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Characterization of beef *semimembranosus* and *adductor* muscles from US and Mexican origin

M.S. Rubio L. [a,*], R.D. Méndez M. [a], N. Huerta-Leidenz [b]

[a] *Laboratorio de Ciencia de la Carne, Facultad de Medicina Veterinaria y Zootecnia, Universidad Nacional Autónoma de México, Av., Universidad 3000, Del. Coyoacán, Ciudad Universitaria, México, D.F. 04510, Mexico*
[b] *US Meat Export Federation, Jaime Balmes #8, Piso 6, Despacho 602, Col. Los Morales Polanco, Mexico, D.F., C.P. 11510, Mexico*

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Abstract

The purpose of this study was to compare the chemical composition and sensory characteristics of two beef muscles (*semimembranosus*, SM and *adductor*, AD) from the inside round of Mexican and US origins. Inside rounds were obtained from 20 Mexican bull carcasses, representing beef of Mexican origin. Forty-vacuum packaged USDA Choice and Select inside rounds were purchased from a local trader, representing US beef. Muscles were analyzed for chemical composition, Warner–Bratzler shear force (WBSF), cooking loss percentage, instrumental color, textural profile, and consumer acceptability. Muscles imported from the US contained more intramuscular fat, had higher cooking loss percentages, lower shear force values, and higher consumer ratings for overall desirability than Mexican counterparts ($P < 0.05$). Choice and Select beef samples had similar WBSF values ($P > 0.05$). Consumers found differences in juiciness and tenderness ratings between the two muscles, with the SM being tougher and less juicy than the AD ($P < 0.05$).

Keywords: Beef; Semimembranosus; Adductor; Mexico; USA; Quality

1. Introduction

Mexico's meat market is open for new trends. In 2002, 40% of the meat sold in Mexican retail outlets was US meat (SAGARPA, 2003; Villegas, 2003). Most of the meat was marketed as typical US cuts, which were welcomed by Mexican consumers. The Mexican meat industry could benefit from marketing new and under-utilized cuts, such as those obtained from the chuck or round. Recent data has shown that the wholesale value of beef retail cuts has been decreasing (Von Seggern, Calkins, Johnson, Brickler, & Gwartney, 2005). Therefore, it is important to explore comparative characteristics of low-impact wholesale cuts, differing in country of origin, in order to create respective to muscle and profiles of these cuts so they can be better utilized in retail and processing segments.

In Mexico, beef carcasses are marketed without grades. However, certain criteria are applied; for instance, the markets' target is lean meat, and accordingly, the majority of the carcass supply is composed of young, well-fed bulls. On the other hand, the US meat is commonly sold in Mexico under USDA quality grades (USDA, 2000); USDA Choice for food service, and USDA Select for retail outlets. This study was designed to characterize underutilized muscles, the *semimembranosus* and *adductor*, from the beef round, in terms of their composition and quality traits, of which are of potential value in the Mexican retail market.

2. Materials and methods

A total of 60 inside rounds were used in this study. Twenty bull carcasses selected to match the retail beef available in Mexican supermarkets, were evaluated by trained personnel at two meat (wholesale) distribution centers located at Aguascalientes and Veracruz using the

* Corresponding author. Tel.: +525558480810; fax: +5255848514.
E-mail address: msalud@servidor.unam.mx (M.S. Rubio L.).

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USDA grading procedure (USDA, 2000). After selection, carcasses were fabricated and inside rounds were collected ($N = 20$). Mexican carcasses were USDA Standard compared to the imported carcasses which were USDA Choice and Select. A summary of the carcasses originating from Mexico are displayed in Table 1. Forty inside rounds, 20 USDA Choice and 20 Select, used to represent US imported beef were purchased from a local importer.

2.1. Sampling beef muscles

Each inside round was fabricated to obtain the *semimembranosus* (SM) and *adductor* (AD) muscles. From each individual muscle, four 2.54-cm-thick steaks were cut and randomly assigned to Warner–Bratzler shear force (WBSF), chemical analyses, sensory evaluation, color, and texture profile. Samples were then labeled, vacuum-packaged and frozen (−30 °C) until further analysis. Prior to each test, the steaks were thawed for 24–30 h at 2–4 °C. For chemical composition, the external fat and epimysium were trimmed off and the lean portion was thoroughly ground in a food processor unit (Braun Food Preparation Center 5 in 1, Braun Inc., Lynnfield, MA, USA).

2.2. Chemical composition

Samples of ground beef were analyzed for moisture, fat and protein contents according to AOAC methods (AOAC, 1990). Moisture (g water/100 g sample) was determined by drying 3 g of sample at 100 °C to constant weight. Fat (g fat/100 g sample) was calculated by weight loss after a 6-cycle extraction with petroleum ether in a Soxhlet apparatus. Protein (g protein/100 g sample) was analyzed according to the Kjeldahl method. Percent protein was determined as follows: Crude protein = $N \times 6.25$.

2.3. Meat quality traits

After steaks were allowed to bloom for 15 min, objective color measurements were performed in duplicates, by means of a Minolta Chroma Meter CR-310 (Minolta, Osaka, Japan). The lightness (L^*), redness (a^*), and yellowness (b^*) of each sample were measured. WBSF and cooking loss percentage were determined according to AMSA (1995). The steaks were broiled to an internal temperature of 70 °C (Broiler Daweood, Mod DEG-22, 1500W, Imported by Gigante S.A de C.V, Mexico DF, Mexico), which was monitored with iron-constantan thermocouples (Omega Engineering Inc., Stamford, CT, USA) and a portable recording thermometer. Upon reaching an internal temperature of 70 °C, the steaks were removed from the broilers and allowed to cool to room temperature (20–25 °C). For WBSF measurements, eight 2.5-cm long cores were removed from each steak, parallel to the longitudinal orientation of muscle fibers. Each core was sheared once perpendicular to muscle fiber orientation using a Warner–Bratzler machine (G-R Elec. Mfg. Co., Manhattan, KS 66502, USA). Each steak was weighed before and after cooking in order to calculate cooking loss percentage: $100 \times (\text{raw wt.} - \text{cooked wt.})/\text{raw wt.}$

Table 1
Means and standard deviations for traits of the selected Mexican bull carcasses

Trait	
N	20
CCW[a](kg)	342.99 ± 37.80
Ribeye area (cm^2)	84.99 ± 10.23
Actual back fat thickness (mm)	0.39 ± 0.23
Maturity	A50
Marbling score[b]	193 ± 92.77
Kidney, pelvic and heart fat (%)	1.4 ± 0.57
USDA yield grade	1.47 ± 0.44
USDA quality grade	Standard

[a] Cold carcass wt.
[b] Marbling score 100 = practically devoid 0; 200 = traces 0; 300 = slight 0; 400 = small 0.

2.4. Sensory evaluation

The steaks were cooked as previously described (AMSA, 1995), then portioned into cubes of uniform dimensions ($2 \times 2 \times 2$ cm). Warm portions of Mexican and both grades of imported beef (USDA Choice and USDA Select) were randomly selected and served immediately. Consumer panelists ($n = 118$) were presented with three samples and asked to assign scores to each sample for appearance, flavor, flavor intensity (taste), texture and overall desirability using a seven-point hedonic scale from: (1) dislike very much; to (7) like very much.

2.5. Texture profile

The Texture Analyser TA.XT2i (Stable Micro Systems, Surrey, England) had a 5.0 kg load cell fitted and a 4.0 cm diameter acrylic compression plates. Pre- and post-test velocity was 2.0 mm/s, with a test velocity of 1.0 mm/s, data acquisition velocity of 200 pps. Texture profile procedure was applied to 1.0-cm diameter × 1 cm length meat cores at 10 °C. Cores were pressed twice with a time interval between compressions of 5.0 s. Texture attributes were obtained from the Software Expert program (Stable Microsystems, Surrey, England) graphs.

2.6. Statistical analysis

The data was analyzed with SAS statistical software (SAS, 1995), using the GLM procedure to perform an analysis of variance for each of the measured variables (Lentner & Bishop, 1986). The effects of the country of origin (Mexican and imported) and muscle type were the independent variables in the model the quality measurements were the dependent variables. The statistical model was as follows:

$$Y_{ijkl} = \mu + R_j + S_l + (R * S)_{jl} + E(_i)_{jkl}$$

in which Y_{ijkl} is the value of the dependent variable, μ the overall mean; R_j the effect of the j-esim origin; Sl the effect of the l-esim muscle; $(R * S)_{jl}$ the interaction origin × muscle and $E_{(i)jkl}$ the random error. Means were separated using the Duncan's range procedure. No interactions were found between origin and muscle type. Sensory analyses were performed using a non-parametric procedure (Kruskall–Wallis).

3. Results and discussion

3.1. Chemical composition and quality traits

Proximate composition and quality trait differences among SM and AD muscles from different origins are shown in Tables 2 and 3 respectively. USDA Choice SM muscles contained significantly more ($P < 0.05$) moisture and fat than the USDA Select and Mexican counterparts. On the other hand, US AD muscles had more ($P < 0.05$) intramuscular fat than Mexican AD muscles. A comparative study between Mexican and US meat (Delgado et al., 2005), showed similar results regarding fat content of *M. longissimus dorsi*. Both studies have shown that Mexican meat is leaner than US meat, which usually implies more moisture and less fat. In the muscle profiling study by Von Seggern et al. (2005), SM muscles from USDA Choice and Select grades were shown to have an average of 72.79% moisture and 4.36% fat. Research by Walter, Goll, Kline, Anderson, and Carlin (1965) found similar results. All these studies support the fact that percentage moisture decreases and fat percentage increases with higher marbling scores. Several studies (Brewer, Zhu, & McKeith, 2001; Robbins et al., 2003; Shearer, Burgess, & English, 1986) have shown that visible fat influences consumer buying decisions. Historically, Mexican consumers have demanded lean meat; however, it is difficult to satisfy this demand without adversely affecting meat quality. Much research has revealed that between 2% and 3% of fat is necessary to provide satisfactory sensory characteristics (Bejerholm & Barton-Gade, 1986; DeVol et al., 1988).

Table 2
Mean values for proximate components and quality-related traits of *semimembranosus* samples according to origin and USDA grade

		Imported US beef	
	Mexican beef	USDA Select	USDA Choice
Proximate component			
N	20	20	20
Moisture (%)	$73.29^a \pm 1.47$	$72.86^a \pm 1.00$	$70.90^b \pm 1.50$
Fat (%)	$3.08^a \pm 1.42$	$3.60^a \pm 1.04$	$4.67^b \pm 1.87$
Protein (%)	20.80 ± 1.20	20.61 ± 0.86	21.11 ± 1.15
Quality trait			
Warner–Bratzler shear force (*N*)	$61.19^a \pm 21.57$	$45.70^b \pm 16.18$	$44.13^b \pm 15.20$
Cooking loss (%)	$24.54^a \pm 8.72$	$26.31^b \pm 5.99$	$28.44^c \pm 4.05$
Lightness	$42.19^a \pm 5.19$	$40.94^b \pm 4.29$	$42.65^a \pm 3.35$
Redness	$19.62^a \pm 2.06$	$21.42^c \pm 3.44$	$23.72^b \pm 3.98$
Yellowness	$6.12^a \pm 1.98$	$8.59^b \pm 2.08$	$8.26^b \pm 6.87$

abc Means with different superscripts in the same row are significantly different ($P < 0.05$).

Table 3
Mean values for proximate components and quality-related traits of *adductor* samples according to origin and USDA grade

		Imported US beef	
	Mexican beef	USDA Select	USDA Choice
Proximate component			
N	20	20	20
Moisture (%)	73.77 ± 1.30	73.71 ± 3.18	73.16 ± 4.10
Fat (%)	$2.73^a \pm 0.29$	$3.56^b \pm 0.29$	$3.83^b \pm 0.30$
Protein (%)	$20.64^a \pm 1.30$	$19.88^{ab} \pm 2.41$	$19.48^b \pm 2.94$
Quality trait			
Warner–Bratzler shear force (N)	$47.95^a \pm 19.22$	$33.93^b \pm 18.24$	$34.23^b \pm 11.38$
Cooking loss (%)	$24.43^a \pm 9.98$	$27.74^b \pm 4.24$	$30.60^c \pm 5.57$
Lightness*	$48.25^a \pm 5.42$	$43.84^b \pm 4.43$	$45.51^c \pm 3.69$
Redness*	$18.23^a \pm 1.94$	$20.63^b \pm 3.78$	$22.74^c \pm 2.69$
Yellowness*	$7.25^a \pm 1.72$	$8.10^a \pm 2.23$	$9.25^b \pm 1.55$

abc Means with different superscripts in the same row are significantly different ($P < 0.05$).

No significant differences ($P > 0.05$) in protein content were found among SM samples of differing origins. Protein percentage was approximately 20%, which is in accordance with that reported in the literature (Renand, Picard, Touraille, Berge, & Lepetit, 2001; Wheeler, Cundiff, Shackelford, & Koohmaraie, 2001). No significant differences ($P > 0.05$) were found for moisture, but small ($P < 0.05$) differences were found in protein content among AD muscles.

Cooking loss percentage for SM and AD steaks ranged from 24.43% to 30.60%; within the range which has been reported in the literature (Camfield, Brown, Lewis, Rakes, & Johnson, 1997; Johnson, Lunt, Savell, & Smith, 1988; Jeremiah, Dugan, Aalhus, & Gibson, 2003; Luchak et al., 1998; Silva, Patarata, & Martins, 1999; Wheeler, Shackelford, & Koohmaraie, 1999). Mexican SM muscles are tougher ($P < 0.05$) and have lower cooking loss percentage than US. counterparts. USDA Choice samples had the highest ($P < 0.05$) cooking loss percentage of all samples, which has been previously reported by Sheard, Nute, and Chappell (1998).

USDA Choice and Select samples had similar ($P > 0.05$) Warner–Bratzler shear force values, which are similar to those reported in the literature (George, Tatum, Belk, & Smith, 1999; Lorenzen et al., 2003; Luchak et al., 1998). Shear force values for Mexican beef were in the tough category; in agreement with those reported for lower-grade beef rather than USDA quality grade Choice (Luchak et al., 1998; Tatum, Smith, Berry, & Murphey, 1980; Wheeler et al., 1999). As in SM muscles, AD muscles from Mexican inside rounds were tougher ($P < 0.05$) than US counterparts and exhibited the lowest ($P < 0.05$) cooking loss percentage of all samples. Studies carried out in Puerto Rico (Acevedo-Salinas, 2004), Venezuela (Huerta-Sanchez, Huerta-Leidenz, & Rodas-González, 2004), and Mexico (Delgado et al., 2005), comparing shear force between domestic and imported meat have always shown US beef to have lower shear force with the exception of the "No Roll" beef (Delgado et al., 2005). These effects could be the result of the type of cattle, Zebu and Zebu-crossbreds, which are produced in the American Tropical and Subtropical areas. It is well known that *Bos indicus* and *Bos taurus* tenderness differences are caused by differences in the calpain–calpastatin system (Crouse, Cundiff, Koch, Koohmaraie, & Seideman, 1989). Mexican meat was obtained from bulls, which also helps to explain the inferior quality (Huerta-Leidenz & Ríos-Fuenmayor, 1993; Renand et al., 2001).

Mexican SM muscles were lighter ($P < 0.05$) (higher L^* value) than Select SM, but similar ($P > 0.05$) to Choice SM. USDA Choice SM and AD muscles were redder ($P < 0.05$) compared to Select and Mexican SM muscles. A study carried out in Puerto Rico showed higher values in redness (a^*) for US meat when compared to local meat (Acevedo-Salinas, 2004). Mexican SM muscles presented the lowest ($P < 0.05$) values in yellowness (b^*). A previous study comparing US to Mexican meat (Delgado et al., 2005), found US meat to be paler than south and central Mexico meat, which disagrees with previous studies.

3.2. Textural properties

Important differences were found for hardness, adhesiveness, and springiness between Mexican and US muscles (Table 4). Mexican beef AD and SM proved to be much harder ($P < 0.05$) than USDA Select and Choice muscles. These findings support results regarding shear force values as reported by Bouton and Harris (1972), Caine, Aalhus, Best, Dugan, and Jeremiah (2003) Peachy, Purchas, and Duizer (2002). Also, Choice AD and SM muscles were found to have less ($P < 0.05$) adhesiveness compared to USDA Select and Mexican SM muscles. Mexican and USDA Select AD muscles had less ($P < 0.05$) springiness and cohesiveness than the Choice AD muscles. In contrast, with SM, chewiness for Mexican AD muscles, despite their higher values, were statistically similar ($P > 0.05$) to muscles of US origin.

Table 4
Texture profile of *semimembranosus* and *adductor* samples according to origin and USDA grade

Textural parameter	Imported US beef		
	Mexican beef	USDA Select	USDA Choice
Semimembranosus			
N	20	20	20
Hardness (g)	$217.65^a \pm 237.96$	$161.25^b \pm 124.57$	$79.19^c \pm 51.20^c$
Adhesiveness (g.s.)	$-3.88^a \pm 2.22$	$-6.13^b \pm 3.46$	$-9.37^c \pm 4.07^c$
Springiness	$0.45^a \pm 0.09$	$0.55^b \pm 0.16$	$0.67^c \pm 0.16^c$
Cohesiveness	0.44 ± 0.06	0.44 ± 0.05	0.49 ± 0.07^a
Chewiness (g)	$47.83^b \pm 49.67$	$36.75^{ab} \pm 27.39$	$26.91^a \pm 17.41^a$
Adductor			
N	20	20	20
Hardness (g)	$206.81^a \pm 154.74$	$112.27^b \pm 120.90$	$68.81^b \pm 44.64$
Adhesiveness (g.s.)	$-3.83^a \pm 1.60$	$-3.74^a \pm 2.76$	$-6.08^b \pm 3.06$
Springiness	$0.41^a \pm 0.08$	$0.48^a \pm 0.13$	$0.62^b \pm 0.14$
Cohesiveness	$0.41^a \pm 0.05$	$0.43^a \pm 0.06$	$0.61^b \pm 0.97$
Chewiness (g)	37.18 ± 27.67	24.06 ± 24.79	31.94 ± 70.73

abc Means with different superscripts in the same row are significantly different ($P < 0.05$).

3.3. Sensory attributes

Table 5 shows the sensory characteristics of SM and AD muscles as rated by a consumer panel. Consumers found no differences ($P > 0.05$) in appearance or flavor of the samples tested. However, consumers rated beef originating from Mexico to be less juicy, less tender, and less flavorful ($P < 0.05$) and therefore, of lower overall desirability when compared to imported (US) muscles. Different results were obtained by Delgado et al. (2005) using *M. longissimus dorsi* muscles from Mexico and US. It is known that differences in fat content and composition cause variation in juiciness and flavor intensity (Enser et al., 1998; French et al., 2000; Gandemer, 1999; Gregory, Cundiff, & Koch, 1995; Wheeler, Shackelford, & Koohmaraie, 1996). No significant differences ($P > 0.05$) for sensory traits were found between USDA Select and Choice SM muscles. USDA Select AD muscles shared similarities in sensory characteristics with Mexican and USDA Choice AD samples.

3.4. Comparison between selected muscles

No differences ($P > 0.05$) in chemical composition were found between SM and AD muscles. Similar results were reached by Von Seggern et al. (2005). SM muscles contained less moisture and more protein than AD muscles ($P < 0.05$), but both muscles had the same ($P > 0.05$) concentration of intramuscular fat. AD muscles were found to have lower

Table 5
Consumer test mean scores[A] for sensory attributes and overall desirability of *semimembranosus* and *adductor* samples according to origin and USDA grade

	Imported US beef		
	Mexican beef	USDA Select	USDA Choice
Semimembranosus			
Appearance	4.59 ± 1.35	4.76 ± 1.54	4.51 ± 1.51
Flavor	4.51 ± 1.21	4.58 ± 1.10	4.47 ± 1.23
Juiciness	$4.09^a \pm 1.54$	$5.05^b \pm 1.46$	$5.00^b \pm 1.51$
Aroma	$4.48^a \pm 1.40$	$4.96^b \pm 1.33$	$4.99^b \pm 1.42$
Tenderness	$4.31^a \pm 1.58$	$5.24^b \pm 1.40$	$5.19^b \pm 1.40$
Overall desirability	$4.53^a \pm 1.42$	$5.19^b \pm 1.27$	$5.08^b \pm 1.30$
Adductor			
Appearance	4.81 ± 1.41	4.50 ± 1.55	4.59 ± 1.55
Flavor	4.52 ± 1.23	4.85 ± 1.34	4.55 ± 1.32
Juiciness	$4.72^a \pm 1.55$	$4.93^{ab} \pm 1.49$	$5.23^b \pm 1.45$
Aroma	4.81 ± 1.52	4.81 ± 1.59	4.99 ± 1.55
Tenderness	$4.85^a \pm 1.48$	$5.12^{ab} \pm 1.46$	$5.46^b \pm 1.44$
Overall desirability	$4.77^a \pm 1.48$	$5.01^{ab} \pm 1.49$	$5.20^b \pm 1.39$

ab Means with different superscripts in the same row are significantly different ($P < 0.05$).

A Assigned by a 118-member panel using a 7-point hedonic scale: 1 = I dislike it very much; 7 = I like it very much.

WBSF and had a higher yield regarding cooking loss than SM muscles ($P < 0.05$). AD muscles were lighter and had lower red intensity than SM muscles ($P < 0.05$), agreeing with the data presented by Von Seggern et al. (2005). Consumers' ratings for tenderness agreed with WBSF results. Panelists found AD muscles to be more tender and juicier ($P < 0.05$) than SM muscles; however, no differences ($P > 0.05$) were found for other sensory characteristics. The general acceptability as described by the consumer panel for these two inside round beef muscles was quite similar. Hardness values in the texture profile indicated that SM muscles were similar ($P > 0.05$) to AD muscles. Adhesiveness and cohesiveness were the only textural parameters that showed significant differences between these muscles, the SM exhibiting higher values for both parameters ($P < 0.05$). The main discrepancy with Von Seggern et al. (2005) report is that they found both muscles to have similar tenderness, while we showed that SM muscles were much tougher than AD muscles.

4. Conclusions

Country of origin has a great influence in the compositional, textural and sensory attributes of the *semimembranosus* muscles. On the other hand, small differences due to origin are expected to be found in compositional and quality related traits of *adductor* muscles. Due to its paler color, a possible disadvantage in the retail market, the AD could have a higher potential value for restaurant and other selected markets. With greater tenderness and juiciness, the AD will offer greater consumer satisfaction than the SM.

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