Published August 16, 2018

Meat and Muscle Biology™

Honduran and U.S. Consumer Assessment of Beef from Various Production Systems with or Without Marinating

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Abstract: Our objective was to evaluate the effects of different Honduran cattle production systems, enhancement, and country of origin on palatability of the *longissimus* muscle aged 21 d postmortem as determined by U.S. and Honduran consumers (n = 240/country). U.S.-sourced strip loins (n = 10/treatment) were selected: USDA Select (SE) and Top (upper 2/3) Choice (TC). Honduran-sourced strip loins (n = 10/treatment) included: 1) dual-purpose bulls, raised on native pasture (HDP), 2) F1 crossbred Brahman bulls finished on a corn-based grain diet for 180 d (HCF), and 3) purebred Brahman bulls finished on a sugarcane-based diet for 180 d (HSC). Ten additional strip loins from each Honduran treatment were selected and enhanced (E; 112% ± 3.5%) with water, salt, and tripolyphosphate, resulting in EHDP, EHCF, and EHSC. Steaks were cooked to 77°C prior to consumer evaluation of tenderness, juiciness, and flavor and overall liking, with classification of each trait as acceptable or unacceptable. Consumers indicated if they were willing to pay 0, 3, 6, or 10 USD/0.45 kg. Consumer data were analyzed using the GLIMMIX procedure of SAS as a split plot design, with treatment as the whole plot factor and country and the country × treatment interaction as the subplot factors, including panel as a random effect. The EHCF had greater ($P < 0.05$) scores for tenderness, juiciness, flavor and overall liking. No differences ($P > 0.05$) were found between TC and SE when scoring palatability traits, but more ($P < 0.05$) consumers found TC acceptable for juiciness compared to SE. Honduran consumers ranked all palatability traits greater than U.S consumers and found a greater percentage of samples acceptable for tenderness ($P < 0.05$). Enhancement of Honduran treatments had a positive effect on palatability traits, as well as the acceptability of those traits. Regardless of the differences in breeds, using high-energy diets and enhancement resulted in greater palatability scores.

Keywords: beef, consumers, enhancement, Honduras, palatability
Meat and Muscle Biology 2(1):242–253 (2018) **doi:10.22175/mmb2018.03.0004**
Submitted 30 Mar. 2018 Accepted 17 July 2018

Introduction

The United States is the largest producer of high quality beef in the world, with most cattle fed a high-concentrate grain-based finishing diet. Moreover, according to United States Department of Agriculture (USDA, 2015), the U.S. is the fourth largest beef exporting country in the world and the largest importer of beef. The U.S. has increased its share of imported meat from countries with alternative beef production practices, such as Central and South American countries (USDA, 2012). Central and South American beef production, however, is mainly based on a grazing system utilizing *Bos indicus* cattle.

Previous studies have found differences in carcass composition from grain finished and grass finished cattle (Riley et al., 2005; Van Elswyk and McNeill, 2014). Additionally, fat deposition varies depending on breed or biological cattle type with *Bos taurus* having a higher fat deposition than *Bos indicus* (Crouse et al., 1989; Warren et al., 2008). Previous studies suggest breed variance can increase intramuscular fat to improve meat palatability traits (Muir et al., 1998; Sadkowski et al., 2014), ultimately affecting meat quality and acceptability with the consumer (Koch et al., 1976; Koch et al., 1979; Maughan et al., 2012).

Crossbreeding has been implemented, especially in tropical and subtropical areas, to achieve heterosis, thereby enhancing cattle's genetics and contributing to more efficient meat production. In addition to crossbreeding, Latin American countries have been implementing the incorporation of feed supplements to improve growth performance or meat quality. In particular, corn has been added to the diets as an alternative to accelerate cattle fattening.

Additionally, as the world population increases, there is an increase in food demand, especially in developing countries. In 2015, the Food and Agriculture Organization reported 1 million undernourished people living in Honduras (FAO, 2015). To improve population nutritional conditions, more efficient production systems and alternatives for improving animal protein access are needed. Due to the success of U.S. beef in international markets, some countries have tried to adapt their production systems to produce beef similar in quality and composition to U.S. beef. Currently, however, there are no data describing consumer (Honduran or U.S.) perception of grain-finished U.S. beef compared to Honduran beef derived from these various alternative cattle finishing systems.

To overcome problems with consumer acceptability of low quality meat, enhancement of beef products with the addition of brines containing water, phosphates and salt has also been used in the industry. It has been demonstrated that the application of enhancement results in improved palatability and greater yields (Lee et al., 2014; Scanga et al., 2000; Sheard and Tali, 2004).

The objective of this study was to characterize the eating quality of beef from the United States compared to non-enhanced and enhanced Honduran beef from cattle raised using alternative finishing practices according to both Honduran and U.S. consumers to compare consumer preferences between these 2 countries.

Materials and Methods

Product collection

Eight total treatments were utilized for this study including 2 U.S. treatments and 6 Honduran treatments. U.S. treatments included USDA Select strip loins (SE; *n* = 10) and USDA Top (upper 2/3) Choice strip loins (TC; *n* = 10). The U.S.-sourced strip loins (IMPS #180; NAMP, 2011) were collected at a federally inspected commercial beef processing facility by trained Texas Tech personnel. Carcasses were chilled for approximately 24 h before grading. Carcass fabrication occurred between 24 and 32 h postmortem. Strip loins were transported to the Gordon. W. Davis Meat Science Laboratory located in Lubbock, Texas. Honduran treatments were collected at Agroindustrias Del Corral located in Siguatepeque, Honduras. All experimental procedures with Honduran animals were conducted in accordance with a Texas Tech University Animal Care and Use Committee protocol (Protocol # 14071–09). Strip loins collected in Honduras included 3 different treatments, consisting of 1) predominantly Brahman, Holstein, and Brown Swiss crossbred (information about the exact breed composition was unknown), dual-purpose cattle [HDP (milk and beef production); *n* = 10], that were raised solely on native pasture (*Hyparrhenia rufa*) and improved grasses (*Panicum maximum, Cynodon plectostachyus, Digitaria swazilandensis, Brachiaria decumbens,* and *Brachiaria brizantha*) resulting in an age at slaughter of approximately 40 mo; 2) cattle finished on a high energy diet consisting of cracked corn, palm kernel, and sugarcane for 180 d (HCF; *n* = 10). Cattle used for HCF treatment were F1 crosses between Brahman and either Senepol, Red Angus, or Simmental that averaged 24 mo at slaughter. A third treatment group consisted of cattle finished on a by-product-based diet consisting of sugarcane, palm kernel meal, poultry litter, and cracked corn for 180 d, (HSC; *n* = 10) but were predominantly native purebred Brahman that were approximately 24 mo of age at slaughter. All Honduran cattle involved were bulls, as it is customary to leave male cattle intact during growing and finishing in Honduras. Ingredient composition for HCF and HSC can be found in Table 1. Diets were formulated to provide approximately 13.5% crude protein on a DM basis, but feed composition was not tested. Carcass fabrication occurred between 18 and 24 h postmortem. Ten additional paired strip loins from each of the 3 Honduran sourced treatments were collected from the other side of the carcass and enhanced at 24 h postmortem at a 112% (± 3.5%)

Table 1. Ingredient composition (DM basis) of the experimental diets fed in finishing diets to Honduran cattle

Item	Treatment	
	HCF[1]	HSC[1]
Ingredient, %		
Fresh Sugar Cane	15.00	37.30
Palm Kernel Meal	20.00	20.40
Poultry Litter, dry	8.00	19.90
Soybean Meal	5.00	--
Cracked Corn	46.00	15.80
Molasses	5.00	6.5
Calcium Carbonate	1.00	--

[1]HCF – Honduran corn-fed, HSC – Honduran sugar cane.

pump rate using a multi needle injector (Accujector 450, GEA Group; Bogotá D. C., Colombia) with a target concentration of 0.25% tripolyphosphate and 0.50% salt in the final product. Enhancement resulted in the following three treatments: enhanced HDP (EHDP), enhanced HCF (EHCF), and enhanced HSC (EHSC).

Sample preparation

Strip loins from both countries were aged for 21 d at 0 to 4°C under vacuum. Eight 2.5-cm steaks were fabricated from each strip loin starting at the anterior end using a manual meat slicer (Model X13E, 33 cm; ITW Food Equipment Group LLC, Louisville, KY) to ensure uniform thickness. The anterior-most steak from each strip loin was assigned to proximate analysis, and the next steak was assigned to Warner-Bratzler shear force (WBSF). The next 6 steaks were assigned randomly to consumer sensory panel evaluation. Consecutively cut steaks were paired, with 1 steak from each pair assigned to consumer testing in the U.S. and the other steak assigned to consumer testing in Honduras. Steaks were frozen (–20°C) at 21 d post mortem and remained frozen until each evaluation. Any steaks destined to be tested in the country other than where collection took place, including all Honduran steaks destined for shear force and compositional analyses, were shipped via commercial air in a frozen state (0°C), and were stored frozen (–20°C) on arrival until further sample evaluation. Steaks were thawed for 24 h at 2 to 4°C prior to consumer evaluation, shear force analysis and proximate analysis.

Proximate analysis

Proximate analysis was conducted to determine chemical values of fat, protein and moisture. Frozen samples were thawed at 2 to 4°C for 24 h prior to analysis. Steaks were trimmed of external fat and additional muscles (*longissimus costarum* and the *multifidus dorsi*). Samples were ground in a commercial food grinder (Krups 150-Watt Meat Grinder item #402–70, Krups, Shelton, CT). Proximate analysis was conducted on approximately 200-g samples using an AOAC-approved (Official Method 2007.04; Anderson, 2007) near infrared spectrophotometer (FoodScan, FOSS NIRsystems, Inc., Laurel, MD). Chemical values (%) of fat, protein, and moisture were determined.

Warner-Bratzler Shear Force analysis

Tenderness was determined using a WBSF analyzer (G-R Elec. Mfg., Manhattan, KS). . Frozen steaks were thawed at 2 to 4°C for 24 h prior to analysis. All steaks were cooked on non-stick clamshell grills (George Foreman, Wilkes Barre, PA) to an internal temperature of 77°C and then cooled overnight at 2°C for 24 h. Six 1.3-cm core samples were removed parallel to the orientation of the muscle fibers, from each steak and sheared once, perpendicular to the orientation of the muscle fibers. The 6 values were averaged to determine 1 shear force value (kg) for each steak sample.

Consumer sensory evaluation

The Texas Tech University Institutional Review Board approved procedures for use of human subjects for consumer panel evaluation of sensory attributes in the U.S. and Honduras. Consumer sensory evaluation was based on the American Meat Science Association's sensory guidelines (American Meat Science Association, 2015). Strip loin samples were thawed at 2 to 4°C for 24 h prior to cooking for consumer evaluation. Steaks were cooked on non-stick clamshell grills (George Foreman, Wilkes Barre, PA) to an internal temperature 77°C, monitored using a thermocouple probe (Type J; Cole-Parmer Instrument Company, Vernon Hills, IL) attached to a thermometer (Digi-sense; Cole Parmer). Each steak was then portioned into 8 uniform pieces. Consumer panelists (n = 240) in the U.S. were recruited in Lubbock, Texas; consumer panelists (n = 240) in Honduras were recruited either at Zamorano University in Tegucigalpa, Honduras or Siguatepeque, Honduras. U.S. consumer panels were conducted in the Animal and Food Sciences building at Texas Tech University. Panelists were seated individually in numbered booths and were each provided with a ballot, toothpick, napkin, plastic utensils, cup of water, and unsalted crackers (used as palate cleanser). Honduran consumer panels were conducted at an outdoor booth at the annual Pan- American Celebration Fair and at a supermarket in Siguatepeque, Honduras. Consumers were seated at open tables in Honduras, but were instructed not to communicate with each other during assessment and were provided the same supplies as U.S. consumers. Each ballot included an information sheet about the project for the consumer, demographic survey, and 8 sample evaluation ballots. Verbal instructions were given to consumers prior to each panel regarding the ballot, the procedure to follow for the panel, and the use of palate cleansers. Ballots for Honduran consumer panels were translated and provided in Spanish.

Eight samples were served to each consumer in a predetermined order. All samples were identified with a unique 4-digit identification number. An 8-point hedonic scale was used to rate juiciness, flavor liking, tenderness, and overall liking. On the scale, tenderness (1 = extremely tough, 2 = very tough, 3 = moderately tough, 4 = slightly tough, 5 = slightly tender, 6 = moderately tender, 7 = very tender, 8 = extremely tender), juiciness (1 = extremely dry, 2 = very dry, 3 = moderately dry, 4 = slightly dry, 5 = slightly juicy, 6 = moderately juicy, 7 = very juicy, 8 = extremely juicy), and flavor and overall liking (1 = extremely dislike, 2 = very much dislike, 3 = moderately dislike, 4 = slightly dislike, 5 = slightly like, 6 = moderately like, 7 = very much like, 8 = extremely like) were evaluated. Consumers were also asked to indicate whether the tenderness, juiciness, flavor, and overall eating quality of the sample were acceptable (Si) or unacceptable (No). Additionally, panelists indicated how much they were willing to pay for each sample by selecting 1 of 4 monetary values (U. S. consumers selected either $0, 3, 6, or 10 per 0.45 kg). The national Honduran currency (Lempiras; L.) was used in Honduras so that consumers selected L. 0, 60, 120, or 200 per 0.45 kg. At the time of testing, one U.S. dollar was equivalent to L. 20.00.

Statistical methods

Statistical analysis was conducted in SAS (Version 9.4; SAS Inst. Inc., Cary, NC). Proximate and shear force data were analyzed using the GLIMMIX procedure as a completely randomized design, with a fixed effect of treatment. The model for consumer rating data was analyzed as a split plot, with treatment as the whole plot factor and country and the country × treatment interaction as the subplot factors. Consumer acceptability data and willingness to pay data were analyzed using a model with a binomial error distribution. For all consumer data, panel was included as a random effect. Treatment least square means were separated with the PDIFF option of SAS at a significance level of $P < 0.05$. For all analyses, denominator degrees of freedom were calculated using the Kenward-Roger approximation.

Results and Discussion

Proximate analysis

Proximate composition results are presented in Table 2. Treatment had an effect ($P < 0.01$) on fat, protein and moisture. Fat percentages ranged widely among treatments (1.63 to 9.24%). Fat percentage of TC was greater ($P < 0.05$) than all other treatments, and consequently moisture percentage was the lowest ($P < 0.05$) for this treatment. Select had greater ($P < 0.05$) fat than both the enhanced and non-enhanced HDP and HSC treatments, but did not differ ($P > 0.05$) from either HCF treatment. Fat percentages of U.S. samples in this study were slightly higher than previously published values for top loin steaks of their respective quality grades (Corbin et al., 2015; Emerson et al., 2013; Hunt et al., 2014). However, fat percentages were lower in our study than previously reported values of Honduran grass fed (5.78%) and Honduran grain fed (6.47%) top loin steaks (Bueso, 2015). The difference in breed composition between North and Central American cattle as well as differences in diet likely contributed to the elevated fat percentage of U.S. samples. Moisture content was similar ($P > 0.05$) in all three enhanced treatments as well as HDP, and was greater ($P < 0.05$) compared to HCF, SE, and TC. Moisture content increases with addition of moisture enhancement in meat products (Stetzer et al., 2008). Moreover, these results agree with other studies reporting an inverse relationship between moisture and fat (Delgado et al., 2005; Smith et al., 2011). There were expected differences in moisture and fat content; however, a 5% range in protein composition was also observed. Protein was greatest ($P < 0.05$) in SE and lowest in EHCF.

Table 2. Least squares means of proximate analysis for chemical fat, protein, and moisture and Warner-Bratzler shear force values

Treatment	Fat, %	Protein, %	Moisture, %	WBSF, kg
EHDP[1]	1.63^{de}	21.51^{c}	75.53^{a}	4.81^{ab}
EHCF[2]	2.81^{bcd}	19.35^{e}	74.59^{ab}	2.50^{e}
EHSC[3]	2.37^{cde}	20.51^{d}	74.94^{ab}	4.18^{bc}
HDP[4]	1.53^{e}	22.64^{b}	74.92^{ab}	5.65^{a}
HCF[5]	3.51^{bc}	22.62^{b}	72.06^{c}	3.74^{cd}
HSC[6]	2.59^{cde}	22.08^{bc}	73.73^{b}	5.19^{ab}
SE[7]	4.00^{b}	24.28^{a}	71.14^{c}	2.72^{de}
TC[8]	9.24^{a}	22.51^{b}	67.41^{d}	2.69^{e}
SEM[9]	0.47	0.32	0.47	0.44
P-value	< 0.01	< 0.01	< 0.01	< 0.01

[a-e]Least square means in the same column with different superscripts differ, $P < 0.05$.

[1]EHDP = Enhanced (112% with a target concentration of 0.25% tripolyphosphate and 0.50% salt of the final product) Honduran dual purpose.

[2]EHCF = Enhanced (112% with a target concentration of 0.25% tripolyphosphate and 0.50% salt of the final product) Honduran corn-fed diet.

[3]EHSC = Enhanced (112% with a target concentration of 0.25% tripolyphosphate and 0.50% salt of the final product) Honduran sugar cane diet.

[4]HDP = Honduran dual purpose.

[5]HCF = Honduran corn-fed diet.

[6]HSC = Honduran sugar cane diet.

[7]SE = USDA Select.

[8]TC = USDA top (upper 2/3) Choice.

[9] SEM (largest) of the least square means.

Warner-Bratzler Shear Force

As seen in Table 2, treatment influenced ($P < 0.01$) shear force values. HDP had greater ($P < 0.05$) WBSF values when compared to all other treatments except EHDP and HSC. The 2 US treatments along with EHCF had lower WBSF values than all other Honduran treatments, regardless of enhancement ($P < 0.05$), except that SE and HCF were similar ($P > 0.05$). Enhancement did not statistically reduce WBSF for HDP or HSC when compared to their non-enhanced counterparts even though there was a mean difference of 0.8 kg and 1.0 kg, respectively. However, previous research reports that consumers have been able to detect differences in WBSF of this magnitude (0.8 to 1.0 kg) when evaluating tenderness (Miller et al., 1995). Lower WBSF values in HCF when compared to HDP could have been a result of breed differences between these treatments, as well as a dietary effect, and/or variable age at slaughter. Tenderness in *Bos indicus* cattle can be of concern, especially as the percentage of *Bos indicus* increases (Crouse et al., 1989). High shear force values of steaks from *Bos indicus* cattle can be influenced by the elevated calpastatin levels (Whipple et al., 1990) and less intramuscular fat (Highfill et al., 2012). Additionally, greater WBSF values for HDP could have been affected by the fact that the animals used in this study were killed at an older age (typically 40 mo), potentially influencing collagen solubility (Riley et al., 2005). Previous studies have demonstrated a correlation between connective tissue, collagen solubility, and meat tenderness (Campo et al., 2000) and an effect of age on connective tissue (Allingham et al., 1998). As the age of animals increases, tenderness decreases (Hiner and Hankins, 1950). Evidence of the effect of calpastatin and collagen on tenderness when Brahman is included in the breeding is presented by Riley et al. (2005). Additionally, Crouse et al. (1989) found that with an increase in *Bos indicus* inheritance, an increase in shear force values was observed. Previous studies have demonstrated that enhancement lowers shear force values (Wicklund et al., 2006). In addition, differences in shear force values between USDA quality grades have been reported in previous research (Emerson et al., 2013; Garmyn et al., 2011; Hunt et al., 2014) even though no difference in WBSF between SE and TC was observed in our study.

Consumer demographics

Demographic profiles of consumers fed in Lubbock, Texas are shown in Table 3. More females participated in this study than males. The ages of the consumers were distributed from < 20 to > 60 yr old, with the 20 to 29 age group having the largest number of participants, followed by 30 to 39 and > 60 groups. Most of the consumers were from the U.S., with Canada, Mexico, and any other country of origin each contributing < 0.5% each. Most consumers were employed as a tradesperson, in administration, or a laborer, rather than being a student or unemployed.

Table 3. Demographic characteristics of consumers (n = 240) who participated in U.S. consumer sensory panels

Characteristic	Response	Consumers, %
Gender	Male	42.9
	Female	57.1
Age	<20	8.3
	20-29	31.4
	30-39	19.7
	40-49	12.7
	50-59	8.3
	>60	19.7
Occupation	Student	27.9
	Not currently employed	11.7
	Other (tradesperson, administration, ales, laborer)	60.4
Country of Origin	United States of America	98.8
	Canada	0.4
	Mexico	0.4
	Other	0.4

Honduran consumers were recruited from different cities around Honduras in the Pan-American Annual Fair at Zamorano University located in Tegucigalpa and at a supermarket located in Siguatepeque, Honduras. As seen in Table 4, most consumers were males, with nearly two-thirds of the participants representing college aged people under the age of 30 yr old. Much like the U.S. consumers, however, the highest percentage of consumers stated their occupation fell within the "other", category including tradesperson, administration, sales, laborer, etc. Most consumers were from Honduras, followed by Ecuador, but at least 6 other Central/South American countries were represented.

Consumer tenderness

As seen in Table 5, treatment and country where product was evaluated both influenced ($P < 0.01$) consumer ratings for tenderness, but were not interactive ($P = 0.23$). Tenderness acceptability followed a similar trend as no 2-way interaction was observed ($P = 0.96$; Table 6), while treatment (Table 7) influenced ($P < 0.01$) the proportion of samples considered acceptable for tenderness as did country where product was evaluated ($P < 0.01$). Honduran consumers rated the samples more tender ($P < 0.05$) than U.S. consumers, regardless of

Table 4. Demographic characteristics of consumers (n = 240) who participated in Honduran consumer sensory panels

Characteristic	Response	Consumers, %
Gender	Male	54.5
	Female	45.5
Age	<20	15.8
	20-29	49.1
	30-39	18.4
	40-49	10.7
	50-59	3.0
	>60	3.0
Occupation	Student	32.90
	Not employed	1.28
	Other	65.81
Country of Origin	Honduras	80.85
	Guatemala	2.12
	Nicaragua	1.70
	El Salvador	0.85
	Panama	1.27
	Colombia	1.70
	Ecuador	6.38
	Other	5.10

Table 5. Least square means for consumer (n = 480) ratings for each palatability trait by treatment and country where product was evaluated

Treatment	Tenderness[1]	Juiciness[2]	Flavor liking[3]	Overall liking[3]
EHDP[4]	3.62^{ef}	3.62^{f}	4.02^{cd}	3.89^{d}
EHCF[5]	6.49^{a}	5.82^{a}	6.22^{a}	6.34^{a}
EHSC[6]	4.59^{cd}	4.62^{bc}	4.75^{b}	4.76^{bc}
HDP[7]	2.93^{f}	3.25^{f}	3.28^{e}	3.15^{e}
HCF[8]	4.73^{c}	4.32^{cd}	4.35^{bc}	4.54^{c}
HSC[9]	3.88^{de}	3.75^{ef}	3.66^{de}	3.75^{d}
SE[10]	5.24^{bc}	4.46^{bc}	4.63^{b}	4.85^{bc}
TC[11]	5.62^{b}	4.94^{b}	4.82^{b}	5.17^{b}
SEM[12]	0.26	0.19	0.19	0.21
P-value	< 0.01	< 0.01	< 0.01	< 0.01
Country				
U.S.	4.39^{b}	4.10^{b}	4.26^{b}	4.22^{b}
Honduras	4.88^{a}	4.66^{a}	4.67^{a}	4.90^{a}
SEM	0.10	0.07	0.07	0.08
P-value	< 0.01	< 0.01	< 0.01	< 0.01
P-value[13]	0.23	0.09	0.15	0.42

[a-f]Least square means in the same column with different superscripts differ, $P < 0.05$.

[1]Tenderness: 1 = extremely tough, 2 = very tough, 3 = moderately tough, 4 = slightly tough, 5 = slightly tough, 6 = moderately tender, 7 = very tender, 8 = extremely tender.

[2]Juiciness: 1 = extremely dry, 2 = very dry, 3 = moderately dry, 4 = slightly dry, 5 = slightly juicy, 6 = moderately juicy, 7 = very juicy, 8 = extremely juicy.

[3]Flavor/Overall Liking: 1 = extremely dislike, 2 = very much dislike, 3 = moderately dislike, 4 = slightly dislike, 5 = slightly like, 6 = moderately like, 7 = very much like, 8 = extremely like.

[4]EHDP = Enhanced (112% with a target concentration of 0.25% tripolyphosphate and 0.50% salt of the final product) Honduran dual purpose.

[5]EHCF = Enhanced (112% with a target concentration of 0.25% tripolyphosphate and 0.50% salt of the final product) Honduran corn-fed diet.

[6]EHSC = Enhanced (112% with a target concentration of 0.25% tripolyphosphate and 0.50% salt of the final product) Honduran sugar cane diet.

[7]HDP = Honduran dual purpose.

[8]HCF = Honduran corn-fed diet.

[9]HSC = Honduran sugar cane diet.

[10]SE = USDA Select.

[11]TC = USDA top (upper 2/3) choice.

[12]SEM (largest) of the least square means.

[13]*P*-value of treatment x country interaction.

treatment. Consequently, a generally greater percentage of Honduran consumers found the samples acceptable for tenderness than the U.S. consumers (Table 6). Regardless of country where product was evaluated, consumers rated EHCF samples most tender ($P < 0.05$) followed by similar ($P > 0.05$) scores for TC and SE (Table 5). Results of the current study demonstrate the positive effect of enhancement on tenderness scores (Table 5) and tenderness acceptability (Table 7) when evaluated by consumers. Greater tenderness ratings were observed only for EHCF when compared to HCF. Although numerical increases were seen, no differences ($P > 0.05$) were detected between HDP with EHDP or between HSC with EHSC. Even so, in terms of the percentage of samples rated as acceptable for tenderness, enhancement had a positive effect when comparing all 3 Honduran treatments to their enhanced counterparts.

Greater tenderness scores, coupled with greater tenderness acceptability from Honduran consumers could have been due to their acclimation of their domestic beef supply and preference for beef to which they are accustomed. Delgado et al. (2005) reported a similar trend when comparing U.S. and Mexican beef. In the Delgado study, despite registering a lower shear force value than Northern Mexican beef, USDA Choice was rated similar for tenderness by Mexican consumers, attributing this phenomenon to Mexican beef consumers' familiarization with the taste, flavor, and aroma of locally produced beef due to the rich tradition of beef consumption in Mexico (Delgado et al., 2005). Moreover, the higher degree of doneness was more suited to Honduran than U.S. consumers, which also could have influenced tenderness ratings and acceptability between the two countries.

Previous research has shown that enhancement can improve palatability traits, including tenderness (Jensen et al., 2003; Scanga et al., 2000). Improvement of consumer tenderness scores in enhanced samples can be attributed

Table 6. The effects of country where product was evaluated and treatment on least square means for consumer (n = 480) acceptability for each palatability trait

Treatment	Tenderness, %	Juiciness, %	Flavor liking, %	Overall liking, %
U.S.				
EHDP[1]	41.71	49.74[ef]	50.93[efg]	57.56
EHCF[2]	96.19	85.81[a]	90.71[a]	82.62
EHSC[3]	67.81	67.83[bc]	67.51[bc]	61.40
HDP[4]	25.02	34.80[g]	36.94[hi]	37.55
HCF[5]	66.64	55.36[cde]	60.24[cde]	60.96
HSC[6]	42.85	38.97[fg]	39.89[ghi]	45.20
SE[7]	75.61	60.25[cde]	65.75[bcd]	69.40
TC[8]	85.34	78.31[ab]	72.97[b]	70.84
Honduras				
EHDP	50.46	54.23[de]	57.34[cdef]	51.47
EHCF	97.87	86.16[a]	87.38[a]	89.79
EHSC	72.27	67.67[bc]	68.27[bc]	70.56
HDP	29.70	38.34[fg]	33.11[i]	32.42
HCF	74.24	56.36[cde]	53.82[def]	61.63
HSC	51.22	49.18[ef]	45.23[fgh]	46.60
SE	81.96	59.02[cde]	60.19[cde]	69.82
TC	85.72	65.24[cd]	58.20[cde]	73.25
SEM[9]	0.56	0.31	0.31	0.29
P-value	0.96	0.04	0.03	0.13

[a-i]Least square means in the same column with different superscripts differ ($P < 0.05$).

[1]EHDP = Enhanced (112% with a target concentration of 0.25% tripolyphosphate and 0.50% salt of the final product) Honduran dual purpose.

[2]EHCF = Enhanced (112% with a target concentration of 0.25% tripolyphosphate and 0.50% salt of the final product) Honduran corn-fed diet.

[3]EHSC = Enhanced (112% with a target concentration of 0.25% tripolyphosphate and 0.50% salt of the final product) Honduran sugar cane diet.

[4]HDP = Honduran dual purpose.

[5]HCF = Honduran corn-fed diet.

[6]HSC = Honduran sugar cane diet.

[7]SE = USDA Select.

[8]TC = USDA top (upper 2/3) Choice.

[9]SEM (largest) of the least square means.

Table 7. The effects of treatment on least square means for consumer (n = 480) acceptability for each palatability trait

Treatment	Tenderness, %	Juiciness, %	Flavor liking, %	Overall liking, %
EHDP[1]	45.05[d]	51.99[de]	54.15[d]	54.53[cd]
EHCF[2]	97.15[a]	85.99[a]	89.16[a]	86.61[a]
EHSC[3]	70.09[c]	67.75[bc]	67.89[b]	66.13[b]
HDP[4]	27.30[e]	36.55[f]	35.00[e]	34.94[e]
HCF[5]	70.58[c]	55.86[de]	57.06[cd]	61.30[bc]
HSC[6]	47.01[d]	44.01[ef]	42.54[e]	45.95[de]
SE[7]	78.96[bc]	59.64[cd]	63.01[bcd]	69.61[b]
TC[8]	85.53[b]	72.74[b]	65.97[bc]	72.06[b]
SEM[9]	0.63	0.42	0.38	0.42
P-value	< 0.01	< 0.01	< 0.01	< 0.01

[a-f]Least square means in the same column with different superscripts differ ($P < 0.05$).

[1]EHDP = Enhanced (112% with a target concentration of 0.25% tripolyphosphate and 0.50% salt of the final product) Honduran dual purpose.

[2]EHCF = Enhanced (112% with a target concentration of 0.25% tripolyphosphate and 0.50% salt of the final product) Honduran corn-fed diet.

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[4]HDP = Honduran dual purpose.

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[6]HSC = Honduran sugar cane diet.

[7]SE = USDA Select.

[8]TC = USDA top (upper 2/3) Choice.

[9]SEM (largest) of the least square means.

to higher water content, as Offer and Trinick (1983) highlighted the positive effect of salt and polyphosphates helping myofibrils retain twice the volume and providing the capacity for actin and myosin disassociation, respectively.

Differences between cattle production systems and diets can affect tenderness, as animals fed a grain-based diet have higher tenderness scores (Nuernberg et al., 2005). Nuernberg et al. (2005) proposed that grazing animals have a slower growth rate when compared to animals produced under higher energy diets, thus resulting in tougher meat.

Differences in all palatability trait scores between EHCF, EHSC, and EHDP may indicate that breed influenced consumer scores. Differences in tenderness between breeds can be a result of variable levels of calpain and calpastatin, as previous research has shown that increasing the percentage of Brahman will increase the calpastatin activity (Pringle et al., 1997), thus resulting in lower tenderness.

Despite similar ($P > 0.05$) consumer palatability scores and acceptability percentages between TC and SE in our study, differences in palatability between quality grades in U.S. treatments have been previously reported when comparing strip loin tenderness scores (Corbin et al., 2015; O'Quinn et al., 2012; Tedford et al., 2014).

Consumer juiciness

Much like tenderness, both the country where product was evaluated and the treatment independently influenced ($P < 0.01$) juiciness scores, while no interaction was detected (Table 5; $P = 0.09$); however, those two effects interacted ($P = 0.04$) to impact juiciness acceptability (Table 6). Honduran consumers rated samples juicier ($P < 0.01$) than U.S. consumers. Regardless of country, EHCF samples had greater ($P < 0.05$) consumer juiciness scores than any other treatment, followed by similar ($P > 0.05$) scores for TC, EHSC, and SE.

The treatments that received the lowest juiciness ratings were HDP, EHDP, and HSC. Despite the fact EHDP was enhanced, no differences ($P > 0.05$) in juiciness were detected between HDP and EHDP, indicating that enhancement had negligible effect on EHDP. However, enhancement could be detected by consumers resulting in greater ($P < 0.05$) juiciness for EHCF and EHSC when compared to their non-enhanced counterparts. When examining the percentage of samples rated as acceptable for juiciness, enhancement had a positive effect when comparing all 3 Honduran treatments to their non-enhanced counterparts for both U.S. and Honduran consumers. Moreover, TC was the only treatment that a greater ($P < 0.05$) proportion of U.S. consumers found acceptable for juiciness than Honduran consumers, but those percentages were similar between the two countries for all other treatments ($P > 0.05$) – an interesting finding, given Honduran consumers were less discriminative when scoring juiciness than U.S. consumers.

Country where product was evaluated influenced juiciness scores, as Honduran consumers gave greater ($P < 0.05$) juiciness scores when compared to U.S consumers. This could be partly attributed to the degree of doneness (77°C) that was selected because Central American consumers prefer well done beef (McDonald, 2009). Research has revealed that degree of doneness affects consumer attitudes toward beef (Luo et al., 2009). Previous consumer research in Lubbock, TX has shown most consumers (59.8 to 76.8%) prefer their steaks cooked to medium rare or medium, and as the degree of doneness increases past medium, there is a decline in consumer satisfaction (Claborn et al., 2011).

Enhancement can increase palatability scores, specifically when treatments are enhanced with phosphate and salt, compared to the use of water only (Baublits et al., 2005). Consumer juiciness scores can be positively affected by enhancement (Robbins et al., 2003; Wicklund et al., 2006) as well as other production factors such as diet, demonstrating that a diet in which grains have been included will improve palatability of meat (Muir et al., 1998). Despite the positive effect of enhancement on EHCF and EHSC compared to HCF and HSC, respectively, consumers rated EHCF considerably juicier than EHSC. This difference is likely due to the dietary effect on meat from the HCF treatment.

Consumer flavor liking

As seen in Table 5, no interaction was observed ($P = 0.15$) but both country where product was evaluated and treatment independently influenced ($P < 0.01$) flavor-liking scores; however, treatment and country where product was evaluated interacted ($P = 0.03$) to influence flavor acceptability (Table 6). Honduran consumers liked the flavor of the beef samples more ($P < 0.01$) than U.S. consumers (Table 5). As with tenderness and juiciness, EHCF was rated with the highest ($P < 0.05$) flavor liking score compared to all other treatments. Once again, TC and SE were rated similarly ($P > 0.05$) for flavor liking along with EHSC and HCF, while flavor liking for HDP was lower ($P < 0.05$) than all other treatments, except HSC. A trend similar to that observed for juiciness acceptability was noted for flavor acceptability as well. Again, TC was the only treatment with a greater ($P < 0.05$) proportion of U.S. consumers finding it acceptable for flavor than Honduran consumers (Table 6), with the remaining percentages being similar between the 2 countries for all other treatments ($P > 0.05$). Also, when examining the percentage of samples rated as acceptable for flavor, enhancement had a positive effect when comparing all three Honduran treatments to their non-enhanced counterparts for both U.S. and Honduran consumers.

Greater flavor liking scores from Honduran consumers could be a result of differences in production systems between Honduras and U.S, as more than 50% of Hispanic consumers prefer pasture fed beef (Luo et al., 2009). On the other hand, U.S consumers typically consuming conventional beef have shown to perceive grass fed beef flavors as “intense” (Martz, 2000). Despite previous results showing differences in flavor liking between TC and SE top loins steaks (Corbin et al., 2015; Hunt et al., 2014; Tedford et al., 2014), TC and Select were rated similarly ($P > 0.05$) for flavor liking in our current study. However, differences in beef production systems, such as those in the U.S. compared to those in Central America, can affect flavor (Smith et al., 1985; Savell et al., 1987). Beef from animals raised on a finishing diet with grains tend to deposit more fat (Duckett et al., 2007; Duckett et al., 2013), positively affecting flavor (Umberger et al., 2000). The grain finishing diet of HCF may have been responsible for similar scores between HCF and U.S. treatments. Although biological type can certainly influence carcass fat deposition (Ito et al., 2012), the grain-based diet of HCF had a positive effect on flavor liking despite the *Bos indicus* influence of those cattle. Grass fed beef has been reported by U.S. consumers to have less acceptance for beef flavor due to off-flavors (Duckett et al., 2013). Despite previous evidence of a reduction of “grassy” off-flavor from including grain in the animal diet (Larick et al., 1987), in our study no differences in flavor liking scores were observed between HSC and HDP, whereas HCF was more liked than either.

Enhancement had a positive effect on flavor liking as each enhanced treatment was scored greater than its respective non-enhanced counterpart. Improvement of flavor may be attributed to salt in the brine solution. Previous researchers (Papadopoulos and Miller, 1991; Vote et al., 2000) have shown increased flavor ratings from enhancement with brine solutions containing salt (0.5%).

Consumer overall liking

Both country where the product was evaluated and the treatment influenced ($P < 0.01$) overall liking (Table 5) but only treatment influenced ($P < 0.01$) overall acceptability (Table 7), as overall acceptability was similar between the 2 countries ($P = 0.20$). No interactions for overall liking ($P = 0.42$) or overall acceptability ($P = 0.13$) were observed. Honduran consumers had greater ($P < 0.01$) scores for overall liking than U.S. consumers. For each Honduran treatment, enhancement improved ($P < 0.05$) both overall liking and overall acceptability compared to the non-enhanced version of the respective treatment. Once again, EHCF was more liked than any other treatment, followed by similar ($P > 0.05$) scores for both U.S. treatments and EHSC. Despite differences in quality grades, consumers rated TC and SE similarly ($P > 0.05$) in overall liking as well as the percentage of consumers finding TC and SE acceptable overall. The HDP samples had the lowest ($P > 0.05$) consumer overall liking scores and the lowest ($P > 0.05$) overall acceptability, with the exception that a similar proportion of consumers found HSC acceptable overall.

Consumer ratings in tenderness, juiciness and flavor are related to consumer overall liking ratings (Platter et al., 2003); however, other researchers suggest overall liking scores are attributed more so to flavor liking than tenderness or juiciness (Corbin et al., 2015; Neely et al., 1998) when tenderness reaches an acceptable level. Low values in tenderness, juiciness and flavor likely influenced HDP achieving the lowest overall liking scores and overall acceptability.

Willingness to pay

As seen in Table 8, no interactions between country where product was evaluated and treatment were observed for the percentage of consumers willingness to pay at each of the 4 values ($P \geq 0.09$). Treatment influenced ($P < 0.01$) the percentage of consumers willing to pay at each value ($0, 3, 6, and 10/0.45 kg), but country where product was evaluated only influenced the proportion of consumers willing to pay for 3 of the 4 values ($0, 3, and 10/0.45 kg). Consumers were least willing to pay for HDF and HSC, as the greatest percentage of consumers indicated they would not pay for those treatments ($0/0.45 kg). Consumers were willing to pay the most for EHCF, as the highest percentage of consumers indicated they would pay $6 or 10/0.45 kg for EHCF compared to all other treatments, followed by a similar percentage of consumers willing to pay $10/0.45 kg for TC, SE, and EHSC or $6/0.45 kg for EHSC, SE, TC, and HCF. A similar ($P > 0.05$) percentage of consumers indicated they would pay $3/0.45 kg for HCF, TC, SE, and EHSC, which is in alignment for intermediate palatability scores and acceptability for those 4 treatments. Consequently, consumers were most often willing to pay $3/0.45 kg as opposed to $6/0.45 kg for HCF, TC, SE, and EHSC. A positive effect of enhancement of Honduran treatments was observed, as the percentage of consumers willing to pay $0/0.45 kg was reduced with a concurrent increase in the proportion of consumers willing to pay $3/0.45 kg and $6/0.45 kg compared to the non-enhanced version of those treatments.

Table 8. Percentage of consumers (n = 480) willingness to pay ($/0.45 kg) for U.S. and Honduran sourced treatments

Treatment	$0	$3	$6	$10
EHDP[1]	41.91^{b}	38.52^{cd}	14.29^{cd}	1.02^{c}
EHCF[2]	3.91^{e}	32.62^{d}	44.97^{a}	15.02^{a}
EHSC[3]	24.55^{cd}	42.02^{abc}	27.94^{b}	2.24^{bc}
HDP[4]	56.60^{a}	34.98^{cd}	6.19^{e}	1.09^{c}
HCF[5]	26.59^{c}	50.29^{a}	18.91^{bc}	1.22^{c}
HSC[6]	45.08^{a}	39.56^{bcd}	10.94^{de}	1.56^{c}
SE[7]	22.62^{cd}	47.62^{a}	23.90^{b}	2.50^{bc}
TC[8]	15.62^{d}	49.18^{a}	23.63^{b}	5.13^{b}
SEM[9]	0.37	0.17	0.35	0.76
P-value	< 0.01	< 0.01	< 0.01	< 0.01
Country				
U.S.	28.15^{a}	36.90^{b}	19.91^{a}	3.79^{a}
Honduras	23.27^{b}	46.50^{a}	18.34^{a}	1.50^{b}
SEM[9]	0.09	0.06	0.09	0.24
P-value	< 0.01	< 0.01	0.27	< 0.01
P-value[10] (T × C)	0.60	0.90	0.87	0.09

[a-e]Least square means in the same column with different superscripts differ, $P < 0.05$.

[1]EHDP = Enhanced (112% with a target concentration of 0.25% tripolyphosphate and 0.50% salt of the final product) Honduran dual purpose.

[2]EHCF = Enhanced (112% with a target concentration of 0.25% tripolyphosphate and 0.50% salt of the final product) Honduran corn-fed diet.

[3]EHSC = Enhanced (112% with a target concentration of 0.25% tripolyphosphate and 0.50% salt of the final product) Honduran sugar cane diet.

[4]HDP = Honduran dual purpose.

[5]HCF = Honduran corn-fed diet.

[6]HSC = Honduran sugar cane diet.

[7]SE = USDA Select.

[8]TC = USDA top (upper 2/3) Choice.

[9]SEM (largest) of the least square means.

[10]*P*-value of treatment × country interaction.

A greater ($P > 0.01$) percentage of U.S consumers were willing to pay $0/0.45 kg ($P < 0.01$) and $10/0.45 kg when compared to Honduran consumers. Consequently, a greater ($P < 0.01$) percentage of Honduran consumers were willing to pay $3/0.45 kg compared to U.S. consumers. However, there was no difference in the proportion of Honduran and U.S. consumers that were willing to pay $6/0.45 kg ($P > 0.01$).

Consumers' willingness to pay has been linked to overall liking scores in previous studies (Kukowski et al., 2005; Reicks et al., 2011). Consumers have reportedly been willing to pay more as tenderness increases (Boleman et al.,1997). In this study, enhanced treatments were scored greater for overall liking, partially due to tenderness, which can explain differences in willingness to pay between enhanced and non-enhanced Honduran treatments.

Results suggest that enhancement increases the value consumers are willing to pay for Honduran treatments. According to WageIndicator (2015), Honduran minimum wage was lower, ranging from 22.44 to 37.01 L. ($1.04 USD to $1.71 USD) depending on the industry and the number of employees at the firm than in the U.S ($7.25/hour; USDL, 2017). However, a higher percentage of Honduran consumers were willing to pay $3/0.45 kg and a higher percentage of U.S consumers were willing to pay $0/0.45 kg. These results could suggest that U.S consumer beef quality expectations might be higher than Honduran consumers because if consumers indicated they were willing to pay $0/0.45 kg, those consumers found the sample unsatisfactory in some regard as they would not pay any money for that sample.

Conclusions

Greatest palatability traits scores were obtained in EHCF treatment in U.S. and Honduras. Enhancement of Honduran treatments had a positive effect on palatability traits, as well as acceptability of each of those traits. Honduran consumers ranked all palatability traits more favorably than U.S. consumers along with greater acceptability for tenderness. Regardless of the differences in breeds, including diets utilizing grain and/or by-products along with enhancement resulted in greater palatability scores. The U.S. consumers were willing to pay more indicating higher expectations for beef quality.

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