Meat Science 83 (2009) 782–787

Contents lists available at ScienceDirect

Meat Science

journal homepage: www.elsevier.com/locate/meatsci

Consumer acceptance and steak cutting yields of beef top sirloin and knuckle subprimals ☆

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ARTICLE INFO

Article history:
Received 29 May 2009
Received in revised form 22 July 2009
Accepted 10 August 2009

Keywords:
Beef
Consumer acceptance
Gluteus medius
Rectus femoris
Vastus lateralis
Tenderness

ABSTRACT

Beef knuckles ($n = 150$) and center-cut top sirloin butts ($n = 150$) were used to determine portion-controlled steak cutting yields, palatability characteristics, and consumer acceptance of *rectus femoris* (RF), *vastus lateralis* (VL), and *gluteus medius* (GM) steaks. Steak yields were higher ($P < 0.05$) for top sirloins than knuckles. Trained sensory panel ratings for overall tenderness, juiciness, and flavor were similar between RF and GM. Consumer panel ratings for tenderness and juiciness were higher ($P < 0.05$) for GM than RF; however, consumer perceptions of overall like and flavor were similar for GM and RF. *Vastus lateralis* received lower ($P < 0.05$) trained panel and consumer ratings for all traits than either RF or GM. Palatability of VL will need improvement to be a viable foodservice offering. Yet, these data suggest that RF would amply substitute for GM in foodservice settings, and that knuckle steak yields would be adequate for foodservice applications.

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1. Introduction

Rising beef prices have made it difficult for foodservice operators to maintain profitable margins while continuing to meet customers' price and palatability expectations. Therefore, foodservice operators are seeking cost effective alternatives to traditional steak cuts. Muscles used in this manner must possess sufficiently acceptable palatability characteristics to maintain customer satisfaction, and provide suitable yields in steak cutting operations to be profitable.

Traditionally, foodservice steak offerings have been composed of steaks from muscles in the rib and loin regions of the carcass. Of these, the top sirloin (*gluteus medius*) steak has been marketed as the cost effective alternative. Unfortunately, the top sirloin has been associated with a lack of consistency with regard to tenderness (Neely et al., 1998; Savell et al., 1999). Thus, the development of steak cuts from the round or chuck with equal, or greater palatability characteristics would benefit both the industry and consumers.

Studies characterizing the properties of individual muscles have been conducted with the goal of improving utilization and value of muscles from the round and chuck, and the *rectus femoris* has been demonstrated to possess characteristics amenable to foodservice applications (Rhee, Wheeler, Shackelford, & Koohmaraie, 2004; Von Seggern, Calkins, Johnson, Brickler, & Gwartney, 2005). The *rectus femoris* is currently marketed as part of the quadriceps muscle group along with the *vastus lateralis*, *vastus medialis* and *vastus intermedius*. Studies have compared the tenderness of these muscles to the *gluteus medius* at 14 d postmortem, but little information is available regarding the tenderness of these muscles after the extended aging times generally used by purveyors.

This study was planned to evaluate *rectus femoris* and *vastus lateralis* steaks for use in foodservice establishments as an alternative to *gluteus medius* steaks. Specifically, this study was designed to: (1) characterize portion-controlled steak yields of intact *rectus femoris* and *vastus lateralis* muscles (from whole knuckles) in comparison to the steak yields of *gluteus medius* (center-cut top sirloin butts); (2) determine the tenderization effect of extended aging periods in beef *rectus femoris* and *vastus lateralis* muscles relative to the top sirloin; and (3) appraise consumer acceptance of *rectus femoris* and *vastus lateralis* steaks relative to the *gluteus medius* steaks when presented in a foodservice setting.

☆ Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product to the exclusion of other products that may also be suitable.

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0309-1740/$ - see front matter Published by Elsevier Ltd.
doi:10.1016/j.meatsci.2009.08.021

2. Materials and methods

2.1. Product selection and handling

Beef, round, knuckle, full (IMPS #167C; USDA, 1996; $n = 150$) and beef loin, top sirloin butt (center-cut, boneless; IMPS #184B; USDA, 1996; $n = 150$) were obtained from the fabrication tables of a large commercial beef processing facility. Subprimals were from US Choice carcasses. Subprimals then were transported to the facilities of a large foodservice purveyor and aged (−1 °C) until 21, 35, or 49 d postmortem before being portioned into steaks. These aging times approximated the mean aging times for retail and foodservice operations as reported by Brooks et al. (2000), as well as the maximum time observed by those investigators in foodservice outlets. Additionally, these aging times are consistent with more recent reports of aging times used in foodservice product lines (Voges et al., 2007).

2.2. Cutting tests and steak fabrication

After the appropriate aging time, subprimal weights were recorded before and after removing them from the vacuum package to allow purge losses to be calculated. Each subprimal was then subjected to a single pass through a blade tenderizer (TC700M; Ross Industries, Inc., Midland, VA). After blade tenderization, a third weight was taken to assess losses due to blade tenderization; however, losses due to blade tenderization were negligible, and, consequently, were combined with purge loss in subsequent calculations.

Top sirloin subprimals were divided in half (anterior to posterior along the sciatic ligament), as is commonly done in steak portioning. The two halves of each subprimal were trimmed of heavy connective tissue and external fat exceeding 0.64 cm. Intact knuckle subprimals were separated along the natural seams to produce *rectus femoris* and *vastus lateralis* muscles (*vastus medialis* and *vastus intermedius* muscles were regarded as lean trim). These two muscles were trimmed of heavy connective tissue. The weight of pre-trimmed muscles and associated trimmings were determined. *Gluteus medius, rectus femoris* and *vastus lateralis* muscles were portioned into steaks (199 or 256 g) by an automated portioning machine (model # IPM-03-X600; Marel Food Systems, Inc., Lenexa, KS). To ensure the resulting steaks were suitable for consumer or trained sensory panel evalution, parameters required steak thickness be at least 2.0 but not more than 4.1 cm in thickness. Finally, the steak weights and lean trim weights were determined after steak cutting. Steaks from each cut were assigned to trained sensory panel and consumer panel evaluations in a manner to ensure that the selected steaks were of suitable thickness for belt grill cookery and to minimize variation in steak thickness at cooking. All steaks were vacuum packaged and frozen (−20 °C) until further analysis.

2.3. Simulated restaurant consumer evaluations

Consumer evaluations were conducted during meals in a simulated restaurant environment using methodology similar to Hoover et al. (1995). Panelists ($n = 300$) were recruited from civic organizations in the Lubbock, TX area. Participants were targeted to represent the typical customers of mid-price range steakhouse restaurants. Consumers were served in a restaurant setting with each table of 8 consumers seated by a waiter at 15 min intervals. Water, iced tea, and dinner rolls were furnished on each table before consumers arrived. As consumers were seated, the server provided instructions regarding the questionnaire and provided additional assistance with recording consumer responses, as needed, throughout the meal. The first course was served when all eight consumers were seated and instructions had been given. The first course included a salad. Upon completion of the salad course, the plates were removed and the main course was served. The main course consisted of three steaks (one of each muscle) on each plate with green beans and a baked potato. Steak order on the ballot was rotated across consumers so to eliminate potential bias associated with sample order. Each panelist was asked to evaluate a portion from the center of each steak (in the order presented on the ballot) and record their observations. Panelists rated their overall liking of the sample, as well as their liking of the tenderness, juiciness, and flavor characteristics of the sample on an 8-point scale (1 = dislike extremely; 8 = like extremely). Panelists then indicated whether each attribute was acceptable or unacceptable. After completion of the main course, consumers were served a dessert of their choice. Consumers were allowed to finish their meal as desired, and ballots were collected as the panelists left the table.

Each steak had been thawed for 24 h to 5 °C and was cooked on an electric belt grill as described by Wheeler, Shackelford, and Koohmaraie (1998) to an end-point temperature of 70 °C. Because steak thickness varied slightly, end-point temperature was monitored by inserting a 6.4-cm Type J hypodermic needle thermocouple (Iomega, Stamford, CT) attached to a hand-held thermometer (Model 91100-00 Cole Parmer Instrument Co., Vernon Hills, IL) into the geometric center of each steak to ensure steaks reached the proper cooking end-point before being presented to consumers. Each steak was seasoned with salt and pepper prior to cooking.

2.4. Trained sensory panel evaluation

Steaks designated for trained sensory panel evaluation were thawed at 5 °C for 24 h and cooked to an end-point temperature of 70 °C on an electric belt grill according to the procedures outlined by Wheeler et al. (1998). End-point temperature was monitored by inserting a 6.4-cm Type J hypodermic needle thermocouple (Iomega, Stamford, CT) attached to a hand-held thermometer (Model 91100-00 Cole Parmer Instrument Co., Vernon Hills, IL) into the geometric center of each steak to ensure that the slightly varying steak thickness did not affect the final cooked temperature. Samples were served to an eight-member trained sensory panel that had been recruited, trained, and conducted as described by Cross, Moen, and Stanfield (1978). Cooked steaks were cubed and each panelist received three random cubes (1.3 cm × 1.3 cm × cooked steak thickness). Panelists evaluated steaks for tenderness, juiciness, beef-flavor intensity, and off-flavor intensity (1 = extremely tough, dry, bland, or extremely intense and 8 = extremely tender, juicy, intense, or none) for each steak. Data for each attribute was reported as the mean of all panelists' scores for each steak. Nine samples (one from each muscle × aging time combination) were presented to the panel in a randomized order in each panel session. The panel was presented a warm up sample followed by the first four samples and allowed to rest for 15 min. Following the break, panelists evaluated the remaining five samples. Paired *gluteus medius* steaks (one from each half of the divided muscle) were used for sensory panel evaluation. Two adjacent *rectus femoris* and two adjacent *vastus lateralis* steaks from each subprimal were cooked and presented to the sensory panel.

2.5. Sarcomere length and immunoblotting of desmin

To facilitate greater understanding of the factors affecting the tenderness of these muscles, sarcomere length and the extent of proteolytic degradation of desmin were assessed on six cubes (1 cm × 1 cm × steak thickness) removed from each of the 450 (150 *gluteus medius*, 150 *rectus femoris*, and 150 *vastus lateralis*) cooked steaks or pair of steaks used for trained sensory panel evaluations.

Sarcomere length was measured on 0.5 × 0.5 × 0.5 cm pieces ($n = 1$ from each core) removed from each cube that had been removed from the steak as it was presented to the trained sensory panel. Excised pieces were fixed in glutaraldehyde according to the procedure of Koolmees, Korteknie, and Smulders (1986). Sarcomere length was measured by the laser diffraction method of Cross, West, and Dutson (1981). Tissue remaining after sarcomere length sampling was pulverized in liquid nitrogen, and intact desmin was measured by SDS PAGE and Western immunoblotting analysis as described by Wheeler, Shackelford, and Koohmaraie (2002), with the following modifications. Blots were simultaneously probed for desmin (clone D3, developed by D.A. Fischman and obtained from Studies Hybridoma Bank HD-7-3263 from the NICHD) and α-actinin (monoclonal anti-α-actinin clone EA-53; Sigma Chemical Co., St. Louis, MO, USA). Data were expressed as the ratio of the intensity of the desmin band to the intensity of the α-actinin band.

2.6. Statistical analysis

Data were analyzed as a completely randomized design using the PROC GLIMMIX procedure of SAS (SAS Inst., Inc. Cary, NC, USA). For all traits except consumer panel ratings, the model tested for the fixed effects of muscle and aging time, as well as the two-way interaction. For trained sensory panel data, panel session was included as a random effect. Additionally, consumer panelist was included as a random effect for consumer panel ratings. Because aging time was confounded with consumer panelist, the analysis of consumer panel ratings did not test aging time effects. Muscle-effect means were separated using the DIFF option. Aging effects were evaluated using orthogonal polynomial contrasts. Chi-square tests were used to compare the proportion of samples deemed to be acceptable for each palatability attribute within each muscle. Initial F-tests comparing the proportion of acceptable steaks from all three muscles were highly significant ($P < 0.001$) for all palatability attributes; thus, separate tests were conducted for pair-wise comparisons of the muscles. A pre-determined level of 0.05 was used for judgments of statistical significance.

3. Results and discussion

3.1. Cutting yields of whole knuckle and top sirloin subprimals

The most commonly used carcass fabrication techniques in US commercial packing plants bisect the whole knuckle during the round-loin separation, resulting in a round, knuckle (IMPS #167; USDA, 1996; NAMP, 1997) and a loin, balltip (IMPS #185B; NAMP, 1997; USDA, 1996), which reduces the number of steaks that can be obtained from the *rectus femoris* and *vastus lateralis* muscles which are located in these subprimals. Pfeiffer, Voges, King, Griffin, and Savell (2005) reported that whole knuckles had greater total steak yields and less purge and cutting losses than knuckle and balltip subprimals (combined) when fabricated to a retail endpoint. Currently, whole knuckles are commercially available on a limited basis. Furthermore, trends of marketing individual muscle cuts will likely increase the production of intact muscles. Pfeiffer et al. (2005) reported that fabricating carcasses in a manner designed to maximize the production of whole muscles increased carcass value, primarily by keeping muscles intact rather than separating them into small pieces.

Center-cut top sirloin butt subprimals produced a greater ($P < 0.05$) percentage of their initial weight as steaks than did whole knuckles (Table 1). The center-cut top sirloin is comprised primarily of one muscle (*gluteus medius*), whereas the knuckle subprimal is comprised of a complex of four muscles, only two of which were deemed suitable for steak cutting. Additionally, because the *vastus intermedius* and *vastus medialis* were designated as lean trimmings, there was a greater percentage ($P < 0.05$) of trim from the knuckle compared to the top sirloin.

Table 1
Least-squares means for portion-controlled cutting yield parameters of top sirloin butt and intact knuckle subprimals.

Trait	Top sirloin butt	Whole knuckle	SEM	P > F
Initial weight (kg)	3.29	5.59	0.05	<0.001
Purge loss (%)[a]	1.70	1.11	0.06	<0.001
Pre-trimmed GM[a] (%)	85.38	–	0.28	–
Pre-trimmed RF[b] (%)	–	30.86	0.15	–
Pre-trimmed VL[c] (%)	–	33.56	0.17	–
GM[b] steaks (%)	78.32	–	0.29	–
GM[b] steaks (n)	11.5	–	0.15	–
RF[c] steaks (%)	–	28.07	0.16	–
RF[c] steaks (n)	–	6.9	0.07	–
VL[d] steaks (%)	–	31.10	0.18	–
VL[d] steaks (n)	–	7.5	0.08	–
Steak yield (%)	78.32	59.17	0.26	<0.001
Total trim (%)	19.71	39.51	0.02	<0.001

[a] Includes losses due to blade tenderization, which were negligible.
[b] *Gluteus medius* steaks (center-cut top sirloin).
[c] *Rectus femoris* (tip center).
[d] *Vastus lateralis* (tip side).

Purge loss was higher ($P < 0.05$) for the top sirloin butt than for the whole knuckle. This may be attributable to the removal of a large portion of external fat and connective tissue when the *gluteus medius* was removed from the hip bone and when the cap (proximal portion of the *biceps femoris*) was removed from the *gluteus medius* at the processing plant. In contrast, external connective tissue was largely undisturbed on the knuckle subprimals. Purge loss also increased ($P < 0.05$) progressively in both muscles with increased aging time (1.08%, 1.38%, and 1.76% at 21, 35, and 49 d, respectively; data not shown).

Examining steak yields of the three muscles beginning with the pre-trimmed muscle weights allows the *rectus femoris*, *vastus lateralis,* and *gluteus medius* to be compared to the *gluteus medius* on an equal basis (Table 2). Pre-trimmed *gluteus medius* muscles were heavier ($P < 0.05$) than pre-trimmed *vastus lateralis* muscles, which were slightly heavier ($P < 0.05$) than pre-trimmed *rectus femoris* muscles. Differences in pre-trimmed muscle weights corresponded to the number of steaks obtained from each muscle. Steak yields of the *vastus lateralis* were greater ($P < 0.05$) than those of the *gluteus medius*, which had greater ($P < 0.05$) steak yields than the *rectus femoris*. These differences in steak yields are large enough to be of economic importance, but would likely be profoundly affected by using different portioning parameters (i.e., target steak weights, minimum steak thicknesses, etc.). These findings suggest that, if *rectus femoris* and *vastus lateralis* steaks can be marketed at prices comparable to those of *gluteus medius* steaks, the whole knuckle would be an economically-feasible alternative to center-cut top

Table 2
Least-squares means for portion-controlled cutting yield parameters of pre-trimmed *gluteus medius*, *rectus femoris*, and *vastus lateralis* subprimals.

Trait	*Gluteus medius*	*Rectus femoris*	*Vastus lateralis*	SEM	P > F
Pre-trimmed weight (kg)	2.78a	1.72c	1.87b	0.25	<0.001
Steak yield (%)	91.73b	90.94c	92.65a	0.20	<0.001
Trimmings (%)	8.30b	9.11a	7.48c	0.20	<0.001
Steak number	11.5a	6.9c	7.5b	0.10	<0.001

Least-squares means within a row with differing letters (a–c) differ ($P < 0.05$).

sirloin butts. Additionally, if individual *rectus femoris* and *vastus lateralis* muscles were made available, their cutting yields would compare favorably to those of center-cut top sirloin butts.

3.2. Trained sensory panel analysis

The *rectus femoris* received ratings for overall tenderness, juiciness, beef-flavor intensity, and off-flavor intensity that were similar to those given to *gluteus medius* steaks (Table 3). Steaks from both of these muscles received higher ($P < 0.05$) ratings for overall tenderness than *vastus lateralis* steaks. *Vastus lateralis* steaks received lower ($P < 0.05$) juiciness ratings than *gluteus medius* or *rectus femoris* steaks. *Vastus lateralis* flavor intensity and off-flavor intensity ratings were lower ($P < 0.05$) than those for *gluteus medius* and *rectus femoris* steaks, but these differences were extremely small (0.1 panel units). Lower ratings for flavor intensity and off-flavor intensity in *vastus lateralis* steaks may be due to halo effects associated with the reduced tenderness of the *vastus lateralis* steaks. These findings are in partial agreement with those of McKeith, De Vol, Miles, Bechtel, and Carr (1985) who reported that *rectus femoris* and *gluteus medius* steaks received similar overall tenderness, myofibrillar tenderness, and connective tissue amount ratings at 1 d postmortem. In contrast, Carmack, Kastner, Dikeman, Schwenke, and Garcia Zepeda (1995) reported higher tenderness ratings for *rectus femoris* samples than for *gluteus medius* samples at 7 d postmortem, but found no difference in juiciness or beef-flavor intensity between *rectus femoris* or *gluteus medius* samples. Moreover, Rhee et al. (2004) reported *rectus femoris* was more tender than *gluteus medius* when aged for 14 d, but found no difference in juiciness or flavor between those muscles. Data from the present experiment, as well as other studies, suggest that *rectus femoris* steaks possess palatability characteristics that are equal or greater to those of the *gluteus medius*. However, *vastus lateralis* steaks may not possess sufficient tenderness and juiciness characteristics to meet consumer expectations for center-of-the-plate items.

The *rectus femoris* had the longest ($P < 0.05$) sarcomere lengths of the three muscles evaluated, while sarcomere lengths were shortest ($P < 0.05$) in *gluteus medius* steaks. Sarcomere lengths of *gluteus medius* and *rectus femoris* steaks in this study were notably shorter than those previously reported by our laboratory (Rhee et al., 2004). The muscles in the present experiment were blade tenderized while those of Rhee et al. (2004) were not. It is not known what effect blade tenderization might have had on sarcomere length. McKeith et al. (1985) also reported that *rectus femoris* steaks had much longer sarcomere lengths than *gluteus medius* steaks. Also, in agreement with the present study, Stolowski et al. (2006) reported that sarcomere lengths were similar between *vastus lateralis* and *gluteus medius*.

The amount of intact desmin that was detected did not differ ($P > 0.05$) between *rectus femoris* and *gluteus* medius steaks, regardless of aging time. *Vastus lateralis* steaks had less ($P < 0.05$) intact desmin detected than *rectus femoris* steaks, indicating that a greater amount of proteolysis had occurred in the *vastus lateralis* than in the *rectus femoris*. The amount of intact desmin in *gluteus medius* steaks was intermediate to the amount of intact desmin found in *rectus femoris* and *vastus lateralis* steaks. In contrast to the current study, Rhee et al. (2004) found that, at 14 d postmortem, *gluteus medius* steaks had a greater proportion of desmin degraded than *rectus femoris* steaks.

The *vastus lateralis* was the least tender of the three muscles evaluated in this study, even though sarcomere length was longer and proteolysis was similar to *gluteus medius* steaks. Additionally, *vastus lateralis* muscles had undergone greater proteolysis, but had shorter sarcomere lengths than *rectus femoris* steaks. Based on these data, it is surmised that connective tissue is the primary component contributing to toughness in the *vastus lateralis* muscles. This is in consistent with the report by Stolowski et al. (2006) that the *vastus lateralis* had greater total collagen concentration and less collagen solubility than the *gluteus medius*. In contrast, Von Seggern et al. (2005) reported that the *vastus lateralis* and *rectus femoris* to be similar in total collagen concentration and that both had less total collagen than the *gluteus medius*. Perhaps, tenderization strategies developed for the *vastus lateralis* should concentrate on those technologies that address connective tissue integrity.

Increasing aging time from 21 to 49 d produced a linear reduction ($P < 0.05$) in the amount of intact desmin detected in all three muscles (Table 3). Tenderness ratings increased quadratically with a greater increase occurring between 21 and 35 d than between 35 and 49 d. The finding that considerable proteolysis (but relatively small tenderness differences) can be detected between prolonged aging times is consistent with previous results reported by King, Wheeler, Shackelford, and Koohmaraie (2009) and King et al. (2009). Gruber et al. (2006) reported diminishing aging responses with increased aging (up to 28 d) in *rectus femoris*, *vastus lateralis*, and *gluteus medius* steaks. From these data, it is evident that longer aging times will increase the extent of postmortem proteolysis, and consequently, improve tenderness, though these changes are not linear and may not be statistically or practically significant with all incremental increases in time. There were linear ($P < 0.05$) increases in juiciness and beef-flavor intensity, as well as a linear ($P < 0.05$) decrease in off-flavor intensity with increasing aging time; however differences in these attributes across aging

Table 3
Least-squares means for trained sensory panel ratings of blade tenderized *gluteus medius*, *rectus femoris*, and *vastus lateralis* steaks aged for 21, 35, or 49 d.

	Overall tenderness[a]	Juiciness[a]	Flavor intensity[a]	Off-flavor intensity[a]	Sarcomere length (μm)	Desmin: α-actinin ratio[b]
Muscle main effect						
Gluteus medius	6.0a	5.7a	4.1a	3.6a	1.50c	0.37ab
Rectus femoris	5.9a	5.7a	4.1a	3.6a	1.92a	0.40a
Vastus lateralis	4.8b	5.4b	4.0b	3.5b	1.77b	0.33b
SEM	0.04	0.02	0.04	0.03	.001	0.01
$P > F$	<0.001	<0.001	<0.01	<0.01	<0.001	<0.001
Aging time main effect						
21 d	5.2	5.5	4.1	3.6	1.73	0.48
35 d	5.6	5.6	4.1	3.6	1.74	0.35
49 d	5.8	5.6	4.1	3.5	1.71	0.27
SEM	0.04	0.02	0.04	0.03	0.01	0.01
Linear $P > F$	<0.001	<0.001	<0.01	0.01	0.06	<0.001
Quadratic $P > F$	0.001	0.01	0.63	0.54	0.10	0.10

Least-squares means within a column with differing letters (a–c) differ ($P < 0.05$).
[a] 1 = extremely tough; dry, bland, or extremely intense; 8 = extremely tender, juicy, intense, or none.
[b] Intensity of desmin band/intensity of α-actinin band.

Table 4
Demographic information about consumer panelists.

Age	18–34		35–50		>50	
% (*n*)	17 (51)		42.3 (127)		40.3 (121)	
Gender	Male			Female		
% (*n*)	41 (123)			56 (168)		
Ethnicity	African American	Caucasian	Native American	Hispanic	Asian	Other
% (*n*)	0 (0)	84.3 (253)	1 (3)	13.7 (41)	0.33 (1)	0.67 (2)
Household size	1	2	3	4	5	⩾6
% (*n*)	9.0 (27)	33.3 (100)	14.7 (44)	26.0 (78)	10.7 (32)	6 (18)
Household income	Single			Dual		
% (*n*)	32.3 (97)			65.7 (197)		
Annual household income (thousands)	<20	20–29	30–49	50–69	70–100	>100
% (*n*)	3.33 (10)	9.7 (29)	22 (66)	21.0 (63)	29.3 (88)	13.3 (40)
Beef consumption[a]	None	1–2		3–4	5–6	⩾7
% (*n*)	0 (0)	25.7 (77)		46.7 (140)	19.7 (59)	8.0 (24)

[a] Number of times beef consumed each week.

Table 5
Least-squares means for consumer ratings and level of consumer acceptance of palatability attributes of *gluteus medius*, *rectus femoris*, and *vastus lateralis* steaks served in a simulated upscale dining environment.

Muscle	Overall like[a]		Tenderness like[a]		Juiciness like[a]		Flavor like[a]	
	Rating	Acceptable (%)	Rating	Acceptable (%)	Rating	Acceptable (%)	Rating	Acceptable (%)
Gluteus medius	6.3a	95.0x	6.3a	95.3x	6.6a	95.7x	6.1a	93.3x
Rectus femoris	6.2a	94.7x	6.1b	91.3x	6.4b	95.3x	6.2a	93.7x
Vastus lateralis	5.7b	84.3y	5.4c	78.3y	5.7c	84.3y	5.8b	87.3y
SEM	0.07	–	0.08	–	0.07	–	0.07	–
P > *F*	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.01

Least-squares means, within an attribute, with differing letters (a–c) differ ($P < 0.05$).
Percentages of acceptable steaks, within an attribute, with differing letters (x, y) differ ($P < 0.05$).
[a] 1 = dislike extremely; 8 = like extremely.

times were less than 0.1 panel units, and, thus, of little practical importance.

3.3. Simulated restaurant consumer evaluations

Consumer sensory data were collected from a capture panel. Demographic information regarding the consumers recruited to evaluate steaks in this study is presented in Table 4. This consumer panel was comprised mostly of moderate to heavy beef users recruited from civic organizations in the Lubbock, TX area. Additionally, participants were primarily individuals of Caucasian descent; however, they were largely representative of diverse age, income, and gender groups.

Consumers rated the tenderness and juiciness of *gluteus medius* steaks slightly higher ($P < 0.05$) than *rectus femoris* steaks and both received much higher ($P < 0.05$) tenderness and juiciness ratings than *vastus lateralis* steaks (Table 5). Additionally, flavor ratings were lower ($P < 0.05$) for *vastus lateralis* steaks than for *gluteus medius* and *rectus femoris* steaks. Overall like ratings were in agreement with the trained sensory panel ratings in that *gluteus medius* steaks did not differ ($P > 0.05$) from *rectus femoris* steaks. However, steaks from both the *gluteus medius* and *rectus femoris* received higher ($P < 0.05$) overall like ratings than *vastus lateralis* steaks. The differences between *rectus femoris* and *vastus lateralis* consumer ratings for all attributes in the present study were similar to those reported by Mueller et al. (2006). However those investigators did not compare *rectus femoris* and *vastus lateralis* steaks.

Only 5% of *gluteus medius* steaks were unacceptably tough. The percentage of *rectus femoris* steaks that were unacceptably tough was slightly higher (8%), though not statistically different ($P > 0.05$). However, a much greater proportion ($P < 0.05$) of *vastus lateralis* steaks was determined to be unacceptable (22%) with regard to tenderness by consumers. The percentage of consumers indicating that *vastus lateralis* possessed overall palatability characteristics that were unacceptable was three times greater ($P < 0.05$) than the percentage that rated the *gluteus medius* or *rectus femoris* as unacceptable.

4. Conclusions

Overall, trained sensory and consumer panels' ratings suggest that *rectus femoris* steaks would be a desirable substitute for *gluteus medius* steaks on foodservice menus. Furthermore, at current prices, the portion-controlled steak cutting yields of muscles from whole knuckles would be economically viable to purveyors. However, in order for knuckle subprimals to be cost-effective to purveyors, the *vastus lateralis* must be marketed as a steak item. The present study indicates that the palatability characteristics of *vastus lateralis* steaks are not adequate to consistently meet consumer expectations for tenderness, even when blade tenderized. Thus, further research is warranted to identify tenderization strategies that will improve *vastus lateralis* tenderness.

Acknowledgements

This project was funded, in part, by The Beef Checkoff. The authors are grateful to Jonathan Savell, Patty Beska, Peg Ekeren, Kathy Mihm, and Pat Tammen for their assistance in the execution of this experiment and to Marilyn Bierman for her secretarial assistance.

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