IDENTIFYING BEEF MUSCLES AND PROCESSING TREATMENTS SUITABLE FOR USE IN FAJITA APPLICATION

A Thesis

by

DIANA LORENA HUERTA SANCHEZ

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2006

Major Subject: Animal Science

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Approved by:

Chair of Committee,	Jeffrey W. Savell
Committee Members,	Rhonda K. Miller
	Jimmy Keeton
	M. Sam Mannan
Head of Department,	Gary R. Acuff

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ABSTRACT

Identifying Beef Muscles and Processing Treatments Suitable for Use in Fajita Application.

(August 2006)

Diana Lorena Huerta Sanchez, B.S., La Universidad del Zulia

Chair of Advisory Committee: Dr. Jeffrey W. Savell

Beef fajitas have become a popular food item, but the supply of traditional muscles is insufficient to meet the growing demand. There is a need for alternative muscles that have similar eating characteristics to those currently marketed as beef fajitas. Four different treatments - papain (P), blade tenderization (B), papain + blade tenderization (P+B), and control (C) - were applied to sixty USDA Choice *M. diaphragma pars costalis*, *M. transversus abdominis*, *M. obliquus abdominis internus*, *M. rhomboideus*, *M. trapezius*, *M. latissimus*, and *M. serratus ventralis*. Muscles were cut into sections and frozen at -10ºC for evaluation by a trained sensory panel, consumer panel, and Warner-Bratzler shear force (WBSF) measurements.

Trained panelists found that regardless of muscle, the addition of papain improved palatability scores. In general, treatment tended not to affect the palatability scores of the *M. diaphragma pars costalis* and *M. serratus ventralis*, which tended to receive higher scores in comparison to the other muscles. In general, the control and blade tenderized *M. trapezius* received the lowest trained and consumer panel palatability scores and had the highest WBSF values ($P < 0.05$). Regardless of muscle (except for *M. diaphragma pars costalis* and *M. serratus ventralis*), P and P+B treatments reduced WBSF values ($P < 0.05$). Consumers (n=81) gave the *M. transversus abdominis*, *M. serratus ventralis,* and *M. latissimus* similar ($P > 0.05$) tenderness ratings when the P treatment was applied. Consumers tended to prefer the flavor and tenderness of beef fajita strips that were treated with P and P+B and indicated a preference to purchase muscles with these treatments. Consumers were willing to purchase *M. serratus ventralis* treated with P+B and *M. latissimus* treated with P the majority of the time. Papain improved the eating quality of the muscles studied. The *M. latissimus* and *M. serratus ventralis* when treated with papain alone or in combination with blade tenderization, performed well enough to be considered as alternatives for traditional beef fajitas.

DEDICATION

I dedicate this work to my husband Juan Gabriel Montauti and my success is thanks to him. I have, if not the most, one of the top 10 of the most supportive husbands there can be. Gabriel, I love you and thank you for your wonderful companionship, friendship, patience and, most important, your love. I also dedicate this to my parents, Nelson and Ysis Huerta, who have always believed in me and given me the best example of hard work and persistence. They are exceptional and admirable people and I truly try to follow their steps. Thanks to my brothers, Daniel and Damian, for being so goofy and always making me feel good and making me laugh, I love you guys. Finally, thanks to the rest of my family for always raising my hopes and being there for me.

ACKNOWLEDGEMENTS

This project was funded, in part, by beef and veal producers and importers through their $1-per-head checkoff, and was produced for the Cattleman's Beef Board and state beef councils by the National Cattlemen's Beef Association.

First of all, thanks to God! He loves me and has shown it with his presence in my life and by placing in my path all the wonderful people that helped me finish my work. Thanks to my husband, Gabriel, for being with me day and night working on this project and giving me all his support. Thanks to Dr. Rhonda Miller for her knowledge and assistance which allowed me to do my work in the appropriate manner by showing me the correct way to accomplish a sensory project by taking into account many factors that influence these types of studies and for helping on all the statistical analysis. Thanks to Dr. Osburn for helping on the processing portion of this study; his participation was crucial for the beginning of the study. Thanks to Dr. Savell for giving me the great opportunity to come and work in the United States, because it has been a true life-learning experience.

Thanks to Dr. Miller's group, Tess Aldredge, Katelyn Edwards, and Margaret Schell, who were very supportive and helpful. Thanks to all my co-workers, Kristin Voges, Jason Bagley, Lyda Garcia, LeeAnn Sitka, Carrie Adams, Brad Kim, Eric Metteauer, Robby Smith, John David Nicholson, Bridget Baird, Stacy Mueller, Andy King, and Danielle Espitia for all your help in the meat and sensory lab. Special thanks to Hakan Benli for taking all the pictures which helped to keep this work documented. Thanks to the student workers, Megan Maenius, Keri Bagley, Megan Laster, Katie

Leigh, Stephanie Bradley, and Kyle Baker. I would also like to thank all the people on the third floor that helped with the project: Elisa Cabrera, Dae Keun Shin, Carlos Narciso, Mayra Marquez, Mary Pia Cuervo, Jay Neal, Betsy Booren, Kevin Hawks, Veronica Molina, Matt Brooks, and Ki Yong Chung. I could not have done it without all of your help; you guys were life-savers. Many thanks to Christian Ramirez and Washington Armando Orellana, who came from Honduras to work on their internship and were of great help to the project. Finally, thanks to my brother Daniel Huerta who helped recruit consumers.

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CHAPTER I

INTRODUCTION AND REVIEW OF LITERATURE

Several studies, such as the Muscle Profiling and Bovine Myology (Jones, Burson, & Calkins, 2001) and the Beef Value Cuts program (NCBA, 2001), have identified new steaks and more options for the consumer. Armed with the goal of increasing the overall value of the beef chuck and round, and thus the entire beef carcass, these attempts focused on the chuck shoulder clod, round tip, and bottom round flat. These subprimals, traditionally fabricated into large, multi-muscled cuts, were fabricated into individual muscles and portioned into high quality, consistent steak cuts. Success stories from the examination of these subprimals include the now popular flat iron steak, shoulder tender petite medallions, ranch cut steak, tip center steak, and the tip side steak. These high quality cuts can be moderately priced and help to bridge the wide gap between high priced rib and loin cuts and lower valued roasts and ground beef.

The Bovine Myology and Muscle Profiling study (Jones et al., 2001) additionally examined 39 muscles of the beef chuck and round for palatability and functionality characteristics. This study defined processing methods that can help the industry greater utilize each muscle individually according to its specific characteristics. The immense knowledge gained from these data have provided the industry with valuable information and the opportunity to merchandize individual muscles. Therefore, the next logical step seems to be to evaluate alternative merchandizing methods to optimize the value of each individual muscle, thus increasing the value of the entire beef carcass.

This thesis follows the style of *Meat Science*.

Differences in beef ultrastructure and composition have a strong impact on tenderness (Lopp & Weber, 2005). Belew, Brooks, McKenna, and Savell (2003) concluded that tenderness, as measured by WBSF, varied among and within bovine muscles, and knowledge of this variation allows for more appropriate and specific uses in the marketplace because consumers are able to distinguish tenderness categories and are willing to pay a premium for more tender beef (Boleman et al., 1997). Aalhus, Jeremiah, Dugan, Larsen, and Gibson (2004) suggested that strategies used by the industry to improve tenderness may need to be muscle specific.

Several studies have already looked at individual muscles to study their variation and to increase the tenderness of these muscles (Carmack, Kastner, Dikeman, Schwenke, & García Zepeda, 1995; Jeremiah, Gibson, & Cunningham, 1999; Kolle, McKenna, & Savell, 2004; Rhee, Wheeler, Shackelford, & Koohmaraie, 2004; Molina, Johnson, West, & Gwartney, 2005; Von Seggern, Calkins, Johnson, Brickler, & Gwartney, 2005; Mueller, King, Baird, McKenna, Osburn, & Savell, 2006). A few of these studies have examined the addition of salt and phosphates to beef and have demonstrated that beef tenderness and other palatability attributes of some muscles can be improved by the application of this treatment (Kolle et al., 2004; Molina et al., 2005; Mueller et al., 2006). Boleman et al. (1997) asked consumers what they added to the beef as it was prepared or cooked: 45.5% said salt, 9.8% added a tenderizer, and 14% added nothing.

Papain is a plant enzyme that comes from the fruit papaya and has been used to improve beef tenderness. Studies evaluating the proteolytic activity of papain have shown that it has a higher activity for the myofibrillar fraction (Kang & Rice, 1970) and that it degrades both myosin heavy chains and actin with almost equal efficiency (Kim &

Taub, 1991). However, Lopp & Weber (2005) found that papain had an inconsistent effect on beef from the forequarter.

Investigators also have looked at blade tenderization as a treatment to improve beef tenderness. Blade tenderization increases tenderness by disrupting connective tissue and muscle fibers (Miller, 1975; Seideman, Smith, Carpenter, & Marshall, 1977; Shackelford, Reagan, Mann, Lyon, & Miller, 1989), which leads to the resistance to shear force, mastication, and swallowing (Miller, 1975). Blade tenderization response is greater for less tender cuts than for more tender muscles (Smith, Seideman, & Carpenter, 1979b). However, it is difficult for blade tenderized muscles high in connective tissue to be used interchangeably with untreated muscles low in connective tissue content (Seideman et al., 1977). Smith et al. (1979b) reported that blade tenderization, though it will usually improve tenderness, will not improve the product enough to make beef of unsatisfactory quality comparable to that of high quality beef.

The effects of blade tenderization on sensory panel attributes has given mixed results. Depending on the specific muscle and number of passes through the blade tenderizer, blade tenderization can improve palatability attributes of beef (Seideman et al., 1977, Smith et al., 1979b; George-Evins, Unruh, Waylan, & Marsden, 2004). However, Smith et al. (1979b) found that passage of muscles through the blade tenderizer two times was detrimental to juiciness ratings. George-Evins et al. (2004) reported that steaks blade tenderized two times had lower ($P < 0.05$) WBSF values than steaks blade tenderized once or not at all. Medeiros, Field, Menkhaus, Riley, and Russell (1989) reported that blade tenderization did not affect flavor nor juiciness of the *longissimus dorsi* muscle but did improve tenderness. Shackelford et al. (1989) reported that blade tenderization improved first impression tenderness of chuck roasts by the sensory panel but not overall tenderness. According to Bidner, Montgomery, Bagley, and Koonce (1981), blade tenderization increased the tenderness of loin steaks as measured by WBSF and trained taste panel and decreased the amount of connective tissue, but had a significant negative effect on juiciness and flavor intensity. Other studies have shown that blade tenderization improves WBSF values when it is applied with other postmortem technologies such as tumbling and/or electrical stimulation (Pietrasik & Shand, 2004; Smith, Jambers, Carpenter, Dutson, Hostetler, & Oliver, 1979a).

Studies have found that peak WBSF values are influenced more by muscle fibers than by connective tissue (Bouton & Harris, 1972; Cross et al., 1973) whereas sensory panel members evaluate other factors and are influenced by both connective tissue and muscle fiber characteristics (Cover, Ritchey, & Hostetler, 1962; Seideman et al., 1977). Shear force measurements have been shown to sometimes over-estimate tenderness differences between untreated and blade tenderized meat as a result of the shear blade following the fracture planes created by tenderizer blades (Bowling, Smith, Carpenter, Marshall, and Shelton, 1976; Seideman et al., 1977; Tatum, Smith, & Carpenter, 1978).

Smith et al. (1979b) suggested that it is likely that trained sensory panel members rate all palatability traits higher if tenderness is adequate; tough samples may be perceived as generally unsatisfactory in all palatability traits. Results reported by Huffman, Miller, Hoover, Wu, Brittin, and Ramsey (1996) showed that consumers were able to detect tenderness levels similar to the WBSF. They found that WBSF values less than 41.21 N would ensure a customer satisfaction level of 98% in both the home and restaurant. Also, consumers were asked which sensory attribute, tenderness, flavor, or juiciness, was the most important in determining their eating satisfaction. Results showed that 51% of consumers considered tenderness the attribute they want most in a steak in the home and restaurant environments. Flavor was rated most important by 39% of the consumers and juiciness by 10%. This study suggests that consumers will accept slightly tough meat if the flavor and juiciness are acceptable (Huffman et al., 1996). Boleman et al. (1997) found that the most tender steaks were given higher juiciness and flavor ratings.

Lorenzen et al. (2003), who compared in-home consumer data to trained sensory panel and WBSF values, concluded that there is inherent difficulty in predicting consumer responses from objective laboratory procedures, such as trained panels and WBSF. However, other studies have found that consumer panel findings can be supported by trained panel and WBSF values (Neely et al., 1998). Aalhus et al. (2004) found that consumers were not as sensitive to differences in tenderness as trained panelists, however, the relationship between consumer and trained panelists score was moderate.

According to data in “Creating Crave…The Beef Factor” (NCBA, 2003) and Boleman et al. (1997), consumers stated grilling outdoors as their preferred method of preparing steaks (77% and 67%, respectively). Skirt steaks, or fajitas, are an extremely popular cut to grill outdoors, especially in Texas and the southern region of the U.S. Recio et al. (1988) stated that “fajitas are a Mexican dish, originating in South Texas along the Mexican border.” Part of the pay for Mexican cowboys after cattle roundups were the by-products of carcasses such as the head, hide, viscera, and trimmings. At that time, the skirt was considered to be a meat trimming and would go to ground beef. Wood

(2005a) stated that this practice is where barbacoa de cabeza (head barbecue), menudo (tripe stew), and Fajitas/arracheras (grilled skirt steak) originated.

Juan Antonio "Sonny" Falcon claims that he was the one that came up with the term fajita and the dish. Sonny was an employee of the shipping-and-receiving department of the old Austin Meat Company (Wood, 2005b) where he and other employees would prepare creative dishes with trimmings. One of the dishes that evolved were fajitas but no one paid much attention to it. In the 1960s, Sonny worked in his in-law's store as the meat-market manager. He says that he looked at the skirt steak and would say to himself that it looked just like a belt, which, in Spanish, is called "faja," with "fajita" as the diminutive form. Sonny thought that he could attract more people to the family business by marketing this cut so he set up a concession booth at a weeklong outdoor event at the Dies y Seis celebration in Kyle, Texas. At this event, he sold some fajitas but made little money. Sonny kept promoting the product at different events to the point that he was christened "The Fajita King," for which he owns the trademark (Wood, 2005b).

Over the years, the demand for both inside and outside skirt steaks has dramatically increased due to the popularity of fajitas, thus increasing purchasing costs for consumers, retailers, and foodservice. Many entities, especially those in foodservice, need other thin muscle alternatives to serve as fajitas and compete successfully with the demand for inside and outside skirt steaks. Thus, there is a substantial need to evaluate alternative muscles from the beef carcass in combination with traditional processing techniques, such as tenderization and marination, to provide the industry and consumers with highly palatable, fajita options from the under-utilized thin muscles of the chuck.

CHAPTER II

MATERIALS AND METHODS

2.1. Product selection and fabrication

Specifications for all subprimals compiled with Institutional Meat Purchase Specifications (IMPS) as described by USDA (1996) and NAMP (2003). Sixty USDA Choice Beef Arm Chucks; Beef Plate, Short Plates (IMPS # 121); Beef plate, Outside Skirts (IM) (IMPS # 121C); Beef Plate, Inside Skirts (IM) (IMPS # 121D); and Beef Loin, Bottom Sirloin Butt, Flaps, Boneless (IM) (IMPS # 185A) were purchased from Smithfield Beef Group (Green Bay, WI) and shipped to the Rosenthal Meat Science and Technology Center at Texas A&M University. Beef chucks and plates were selected at the packing plant within one production day.

M. rhomboideus and *M. trapezius* were removed from beef chucks, and *M. latissimus dorsi* and *M. serratus ventralis* were removed from beef plates. All muscles were stored at refrigerated temperatures (~1-3º C). Approximately 24 hours later, all muscles within type were sorted randomly into four groups of approximately 15 muscles each. The tenderization treatment groups were: control (C), blade tenderization (B), papain (P), and papain + blade tenderization (P+B).

2.2. Application of treatments

After sorting, C muscles were individually vacuum packaged and frozen. Blade tenderized muscles were passed through the blade tenderizer two times (Tend-R-Rite, Bettcher Industries Inc., Birmingham, Ohio, Model TR-2), once horizontally and once turned over and rotated 90º.

To apply the papain treatment (Liquipanol® T-100, Enzyme Development Corporation, New York, NY), a brine to obtain 10% of the original meat weight was prepared. The brine consisted of 6.50% salt, 3.50% sodium tripolyphosphate (5000ppm/0.5% ingoing), 89.97% water, and 0.033% papain. All ingredients were solubilized in water and combined with the appropriate groups of muscles. The muscles were placed in vacuum package bags (Cryovac®) and sufficient brine (pH = 7.2) added to achieve 10% above the total muscle weight. The bags were then sealed without a vacuum in an Ultravac® (Koch Packaging, Kansas City, MO, Model 2100-D) packaging machine to ensure uniform distribution of the brine treatment. These were then placed in a vacuum tumbler (Leland Southwest, Fort Worth, TX, Model UT500) under vacuum (172.37 kPa) and rotated at a speed of 11 rpm for 30 min. Both the P and P+B (after blade tenderization treatment was applied) treatments followed the same procedure and were the only treatments that were marinated with a brine. After tumbling, all muscles were vacuum packaged (Bivac® packaging machine, American Can Company™, American Lane, Greenwich, NJ) and frozen at -10ºC for 10 wk.

2.3. Muscle sectioning

After treatments were applied and frozen for 10 wk, muscles were tempered (~5ºC) in a refrigerated cutting room (approximately 12ºC) to facilitate slicing into smaller sections. Due to muscle variation, the sections obtained were of different lengths, widths, and thicknesses. The biggest sections were obtained from the *M. serratus ventralis* (~11 cm × 9.5 cm × 2.5 cm) and flap (~13 cm × 11 cm × 2 cm). The *M. rhomboideus* sections were usually very thick (~12 cm × 8 cm × 3 cm) but shorter in length and width. The *M. latissimus* gave more consistent sections with a rectangular shape (~16 cm × 6 cm × 1 cm). The outside skirts (~9 cm × 6.5 cm × 0.7 cm), inside skirts (~14 cm × 9 cm × 1 cm), and *M. trapezius* (~10 cm × 9 cm × 0.4 cm) yielded smaller sections, and was extremely thin.

After sections were cut, they were individually identified with tags (containing the muscle and treatment) placed in oxygen impermeable bags (Cryovac®) vacuum packaged using the Ultravac®, and frozen at -10ºC for trained panel, consumer, and Warner-Bratzler shear force (WBSF) evaluation.

2.4. Cooking procedures

Prior to each consumer and trained sensory analysis, randomly selected sections were thawed 48 hours at 5ºC. To determine the amount of cook loss individual muscle sections, a precooked weight was obtained. Sections were cooked on a grill (Hamilton Beach, Portafolio, Indoor/Outdoor grill, Hamilton Beach/Proctor-Silex, Inc., 263 Yadkin Road, Southern Pines, NC 28387) to an internal temperature of 35ºC and then turned. Internal temperature was monitored by the use of handheld Omega Type T thermometers. Upon reaching an internal temperature of 70°C, sections were removed from the grill and placed on a plate to capture the final cook weight. Final cooked weights were obtained and recorded. Sections were identified and wrapped in aluminum foil and held in an Alto-Shaam® (Halo Heat, Alto-Shaam Inc. Milw, WI, Model 750-TH-II) oven at 48.8ºC for no more than 20 min.

2.5. Trained panel

A six-member expert meat and flavor descriptive attribute panel was trained for two days to familiarize them with samples that would be used in the study. Panelists were trained as defined by AMSA (1995) and Meilgaard, Civille, and Carr (1999). This panel had over 18 years of extensive training and experience in evaluation of beef. Analyses were performed over ten sensory days. Each panelist first received a warm-up sample (unseasoned top loin) that was standardized across sensory days. Panelists were seated in individual booths under red lights to reduce communication and mask differences in visual appearance of samples.

After cooking, sections were cut into $1cm^3$ cubes placed in plastic weigh boats and served to the panelists. Panelists evaluated 14 samples each day during two sessions (7 samples per session) with a 15 min break between sessions. Panelists cleansed their palate between samples with double distilled deionized water and whole milk ricotta cheese. Samples were served 5 min apart.

Trained panelists evaluated juiciness, muscle fiber tenderness, connective tissue, and overall tenderness of beef samples using 8-point scales (1 = extremely dry, extremely tough, abundant, and extremely tough; 8 = extremely juicy, extremely tender, none, and extremely tender, respectively). They also evaluated the aromatics: cooked beef lean, cooked beef fat, serumy/bloody, burned/burnt, chemical (which was given by the papain treatment); mouthfeels: astringent and metallic; tastes: salt, sour, bitter, and sweet; and aftertastes: acid, sour, brown, chemical, fat, salt, bitter, serum/bloody, metal, and burn using a 9-point scale (0 = none and 8 = extremely intense).

2.6. Consumer panel

Consumers were randomly selected from the Bryan/College Station, TX phone book during the evening hours. Callers were assigned a random location with the phone book and they called approximately every 5 people. To be able to participate in the study, consumers were screened by using a telephone script (Appendix 1).

Consumers arrived and filled out a demographic form (Appendix 2), signed a consent form, and a W-9 form (to receive U.S $40). They were given the instructions on how to cleanse their palate and not to speak during testing. There were two evening sessions for the consumer panel (5:30 and 7pm), and consumers had to come on two different days. Each day they evaluated 14 samples. In-between samples, they drank water and ate unsalted Saltines™ crackers to cleanse their palate. They were seated in the same booths as trained panelists, but white lights were used.

Randomly selected consumer panelists (n=81) evaluated overall like/dislike of the fajita, overall like/dislike of the flavor, intensity of the flavor, level of saltiness, level of any undesirable flavor, overall like/dislike of the tenderness, level of tenderness, and amount of connective tissue using 9-point scales (1 = dislike extremely, dislike extremely, extremely intense, extremely intense salt flavor, extremely intense undesirable flavors, dislike extremely, extremely tough, and very abundant or a lot; 9 = like extremely, like extremely, none or extremely bland, none or no salt flavor, none or no undesirable flavors, like extremely, extremely tender, and none). Sections were cut against the grain into ten fajita strips (4.5 cm×1 cm), eight strips were used for consumer evaluation and the remainder were utilized for WBSF. Flour tortillas, cut into 12 cm × 4.5 cm sections, were maintained warm in a Hatco® cook-and-hold oven at 60ºC. Two fajita strips were rolled in one tortilla and served to each consumer. Consumers were asked if they would purchase each sample evaluated, and responded with, “yes,” “no,” or “do not know.”

2.7. Tenderness determination

After cutting, beef fajita strips (cut as described before) were placed in glass containers and cooled to room temperature. Strips were placed in the cooler at 5ºC overnight. The next morning, strips were taken out of the cooler 4 hours before shearing to allow them to reach room temperature. Beef fajita strips then were sheared on a Warner-Bratzler shear force machine (United Calibration Corp, Huntington Beach, CA, Model SSTM-500) to determine the force required to segment each strip of meat. Individual shear measurements were recorded and the mean and standard deviation for each muscle was calculated.

2.8. Statistical analyses

Data were analyzed as a 7 × 4 factorial arrangement where main effects of muscle and treatment and their two-way interaction were included in the model. Sensory day for trained and consumer panel was included in the model as a block. Panelist effect and panelist × treatment effect were analyzed and were not significant. Sensory day was included in the model as a block for trained and consumer panel. Statistical analyses were performed using SAS PROC MIXED (v. 6.12). For consumer data, Box-Cox transformations were used to produce normally distributed standard errors. Least squares means were generated and tested for significance ($P < 0.05$) using PDIFF function for main effects and interactions when significance was defined in the Analysis of Variance table. Simple means and standard deviation were analyzed using the GLM procedure of SAS. A frequency distribution was generated for the purchase percentage of fajita strips.

CHAPTER III

RESULTS AND DISCUSSION

3.1. Simple means

Simple means and standard deviations of cook time and cook yield for sections used for the trained sensory panel, and WBSF are reported in Appendixes 3 and 4. Palatability attributes, aromatics, mouthfeels, tastes, and aftertastes evaluated by the trained sensory panel are reported on Appendixes 5, 6, 7, 8, and 9. Simple means and standard deviations for palatability attributes evaluated by the consumer panel are reported on Appendix 10. These means are reported due to multiple muscle × treatment interactions and to document these data.

3.2. Trained panel

Least squares means for the interaction of muscle × treatment on trained panel juiciness scores are reported in Figure 1. In general, regardless of muscle, papain treatments (P and P+B) improved juiciness especially for the *M. obliquus abdominis int.*, *M. latissimus*, and *M. trapezius*. Juiciness did not differ across treatments for *M. diaphragma pars costalis* muscles. Where as *M. transversus abdominis* and *M. rhomboideus* containing papain were juicier and the *M. serratus ventralis* from the P+B were juicier within muscles respectively.

In previous studies, untreated *M. serratus ventralis* has been rated as “moderately juicy” (Carmack et al., 1995; Jones et al., 2001) and *M. rhomboideus* as “slightly juicy” (Lamkey, Dunlavy, & Dolezal, 1993; Jones et al., 2001). Jones et al. (2001) reported untreated (control) *M. latissimus* as “slightly juicy,” which is higher in comparison to the juiciness level reported here (“slightly dry”). Molina et al. (2005) found that oven-roasted *M. latissimus* and grilled *M. serratus ventralis* that were marinated, needle-pumped, or vacuum tumbled improved trained panel juiciness scores while these same treatments when applied to the oven roasted *M. rhomboideus* did not differ from the control.

George-Evins et al. (2004) reported that juiciness of blade tenderized *gluteus medius* was not affected by this treatment, which was the same trend found in the current study for different muscles. Conversely, Bidner et al. (1981) found that blade tenderization had a significant by negative effect on juiciness.

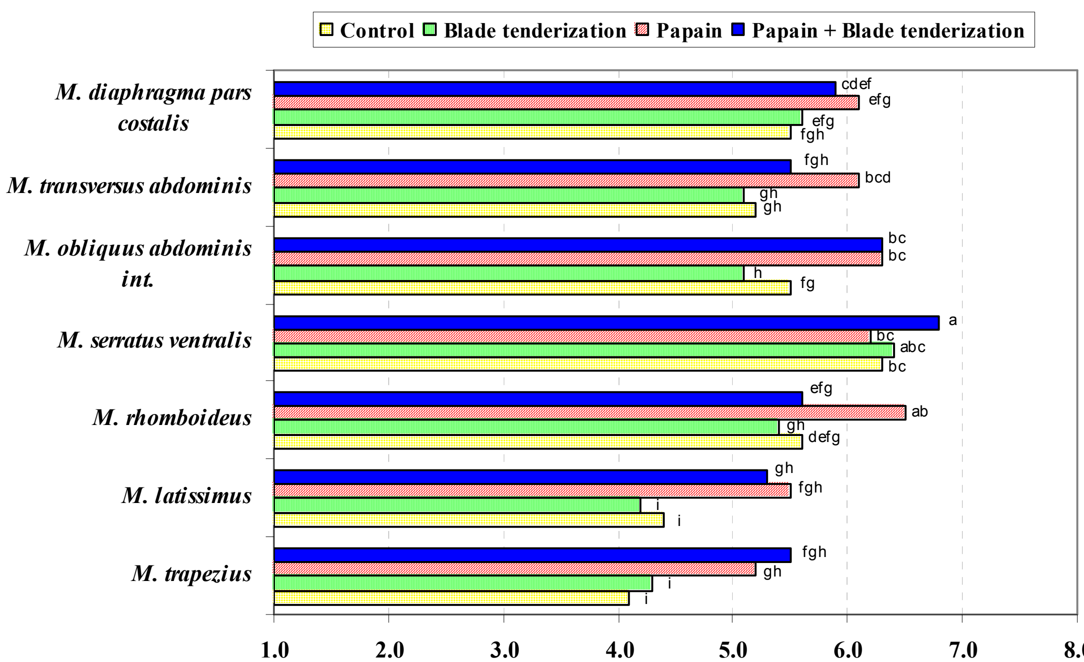

Figure 1. Trained sensory panel juiciness scores (1 = extremely dry; 8 = extremely juicy) for the muscle X treatment interaction (n = 714; RMSE = 0.68). Least squares means lacking common letters (a-i) differ (*P* < 0.05).

Least squares means for the interaction of muscle × treatment on trained panel muscle fiber tenderness scores are reported in Figure 2. Papain treatments (P and P+B) improved ($P < 0.05$) the muscle fiber tenderness of the *M. obliquus abdominis int.*, *M. rhomboideus*, *M. latissimus*, and *M. trapezius*. The *M. serratus ventralis* and *M. diaphragma pars costalis* had the least tenderness improvement due to treatment but were still considered to be the most tender except for their control muscles. The trained panel scored the C and B (2.6 and 3.2, respectively) sections of the *M. trapezius* as toughest ($P < 0.05$). The tenderness of the *M. obliquus abdominis int.* was greatly improved ($P < 0.05$) when treated with papain (P and P+BT) and these were considered among the most tender.

Blade tenderization increased tenderness in the *M. transversus abdominis*, *M. obliquus abdominis int*., *M. rhomboideus*, and *M. trapezius*, whereas in other muscles, blade tenderization did not improve muscle fiber tenderness scores. The addition of P and P+B improved muscle fiber tenderness for all muscles except the *M. diaphragma pars costalis* and M. serratus ventralis. Interestingly, the *M. diaphragma pars costalis* and M. serratus ventralis were tender, regardless of treatment. It was observed that when the treatment P+B was applied to the *M. transversus abdominis* and *M. trapezius*, there was a negative effect on muscle fiber tenderness instead of a synergistic effect. It can be hypothesized that these muscles were the thinner cuts of the study and that might have influenced the absorption of the brine containing papain which according to these results was the treatment that improved tenderness.

Studies have shown that papain can degrade myosin heavy chains and actin (Kang & Rice, 1970; Kim & Taub, 1991), which explains the improvement of muscle fiber tenderness scores when this enzyme is added to muscles. George-Evins et al. (2004) and Savell, McKeith, Murphey, Smith, and Carpenter (1982) found that blade tenderized steaks received higher trained panel ratings for myofibrillar tenderness than non blade tenderized steaks, this explains the improvement of some of the muscles in this study when this treatment was applied. In this study, papain worked more effectively than blade tenderization. Papain was added to the meat in a brine form and then tumbled, this permitted the distribution of the enzyme throughout the entire muscle and allowed the breakdown of structural proteins. On the other hand, blade tenderization only severed some areas of the muscle not working on the entire muscle like papain does.

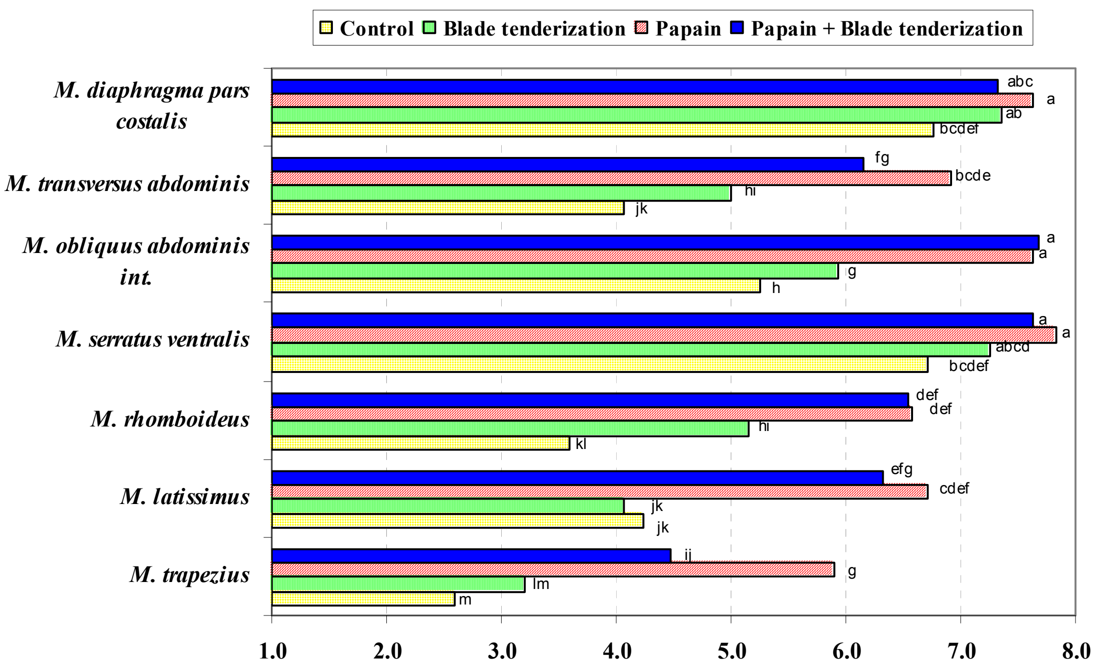

Figure 2. Trained sensory panel muscle fiber tenderness scores (1 = extremely tough; 8 = extremely tender) for the muscle X treatment interaction (n = 714; RMSE = 0.76). Least squares means lacking common letters (a-m) differ (P < 0.05).

Least squares means for the interaction of muscle × treatment on trained panel connective tissue scores are reported in Figure 3. Detection of connective tissue by the trained sensory panel was less apparent for *M. transversus abdominis*, *M. obliquus* *abdominis int.*, *M. rhomboideus*, and *M. trapezius* when any treatment was applied to the muscles. Samples from the control *M. trapezius* had the highest amount of connective tissue influence, but when treated with the P treatment, detectable connective tissue was more than halved. The P treatment also improved ($P < 0.05$) the connective tissue scores of the *M. transversus abdominis* in comparison to the other treatments. The *M. diaphragma pars costalis* had little panel-detectable connective tissue regardless of the treatment.

The trained panel rated the untreated (control) *M. latissimus* and *M. rhomboideus* as having a "slight amount" and "moderate amount," respectively, of connective tissue, similar values reported by Jones et al. (2001) for dry cooked steaks from these same muscles. Lamkey et al. (1993) rated the *M. rhomboideus* as containing a "slight amount" of connective tissue. Jones et al. (2001) found that the *M. serratus ventralis* was rated as having a "slight amount" of connective tissue which was almost two points less then the current study where a rating of 6.7 ("practically none") was reported. Molina et al. (2005) found that treatments (marinated, needle-pumped, or vacuum-tumbled) did not influence the amount of connective tissue perceived in oven-roasted *M. latissimus* and *M. rhomboideus*. However, the panel-detectable connective tissue of grilled *M. serratus ventralis* was lower when marinated, needle-pumped, or vacuum-tumbled (Molina et al., 2005).

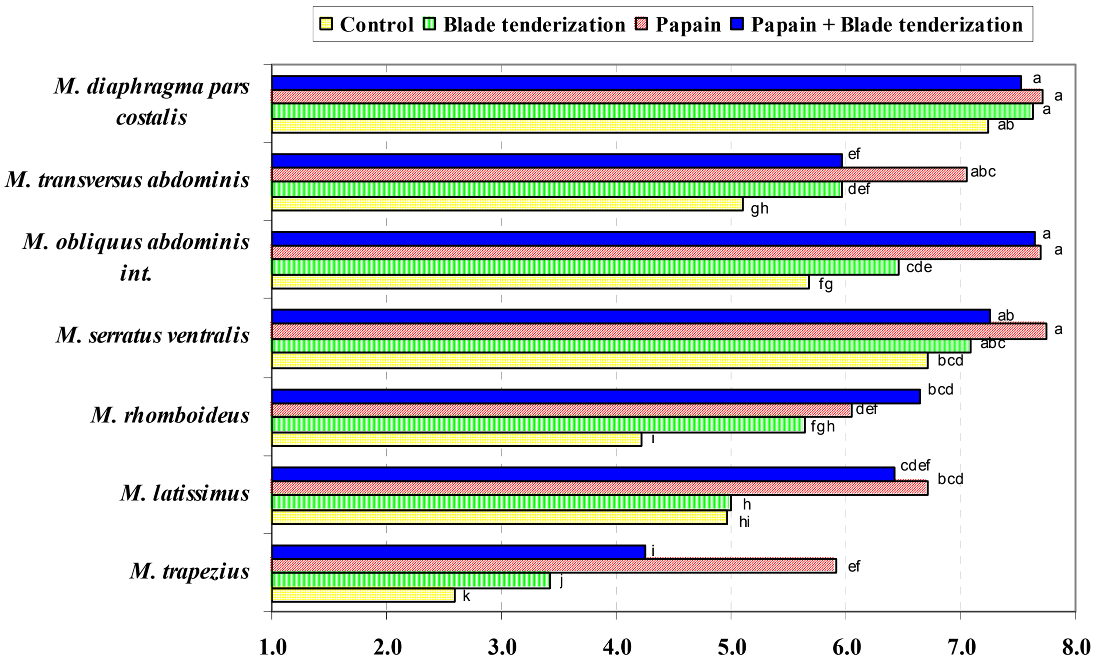

Figure 3. Trained sensory panel connective tissue scores (1 = abundant; 8 = none) for the muscle X treatment interaction (n = 714; RMSE = 0.80). Least squares means lacking common letters (a-k) differ ($P < 0.05$).

Least squares means for the interaction of muscle × treatment on trained panel overall tenderness scores are reported in Figure 4. In general, application of treatments improved overall tenderness. The *M. obliquus abdominis int.*, when treated with papain (P and P+B), received scores comparable to the most tender sections from other muscles. The panel found that the *M. diaphragma pars costalis* (B, P, and P+B), *M. obliquus abdominis int.* (P and P+B), and *M. serratus ventralis* (B, P, and P+B) were the most tender combinations. The *M. rhomboideus* and *M. latissimus* treated with papain (P and P+B) were as tender as the control *M. serratus ventralis* and *M. diaphragma pars costalis*.

The trained panel rated the untreated (control) *M. latissimus* as “slightly tough,” which was lower than the reported tenderness for *M. latissimus* sections prepared by dry cookery (Jones et al., 2001), they rated the same steaks as "slightly tender." In the same study, the *M. rhomboideus* and *M. serratus ventralis* were given tenderness scores of 4.2 and 6.0, respectively. Lamkey et al. (1993) stated that panelists gave *M. rhomboideus* an average score of 5.0 ("slightly tender"). Carmack et al. (1995) reported a score of 6.5 for the *M. serratus ventralis*. The trained panel in the current study found the *M. rhomboideus* to be less tender (tenderness score: 3.6) and the *M. serratus ventralis* more tender (tenderness score: 6.7) when compared to the previous studies. Molina et al. (2005) found that oven roasted *M. latissimus* and *M. rhomboideus* did not improve in tenderness when marinated, needle-pumped, or vacuum-tumbled. However, the overall tenderness of the grilled *M. serratus ventralis* did improve with these treatments.

It was observed that tenderness variation between muscles was generally significant. This is in agreement with Rhee et al. (2004) who stated that tenderness and tenderness related traits were highly variable within and among the muscles, and explained that the cause of this was the complex interaction of various biochemical traits from muscle to muscle.

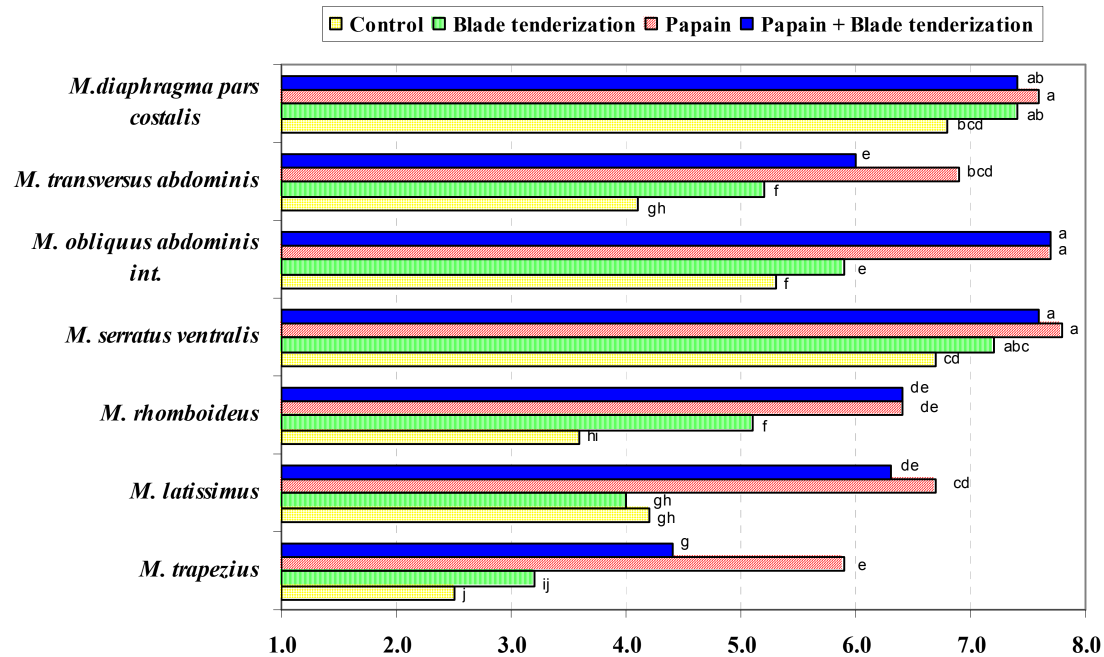

Figure 4. Trained sensory panel overall tenderness scores (1 = extremely tough; 8 = extremely tender) for the muscle X treatment interaction (n = 714; RMSE = 0.77). Least squares means lacking common letters (a-j) differ (*P* < 0.05).

Least squares means for the interaction of muscle × treatment on trained panel cooked beef lean scores are reported in Figure 5. None of the treatments seemed to have much influence on the cooked beef lean aromatic except for the *M. trapezius*. The *M. obliquus abdominis int.* (B, P, and P+B) received among the highest cooked beef lean scores and the control *M. trapezius* among the lowest.

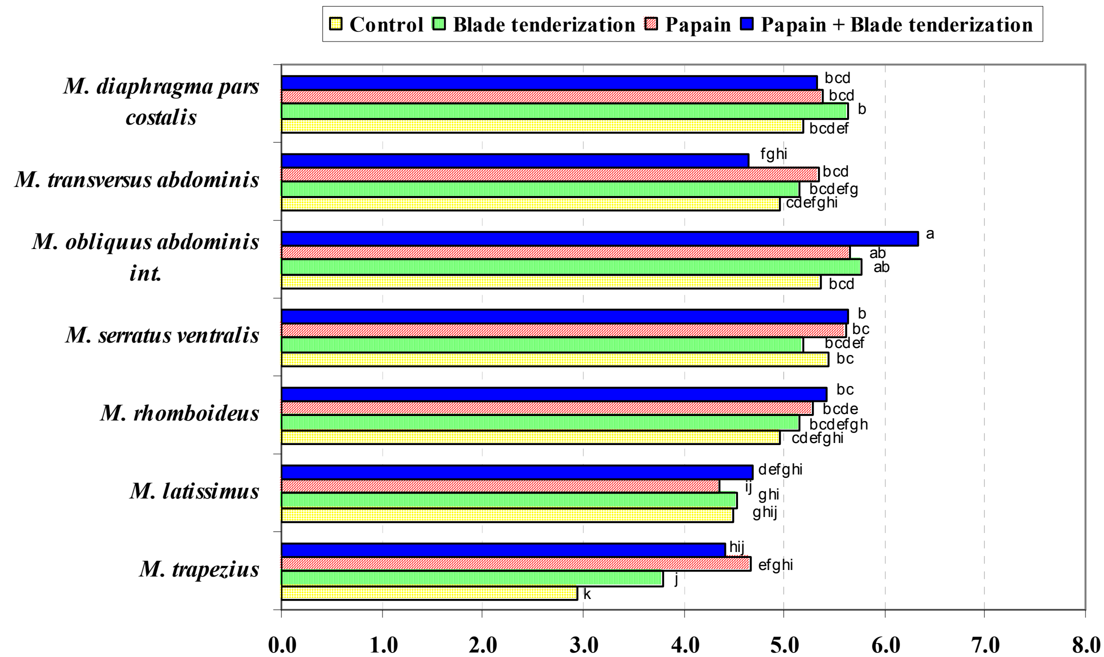

Figure 5. Trained sensory panel cooked beef lean scores (0 = none; 8 = extremely intense) for the muscle X treatment interaction (n = 714; RMSE = 0.77). Least squares means lacking common letters (a-k) differ (*P* < 0.05).

Least squares means for the main effects of muscle and treatment on trained panel aromatic scores are reported in Tables 1 and 2. The *M. serratus ventralis* and *M. rhomboideus* received the highest serumy/bloody scores. Burned scores tended to follow the same trend of the general attributes evaluated by the trained panel. Higher burned scores for muscles apparently were associated with better attribute scores. The *M. latissimus* received the least burned score but was not different from *M. trapezius*.

During training, panelists agreed on assigning a chemical score to samples that contained papain. Consequently, the treatment main effect revealed that papain treatments (P and P+B) received higher chemical scores ($P < 0.05$) in comparison to C and B. Burned scores were lower ($P < 0.05$) for papain treatments. Treatment effects were opposite from muscle effects; the lower the burned score, the better the attribute scores.

Table 1. Least squares means and standard errors of trained panel scores for aromatics within muscles.

	Trained panel score[a]	
	Serumy/Bloody	Burned
Muscle		
M. diaphragma pars costalis	1.5 ± 0.1b	1.8 ± 0.1ab
M. transversus abdominis	1.4 ± 0.1b	1.3 ± 0.1c
M. obliquus abdominis int.	1.6 ± 0.1ab	1.9 ± 0.1a
M. serratus ventralis	1.8 ± 0.1a	1.8 ± 0.1ab
M. rhomboideus	1.8 ± 0.1a	1.7 ± 0.1b
M. latissimus	1.4 ± 0.1b	1.0 ± 0.1d
M. trapezius	1.3 ± 0.1b	1.1 ± 0.1cd

[a]Trained panel used a 9-point scale: 0 = none; 8 = extremely intense. Least squares means within columns lacking common letters (a-d) differ ($P < 0.05$).

Table 2. Least squares means and standard errors of trained panel scores for aromatics within treatments.

	Trained panel score[a]	
	Chemical	Burned
Treatment		
Control	0.3 ± 0.1b	1.7 ± 0.1a
Blade tenderization	0.3 ± 0.1b	1.7 ± 0.1a
Papain	1.8 ± 0.1a	1.3 ± 0.1b
Papain + Blade tenderization	1.8 ± 0.1a	1.3 ± 0.1b

[a]Trained panel used a 9-point scale: 0 = none; 8 = extremely intense. Least squares means within columns lacking common letters (a-b) differ ($P < 0.05$).

Least squares means for the main effects of muscle and treatment on trained panel taste scores are reported in Tables 3 and 4. The *M. diaphragma pars costalis* was slightly more bitter than the *M. transversus abdominis*, *M. serratus ventralis*, and *M. latissimus*, but was not different from the *M. obliquus abdominis int.*, *M. rhomboideus*, and *M. trapezius*. The *M. serratus ventralis* received the highest scores for sweetness but did not differ from *M. transversus abdominis* or *M. obliquus abdominis int.* The papain treatments (P and P+B) were considered to be less bitter and sweeter ($P < 0.05$) in comparison to C and B.

Table 3. Least squares means and standard errors of trained panel scores for tastes within muscles.

	Trained panel score[a]	
	Bitter	Sweet
Muscle		
M. diaphragma pars costalis	2.3 ± 0.1a	0.4 ± 0.1bc
M. transversus abdominis	2.1 ± 0.1c	0.5 ± 0.1abc
M. obliquus abdominis int.	2.3 ± 0.1ab	0.6 ± 0.1ab
M. serratus ventralis	2.2 ± 0.1bc	0.6 ± 0.1a
M. rhomboideus	2.2 ± 0.1abc	0.4 ± 0.1c
M. latissimus	2.1 ± 0.1c	0.3 ± 0.1c
M. trapezius	2.2 ± 0.1abc	0.3 ± 0.1c

[a]Trained panel used a 9-point scale: 0 = none; 8 = extremely intense. Least squares means within columns lacking common letters (a-c) differ ($P < 0.05$).

Table 4. Least squares means and standard errors of trained panel scores for tastes within treatments.

	Trained panel score[a]	
	Bitter	Sweet
Treatment		
Control	2.3 ± 0.1a	0.3 ± 0.1b
Blade tenderization	2.3 ± 0.1a	0.3 ± 0.1b
Papain	2.1 ± 0.1b	0.6 ± 0.1a
Papain + Blade tenderization	2.1 ± 0.1b	0.6 ± 0.1a

[a]Trained panel used a 9-point scale: 0 = none; 8 = extremely intense. Least squares means within columns lacking common letters (a-b) differ ($P < 0.05$).

Least squares means of trained panel aftertaste scores for the main effects of muscle and treatment are reported in Tables 5 and 6, respectively. In general, aftertaste scores were low (less than 1.6). The *M. serratus ventralis* received the highest ($P < 0.05$) fatty aftertaste score in comparison to all other muscles. Papain treatments (P and P+B) received the highest aftertaste scores for salt and chemical attributes, but were lowest for sour and bitter ($P < 0.05$) aftertaste. The difference in salt and chemical scores were expected because papain has a salty taste and panelists gave chemical scores to muscles treated with papain.

In general, trained panelists gave higher ratings to muscles that were treated with papain. These higher ratings may be due to the fact that papain was evenly distributed throughout the muscle by tumbling, allowing the enzyme to work at an ultrastructure level. Molina et al. (2005) concluded that addition of water, salt, and sodium tripolyphosphate increased palatability traits of the *M. complexus, M. latissimus, M. rhomboideus, M. splenius, M. subscapularis, M. serratus ventralis, M. supraspinatus*, and *M. triceps brachii*. They also pointed out that the *M. serratus ventralis* was one of the muscles with the best response to added ingredients, and that the *M. rhomboideus* was the only muscle that did not show improvement due to addition of salt and phosphates (Molina et al., 2005). Papain might not be the only factor responsible for the higher scores given to the treatments P and P+B. The treatments in the present study that contained papain also contained salt and phosphate, this might have helped in the improvement of sensory scores.

Table 5. Least squares means and standard errors of trained panel scores for aftertastes within muscles.

	Trained panel score[a]					
	Sour	Bitter	Acid	Brown	Fatty	Serumy/Bloody
Muscle						
M. diaphragma pars costalis	0.9 ± 0.1bc	0.8 ± 0.1a	1.2 ± 0.1abc	0.5 ± 0.1bcd	0.4 ± 0.1b	0.2 ± 0.1abc
M. transversus abdominis	1.0 ± 0.1abc	0.4 ± 0.1bc	1.2 ± 0.1bc	0.4 ± 0.1bcd	0.2 ± 0.1bc	0.1 ± 0.1bc
M. obliquus abdominis int.	0.9 ± 0.1bc	0.9 ± 0.1a	1.0 ± 0.1c	0.8 ± 0.1a	0.3 ± 0.1b	0.2 ± 0.1ab
M. serratus ventralis	0.9 ± 0.1c	0.5 ± 0.1bc	1.1 ± 0.1c	0.6 ± 0.1abc	0.7 ± 0.1a	0.3 ± 0.1a
M. rhomboideus	1.2 ± 0.1ab	0.3 ± 0.1c	1.4 ± 0.1ab	0.6 ± 0.1ab	0.0 ± 0.1d	0.3 ± 0.1a
M. latissimus	1.3 ± 0.1a	0.4 ± 0.1c	1.5 ± 0.1a	0.3 ± 0.1d	0.1 ± 0.1cd	0.0 ± 0.1c
M. trapezius	0.9 ± 0.1bc	0.7 ± 0.1ab	1.2 ± 0.1bc	0.3 ± 0.1cd	0.3 ± 0.1b	0.2 ± 0.1abc

[a]Trained panel used a 9-point scale: 0 = none; 8 = extremely intense. Least squares means within columns lacking common letters (a-d) differ ($P < 0.05$).

Table 6. Least squares means and standard errors of trained panel scores for aftertastes within treatments.

	Trained panel score[a]				
	Salt	Sour	Bitter	Chemical	Fatty
Treatment					
Control	0.0 ± 0.1b	1.1 ± 0.1a	0.8 ± 0.1a	0.0 ± 0.0b	0.4 ± 0.1a
Blade tenderization	0.0 ± 0.1b	1.2 ± 0.1a	0.7 ± 0.1a	0.0 ± 0.0b	0.3 ± 0.1ab
Papain	1.0 ± 0.1a	0.9 ± 0.1b	0.4 ± 0.1b	0.4 ± 0.0a	0.2 ± 0.1c
Papain + Blade tenderization	1.0 ± 0.1a	0.9 ± 0.1b	0.4 ± 0.1b	0.5 ± 0.0a	0.2 ± 0.1bc

[a]Trained panel used a 9-point scale: 0 = none; 8 = extremely intense. Least squares means within columns lacking common letters (a-c) differ ($P < 0.05$).

3.3. Consumer panel

Least squares means for the interaction of muscle × treatment on consumer panel overall like scores are reported in Figure 6. Overall, consumers preferred fajitas treated with papain alone or in combination with blade tenderization. Consumers tended to like the *M. diaphragma pars costalis*, *M. transversus abdominis*, and *M. obliquus abdominis int.* treated with papain the most and the *M. trapezius* B and C the least. Adding papain to the *M. latissimus* greatly increased the consumer preference of this muscle, and consumers rated it similarly to the P treated *M. transversus abdominis*. The *M. transversus abdominis* (inside skirt) is the muscle mainly sold in the U.S. market as fajita beef.

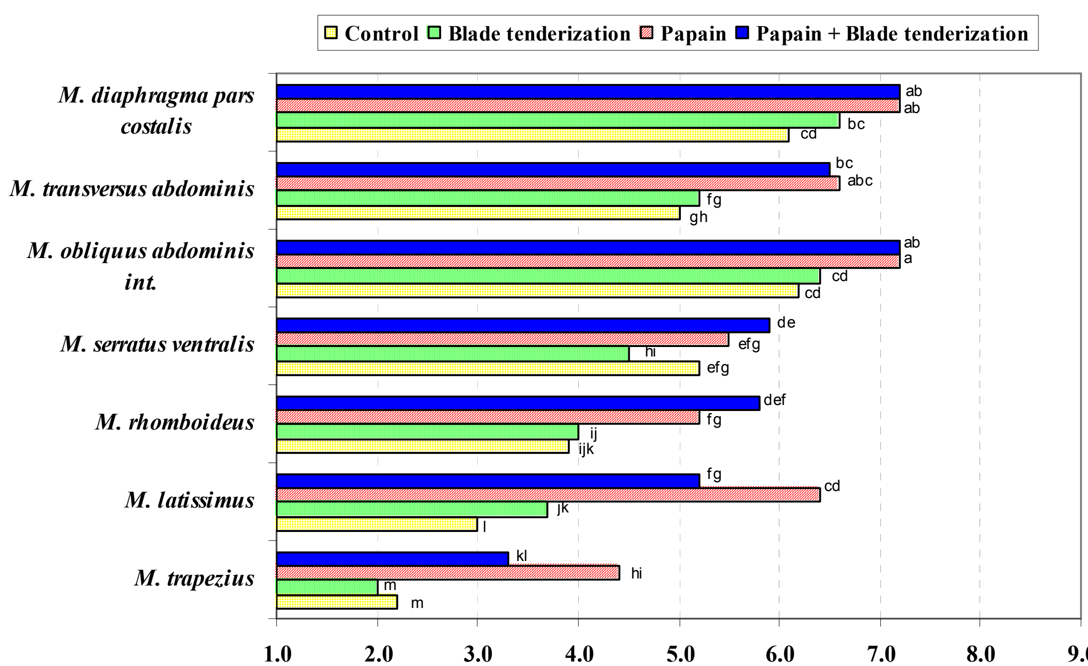

Figure 6. Consumer sensory panel overall like of the fajita scores (1 = dislike extremely; 9 = like extremely) for the muscle X treatment interaction (n = 2234; RMSE = 1.61). Least squares means lacking common letters (a-m) differ (*P* < 0.05).

Least squares means for the interaction of muscle × treatment on consumer panel overall like of the flavor scores are reported in Figure 7. Consumers preferred the flavor of the *M. diaphragma pars costalis* and *M. obliquus abdominis int.* treated with papain. The flavor of *M. trapezius* (C and B) and *M. latissimus* (C) was the least liked by consumers. The flavor of the P treatment on the *M. latissimus* was comparable to the P and P+B treatment on the *M. diaphragma pars costalis* and *M. transversus abdominis* ($P > 0.05$).

Goodson et al. (2002) found that flavor like was the sensory trait most highly correlated to overall like of clod steaks. Even though correlations were not run between overall like of the fajitas and overall flavor in the present study, it can be observed by comparing the figures that these two attributes followed the same trend.

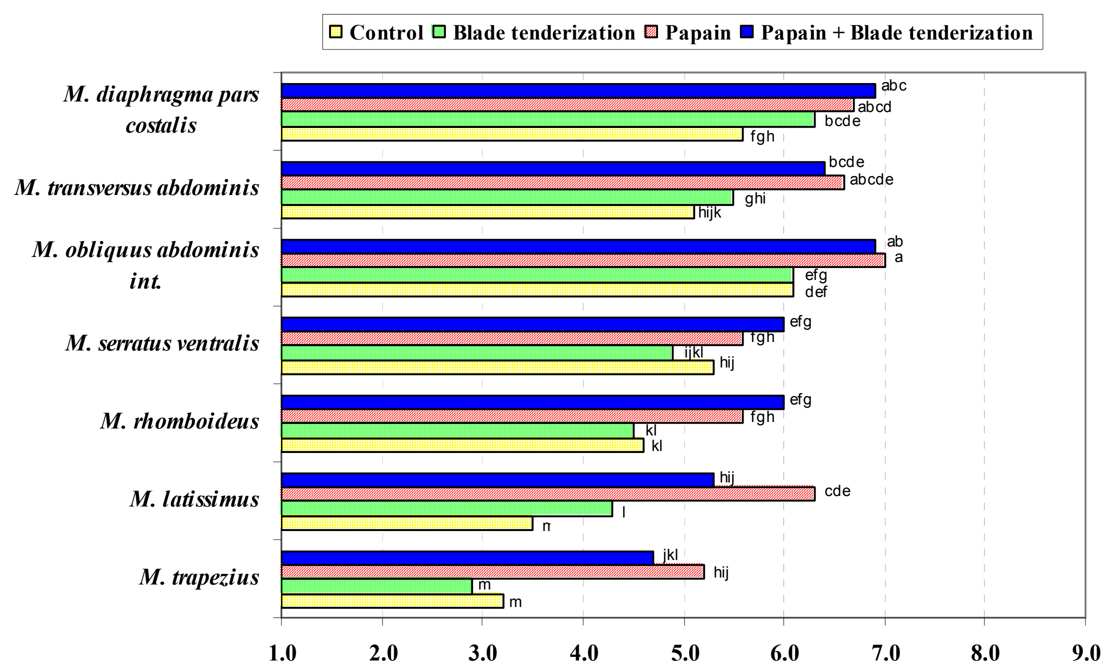

Figure 7. Consumer sensory panel overall like of the flavor scores (1 = dislike extremely; 9 = like extremely) for the muscle X treatment interaction (n = 2239; RMSE = 2.65). Least squares means lacking common letters (a-m) differ (*P* < 0.05).

Least squares means for the main effects of muscle and treatment on consumer panel intensity of flavor, level of salt, and level of undesirable flavor scores are reported in Tables 7 and 8. The muscle main effect revealed that consumers perceived the *M. latissimus* and *M. trapezius* as having the most bland intensity flavor. The *M. latissimus* was also considered to have the least salt flavor but was not different from the *M. serratus ventralis*, *M. rhomboideus*, and *M. trapezius*. The *M. obliquus abdominis int.* had the least intense undesirable flavor and did not differ from the *M. diaphragma pars costalis* and the *M. transversus abdominis*. The treatment main effect revealed that papain treatments (P and P+B) were scored as having more intensity of flavor and salt flavor ($P < 0.05$), and tended to have less undesirable flavors.

Molina et al. (2005) stated that when oven-roasted *M. latissimus* and grilled *M. serratus ventralis* were marinated with a 10% brine (water, 0.5% salt, and 0.4% sodium tripolyphosphate), the trained panel detected higher off-flavors in these muscles. However, the off-flavor for the oven-roasted *M. rhomboideus* did not differ from the control when treatments were applied.

Table 7. Least squares means and standard errors of consumer panel scores within muscles.

	Consumer panel score[a]		
	Intensity of Flavor	Level of saltiness	Level of undesirable flavors
Muscle			
M. diaphragma pars costalis	5.1 ± 0.3d	6.6 ± 1.2bc	8.3 ± 2.9ab
M. transversus abdominis	5.6 ± 0.3bc	6.7 ± 1.2b	8.3 ± 2.9ab
M. obliquus abdominis int.	5.0 ± 0.3d	6.4 ± 1.2c	8.4 ± 2.9a
M. serratus ventralis	5.6 ± 0.3bc	6.8 ± 1.2ab	8.1 ± 2.9cd
M. rhomboideus	5.5 ± 0.3c	6.8 ± 1.2ab	8.2 ± 2.9bc
M. latissimus	5.8 ± 0.3ab	7.0 ± 1.2a	8.1 ± 2.9cd
M. trapezius	6.0 ± 0.3a	6.9 ± 1.2ab	7.9 ± 2.9d

[a]Consumer panel used a 9-point scale: 1 = extremely intense, extremely intense salt flavor, extremely intense undesirable flavors; 9 = none or extremely bland, none or no salt flavor, none or no undesirable flavors. Least squares means within columns lacking common letters (a-d) differ ($P < 0.05$).

Table 8. Least squares means and standard errors of consumer panel scores within treatments.

	Consumer panel score[a]		
	Intensity of flavor	Level of saltiness	Level of undesirable flavors
Treatment			
Control	5.9 ± 0.2a	7.3 ± 1.1a	8.1 ± 2.8bc
Blade tenderization	5.9 ± 0.2a	7.3 ± 1.1a	8.0 ± 2.8c
Papain	5.2 ± 0.2b	6.2 ± 1.1b	8.3 ± 2.8a
Papain + Blade tenderization	5.1 ± 0.2b	6.2 ± 1.1b	8.2 ± 2.8ab

[a]Consumer panel used a 9-point scale: 1 = extremely intense, extremely intense salt flavor, extremely intense undesirable flavors; 9 = none or extremely bland, none or no salt flavor, none or no undesirable flavors. Least squares means within columns lacking common letters (a-c) differ ($P < 0.05$).

Least squares means for the interaction of muscle × treatment on consumer panel overall like of the tenderness scores are reported in Figure 8. Consumers liked the tenderness of the *M. diaphragma pars costalis* (P and P+B), *M. transversus abdominis* (P+B), and *M. obliquus abdominis int.* (P and P+B) more than the other muscles. Tenderness of the C and B treatments for the *M. trapezius* was liked less than the other muscles. The *M. serratus ventralis* and *M. latissimus* with the P treatment can be compared in tenderness to the untreated (control) *M. diaphragma pars costalis*.

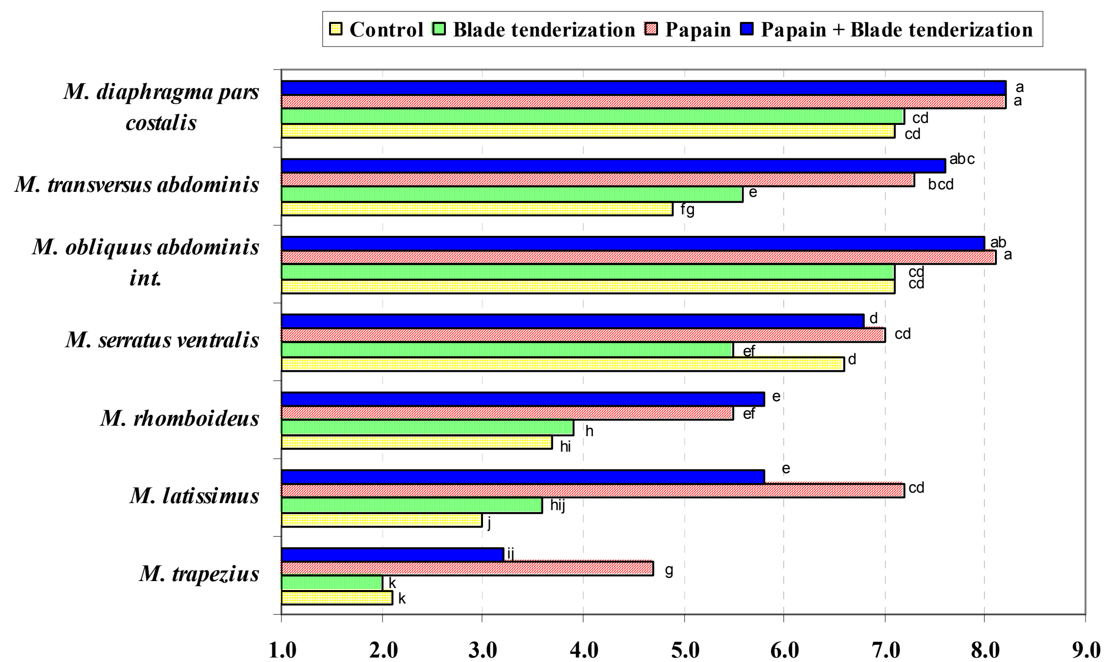

Figure 8. Consumer sensory panel overall like of the tenderness scores (1 = dislike extremely; 9 = like extremely) for the muscle X treatment interaction (n = 2238; RMSE = 1.64). Least squares means lacking common letters (a-k) differ (*P* < 0.05).

Least squares means for the interaction of muscle × treatment on consumer panel level of tenderness scores are reported in Figure 9. *M. diaphragma pars costalis* and *M. obliquus abdominis int.* treated with papain (P and P+B) were the most tender of all ($P < 0.05$). For overall like of tenderness, consumers rated C and B *M. trapezius* fajitas lower than the other muscles. The *M. latissimus* improved the most in tenderness when the P treatment was applied in comparison to the other three treatments and was comparable to the level of tenderness of the C and B treatments of the *M. diaphragma pars costalis*; P and P+B of the *M. transversus abdominis*; C and B of the *M. obliquus abdominis int.*; and C, P, and P+B of the *M. serratus ventralis*.

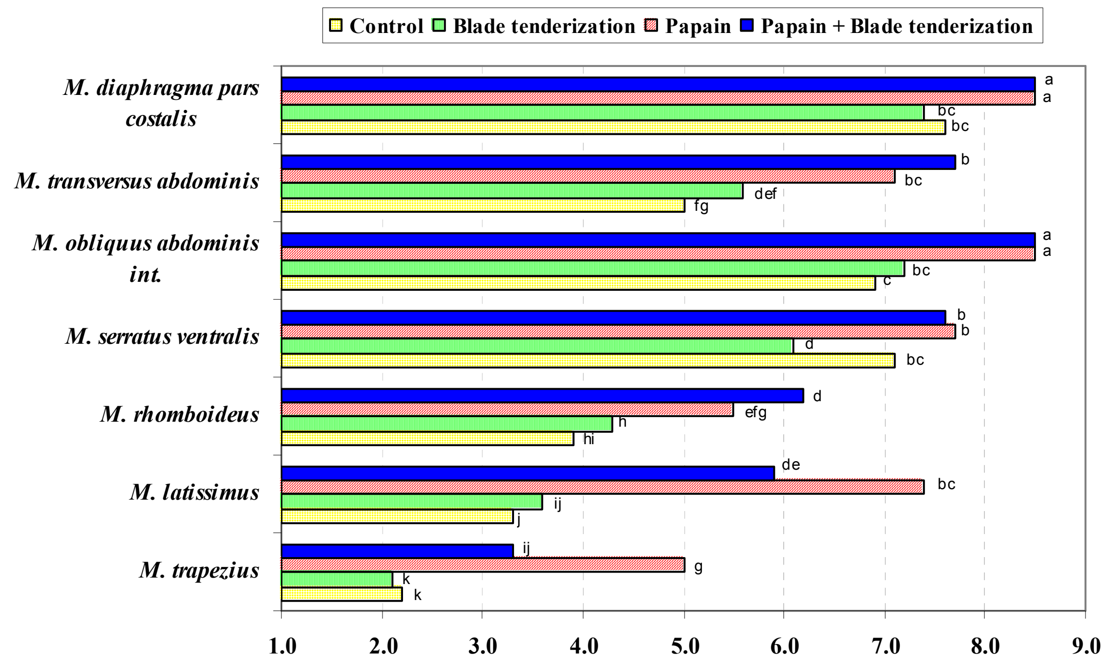

Figure 9. Consumer sensory panel level of tenderness scores (1 = extremely tough; 9 = extremely tender) for the muscle X treatment interaction (n = 2241; RMSE = 1.57). Least squares means lacking common letters (a-k) differ (*P* < 0.05).

Least squares means for the interaction of muscle × treatment on consumer panel amount of connective tissue scores are reported in Figure 10. Consumers did not find much connective tissue in the P and P+B treatment of the *M. diaphragma pars costalis* and *M. obliquus abdominis int.* Detection of connective tissue amount in the *M. latissimus* was significantly reduced by the addition of papain.

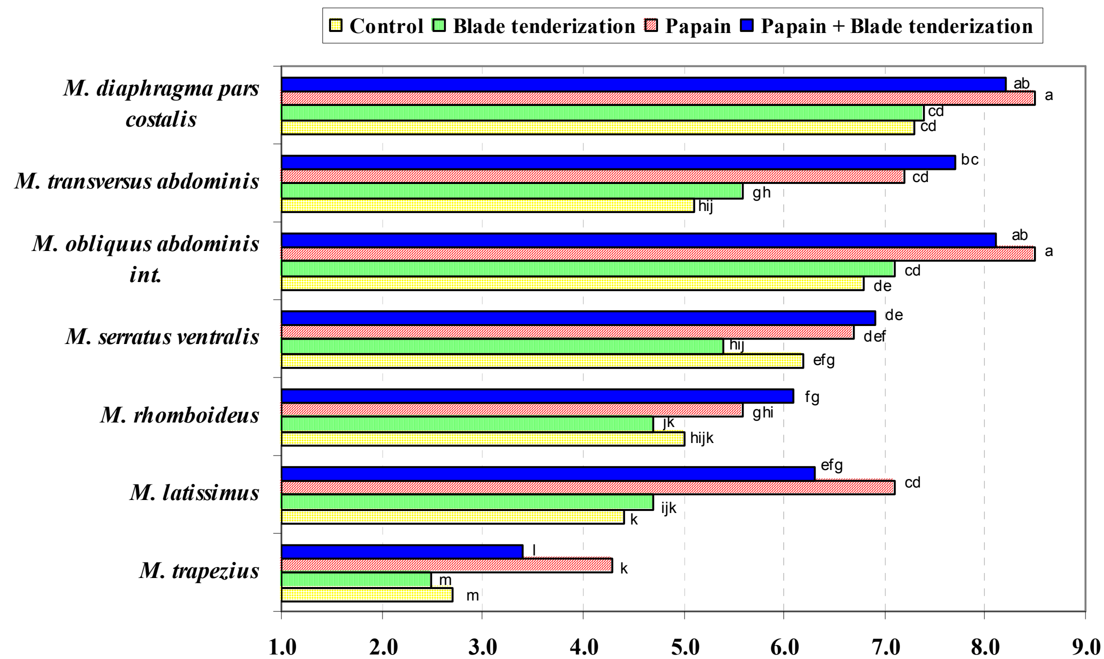

Figure 10. Consumer sensory panel amount of connective tissue scores (1 = very abundant or a lot; 9 = none) for the muscle X treatment interaction (n = 2233; RMSE = 1.74). Least squares means lacking common letters (a-m) differ (*P* < 0.05).

In general, it was observed that consumers assigned higher scores to muscles treated with papain. Interestingly, consumers gave lower scores ($P < 0.05$) to the *M. latissimus* and *M. trapezius* treated with P+B and these muscles were within the most thin ones. It was expected that the P+B treatment would receive the highest scores because it was hypothesized that blade tenderization would act synergistically with the P treatment but this was not the case. Usually the P+B treatment was not significantly different from the P treatment or it received lower scores ($P < 0.05$).

The purchase percentages for each muscle and treatment combination are reported in Figure 11. Consumers tended to prefer the flavor and tenderness of beef fajita strips that were treated with P and P+B and were more willing to purchase these. Consumers said that 50% of the time they would purchase the *M. diaphragma pars costalis* and *M. obliquus abdominis int.* and would not purchase *M. trapezius*, regardless of the treatment applied. Consumers were willing to purchase *M. serratus ventralis* treated with P+B and *M. latissimus* treated with P the majority of the time.

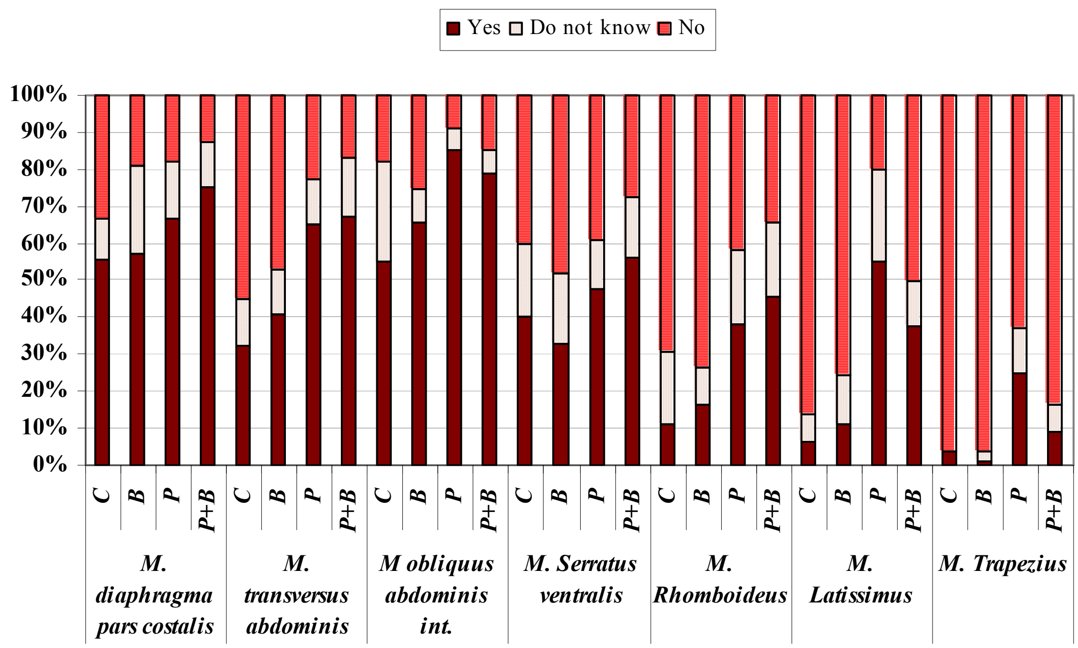

Figure 11. Purchase percentages for each treatment and muscle conmbination given by consumer panel. Letters in the x-axis indicate the treatments where: C = Control; B = Blade tenderization; P = Papain; P+B = Papain + Blade tenderization.

3.4. Tenderness determination

Least squares means for the interaction of muscle × treatment on WBSF values are reported in Figure 12. The *M. diaphragma pars costalis* and *M. obliquus abdominis int.* had the lowest ($P < 0.05$) shear force values. The WBSF values of the *M. serratus ventralis* within treatments were not different ($P > 0.05$) and differences of the *M.*

diaphragma pars costalis were small. The *M. serratus ventralis* and *M. latissimus* treated with papain were comparable ($P > 0.05$) to the *M. diaphragma pars costalis* control. Regardless of muscle, B treatment did not improve WBSF measurements ($P > 0.05$) in comparison to the C treatments.

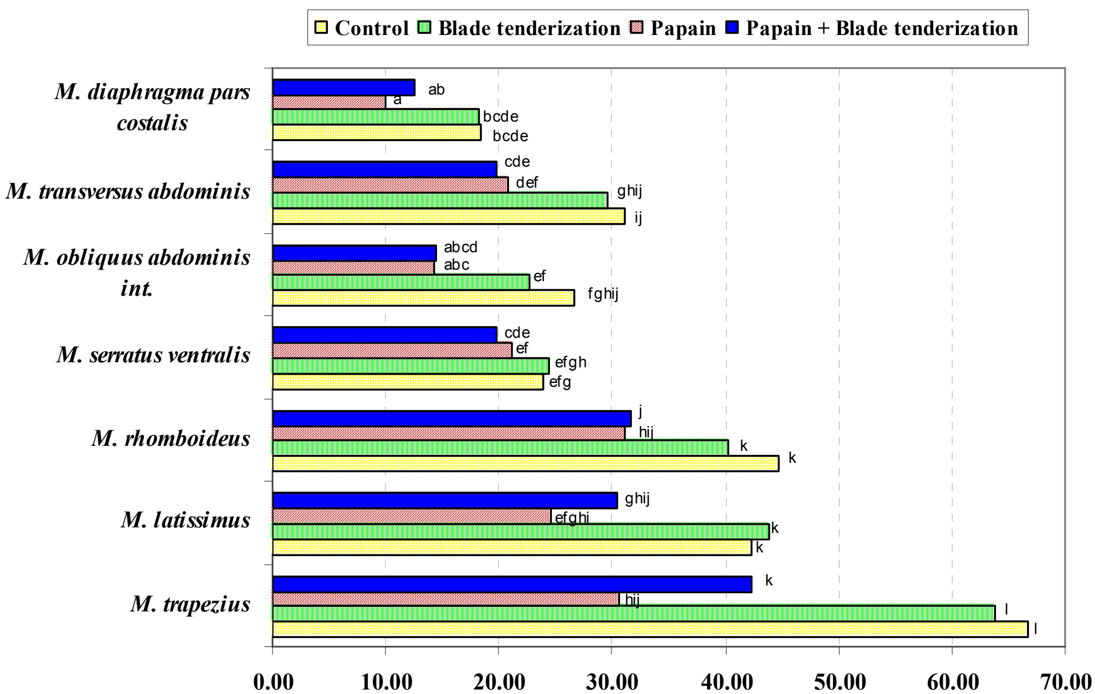

Figure 12. Warner-Bratzler shear force scores (N) for the muscle X treatment interaction (n = 700; RMSE = 1.20). Least squares means lacking common letters (a-l) differ (*P* < 0.05).

Studies have reported that other muscles of the beef carcass have shown WBSF value improvements when blade tenderized (Bidner et al., 1981; Shackelford et al., 1989; Kolle et al., 2004; Pietrasik & Shand, 2005). However, several studies have found that mechanical tenderization did not improve the tenderness of muscle that were already inherently tender (Davis, Huffman, & Cordray, 1975; Tatum et al., 1978; Wheeler, Savell, Cross, Lunt, & Smith, 1990).

Jones et al. (2001) reported a higher (48.04 N) WBSF than the reported in the present study (42.29 N) for the untreated (control) *M. latissimus*. In the same study, untreated *M. rhomboideus* and *M. serratus ventralis* had a WBSF value of 59.61 and 37.37 N, respectively, higher values than the ones found in this study (44.79 and 23.85 N, respectively). The same findings are reported by Von Seggern et al. (2005) because their values come from the same data base as Jones et al. (2001). Molina et al. (2005) found similar WBSF values for oven-roasted *M. latissimus* and *M. rhomboideus*, while grilled *M. serratus ventralis* steaks were 8.5 N tougher than the one reported here. Application of treatments (marinated, needle-pumped, and vacuum-tumbled) did not make any of these muscles significantly different in WBSF from their control muscles (Molina et al., 2005). Other muscles of the beef carcass that have shown WBSF improvements when they are treated with salt and phosphate (Molina et al., 2005; Kolle et al., 2004; Lamkey et al., 1993). Lamkey et al. (1993) found that *M. rhomboideus* treated with salt and phosphate did improve its WBSF ($P < 0.05$) values. Pietrasik & Shand (2004) found that blade tenderization improved WBSF values of cooked roast beef depending on the tumbling time.

Results reported here are similar to the ones found by Belew et al., (2003) which defined the *M. diaphragma pars costalis*, *M. serratus ventralis*, *M. and obliquus abdomins int*. as “very tender” (WBSF < 31.38 N), the *M. rhomboideus* as “tender” (31.38 N < WBSF < 38.25 N), the *M. latissimus* and *M. transversus abdominis* as “intermediate” (38.25 N < WBSF < 45.11 N), and the *M. trapezius* as “tough” (WBSF > 45.11 N) except that if their scale were used for this study the *M. transversus abdominis* would be considered “very tender” and the *M. rhomboideus* “intermediate.”

The WBSF values followed the same trends in tenderness as the overall and level of tenderness of the trained and consumer panel. Lorenzen et al. (2003) found low correlations between trained panel and WBSF ratings to consumer panel, however, the strongest correlations to consumer panel were between muscle fiber tenderness, overall tenderness, and WBSF. On the other hand, Neely et al. (1998, 1999), Lorenzen et al. (1999), and Savell et al. (1999) have been able to support their consumer panel findings with trained panel and WBSF data.

CHAPTER IV

SUMMARY AND CONCLUSIONS

Papain treatments (P and P+B) improved the eating quality and WBSF values of the muscles studied. Salt and phosphate added in the brine with papain might have had some effect on sensory score improvements. Blade tenderization had more effect on connective tissue, muscle fiber tenderness, and overall tenderness scores assigned by the trained panel. The *M. diaphragma pars costalis*, *M. transversus abdominis*, and *M. serratus ventralis* fajitas had acceptable palatability regardless of treatment. Other technologies or cooking methods might need to be applied to the *M. trapezius* for it to receive acceptable palatability and WBSF values. Palatability and WBSF scores among muscles are variable due to the inherent differences in muscle structure and connective tissue amounts.

Consumer panel responses to muscles and treatments followed the same trends as the objective measurements of the trained panel and WBSF. Consumers are willing to purchase the *M. latissimus* and *M. serratus ventralis* treated with P+B and P, respectively, and these muscles performed well enough to be considered as alternatives in the beef fajita market.

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APPENDIX

Appendix 1. Telephone script used to recruit consumers by phone.

Dialogue for Consumer Survey

Date______________ Your name ________________________________
Individual ____
Telephone number _________________________

Hello, my name is ____________________

I am from the Department of Animal Science at Texas A&M University.

We are conducting a consumer survey to evaluate the quality of meat. You have been selected to participate in this study.

It takes about two hours of your time and you will need to come to two sessions on different days. You will receive a one time compensation of $40 for your participation.

Would you be willing to participate? ______________________

Are you an employee of Texas A&M University, the Texas Agricultural or Engineering Experiment Station or the Texas Cooperative Extension Service? _____
[If no, then continue.]
[If yes, then – I am very sorry but we need people that are not employees of the A&M system]

Do you do half or more of the household grocery shopping? ________
[If yes, then continue]
If no ask… Is the person who does half or more of the household grocery shopping available to participate? _______________[if the person changes, change the individual above and start over]

Do you have any food allergies or intolerances (such as religious or ethnic issues) to beef or pork? ___________ [If "no" then continue]
[If yes, then – I am sorry we need participants that can consume beef and pork. Thank you for your time and good evening]

Are you between the ages of 25 and 65? _______
[If yes, then continue.]
[If no, then-I am very sorry we need participants from that range of age. Thank you for your time and good evening]

Are you employed in the food industry, advertising, market research or do you work for a company that manufactures or distributes beef, pork or turkey products? _________(If "no" then continue)

Thank you for your willingness to participate. There are some additional questions that I must ask to assure that you qualify for the study.

Do you consume meat at least 5 times per week? ___________________

How many times per week do you consume poultry? _______________

How many times per week do you consume pork? _________________

How many times per week do you consume beef? __________________

How many times per week do you consume fish? __________________

[if yes for beef and pork, then continue]
[if no, then – I am very sorry, but we must have people in the study that consume meat. Thank you for your time and good evening]

To further qualify, I need to know some additional information.

How many times per month do you consume ground beef? __________

How many times per month do you consume beef steaks? _________________

How many times per month do you consumer beef fajitas? ________________

How many times per month do you consume pork roasts? ____________

How many times per month do you consume pork loin? ____________

How many times per month do you consumer pork chops? ____________

[if yes for fajitas and pork, then continue]
[if no, then – I am very sorry, but we must have people in the study that consume fajitas and pork. Thank you for your time and good evening]

Thank you. You fully qualify to participate in the study.

The study is being conducted at the Kleberg Food and Animal Center on the Texas A&M University campus on _[look at the calendar]_ at _[look at the calendar]_.

[Try to fill up the first days available]

Would any of these times be convenient for you?

If not, what times are best for you?

Time ____________

Date __________________

Are you willing to have us contact you by e-mail, your e-mail address will only be used for this study. [If yes, e-mail address is ___________________________]

If you do not use e-mail , could I please get your name and address now so that we can send you a verification letter, directions to the location and parking information. You should receive the information by mail in about 2 to 3 days.

Name __________________________________

Address __________________________________

____

Your name and address are strictly confidential and will not be disclosed to anyone.

Now, let me tell you a little bit about what we will be doing. When you come to the Kleberg Center, you will be evaluating pork and beef samples with about 15 other people. You will be asked to evaluate the samples using a consumer ballot. It is very simple and should be lots of fun. The meat is perfectly safe. It is similar to meat that you would purchase in the retail store and has been cooked under strict sanitary conditions. Once you are done testing you can sign up for the second session.

Do you have any questions?

If you think of any questions, please call us at 845-3935. My name is ______________________ And if I am not here, whoever answers the telephone should be able to answer your questions or they will find someone who can.

Thank you so much for your willingness to participate and we will look forward to see you on_______________ at ________.

Appendix 2. Demographic form used by consumers.

INSTRUCTIONS

The objective of this study is to evaluate 28 beef samples over two nights. You will evaluate 14 samples the first night and 14 samples the second night. Please take your time and evaluate the samples given to you carefully. Please proceed at your own rate. Each sampling will take you about 45 to 60 minutes each night.

Please answer the following questions as completely as possible. This information is confidential and will not be used to solicit advertising nor will this information be published with your name associated with it. If you have any questions, please ask the monitor for assistance.

BOLD LETTERS throughout the questionnaire we will give you directions on how to complete the evaluation. Thank you very much for your help and opinions.

Please fill out the following information.

1. Please indicate your age by marking the appropriate blank:

   ______ 25-29 years ______ 30-39 years ______ 40-49 years

   ______ 50-59 years ______ 60-65 years

2. Please indicate your income (combined income if both you and your spouse are employed) by marking the appropriate blank:

   _________ Under $20,000 ______ $20,000-$29,000 ______ $30,000-$39,000

   _________ $40,000-$49,000 ______ $50,000-$59,000 ______ $60,000 or more

3. Please indicate your household size, including yourself:

   _____ 1 ______ 2 ______ 3 ______ 4 ______ 5 ______ 6 or greater

4. Please indicate your current working status:

   ______ Not employed ______ Part-time ______ Full-time

5. Please indicate your sex:

   ______ Male ______ Female

6. Please indicate your nationality:

_____ White ______ Hispanic ______ African American ______ Other

7. On average, how many times a **week** do you consume **beef**?

________Never _____ 1 time
_____ 2 times _____ 3 times
_____ 4 or more times (Write in number: _______)

8. On average, how many times a **month** do you consume **beef fajitas**?

________Never _____ 1 time
_____ 2 times _____ 3 times
_____ 4 or more times (Write in number: _______)

YOU ARE READY TO MOVE TO THE TASTE EVALAUTION, PLEASE TURN THE PAGE.

Appendix 3. Cook time and cook yield means (standard deviation) obtained from trained panel within muscles and treatments.

	Broiling data	
	Cook time (min)	Cook yield (%)
Muscle		
M. diaphragma pars costalis	19.8	71.2
	(23.3)	(7.4)
M. transversus abdominis	19.6	78.8
	(18.7)	(7.7)
M. obliquus abdominis int.	37.3	74.4
	(23.7)	(8.8)
M. serratus ventralis	39.2	76.4
	(26.9)	(9.3)
M. rhomboideus	40.1	80.0
	(19.8)	(7.4)
M. latissimus	35.6	78.1
	(26.4)	(7.0)
M. trapezius	26.6	77.0
	(23.7)	(8.1)
Treatment		
Control	33.8	75.2
	(22.5)	(9.1)
Blade tenderization	33.8	74.4
	(27.2)	(8.0)
Papain	23.4	78.7
	(21.1)	(8.3)
Papain + Blade tenderization	33.8	77.8
	(25.2)	(7.3)

Appendix 4. Cook time, cook yield, and average Warner-Bratzler shear force (WBSF) means (standard deviation) obtained from consumer panel within muscles and treatments.

	Broiling data		WBSF
	Cook time (min)	Cook yield (%)	(N)
Muscle			
M. diaphragma pars costalis	15.6	69.0	14.7
	(13.3)	(9.5)	(5.9)
M. transversus abdominis	31.1	75.8	25.5
	(24.2)	(6.1)	(10.8)
M. obliquus abdominis int.	38.9	74.4	19.6
	(23.6)	(6.6)	(8.8)
M. serratus ventralis	46.2	77.1	22.6
	(27.1)	(6.4)	(7.8)
M. rhomboideus	55.2	74.7	37.3
	(28.9)	(8.2)	(14.7)
M. latissimus	48.0	74.8	35.3
	(27.6)	(7.3)	(12.7)
M. trapezius	33.8	78.3	51.0
	(26.3)	(8.4)	(25.5)
Treatment			
Control	38.8	74.6	36.3
	(27.1)	(6.6)	(20.6)
Blade tenderization	39.5	74.1	34.3
	(28.1)	(6.7)	(19.6)
Papain	36.4	74.8	21.6
	(26.7)	(9.4)	(11.8)
Papain + Blade tenderization	38.5	76.0	24.5
	(28.5)	(9.2)	(14.7)

Appendix 5. Trained panel score means (standard deviation) for palatability attributes within muscles and treatments.

	Trained panel score[a]			
	JUICE	MFT	CT	OT
Muscle				
M. diaphragma pars costalis	5.8	7.3	7.5	7.3
	(0.9)	(0.7)	(0.6)	(0.7)
M. transversus abdominis	5.5	5.5	5.9	5.5
	(0.9)	(1.7)	(1.7)	(1.7)
M. obliquus abdominis int.	5.8	6.5	6.7	6.5
	(1.2)	(1.6)	(1.7)	(1.7)
M. serratus ventralis	6.4	7.4	7.1	7.3
	(0.8)	(0.9)	(0.9)	(0.9)
M. rhomboideus	5.8	5.5	5.6	5.4
	(1.0)	(1.8)	(1.7)	(1.7)
M. latissimus	4.8	5.3	5.7	5.2
	(1.2)	(1.6)	(1.6)	(1.6)
M. trapezius	4.8	4.2	4.1	4.1
	(1.1)	(2.1)	(2.2)	(2.1)
Treatment				
Control	5.3	4.8	5.3	4.8
	(1.2)	(1.9)	(2.0)	(1.9)
Blade tenderization	5.1	5.4	5.8	5.4
	(1.2)	(1.8)	(1.9)	(1.8)
Papain	6.0	7.0	6.9	7.0
	(0.9)	(1.1)	(1.3)	(1.1)
Papain + Blade tenderization	5.8	6.6	6.5	6.5
	(1.0)	(1.6)	(1.7)	(1.7)

[a]JUICE = juiciness, MFT = muscle fiber tenderness, CT = connective tissue, OT = overall tenderness. Trained panel used an 8-point scale: 1 = extremely dry, extremely tough, abundant, and extremely tough; 8 = extremely juicy, extremely tender, none, and extremely tender.

Appendix 6. Trained panel score means (standard deviation) for aromatics within muscles and treatments.

	Trained panel score[a]						
	CBL	CBF	S/B	CAR	LIV	BUR	CHE
Muscle							
M. diaphragma pars costalis	5.4	3.0	1.5	0.0	0.3	1.8	1.1
	(1.2)	(0.7)	(1.1)	(0.2)	(0.7)	(1.0)	(1.3)
M. transversus abdominis	5.0	2.8	1.4	0.0	0.0	1.3	1.1
	(1.1)	(0.8)	(1.1)	(0.2)	(0.3)	(1.1)	(1.3)
M. obliquus abdominis int.	5.8	2.9	1.6	0.0	0.1	2.0	1.2
	(1.3)	(0.8)	(1.2)	(0.3)	(0.3)	(1.0)	(1.5)
M. serratus ventralis	5.5	3.7	1.8	0.0	0.1	1.8	1.1
	(1.4)	(0.9)	(1.2)	(0.0)	(0.4)	(1.0)	(1.4)
M. rhomboideus	5.2	2.4	1.8	0.0	0.0	1.7	1.1
	(1.1)	(0.8)	(1.1)	(0.3)	(0.3)	(1.0)	(1.4)
M. latissimus	4.5	2.2	1.4	0.1	0.1	1.0	0.9
	(1.1)	(1.0)	(1.1)	(0.6)	(0.4)	(1.0)	(1.2)
M. trapezius	4.0	2.7	1.3	0.4	0.1	1.1	0.9
	(1.4)	(0.8)	(1.2)	(0.9)	(0.4)	(1.1)	(1.2)
Treatment							
Control	4.9	2.7	1.6	0.2	0.1	1.7	0.3
	(1.3)	(0.8)	(1.1)	(0.6)	(0.5)	(1.1)	(0.8)
Blade tenderization	5.0	2.7	1.5	0.1	0.1	1.7	0.3
	(1.3)	(0.8)	(1.2)	(0.5)	(0.5)	(1.1)	(0.8)
Papain	5.2	2.9	1.5	0.1	0.1	1.3	1.8
	(1.4)	(1.0)	(1.2)	(0.5)	(0.3)	(1.1)	(1.3)
Papain + Blade tenderization	5.2	2.9	1.5	0.0	0.1	1.4	1.8
	(1.4)	(1.0)	(1.2)	(0.2)	(0.3)	(1.0)	(1.3)

[a]CBL = cooked beef lean, CBF = cooked beef fat, S/B = serumy/bloody, CAR = cardboardy, LIV = livery, BUR = burned, and CHE = chemical. Soda, grassy, cowy, smoke, old, and musty were other aromatics that panelists sometimes detected but not frequently enough to include. Trained panel used a 9-point scale: 0 = none; 8 = extremely intense.

Appendix 7. Trained panel score means (standard deviation) for mouthfeels within muscles and treatments.

	Trained panel score[a]	
	Astringent	Metal
Muscle		
M. diaphragma pars costalis	2.4	2.7
	(0.5)	(0.5)
M. transversus abdominis	2.5	2.6
	(0.5)	(0.5)
M. obliquus abdominis int.	2.4	2.7
	(0.5)	(0.5)
M. serratus ventralis	2.3	2.6
	(0.5)	(0.5)
M. rhomboideus	2.5	2.7
	(0.5)	(0.5)
M. latissimus	2.5	2.6
	(0.5)	(0.5)
M. trapezius	2.4	2.6
	(0.5)	(0.5)
Treatment		
Control	2.4	2.7
	(0.5)	(0.5)
Blade tenderization	2.5	2.7
	(0.5)	(0.5)
Papain	2.4	2.6
	(0.5)	(0.5)
Papain + Blade tenderization	2.5	2.6
	(0.5)	(0.5)

[a]Trained panel used a 9-point scale: 0 = none; 8 = extremely intense.

Appendix 8. Trained panel score means (standard deviation) for tastes within muscles and treatments.

	Trained panel score[a]			
	Salt	Sour	Bitter	Sweet
Muscle				
M. diaphragma pars costalis	2.9	2.2	2.4	0.4
	(1.1)	(0.4)	(0.6)	(0.7)
M. transversus abdominis	2.9	2.3	2.2	0.4
	(1.1)	(0.5)	(0.6)	(0.7)
M. obliquus abdominis int.	3.0	2.3	2.4	0.5
	(1.1)	(0.5)	(0.6)	(0.8)
M. serratus ventralis	2.9	2.2	2.2	0.6
	(1.0)	(0.5)	(0.5)	(0.8)
M. rhomboideus	2.9	2.3	2.2	0.3
	(1.2)	(0.5)	(0.5)	(0.6)
M. latissimus	2.7	2.4	2.2	0.3
	(1.0)	(0.5)	(0.5)	(0.6)
M. trapezius	2.8	2.2	2.3	0.2
	(1.1)	(0.5)	(0.6)	(0.6)
Treatment				
Control	2.1	2.2	2.4	0.3
	(0.5)	(0.5)	(0.6)	(0.6)
Blade tenderization	2.2	2.3	2.4	0.2
	(0.5)	(0.5)	(0.6)	(0.6)
Papain	3.6	2.3	2.2	0.6
	(1.0)	(0.5)	(0.6)	(0.7)
Papain + Blade tenderization	3.6	2.3	2.2	0.5
	(1.1)	(0.5)	(0.5)	(0.7)

[a]Trained panel used a 9-point scale: 0 = none; 8 = extremely intense.

Appendix 9. Trained panel score means (standard deviation) for aftertastes within muscles and treatments.

	Trained panel score[a]											
	Salt	Sour	Bitter	Sweet	AC	MET	BRO	CHE	FAT	LIV	S/B	BUR
Muscle												
M. diaphragma pars costalis	0.6	0.9	0.8	0.1	1.2	0.2	0.5	0.2	0.4	0.1	0.2	0.1
	(1.0)	(1.0)	(1.1)	(0.3)	(1.0)	(0.6)	(0.8)	(0.6)	(0.8)	(0.5)	(0.6)	(0.5)
M. transversus abdominis	0.8	1.0	0.4	0.0	1.2	0.2	0.4	0.4	0.2	0.0	0.1	0.1
	(1.1)	(1.0)	(0.9)	(0.2)	(1.1)	(0.6)	(0.8)	(0.8)	(0.7)	(0.2)	(0.5)	(0.5)
M. obliquus abdominis int.	0.6	0.9	0.9	0.1	1.0	0.3	0.8	0.3	0.3	0.1	0.2	0.1
	(1.0)	(1.0)	(1.1)	(0.3)	(1.0)	(0.7)	(1.0)	(0.7)	(0.8)	(0.4)	(0.7)	(0.5)
M. serratus ventralis	0.5	0.9	0.5	0.0	1.1	0.2	0.6	0.2	0.7	0.1	0.3	0.2
	(0.9)	(1.0)	(0.9)	(0.2)	(1.0)	(0.7)	(0.9)	(0.6)	(1.1)	(0.5)	(0.8)	(0.6)
M. rhomboideus	0.7	1.1	0.3	0.0	1.4	0.2	0.6	0.3	0.0	0.0	0.3	0.1
	(1.1)	(1.0)	(0.8)	(0.2)	(1.0)	(0.6)	(0.9)	(0.7)	(0.2)	(0.3)	(0.7)	(0.4)
M. latissimus	0.6	1.3	0.4	0.0	1.5	0.1	0.3	0.2	0.1	0.0	0.0	0.1
	(1.1)	(1.0)	(0.8)	(0.2)	(1.0)	(0.5)	(0.7)	(0.7)	(0.4)	(0.2)	(0.3)	(0.4)
M. trapezius	0.5	0.9	0.7	0.1	1.2	0.2	0.3	0.2	0.3	0.1	0.2	0.3
	(0.9)	(1.0)	(1.0)	(0.4)	(1.0)	(0.7)	(0.8)	(0.6)	(0.8)	(0.4)	(0.6)	(0.7)
Treatment												
Control	0.1	1.1	0.8	0.0	1.4	0.2	0.6	0.0	0.4	0.1	0.3	0.1
	(0.4)	(1.0)	(1.1)	(0.2)	(1.0)	(0.7)	(0.9)	(0.1)	(0.9)	(0.3)	(0.7)	(0.5)
Blade tenderization	0.1	1.2	0.8	0.0	1.3	0.2	0.6	0.0	0.3	0.1	0.2	0.1
	(0.4)	(1.0)	(1.1)	(0.2)	(1.0)	(0.6)	(0.9)	(0.2)	(0.8)	(0.5)	(0.7)	(0.4)
Papain	1.1	0.9	0.4	0.1	1.2	0.2	0.4	0.4	0.2	0.1	0.1	0.2
	(1.2)	(1.0)	(0.8)	(0.3)	(1.0)	(0.6)	(0.8)	(0.8)	(0.6)	(0.3)	(0.5)	(0.6)
Papain + Blade tenderization	1.1	0.9	0.4	0.1	1.1	0.2	0.4	0.5	0.2	0.1	0.2	0.1
	(1.2)	(1.0)	(0.8)	(0.3)	(1.0)	(0.6)	(0.8)	(1.0)	(0.6)	(0.3)	(0.5)	(0.5)

[a]AC = acid, MET = metal, BRO = browned, CHE = chemical, FAT = fatty, LIV = livery, S/B = serumy/bloody, and BUR = burnt. Smoke, cowy, old, rancid, milky, and cardboardy were other aftertastes that panelists sometimes detected but not frequently. Trained panel used a 9-point scale: 0 = none; 8 = extremely intense.

Appendix 10. Consumer panel score means (standard deviation) for palatability attributes within muscles and treatments.

	Consumer panel score[a]							
	OL	LFL	IFL	SAL	UN	OT	LTE	CT
Muscle								
M. diaphragma pars costalis	6.6	6.3	5.3	6.6	7.8	7.2	7.3	7.3
	(1.9)	(2.0)	(2.1)	(1.9)	(1.9)	(1.9)	(1.7)	(1.9)
M. transversus abdominis	5.7	5.8	5.8	6.6	7.8	5.9	5.8	6.0
	(2.3)	(2.1)	(2.1)	(1.9)	(1.9)	(2.5)	(2.5)	(2.5)
M. obliquus abdominis int.	6.6	6.4	5.1	6.3	8.0	7.1	7.1	7.1
	(2.1)	(2.1)	(2.2)	(2.0)	(1.7)	(2.1)	(2.0)	(2.2)
M. serratus ventralis	5.1	5.3	5.8	6.8	7.5	6.1	6.5	5.8
	(2.4)	(2.2)	(2.1)	(1.8)	(2.1)	(2.4)	(2.3)	(2.6)
M. rhomboideus	4.6	5.1	5.7	6.8	7.6	4.3	4.4	4.9
	(2.2)	(2.2)	(2.1)	(1.9)	(2.0)	(2.5)	(2.5)	(2.6)
M. latissimus	4.9	4.7	6.0	7.0	7.4	4.5	4.4	5.2
	(2.4)	(2.3)	(2.2)	(1.9)	(2.2)	(2.7)	(2.6)	(2.6)
M. trapezius	2.8	3.9	6.2	6.8	7.2	2.6	2.6	2.8
	(2.1)	(2.3)	(2.2)	(2.0)	(2.5)	(2.1)	(2.2)	(2.2)
Treatment								
Control	4.4	4.7	6.1	7.3	7.5	4.5	4.5	4.9
	(2.4)	(2.3)	(2.2)	(1.7)	(2.2)	(2.8)	(2.8)	(2.8)
Blade tenderization	4.5	4.8	6.0	7.3	7.3	4.6	4.6	4.9
	(2.5)	(2.3)	(2.2)	(1.7)	(2.3)	(2.7)	(2.7)	(2.7)
Papain	5.9	6.1	5.4	6.2	7.9	6.4	6.5	6.4
	(2.4)	(2.1)	(2.1)	(2.0)	(1.9)	(2.5)	(2.4)	(2.5)
Papain + Blade tenderization	5.7	5.9	5.3	6.1	7.7	6.0	6.2	6.2
	(2.5)	(2.2)	(2.1)	(2.0)	(2.0)	(2.7)	(2.6)	(2.6)

[a]OL = overall like, LFL = like of flavor, IFL = intensity of flavor, SAL = level of saltiness, UN = level of undesirable flavors, OT = overall tenderness, LTE = level of tenderness, and CT = connective tissue. Consumer panel used a 9-point scale: 1 = dislike extremely, dislike extremely, extremely intense, extremely intense salt flavor, extremely intense undesirable flavors, dislike extremely, extremely tough, and very abundant or a lot; 9 = like extremely, like extremely, none or extremely bland, none or no salt flavor, none or no undesirable flavors, like extremely, extremely tender, and none.

VITA

Name:	Diana Lorena Huerta Sanchez
Birthplace:	Maracaibo, Venezuela
Hometown:	Maracaibo, Venezuela
Education:	La Universidad del Zulia B.S., Chemical Engineering October 2003
	Texas A&M University M.S., Animal Science (Meat Science) August 2006
Permanent Address:	Calle 71 # 3ch-55 Sector La Lago Maracaibo-Venezuela 4002