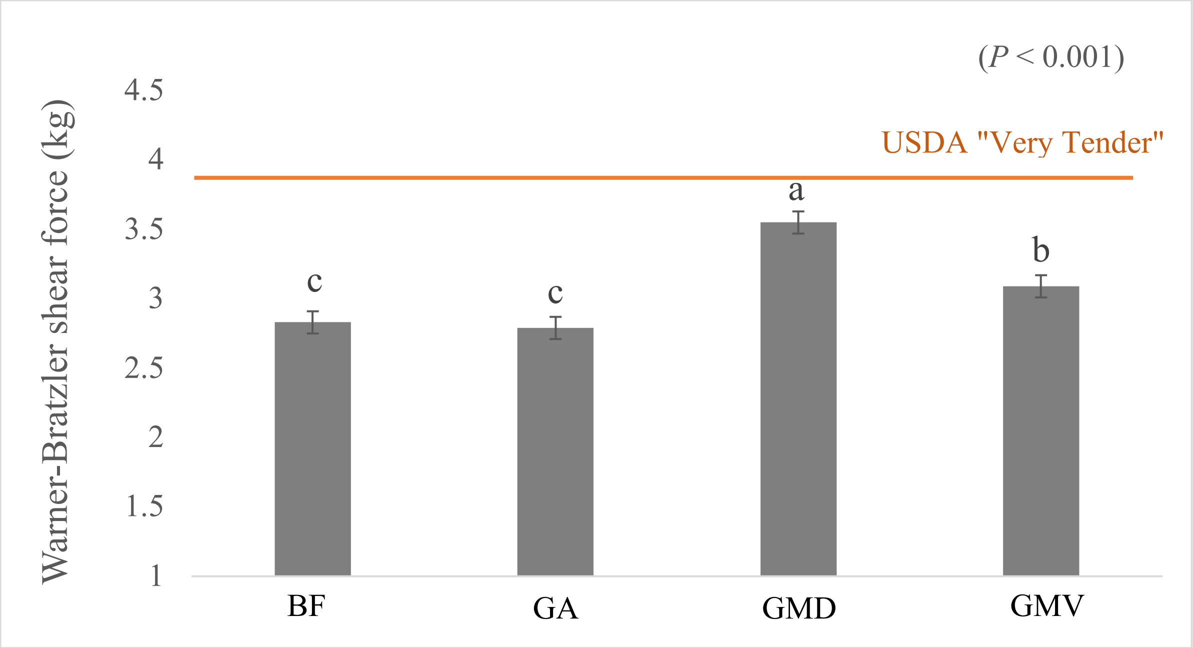

Figure 3.2. Objective tenderness observations of Warner-Bratzler shear force (kg) to compare average peak shear force of individual sirloin muscles and muscle subunits: *Biceps femoris* (BF)*,* *Gluteus accessorius* (GA), *Gluteus medius* dorsal (GMD), and *Gluteus medius* ventral (GMV). A ceiling threshold at 3.9 kg identifies “USDA Very Tender.” ^{abc}Means without a common superscript differ ($P < 0.05$).

APPENDICES

Appendix A**.** Pearson correlation coefficients fitted to weight and dimension of top sirloin butts and individual muscles.

	Pearson correlation coefficients				
	Hot Carcass Weight	Back Fat	Ribeye Area	Final Yield Grade	Marbling Score
TSB[1], whole, weight, bag	0.9207	0.0003	0.2644	0.2955	-0.1102
TSB[1], whole, weight, trim	0.8247	-0.1995	0.4982	-0.0213	-0.2205
TSB[1], length	0.4785	-0.0226	0.1475	0.0715	-0.1129
TSB[1], width	0.6328	-0.1818	0.3806	-0.0278	-0.2970
TSB[1], height	0.4210	-0.1551	0.4056	-0.0607	0.0602
BF[2], fat on, weight	0.6532	-0.2373	0.4669	-0.1359	-0.3073
BF[2], fat on, length	0.3478	-0.3394	0.4001	-0.2918	-0.3239
BF[2], fat on, width	0.1504	-0.0879	-0.0365	-0.0036	-0.3951
BF[2], fat on, height	0.4044	-0.0161	0.1153	0.0748	-0.0706
BF[2], fat off, weight	0.6730	-0.3011	0.5220	-0.1620	-0.2237
BF[2], fat off, length	0.4783	-0.2670	0.5067	-0.2416	-0.2051
BF[2], fat off, width	0.2942	-0.2173	0.2984	-0.1801	-0.3794
BF[2], fat off, height	0.2159	-0.1884	0.3557	-0.1791	0.1365
GA[3], weight	0.4695	-0.1519	0.1381	0.0621	-0.3227
GA[3], length	0.1509	0.1400	0.0629	0.0547	-0.0366
GA[3], width	0.1324	0.0420	-0.0948	0.0583	-0.3046
GA[3], height	0.1335	-0.2083	0.2063	-0.0747	-0.0699
GM[4], whole, weight	0.5628	-0.4198	0.5130	-0.2891	-0.3794
GM[4], whole, length	0.3716	-0.0343	0.1366	0.0553	-0.1193
GM[4], whole, width	0.4470	-0.3038	0.3006	-0.1469	-0.4447
GM[4], whole, height	0.0554	-0.3680	0.4246	-0.4313	-0.1450
GM[4], dorsal, weight	0.5250	-0.3076	0.4422	-0.2004	-0.4465
GM[4], dorsal, length	0.3802	-0.0345	-0.0405	0.1489	-0.2946
GM[4], dorsal, width	0.3473	-0.1543	0.2326	-0.0699	-0.3776
GM[4], dorsal, height	0.2603	-0.2202	0.2472	-0.1451	-0.1308
GM[4], ventral, weight	0.6437	-0.3552	0.5354	-0.1999	-0.2212
GM[4], ventral, length	0.3511	-0.0650	0.0594	0.1125	-0.0388
GM[4], ventral, width	0.3917	-0.1632	0.1708	-0.0603	-0.2726
GM[4], ventral, height	0.2104	-0.1910	0.3178	-0.2065	0.0279
Yield loss[5], weight	0.7667	0.3989	-0.1835	0.7010	0.1805

[1] Top sirloin butt

[2] *Biceps femoris*

[3] *Gluteus accessorius*

[4] *Gluteus medius*, center-cut

[5] Loss calculated from whole, in bag weight – weight of bag – weight of individual muscles after trim and purge loss

Appendix B. Stepwise regression showing coefficients of determination (r^2) and parameter estimates for model fitted to weight of top sirloin butts and individual muscles.

	Parameter estimate[1]						
	Model R-Square						
	HCW[2]	FYG[3]	MS[4]	b_3	b_2	b_1	b_0
TSB[5], whole, weight, bag	0.8477	-	0.8643	0.0181	-	-0.0013	1.0237
TSB[5], whole, weight, trim	0.6802	0.8331	0.8559	0.0158	-0.3257	-0.0013	1.9079
BF[6], fat on, weight	0.4267	0.6261	0.6680	0.0037	-0.1006	-0.0005	0.5410
BF[6], fat off, weight	0.4529	0.6808	0.6978	0.0034	-0.0990	-0.0003	0.2254
GA[7], weight	0.2205	-	0.3309	0.0004	-	-0.0002	0.1822
GM[8], whole, weight	0.3168	0.6389	0.7101	0.0074	-0.2684	-0.0013	1.8502
GM[8], dorsal, weight	0.2756	0.4848	0.6125	0.0024	-0.0724	-0.0007	0.7719
GM[8], ventral, weight	0.4143	0.6702	-	0.0052	-0.1734	-	0.5554

[1] Parameter estimates correspond to the following linear regression model:

$$\text{Weight} = \text{HCW}\ (b_3) + \text{FYG}(b_2) + \text{Marbling score}\ (b_1) + b_0$$

[2] Hot carcass weight

[3] Final yield grade

[4] Marbling score

[5] Top sirloin butt

[6] *Biceps femoris*

[7] *Gluteus accessorius*

[8] *Gluteus medius*, center-cut

Ribeye area was not significant for the model at $P < 0.05$