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Muscle Profiling of the *Biceps Femoris*, *Gluteus Accessorius*, and *Gluteus Medius* Comprising 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. Extensive profiling for individual muscle portions of the NAMI #184 beef top sirloin butt remains understudied. The objective was to compare fluid loss, objective color (L^*, a^*, b^*), pH, and objective tenderness of the *biceps femoris* (BF), *gluteus accessorius* (GA), *gluteus medius*, dorsal (GMD), and *gluteus medius*, ventral (GMV). Beef top sirloin butts ($N = 70$) were collected from carcasses ranging in quality grade (USDA Select and Top Choice), hot carcass weight (light ≤ 362 kg, medium = 363 to 453 kg, heavy ≥ 454 kg), and ribeye area (REA; small ≤ 27.8 cm^2, medium = 27.9 to 40.6 cm^2, large ≥ 40.7 cm^2). Warner-Bratzler shear force values were the lowest for the BF and GA ($P < 0.001$) and were significantly different than the GMD and GMV. The GA reported the lowest percentage of fluid loss in raw and cooked forms ($P < 0.001$, $P < 0.001$) and the highest pH ($P < 0.001$). The GMD exhibited the highest percentage of raw purge ($P < 0.001$), highest L^* value ($P < 0.001$), and highest shear force ($P < 0.001$). The GMV had the highest percentage of cook loss ($P < 0.001$). USDA Top Choice muscles were more tender than Select ($P < 0.001$) with higher L^* value ($P < 0.001$). All 4 top sirloin muscles and muscle subunits had average peak shear force values below 3.9 kg, and thus, all were within the threshold for USDA "very tender." These 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.

Key words: alternative merchandising, beef, muscle profiling, top sirloin
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Introduction

Maximizing carcass utilization while optimizing consumer preference continues to be a key focus of the beef industry (West et al., 2011; Ohman et al., 2015; Jung et al., 2016). 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 with 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, with some portions being underutilized as individual cuts.

Von Seggern et al. (2005) conducted comprehensive muscle profiling research of the beef chuck and round, leading to the creation of beef value cuts such as the flat iron steak and petite shoulder tender, which increased the value of the beef chuck primal by 60%

(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). Although some research has been conducted on muscle characteristics of the beef top sirloin butt (King et al., 2009; Machete, 2009; Hosch et al., 2013; Machete et al., 2013; Apple et al., 2014; Smith et al., 2014; Colle et al., 2015, 2016; Olson et al., 2019; Beyer et al., 2021; King et al., 2021), smaller muscle portions such as the GA remain understudied and underutilized (Clark et al., 2019).

The objective of the study was to compare fluid loss (raw and cooked), objective color, pH, and objective tenderness of individual top sirloin muscles and muscle subunits. It is hypothesized that there will be differences between intrinsic qualities of the top sirloin muscle subunits. There is potential for further value to be added to the top sirloin butt and the entire beef carcass if the GA and BF were to be fabricated individually and sold as single-muscle steaks. These data could preface greater value opportunities for the beef top sirloin butt and new beef value cuts derived from individual sirloin muscles.

Materials and Methods

Product procurement

Beef carcasses ($N = 70$) were selected from Washington Beef (Toppenish, WA) based on a $2 \times 3 \times 3$ factorial matrix of quality grade (QG), hot carcass weight (HCW), and ribeye area (REA) (Table 1). This selection criteria ensured a wide variety of carcass traits were included in the study to represent the diversity of the US beef industry and annual rise in HCW without specific knowledge of cattle breed, management strategy, or feeding ration. Carcasses were selected on the United States Department of Agriculture (USDA) grading line, sourced from youthful cattle determined to be physiologically less than 30 mo of age according to USDA protocol for grading (FSIS, 2017). Left sides of beef carcasses were evaluated 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 $Modest^{00}$ to $Moderate^{99}$ (Top Choice) were the parameters of the first factor. Within each QG, carcasses were selected for HCW: light (≤ 362 kg), medium (363 to 453 kg), and heavy (≥ 454 kg). The third factor was REA: small (≤ 27.8 cm^2), medium (27.9 to 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 postmortem at 4°C. Once removed from vacuum packaging, top sirloins were trimmed to approximately 0.64 cm of subcutaneous fat to achieve industry standards. Top sirloin butts were fabricated into individual muscles and muscle subunits: BF (top sirloin butt cap, NAMI #184D), GA, *gluteus medius* center-cut dorsal side (GMD; NAMI #184F), and *gluteus medius* center-cut ventral side (GMV; NAMI #184B Purchaser Specified Option 1). For the GMV, Purchaser Specified Option 1 indicates that the dorsal portion of the GM was separated from the main portion by cutting through the natural seam (North American Meat Institute, 2014). Muscle profiling characteristics were not analyzed for the GP, with this muscle excluded from further analysis. The GP possesses low consumer appeal because of an abundant presence of connective tissue necessary to join the hip bone to the top sirloin butt subprimal (Jones et al., 2004).

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), and 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 and then allowed to thaw 24 h at 4°C. Steaks were then removed from packaging and weighed in the raw state. A percentage of fluid loss was calculated:

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

$$Purge\ percentage = \frac{Purge}{Steak\ weight, frozen - bag\ weight - label\ weight} \times 100$$

Color

Once thawed, steaks were allowed to bloom under refrigeration for 1 h 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; version 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 intermuscular fat.

Cooking

Steaks were thawed for 24 h at 4°C and then tempered at room temperature for 20 min prior to cooking. Two-sided electric grills were preheated to 232°C, and steaks were probed with a Type K thermocouple (93230-K EconoTemp, Cooper-Atkins, Middlefield, CT) 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.

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

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

Objective tenderness

Warner-Bratzler shear force (WBSF) was used to determine objective tenderness of top sirloin muscles. From each steak, a minimum of 6 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/s. 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 version 9.4 (SAS Institute, Cary, NC), with significance being determined at $P < 0.05$. Prior to full analysis, normality of each dataset was ensured utilizing boxplots and regression models of the residuals to evaluate for skewness or outliers. Upon analysis, the interactions of HCW × individual muscle and REA × individual muscle were not significant factors and thus were excluded from further discussion within the current study. QG, individual muscle, and their interaction were assumed as fixed effects. Treatment least-squares 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 were analyzed for acceptability at USDA tenderness thresholds of 4.4 and 3.9 kg of shear force, which are representative of USDA "tender" and "very tender," respectively (ASTM, 2007).

The original research design intended to utilize a total of 72 top sirloin subprimals. Only 2 carcasses were found during the selection phase for the carcass combination of Top Choice, light HCW, and large REA (Table 1). This resulted in a total of 70 top sirloin

Table 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.

butts being collected. To account for inconsistent sample size, least-squares means were evaluated in data output.

Results and Discussion

Fluid loss and cookery

Of all top sirloin muscles and subunits studied, the GA had the lowest percentage of purge (Table 2) and cooking loss (Table 2). The GMD had the highest fluid loss percentage in the raw state, and GMV had the highest fluid loss percentage in the cooked state (Table 2). QG (Table 3) did not impact raw purge ($P = 0.189$) or cook loss ($P = 0.125$) percentages 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. This difference may be a result of more free water being lost during the 24 h refrigerated thaw of this project, as Machete (2009) only thawed steaks for 16 h and did not report raw purge percentages. Freezing and thawing of steaks used in the present study may have increased purge of raw sirloin muscles compared with fresh sirloin steaks as used by Colle et al. (2015). Colle et al. (2015) found GM purge to be 3.51% on Day 21 of aging, as compared with 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 and 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, regardless of whether 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 well-done. The GA would be an advantageous steak alternative for traditionally cut top sirloin steaks given the low percentage of fluid loss in both raw and cooked forms, thus increasing the likelihood of a juicy eating experience.

Table 2. Least-squares means for fluid loss, color score, pH, and objective tenderness of individual sirloin muscles

Value	*Biceps femoris*	*Gluteus accessorius*	*Gluteus medius*, dorsal	*Gluteus medius*, ventral	SEM	Model *P* value
Purge[1] (%)	8.88[b]	4.95[c]	9.73[a]	8.26[b]	0.25	< 0.001
Cook loss[2] (%)	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[3] (kg)	2.83[c]	2.79[c]	3.55[a]	3.09[b]	0.08	< 0.001

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

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

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

[3]Warner-Bratzler shear force.

Table 3. Least-squares means for quality grade treatment effects on fluid loss, color score, pH, and objective tenderness of individual sirloin muscles

	USDA Quality Grade			
Value	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].

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

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

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

[3]Warner-Bratzler shear force.

Color

The BF had the lowest L^* value ($P < 0.001$); thus, it was the darkest muscle evaluated (Table 2). Assessing a^* values for redness, a two-way interaction was observed between individual sirloin muscle and QG ($P = 0.046$, Figure 1). The BF and GA muscles of either QG were more red than GM muscles, whereas GM Select muscles were more red than GM Top Choice. The GA had the highest b^* value (Table 2). Of all top sirloin muscles evaluated, the GMD subunit displayed the highest L^* value, indicating the lightest color. Given the findings of the present study, further research may be necessary to explore color stability of individual sirloin muscles and subunits, expanding upon findings from Apple et al. (2014), who reported a color gradient does

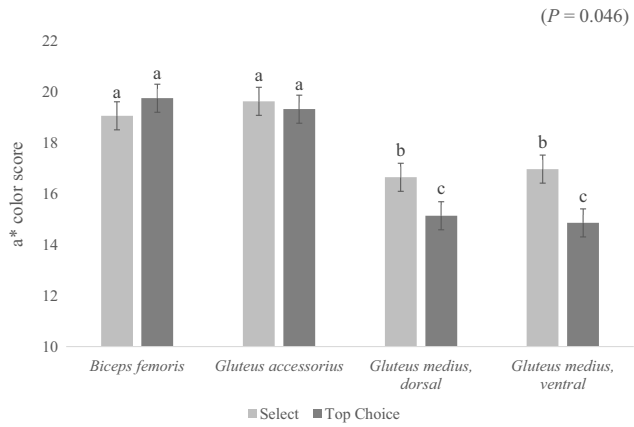

Figure 1. Two-way interaction between individual beef sirloin muscle and quality grade (USDA Select and Top Choice) for *a** color score of the *Biceps femoris*, *Guteus accessorius*, *Gluteus medius* dorsal, and *Gluteus medius* ventral. Steaks were thawed 24 h at 4°C and then allowed to bloom for 1 h 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-squares means ± standard error. [abc]Means without a common superscript differ ($P < 0.05$).

exist within the GM. Additionally, Mancini and Hunt (2005) reported that color of varying muscles may differ because of pH and muscle function or feeding and management practices of the live animal. 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 from the round, and 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 because 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 that variation in physical and chemical properties of muscles was most evident across QG. Our results corroborated these data, showing lower *L** values (darker in color) within USDA Select carcasses than sirloin muscles from Top Choice carcasses ($P < 0.001$, Table 3). Significant differences were not observed between QG for *b** color values ($P < 0.858$, Table 3). O'Sullivan et al. (2003) determined that *b** is less reliable than *L** or *a** for reporting objective fresh muscle color and better suited to describe browning in subjective color score.

Muscle pH

The GA possessed the highest pH ($P < 0.001$, Table 2), possibly confirming why this muscle also displayed the lowest fluid loss percentages. Muscle pH is highly correlated with water holding capacity (Montgomery and Leheska, 2008). As pH nears the isoelectric point of meat (5.1 to 5.2), water is less tightly bound to myofibrillar proteins, creating more space between water molecules for light reflectivity and more water to purge (Mancini and Hunt, 2005; Machete, 2009). The GMD and GMV muscle subunits displayed lower pH values than both the BF and GA ($P < 0.05$; Table 2). 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 an indication as to why GMD muscle subunits displayed higher *L** color than GA and BF muscles and GMV displayed higher *L** color than the BF. 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 2). QG did not influence ultimate pH of sirloin muscles ($P = 0.481$, Table 3).

Objective tenderness

The GA and BF had lower peak WBSF values than both GM subunits ($P < 0.05$; Table 2). Within the GM, the GMD was less tender than the GMV ($P < 0.05$). Top Choice muscles were found to be more tender than Select ($P = 0.008$, Table 3), which agrees with Emerson et al. (2013), who determined increasing degrees of marbling corresponded with greater tenderness, juiciness, meaty/brothy flavor intensity, and buttery/beef fat flavor intensity. In contrast, findings from the 2015 National Beef Tenderness Survey (Martinez et al., 2017) and 2006 National Beef Quality Audit (Voges et al., 2007) 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" because each reported peak WBSF value was below the 3.9 kg of force needed to shear through the sample (ASTM, 2007). 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

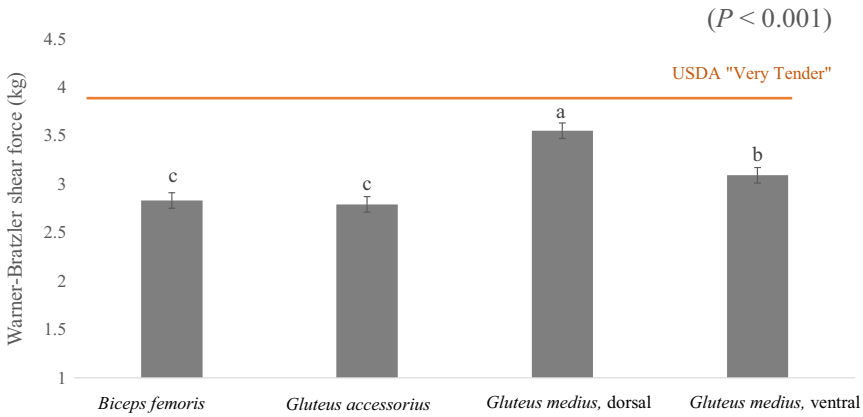

Figure 2. Objective tenderness observations of Warner-Bratzler shear force (kilograms) to compare average peak shear force of individual sirloin muscles and muscle subunits: *Biceps femoris*, *Gluteus accessorius*, *Gluteus medius* dorsal, and *Gluteus medius* ventral. A ceiling threshold at 3.9 kg identifies "USDA Very Tender." [abc]Means without a common superscript differ ($P < 0.05$).

(Figure 2). Even as GMD 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 with high dollar beef cuts such as the *Longissimus lumborum* (Hunt et al., 2014).

Conclusions

Muscle profiling is necessary in order to improve understanding of 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 the GA to have the lowest fluid loss percentages in both raw and cooked forms, with the highest pH. The BF was the darkest in color, and both the GA and BF were more tender than GM muscle subunits. This study suggests higher market value potential and consumer appeal for these alternatively fabricated cuts compared with traditional top sirloin steaks. The present data indicate the GA possesses intrinsic qualities, such as fluid retention and tenderness, 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 with other highly favored cuts of beef.

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