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The Effect of Finishing Diet on Consumer Perception of Enhanced and Non-Enhanced Honduran Beef

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Abstract: The effects of experimental finishing diets and enhancement were tested to determine if they could improve Honduran beef palatability. Fifteen enhanced (ENH) and non-enhanced (NE) paired loins from 7 different finishing diets ($n = 210$ loins) were fed to Honduran consumers ($n = 288$). Diets consisted of a grass-finished control (CON) or diets with the inclusion of distiller's dry grain (DDG), palm kernel meal (PKM), PKM replication (PKMR), sorghum (SORG), soybean meal and corn (SBMC), or sugarcane (SC). An interaction ($P < 0.01$) occurred between diet and enhancement to influence scores for all palatability traits, willingness to pay (WTP), and acceptability of traits. Consumers found enhanced samples were more tender ($P < 0.05$) than NE counterparts, excluding ENH- and NE-CON ($P > 0.05$). Without enhancement, CON was rated more tender ($P < 0.05$) than all other treatments, except PKMR. All ENH samples were juicier ($P < 0.05$) and had a flavor that was liked more ($P < 0.05$) than NE counterparts. Diet alone resulted in similar ($P > 0.05$) juiciness scores between CON, DDG, PKM, and PKMR; however, CON was rated juicier ($P < 0.05$) than all other treatments. Among NE samples, flavor liking scores were not different ($P > 0.05$) between CON, DDG, PKM, PKMR, and SBMC, and CON was liked more ($P < 0.05$) than SORG and SC. All enhanced steaks, except CON, had greater overall liking scores and WTP values ($P < 0.05$) than NE counterparts. Diet alone resulted in similar ($P > 0.05$) overall liking and WTP values between CON, DDG, PKM, PKMR, and SBMC, while SORG and SC were liked less overall ($P < 0.05$) than CON, which reduced ($P < 0.05$) WTP values. Experimental diets in conjunction with enhancement were able to improve the consumers' perception of palatability traits, acceptability, and WTP.

Keywords: beef, finishing diet, enhancement, palatability, Honduras
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Introduction

Due to traditional feeding practices, Central American countries have typically raised beef cattle on native pastureland, such as jaragua (*hyparrhenia rufa*), estrella (*cynodon plectostachius*), swazi (*digitaria swazilandensis*), and Mombasa guinea (*panicum maximum*) grass (Suttie, 2000). Cattle within this feeding region are predominately of *Bos indicus* genetic origin, which are well suited for this environment but can suffer from tenderness issues that reduce eating quality (Wheeler et al., 1994; Shackelford et al., 1995). Although tradition merits rearing cattle on grass, many studies have shown that finishing cattle on grain can increase the palatability of beef products (Bowling et al., 1977; Schroeder et al., 1980; Dolezal et al., 1982; Killinger et al., 2004), which could improve the eating quality of beef in this region.

Grain finishing beef cattle can improve sensory palatability traits, including tenderness (Tatum et al., 1980; Dolezal et al., 1982; Killinger et al., 2004), juiciness (Killinger et al., 2004), and flavor (Larick and Turner, 1990; Killinger et al., 2004). However, consumers may simply prefer what they are accustomed to eating, as Sanudo et al. (1998) showed consumers who traditionally consume grass-finished meat to prefer the flavor of grass-finished meat. Moreover, consumers in Central America prefer steaks cooked to a well-done degree of doneness (McDonald, 2009).

Enhancement is commonly referred to as the injection or marination of meat with non-meat ingredients,

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such as water, salt, water binders, antimicrobials, or flavorings, to alter the palatability and functionality of the final product. Multiple studies have shown the merits of enhancement to improve beef palatability. Numerous researchers have shown that enhanced meat is more tender (Wheeler et al., 1993, Miller et al., 1995, Sheard et al., 1999; Vote et al., 2000; Baublits et al., 2005; Baublits et al., 2006a,b; Rose et al., 2010) and juicier (Vote et al., 2000; Baublits et al., 2005; Baublits et al., 2006a,b; Rose et al., 2010) than non-enhanced meat, even when cooked to 77°C (Vote et al., 2000). In general, an increased presence of a salty flavor can be detected in enhanced meat (Stetzer et al., 2008; Rose et al., 2010; Baublits et al., 2006b), while other off flavors, such as a "soapy" flavor have been identified as well (Rose et al., 2010). Despite detection of certain off flavors, Robbins et al. (2002) reported increased consumer flavor acceptability from enhancement. Increased sensory scores for palatability have resulted in greater overall liking scores and increased percentages of consumers who have determined enhanced meat is more acceptable than non-enhanced meat (Hoover et al., 1995).

The purpose of this study was to identify the effect of various concentrate and by-product-based finishing diets on carcass composition and consumer palatability traits in comparison to traditional grass-finished Honduran beef, and to determine if and to what extent enhancement changed consumer palatability traits of beef from these diets.

Materials and Methods

Product selection and preparation

Traditionally, Honduran beef cattle are raised and finished on native pasture grasses (jaragua, estrella, swazi, and Mombasa guinea grass; Suttie, 2000), without supplementation. Cattle feeding practices in Honduras are highly variable and typically not well-documented. However, cattle are generally grass-finished to an approximate live weight of 400 kg, which occurs around 3 yr of age. *Bos indicus* crossbred bulls of known grass-finished origin were selected at a commercial beef abattoir (Del Corral) in Siguatepeque, Honduras to represent a control population representing traditional finishing practices of cattle in this country [CON; *n* = 25; days on feed (DOF) = N/A].

In addition, feedstuffs regionally available in Honduras were implemented in 6 experimental finishing diets formulated by experienced Texas Tech University personnel. Inclusions of the feedstuffs used in each alternative finishing diets can be found in Table 1. All diets were formulated to provide approximately 13.5% crude protein on a DM basis, but feed composition was not tested. Of the regionally available feedstuffs sourced, all diets contained byproducts, either fresh sugarcane, palm kernel meal, and/or poultry liter. Although each diet contained some percentage of byproduct, treatments have been classified by their primary or unique feed ingredient (distiller's dry grain, palm kernel meal, sorghum, soybean meal/corn, or sugarcane). The formulated diets were released to individual cattle producers (*n* = 4) in this country for incorporation in their feedlot systems. Implementation of cattle management and feeding were subject to the production manager's discretion and cooperation at each operation. At all feedlots, *Bos indicus* crossbred bulls (*n* = 250) were procured by the cattle feeder and weighed by management prior to initiation of feeding. All bulls were fed in a lot as a pen and were finished on 1 of the 6 experimental finishing diets with the inclusion of either distiller's dry grain (DDG; *n* = 38; Initial Weight (IW) = 326.3 kg; DOF = 118; fed 45% byproduct), palm kernel meal (PKM; *n* = 38; IW = 409.6 kg; DOF = 108; fed 50.8% byproduct), an exact dietary replication of the PKM diet (PKMR; *n* = 45; IW = 393.7 kg; DOF = 105; fed 50.8% byproduct), sorghum (SORG; *n* = 33; IW = 418.5 kg; DOF = 74; fed 17% byproduct), soybean meal and corn (SBMC; *n* = 62; IW = 383.6 kg; DOF = 84; fed 43% byproduct), or sugarcane (SC; *n* = 34; IW = 348.4 kg; DOF = 165; fed 77.6% byproduct). Information about the procured animals' backgrounding phase, which most likely occurred on native pasture, and the biological status, or age, at which the animals entered the feedlot was unknown, as selection of cattle that matched each feeder's system was proprietary to their operation. It should be noted the range of reported initial weights (326.3 to 418.5 kg) would indicate that feedlot management most likely procured bulls that were nearing the state at which Honduran grass-finished cattle are slaughtered. Therefore, it is possible and probable that the cattle finished on the experimental diets were of a greater chronological age at the time of slaughter.

Upon completion of finishing, cattle feeders shipped animals to a commercial beef abattoir in Siguatepeque, Honduras to be harvested. Due to variation in the live animals' DOF and the producers' decision on when it was most profitable to market their animals, each dietary treatment was harvested on a different processing day (*n* = 7 or 1 per treatment) ranging from February to November of 2015. After harvest, carcasses were chilled for 18 h at 0 to 4°C for carcass

Table 1. Ingredient composition (DM basis) of the experimental diets fed in finishing diets to Honduran *Bos indicus* cross bred bulls (n = 250)

	Treatment[1]					
Item	DDG	PKM	PKMR	SORG	SBMC	SC
Ingredient, %						
Fresh Sugar Cane	20.00	–	–	–	15.00	37.30
Palm Kernel Meal	15.00	30.90	30.90	17.00	20.00	20.40
Poultry Litter, dry	10.00	19.90	19.90	–	8.00	19.90
Soybean Meal	–	–	–	8.12	5.00	–
Dried Distillers Grain	15.00	–	–	–	–	–
Cracked Corn	30.00	40.80	40.80	–	46.00	15.80
Ground Grain Sorghum	–	–	–	29.86	–	–
Ground Corn Cobs	–	–	–	20.00	–	–
Sorghum Silage	–	–	–	15.00	–	–
Molasses	10.00	8.40	8.40	8.00	5.00	6.50
Calcium Carbonate	–	–	–	1.00	1.00	–
Monensin 20	–	–	–	0.02	–	–
Pecutrin Vitamindo	–	–	–	1.00	–	–

[1]DDG – distillers dry grain (*n* = 38), [2]PKM – palm kernel meal (*n* = 38), PKMR – PKM replication (*n* = 45), SORG – sorghum (*n* = 33), SBMC – soybean meal and corn (*n* = 62), SC – sugar cane (*n* = 34), Cattle on these treatments were given free choice mineral supplementation (Nutrivyn Crecimiento)

evaluation and processing. Regardless of slaughter date, all carcasses were chilled in the same cooler to mitigate differences that can occur between different chilling environments. Animal identity was transferred to the carcass at harvest to maintain identity throughout harvesting, chilling, carcass evaluation, fabrication, and further processing. After chilling, carcasses were ribbed between the 12th and 13th rib, and the cut surface was allowed to oxygenate for 1 h prior to evaluation by trained Texas Tech University personnel. All carcasses were evaluated in accordance with the USDA grading standards (USDA, 1997) for marbling score (100 = Practically Devoid^{00}, 200 = Traces^{00}, 300 = Slight^{00}, 400 = Small^{00}, 500 = Modest^{00}, 600 = Moderate^{00}, 700 = Slightly Abundant^{00}, 800 = Moderately Abundant^{00}, 900 = Abundant^{00}), lean maturity, skeletal maturity, and overall maturity (100 = A^{00}, 200 = B^{00}, 300 = C^{00}, 400 = D^{00}, 500 = E^{00}), ribeye area (cm^2), fat thickness (mm), adjusted fat thickness (mm) and hump height (cm). In addition, lean color, texture, and firmness, as well as, fat color were assessed subjectively. The scales for these traits included ribeye lean color score (scored 1 to 8; 1 = dark lean color, 8 = light pink lean color), lean texture score (scored 1 to 8; 1 = extremely coarse textured lean, 8 = extremely fine textured), lean firmness (scored 1 to 8; 1 = extremely soft lean, 8 = extremely firm lean), degree of dark cutting (scored 1 to 5; 1 = 100% dark cutter, 5 = 0% dark cutter), degree of heat ring (scored 1 to 5; 1 = 100% heat ring, 5 = 0% heat ring), and external fat color score (scored 1 to 5; 1 = bright white fat, 5 = completely yellow fat). Additionally, instrumental CIELab values [L*: 0 = black, 100 = white; positive value = red (a*) or yellow (b*); negative values = green (a*) or blue (b*)] of the exposed lean surface at the 12th/13th rib interface were collected with a hand-held spectrophotometer (Model CR-400 Chroma meter, Konica Minolta Sensing Americas, Inc., Ramsey, NJ) that possessed a 0° viewing angle, an 8-mm aperture, and a pulsed xenon lamp for a light source. The spectrophotometer was calibrated with a calibration plate (Model CR-AR3, Konica Minolta Sensing Americas, Inc., Ramsey, NJ) prior to carcass assessment.

Upon completion of grading, carcasses were fabricated. Paired boneless strip loins (Institutional Meat Purchase Specifications #180; NAMP, 2011; *n* = 210; 15 paired loins per diet) were selected randomly from each treatment and collected to represent a subset of each treatment. Of the paired loins, one was enhanced (ENH) with water, 0.5% NaCl, 0.25% sodium tripolyphosphate, 0.05% monosodium glutamate, 0.04% sodium erythrobate, and 0.02% maltodextrin to 112% (± 3.5%) of the green weight using a multi needle injector (Model Accujector 450, GEA Group AG, Düsseldorf, Germany), while the other remained untreated and was designated as non-enhanced (NE). Strip loins were vacuum packaged and aged at 2 to 4°C until 21 d postmortem and then frozen (–20°C).

Frozen strip loins were fabricated into steaks on a meat band saw (Model 6614, Hobart, Troy, OH). The most anterior steak was cut perpendicular to the length of the subprimal to face the strip loin, and the face steak was removed from the study. The remaining steaks were then numbered starting at the anterior end. No external, subcutaneous fat was removed or trimmed. Steak 1 was retained for fatty acid analysis, steak 2 was designated for raw pH, slice shear force (SSF), cooked proximate analysis, and cooked sarcomere length analysis, and steaks 3 to 8 were retained for consumer sensory analysis. All steaks were individually vacuum packaged and returned to frozen storage until analyses.

Slice shear force analysis and cooking loss determination

Samples were thawed for 24 h at 2 to 4°C prior to cooking. Two 10-gram samples of lean tissue were removed from steaks designated for SSF prior to weighing and cooking. The removed samples were then vacuum packaged and frozen for ultimate pH determination. Individual steaks were cooked to 74°C on a George Foreman clamshell grill (Model GRP99, Spectrum Brands. Inc., Middleton, WI) with the lid closed and a plate temperature set to 218°C. Steak temperature was monitored using a digital, instant read Thermapen thermometer (Model Mk4, ThermoWorks, American Fork, UT). To allow for temperature stability throughout the heating elements and cooking surface, the grill was preheated for 10 min prior to cooking. After cooking, steaks were sheared perpendicular to the muscle fiber orientation at 500 mm/min per slice using a flat blunt blade attached to an electronic testing machine (Model GR-152, Tallgrass Solution, INC., Manhattan, Kansas) using the "hot" shear force protocol as described by Shackelford et al. (1999). Tenderness measurement of each steak was obtained in kg of force. Steaks were weighed on a digital scale (Model AY1501; Sartorius, Göttingen, Germany), with a 0.1g sensitivity, prior to cooking; upon completion of cooking, steaks were reweighed to obtain a cooked weight. Cooking loss was determined as the difference between the steak's raw weight and cooked weight divided by the raw weight.

Ultimate pH determination

Samples were thawed for 24 h at 2 to 4°C prior to analysis. Individual samples were mixed with distilled water for 1 min in a tabletop blender (Model 80335R, Hamilton Beach Brands, Glen Allen, VA) to allow for homogenization. Homogenized samples were placed in a 150 mL beaker with a filter cone. Sample pH was measured with a bench top probe-type pH meter (Model 14703; Denver Instrument Company, Bohemia, NY), and ultimate pH of each sample was determined as the average of the 2 samples.

Cooked proximate analysis

After cooking and shearing, all external fat, connective tissue and hard cooked edges were removed from each residual steak. The remaining muscle was diced and snap frozen in liquid nitrogen. Frozen diced samples were then homogenized in a pre-cooled food processor (Model Blixer 3 Series D, Robot Coupe, Ridgeland, MS), blended into a fine powder, placed in a labeled Whirl-Pak bag, inserted into a second bag for protection of identity and transferred into a freezer for storage at -80°C. Proximate analysis was performed in accordance to approved AOAC protocols to determine the percentages of moisture, ash, protein and fat for each sample. Upon completion of proximate analysis, all unused powder from each sample was retained for sarcomere length determination.

Protein analysis was conducted using a *LECO TruMac N* (St. Joseph, MI) in accordance to an approved AOAC protocol (AOAC, 2005). Ethylenediaminetetraacetic acid (EDTA) samples were ran after the machine was calibrated using blanks. Following EDTA, samples were ran by adding 0.3 g of sample into each boat on the carousel, making sure to properly input sample identification and sample weight. Percent nitrogen was converted to percent protein using a conversion factor of 6.25%.

Moisture analysis was conducted in accordance to an AOAC protocol (AOAC, 2005). Five grams (± 0.05 g) of powered samples were weighed into crucibles. The weight of each sample was recorded, and the crucibles were then placed into a drying oven for 16 h at 100°C. Upon completion of drying, crucibles were removed from the oven and placed into desiccators for 30 min to cool and remove any remaining moisture. Lastly, the crucibles were weighed to calculate the percentage of moisture in each sample.

Upon completion of moisture analysis, crucibles were then placed into a muffle furnace (Model F30420C, Thermo Fisher Scientific, Waltham, MA). Furnace temperature was gradually increased by 100°C per hour until reaching final endpoint temperature of 550°C. After endpoint temperature was reached, the samples remained in the furnace for at least 24 h. After 24 h, samples were cooled in desiccators for 30 min and then weighed to calculate the percentage of ash in each sample.

Analysis of fat was conducted via a modification to the chloroform: methanol method described by Folch et al. (1957) (AOAC 983.23). One gram of frozen powder was weighed out from each sample. After weighing, the lipid portion was extracted from each sample using chloroform and methanol. Upon completion of extraction, the extract was evaporated on a heating block inside of a fume hood for 10 min. All remaining residue was dried in a drying oven (Model 6905, Thermo Fisher Scientific, Waltham, MA) at 101°C. After a constant weight was obtained, each tube was cooled and weighed to obtain a final percentage of total lipid.

Sarcomere length determination

Sarcomere length of each sample was determined with powdered, cooked muscle using the method described by Wheeler and Shackelford (2017). Sarcomere lengths were obtained with a modified neon laser diffraction method described by Cross et al. (1981). Powdered muscle was fixed onto glass slides and moistened with 0.2 M sucrose solution. Thirty-six different diffraction patterns were measured from each sample using a neon laser (Model 117A; SpectraPhysics Inc., Irvine, CA) operated at a wavelength of 632.8 nm. The sarcomere length for each sample was determined by a calculation of the average of these 36 diffractions.

Consumer sensory evaluation

The Texas Tech University Institutional Review Board approved procedures for the use of human subjects for consumer panel evaluation of sensory attributes.

Samples were thawed overnight at temperature 0 to 4°C prior to cooking. Steaks were cooked to a well-done degree of doneness (74°C), to match traditional Honduran consumer's beef preferences (McDonald, 2009), on a George Foreman clamshell grill (Model GRP99, Spectrum Brands. Inc., Middleton, WI) with the lid closed and plate temperatures set to 218°C. Temperature was monitored using a digital, instant read Thermapen thermometer (Model Mk4, ThermoWorks, American Fork, UT). Three steaks were cooked per grill at 1 time. Cooked steaks were rested for 3 min before removal of external fat, connective tissue, and accessory muscles. Steaks were portioned into 6 smaller pieces (2.5 cm × 2.5 cm × cooked thickness) and served warm to 3 predetermined consumers (2 cubes per consumer). After all samples were removed from a grill, it remained empty for 90 s to accommodate cleaning.

To achieve results indicative of Central American consumers, panels were conducted at three locations in Siguatepeque, Honduras, and local panelists (n = 288) were recruited to participate in the study. Thirty-two panel sessions were conducted over 3 d, with each lasting approximately 45 min and consisting of 9 closely monitored panelists.

Attributes for each sample were rated on a paper ballot with all values being presented in Spanish to the consumer. Palatability attributes were collected on an anchored 100-mm line scale representing tenderness, juiciness, flavor liking, and overall liking, as structured for Meat Standards Australia consumer testing (Gee, 2006). The zero anchors were translated as very tough, very dry, and dislike extremely of flavor and overall, while the 100 anchors were translated as very tender, very juicy and like extremely of flavor and overall. 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, consumers were asked to determine their "Willingness to Pay" (WTP) for each sample. Values for WTP were collected in Honduran Lempiras ranging from L. 0/lb. to L. 400/lb. (USD 0/lb. and USD 17.50/lb., respectively). All palatability attributes, acceptability and WTP data were collected in Spanish.

Consumers were served a total of 8 samples always consisting of one ENH-CON and one NE-CON, with six other samples representing the remaining treatments in a predetermined, balanced order. Additionally, panelists were provided with a ballot, a napkin, toothpicks, plastic utensils, an expectorant cup, a cup of water, and palate cleansers (unsalted crackers and diluted apple juice (10% *v/v*)) to use between samples.

Statistical analysis

Data were evaluated in SAS using PROC GLIMMIX (version 9.4, SAS Inst. Inc., Cary, NC). Live animal diet, enhancement, and their interaction (when appropriate) were used as fixed effects, while cooking loss was used as a covariate for SSF (P = 0.01). Analyses were performed using a significance level of α = 0.05. Carcass was included as a random effect for SSF, pH, proximate, and sarcomere length analyses, and consumer was included as a random effect for consumer sensory analysis. Consumer acceptability responses were analyzed as binomial proportions. All tables contain the least squares means (LSM) and the standard error (SEM) of the LSM. Pearson correlations were calculated using PROC CORR in SAS (version 9.4, SAS Inst. Inc.).

Results and Discussion

Carcass characteristics

The finished live weight of cattle selected for this study and their carcass yield characteristics can be found in Table 2, and carcass quality attributes can be found in Table 3. As seen in Table 2, finishing diet significantly impacted ($P < 0.01$) the final weight (FW) of the live cattle and the hot carcass weight (HCW). The CON diet resulted in the lowest FW and HCW ($P < 0.05$) compared to all experimental diets. These results were not unexpected as the aforementioned IW of all cattle admitted into the feedlots was greater than or nearing the FW of CON bulls. Furthermore, this may reiterate that the cattle used in the experimental finishing diets were of a similar or greater chronological age when slaughtered. The PKM diets had greater FW and HCW ($P < 0.05$) compared to all other treatments. Although differences in FW and HCW were detected between experimental diets, these results were not unexpected due to the initial variation in live weight (326.3 to 418.5 kg) coupled with variable days on feed (74 and 165 d). Therefore, comparisons of weight between diets should be made with caution since IW and DOF were not standardized by the cattle producers prior to feeding.

Table 2. The effects of live animal diet on the finishing weight of Honduran *Bos indicus* cross bred bulls and their observed carcass yield characteristics that were selected for laboratory and consumer evaluation (n = 105)[1]

Trait	CON	DDG	PKM	PKMR	SORG	SBMC	SC	SEM[2]	*P*-value[3]
Finished weight, kg	401.1^{d}	468.1^{bc}	544.8^{a}	532.0^{a}	466.6^{bc}	461.1^{c}	492.8^{b}	14.4	< 0.01
Hot carcass weight, kg	209.6^{d}	259.2^{bc}	306.8^{a}	300.9^{a}	252.2^{c}	251.3^{c}	271.9^{b}	8.8	< 0.01
Fat thickness, mm	0.6^{c}	5.6^{a}	5.5^{a}	3.8^{ab}	2.3^{bc}	1.3^{c}	5.3^{a}	0.7	< 0.01
Adjusted fat thickness, mm	0.6^{c}	5.6^{a}	6.2^{a}	5.4^{a}	2.8^{b}	1.4^{bc}	5.3^{a}	0.7	< 0.01
Ribeye area, cm^2	56.1^{d}	74.6^{b}	81.3^{a}	75.3^{ab}	67.5^{c}	70.0^{bc}	67.7^{c}	2.2	< 0.01
Muscle score[4]	2.2^{d}	4.3^{a}	2.5^{d}	4.5^{a}	4.0^{ab}	2.9^{cd}	3.4^{bc}	0.3	< 0.01
Hump height, cm	10.9^{bc}	11.8^{abc}	10.2^{c}	14.5^{a}	14.1^{ab}	8.9^{c}	4.5^{d}	1.2	< 0.01

[a-d]Within a row, least square means without a common superscript differ ($P < 0.05$) due to diet.

[1] CON – grass finished (n = 15), DDG – distillers dry grain (n = 15), PKM – palm kernel meal (n = 15), PKMR – PKM replication (n = 15), SORG – sorghum (n = 15), SBMC – soybean meal and corn (n = 15), SC – sugar cane (n = 15).

[2] Pooled (largest) SE of least squares means.

[3] Observed significance levels for main effects of diet.

[4] Score indicates: 1 = extremely light muscled, 2 = light muscled, 3 = moderately muscled; 4 = heavy muscled; 5 = extremely heavy muscled.

Table 3. The effects of live animal diet on observed carcass quality characteristics of the Honduran *Bos indicus* cross bred bulls that were collected for laboratory and consumer evaluation (n = 105)[1]

Trait	CON	DDG	PKM	PKMR	SORG	SBMC	SC	SEM[2]	*P*-value[3]
Marbling Score[4]	189^{c}	346^{a}	317^{a}	327^{a}	247^{b}	255^{b}	342^{a}	18.3	< 0.01
Skeletal Maturity[5]	182^{c}	260^{abc}	345^{a}	297^{ab}	258^{abc}	184^{c}	237^{bc}	33.1	< 0.01
Lean Maturity[5]	372^{a}	271^{b}	214^{c}	259^{bc}	288^{b}	306^{b}	303^{b}	19.7	< 0.01
Overall Maturity[5]	280^{a}	272^{a}	314^{a}	285^{a}	275^{a}	254^{a}	268^{a}	22.4	0.64
Color Score[6]	1.3^{d}	6.7^{a}	6.0^{a}	4.7^{b}	3.4^{c}	3.2^{c}	4.2^{bc}	0.4	< 0.01
Texture Score[7]	3.2^{d}	6.7^{a}	6.0^{ab}	4.2^{cd}	4.9^{bc}	3.2^{d}	5.4^{b}	0.4	< 0.01
Firmness Score[8]	7.9^{a}	6.5^{b}	6.2^{b}	6.1^{b}	6.8^{b}	6.0^{b}	6.5^{b}	0.3	< 0.01
Heat Ring[9]	5.0^{a}	4.4^{bc}	1.5^{d}	4.9^{ab}	5.0^{a}	3.9^{c}	4.4^{bc}	0.2	< 0.01
Dark Cutting[10]	1.2^{c}	4.4^{a}	1.7^{c}	3.9^{ab}	3.1^{b}	3.1^{b}	4.0^{a}	0.3	< 0.01
$L*$[11]	29.9^{d}	35.6^{ab}	29.7^{d}	35.6^{ab}	32.7^{cd}	32.9^{bc}	33.8^{abc}	1.0	< 0.01
$a*$[11]	16.0^{b}	21.9^{a}	17.7^{b}	18.0^{b}	16.5^{b}	17.1^{b}	17.6^{b}	0.8	< 0.01
$b*$[11]	3.0^{d}	6.3^{ab}	6.4^{ab}	4.6^{c}	4.6^{c}	7.6^{a}	5.3^{bc}	0.5	< 0.01
Fat Color[12]	3.1^{a}	1.8^{c}	1.7^{c}	2.0^{bc}	2.3^{b}	2.4^{b}	1.1^{d}	0.2	< 0.01

[a-d]Within a row, least square means without a common superscript differ ($P < 0.05$) due to diet.

[1] CON – grass finished (n = 15), DDG – distillers dry grain (n = 15), PKM – palm kernel meal (n = 15), PKMR – PKM replication (n = 15), SORG – sorghum (n = 15), SBMC – soybean meal and corn (n = 15), SC – sugar cane (n = 15).

[2] Pooled (largest) SE of least squares means.

[3] Observed significance levels for main effects of diet.

[4] 100 = Practically Devoid^{00}, 200 = Traces^{00}, 300 = Slight^{00}, 400 = Small^{00}.

[5] 100 = A^{00}, 200 = B^{00}, 300 = C^{00}, 400 = D^{00}, 500 = E^{00}.

[6] Score: 1 = black lean color, 2 = dark maroon lean color, 3 = maroon lean color, 4 = light maroon lean color, 5 = dark red lean color, 6 = cherry red lean color, 7 = light red lean color, 8 = light pink lean color.

[7] Score: 1 = extremely coarsely textured lean, 2 = very coarsely textured lean, 3 = coarsely textured lean, 4 = slightly coarsely textured lean, 5 = slightly finely textured lean, 6 = finely textured lean, 7 = very finely textured lean, 8 = extremely finely textured lean.

[8] Score: 1 = extremely soft lean, 2 = very soft lean, 3 = soft lean, 4 = slightly soft lean, 5 = slightly firm lean, 6 = firm lean, 7 = very firm lean, 8 = extremely firm lean.

[9] Score: 1 = 100% heat ring ribeye, 2 = 75% heat ring ribeye, 3 = 50% heat ring ribeye, 4 = 25% heat ring ribeye, 5 = no heat ring ribeye.

[10] Score: 1 = 100% dark cutting, 2 = 75% dark cutting, 3 = 50% dark cutting, 4 = 25% dark cutting, 5 = not dark.

[11] L*: 0 = black, 100 = white; positive value = red (a*) or yellow (b*); negative values = green (a*) or blue (b*).

[12] Score: 1 = bright, white fat, 2 light, white fat, 3 = some yellow fat present, 4 = slightly yellow fat, 5 = completely yellow fat.

Simple calculations of average daily gain may provide some insight on the effectiveness of the experimental diets. Cattle finished using DDG, PKM, PKMR, SBMC, SC, and SORG had average daily gains of 1.20, 1.25, 1.31, 0.92, 0.87, 0.65 kg/d, respectively. Previous research has shown that PKM, which is generally used as a feed stuff in socioeconomically deprived countries (Alimon, 2005), when used at 50 to 80% of the live animal's diet can result in a positive performance and adequate daily gain (Zahari and Alimon, 2004). Our results suggest that when PKM was balanced with other sources of protein, carbohydrates, and non-protein nitrogen (corn, poultry litter, etc.), it impacted rate of daily gain even at a lower dietary inclusion level. In addition, Pate et al. (2002) reported that fresh sugarcane was less nutritious than traditional roughages fed to cattle, but its use as a fodder in times of feed shortages were economically beneficial to deprived countries. Although feeding sugarcane can be economically advantageous, Pate et al. (2002) also determined that increasing the percentage of sugarcane in the diet of cattle can have a negative effect on rate of gain, which is in agreement with our findings.

Dietary treatment influenced ($P < 0.01$) fat thickness, ribeye area, muscle score, and hump height. Distiller's dry grain, PKM, PKMR, and SC had more ($P < 0.05$) subcutaneous fat than SBMC and CON. Similar results to these have been widely noted in literature (Bowling et al., 1977; Schroeder et al., 1980) as grass-finished cattle tend to have leaner carcasses than grain finished cattle and will possess a higher percentage of edible meat in comparison to waste, or fat. Although fat thickness was greater for DDG, PKM, PKMR, and SC than CON, this increase did not necessarily influence lean quality characteristics as CON and PKMR had similar degrees of heat ring ($P > 0.05$) indicating that additional external fat was not the deciding factor for heat ring incidence. While CON yielded trim carcasses, results indicated that grass-finishing was less advantageous for other yield factors. Palm kernel meal had greater ($P < 0.05$) ribeye area than all other treatments except PKMR, while CON ribeyes were smaller than any other treatment. However, PKM and CON had lower ($P < 0.05$) muscle scores than all other treatments, except SBMC. Many authors (Bowling et al., 1977; Schroeder et al., 1980; Tatum et al., 1980; Dolezal et al., 1982) have determined that the grain-finishing cattle will result in heavier muscled carcasses that possess larger ribeyes and will ultimately result in a greater amount of edible red meat, when compared to grass finished cattle. Hump height was also influenced ($P < 0.01$) by treatment, but was likely more related to cattle type represented in each treatment as opposed to the diet that cattle consumed. Even so, SC had the shortest hump height ($P < 0.05$) of all treatments, which was incidentally a third the size of some other treatments, such as PKMR and SORG.

As seen in Table 3, aside from overall maturity, the live animal's diet influenced all carcass characteristics ($P < 0.01$). Carcasses from cattle finished on all of the experimental diet treatments possessed greater ($P < 0.05$) marbling scores when compared to CON. Similarly, numerous researchers (Bowling et al., 1977; Schroeder et al., 1980; Tatum et al., 1980; Dolezal et al., 1982, Sitz et al., 2005; Chail et al., 2017) have shown that grass-finished cattle generally produce carcasses with less marbling than grain finished cattle. Furthermore, it could be reasoned that the use of the experimental grain and by-product diets in the current study could have played a role in the production of beef with a greater amount marbling, since marbling scores can increase as a result of grain-finishing cattle (Dolezal et al., 1982).

Carcass overall maturity did not differ among treatments ($P > 0.05$). These results were most likely due to the diverging results found between skeletal and lean maturity among the treatments. PKM and PKMR had greater ($P < 0.05$) skeletal maturity scores compared to CON, which further supports that animals in these treatments were likely more advanced in chronological age at slaughter. Although not all differences in skeletal maturity between CON and the experimental treatments were significantly different, it is important to note that all treatments, aside from PKM, resulted in a score suitable for USDA B maturity, while CON and SBMC possessed a skeletal maturity score suitable for USDA A maturity. Compared to CON, carcasses from all experimental diets had a less advanced ($P < 0.05$) lean maturity. Our results are in alignment with Schroeder et al. (1980), who found similar overall maturity scores in carcasses from grain-finished cattle, which possessed greater skeletal maturity scores, when carcasses from grass-fed cattle had greater lean maturity scores. The current results indicated that variations in finishing diet should not result in differences in overall maturity scores.

Control carcasses exhibited firmer ($P < 0.05$) ribeyes with darker ($P < 0.05$) lean color scores compared to all other treatments. In addition, CON carcasses had a greater degree of dark cutting compared to all other treatments, except PKM. Moreover, subjective lean color results were supported by instrumental color scores as CON carcasses had lower ($P < 0.05$) L^* values than all other treatments, except PKM and SORG, indicating darker lean color. The CON carcasses also had lower b^* values than all other treatments, suggesting the lean surface was less yellow; however; DDG had greater a^* values than all other treatments, indicating greater redness. Schroeder et al. (1980) determined that beef produced on a higher energy diet may possess lean with more desirable color scores and a brighter, red color compared to grass-finished beef, which aligns with our results. The ability for the experimental diets to alter color values are promising results, as the beef used in this study was subject to multiple inputs, such as the sex hormones of bulls and the use of *Bos indicus* genetics, which can result in darker meat (Lobato et al., 2014). Lastly, CON had greater ($P < 0.05$) fat color scores compared to all other treatments, suggesting the fat was more yellow.

pH, cooked sarcomere length, and cooked proximate analyses

The influence of diet treatment and enhancement on the pH, sarcomere length and proximate components can be found in Table 4. An interaction between diet and enhancement was not observed for any of the aforementioned traits ($P > 0.05$). Although no interaction occurred, pH was affected ($P < 0.01$) by both diet and enhancement. Enhancement with phosphate and sodium chloride has the potential to increase pH of meat by increasing ionic strength (Pearson and Gillett, 1999; Baublits et al., 2005; Baublits et al., 2006a,b). The phenomenon was depicted in our results as ENH had greater ($P < 0.01$) pH compared to NE strip loin samples. Diet also influenced ($P < 0.01$) the ultimate pH of samples, regardless of enhancement. Grass finished control had a greater ($P < 0.05$) ultimate pH than all other treatments. Of the experimental diets, SBMC resulted in a lower ultimate pH ($P < 0.05$) than DDG, PKM and PKMR. Although differences in the experimental diets occurred, results suggested that altering the live animal's diet can produce meat with a more acceptable pH, as no experimental diet resulted in a mean pH greater than 5.74.

The results were as expected since cattle reared on grass will typically intake a lower amount of net energy throughout their life (Larick et al., 1987) and will have greater exposure to environmental stress in their lifetime (Schroeder et al., 1980). Dietary limitations and stress can limit the amount of glycogen available for conversion to lactic acid, resulting in high pH (Hall et al., 1944; Tarrant, 1981; Pearson, 1987). Since CON had greater pH than any of the other experimental treatments, it seems that these processes described by Schroeder et al. (1980) and Larick et al. (1987) most likely took place in the grass-finished cattle. Moreover, further investigation of the non-enhanced treatments indicated that the experimental diets may have increased availability of glycogen in the live animal, which allowed for a reduction in the occurrence of high pH beef (> 6.0). Traditional CON resulted in an extremely high distribution of loins (73%) that possessed a high pH in comparison to the experimental diets. The experimental diets of SORG, SBMC, and SC drastically decreased the occurrence (0%) of high pH beef, while decreases were found in the remaining experimental diets of DDG, PKM and PKMR (10, 11, and 30%, respectively).

As seen in Table 4, diet influenced ($P = 0.02$) sarcomere length, while no difference was observed between ENH and NE samples ($P > 0.05$). Sorghum and SC resulted in shorter sarcomere length than SBMC ($P < 0.05$); however, SBMC sarcomere length was similar ($P > 0.05$) to all other diets. Other than SORG, no differences ($P > 0.05$) in sarcomere length were detected between CON and any other treatments. The results contradict the findings of Bowling et al. (1977) who determined that meat from grass finished cattle was tougher, resulting from shorter sarcomeres than meat from cattle of a grain finished origin; however, it was theorized that these findings were due to differences in carcass fat thickness between dietary treatments (1.27 mm of fat for grass-finished carcasses and 8.9 mm of fat for grain-finished carcasses, respectively). These findings were in agreement with Meyer et al. (1977), who theorized that differences in sarcomere length resulted from differences in carcass fat deposition, suggesting that carcasses from animals with less external fat, such as CON, should possess shorter sarcomeres. Moreover, Thompson (2002) determined that carcasses should possess a minimum of 3 mm of fat to prevent toughening caused by the pH/temperature window during chilling. However, the carcasses that possessed the least subcutaneous fat in our study did not necessarily result in the shortest sarcomeres. Although Thompson (2002) suggested a minimum 3 mm of fat thickness, both CON (0.6 mm) and SBMC (1.3 mm) possessed less than the recommended fat thickness, yet resulted in the longest sarcomeres. These findings indicated that factors other than fat thickness may have influenced the onset of sarcomere shortening. Koohmaraie et al. (1988) believed that sarcomere length was not influenced by postmortem conditions, but was the result of antemortem inputs. Results from our study imply that sarcomere shortening may be the result of conditions that the live animals were subjected to prior to slaughter; however, these conditions may have not been diet related as CON and all experimental diets, other than SORG, resulted in similar ($P > 0.05$) sarcomere lengths.

In addition to live animal inputs, our findings may be relative to the evaluation procedures that were used, as the sarcomere lengths for all diets ranged from 1.54 to 1.34 µm. Varcoe and Jones (1983) found that sar-

Table 4. The main effects of diet and enhancement on the physiochemical traits (pH, sarcomere length and proximate composition) of paired Honduran beef strip loins (n = 105 paired loins)[1]

Diet	pH	Sarcomere, µm	Fat, %	Protein, %	Moisture, %	Ash, %
CON	5.99^{a}	1.54^{ab}	0.93^{c}	32.94^{bc}	60.49^{ab}	1.39^{b}
DDG	5.74^{b}	1.49^{ab}	1.69^{a}	30.93^{c}	61.01^{a}	1.42^{b}
PKM	5.71^{b}	1.49^{ab}	1.90^{a}	33.07^{ab}	58.32^{bcd}	1.51^{b}
PKMR	5.73^{b}	1.51^{ab}	1.75^{a}	31.85^{bc}	59.81^{abc}	1.48^{b}
SORG	5.66^{bc}	1.34^{c}	1.23^{bc}	32.94^{ab}	58.77^{bcd}	1.79^{a}
SBMC	5.52^{c}	1.56^{a}	1.55^{ab}	34.46^{a}	56.97^{d}	1.50^{b}
SC	5.62^{bc}	1.43^{bc}	1.65^{a}	33.42^{ab}	58.20^{cd}	1.37^{b}
SEM[2]	0.1	0.0	0.1	0.7	0.8	0.1
P-value[3]	< 0.01	0.02	< 0.01	< 0.01	< 0.01	0.04
Enhancement						
NE	5.65^{y}	1.50	1.62	32.76	58.97	1.44
ENH	5.77^{z}	1.47	1.44	32.61	59.17	1.55
SEM[2]	0.1	0.1	0.2	1.0	1.1	0.1
P-value[4]	< 0.01	0.33	0.07	0.77	0.72	0.10
P-value[5]	0.92	0.85	0.14	0.96	0.94	0.18

$^{a-d}$Within a column, least square means without a common superscript differ ($P < 0.05$) due to diet.

$^{y-z}$Within a column, least square means without a common superscript differ ($P < 0.05$) due to enhancement.

[1] CON – grass finished (n = 15 paired loins), DDG – distillers dry grain (n = 15 paired loins), PKM – palm kernel meal (n = 15 paired loins), PKMR – PKM replication (n = 15 paired loins), SORG – sorghum (n = 15 paired loins), SBMC – soybean meal and corn (n = 15 paired loins), SC – sugar cane (n = 15 paired loins).

[2] Pooled (largest) SE of least squares means.

[3] Observed significance levels for main effects of diet.

[4] Observed significance levels for main effects of enhancement.

[5] Observed significance levels for main effects of diet x enhancement.

comere lengths for cooked beef *longissimus* were 1.49 µm and uncooked beef *longissimus* were 2.25 µm. The sarcomere lengths of numerous diets, CON, DDG, PKM, PKMR, SBMC, and SC, are in alignment with the results of the cooked samples from this study; however, these results may further indicate that SORG, which resulted in a sarcomere length of 1.34 µm, suffered from sarcomere shortening.

No interaction was observed for any of the proximate components ($P \geq 0.14$), and enhancement had no effect ($P \geq 0.07$) on muscle composition. We were surprised that moisture was not affected by enhancement because tripolyphosphate, which acts as a polyelectrolyte, and sodium chloride, which increases bound water in meat through increased ionic strength (Pearson and Gillett, 1999; Baublits et al., 2005; Baublits et al., 2006a,b) were included as ingredients in our enhancement solution. However, degree of doneness (74°C) could have negated any impact enhancement may have had due to the high final temperature of the cooked product.

Although unaffected by enhancement, percentages of fat, protein, moisture ($P < 0.01$) and ash ($P < 0.05$) were each impacted by finishing diet. Control and SORG had lower fat percentage ($P < 0.05$) than all other treatments, except SORG did not differ ($P > 0.05$) from SBMC. The DDG had lower ($P < 0.05$) protein percentage than most other treatments except PKMR and CON, which were similar ($P > 0.05$). The DDG had greater moisture ($P < 0.05$) than most other treatments except CON and PKMR. Moisture of SBMC was numerically lower than the other treatments but not statistically different from SC, PKM or SORG. Lastly, SORG had the greatest ($P < 0.05$) ash percentage compared to all other treatments, which were similar ($P > 0.05$).

Schroeder et al. (1980) believed that leaner carcasses will lose moisture during the chilling process due to cooler dehydration. The effects of cooler dehydration may have been present in our study; however, losses in moisture may have been combatted by increased pH. As pH increases and moves away from the isoelectric point, ionic strength should become greater, resulting in increased water binding capability in meat. This physiochemical alteration could allow for an increased moisture percentage. Of the carcasses present in this study, CON best demonstrates the ability for pH to combat dehydration. Of all treatments, CON had the leanest carcasses, possessed the greatest ultimate pH, and resulted in numerically the second greatest moisture percentage. Moreover, findings of our study also indicated that fat thickness and pH may work in unison to increase or decrease the moisture percentage of meat. This phenomenon can be observed by further comparing DDG, whose loins had high moisture, and SBMC, which resulted in loins with the lowest moisture percentage. Distiller's dry grain resulted in carcasses with greater fat thickness ($P < 0.05$) and meat with a greater ultimate pH ($P < 0.05$) than SBMC. The composition of DDG would result in water being more tightly bound inside the meat of a carcass that was better insulated from the chilling environment, which may have allowed for a greater amount of water available in the product. Conversely, SMBC displayed the opposite of these traits and a limited amount of water available in the final product. Results of this study indicated that the live animal's diet can influence the physiochemical composition of meat by altering the characteristics of the carcass from which it came.

Slice shear force analysis

Table 5 shows the effects of diet and enhancement on SSF. Diet and enhancement interacted ($P < 0.01$) to influence the shear values. Enhancement reduced ($P < 0.01$) the shear force values for meat from the animals finished on PKM, PKMR, SC, and SORG compared to their NE counterparts, but enhancement had no effect on shear force values of steaks from the remaining diets (CON, DDG, and SBMC). Previous researchers (Vote et al., 2000; Baublits et al., 2005; Baublits et al., 2006a,b; Wicklund et al., 2006) have also reported decreased shear force values as a result of enhancement. Even though CON, DDG, and SBMC resulted in similar ($P > 0.05$) SSF values regardless of enhancement, it is important to note that these values would have aligned with those described as being "tender" by Shackelford et al. (1999) both pre- and post-enhancement. It seems that the decrease in SSF values caused by enhancement were the result of significant reductions in high shear

Table 5. The main effects of diet and enhancement on slice shear force and consumer scores (n = 288) for tenderness, juiciness, flavor liking, overall liking and willingness to pay of 105 paired Honduran beef strip loins[1]

Treatment	SSF, kg	Tenderness[2]	Juiciness[2]	Flavor liking[2]	Overall liking[2]	WTP, L[3]
Enhanced						
CON	17.4^{abc}	65.9^{bc}	65.9^{c}	54.4^{bc}	57.3^{b}	86.4^{cd}
DDG	14.7^{ab}	73.8^{a}	71.2^{ab}	66.4^{a}	69.0^{a}	99.4^{ab}
PKM	14.7^{ab}	66.2^{bc}	71.5^{a}	64.9^{a}	66.2^{a}	96.1^{ab}
PKMR	15.3^{ab}	70.1^{ab}	64.5^{cd}	65.6^{a}	67.5^{a}	101.9^{a}
SORG	15.8^{ab}	65.9^{bc}	68.3^{abc}	64.4^{a}	66.7^{a}	91.6^{bc}
SBMC	12.7^{ab}	62.9^{c}	65.9^{bc}	64.8^{a}	64.9^{a}	96.2^{ab}
SC	17.9^{abc}	54.3^{ef}	58.9^{ef}	56.4^{b}	56.5^{b}	79.7^{de}
Non-Enhanced						
CON	16.1^{ab}	63.7^{c}	60.3^{de}	49.6^{d}	54.1^{bc}	82.7^{de}
DDG	20.6^{abc}	56.7^{de}	59.7^{def}	50.1^{cd}	54.4^{bc}	77.4^{e}
PKM	25.9^{de}	52.8^{ef}	65.0^{cd}	48.4^{ed}	53.2^{bc}	76.5^{e}
PKMR	23.2^{cd}	62.5^{cd}	58.9^{ef}	52.7^{bcd}	57.0^{b}	82.8^{cde}
SORG	34.9^{f}	39.1^{g}	46.4^{h}	41.3^{f}	42.9^{d}	63.7^{g}
SBMC	14.7^{ab}	48.7^{f}	54.5^{fg}	49.1^{de}	50.9^{c}	74.4^{ef}
SC	31.7^{ef}	37.1^{g}	51.0^{gh}	44.3^{ef}	45.3^{d}	66.0^{fg}
SEM[4]	2.7	2.3	2.1	2.1	2.0	3.9
P-value Diet[5]	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
P-value Enhancement[5]	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
P-value D x E[5]	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

[a-h] Within a column, least square means without a common superscript differ ($P < 0.05$) due to diet.

[1] CON – grass finished (n = 15 paired loins), DDG – distillers dry grain (n = 15 paired loins), PKM – palm kernel meal (n = 15 paired loins), PKMR – PKM replication (n = 15 paired loins), SORG – sorghum (n = 15 paired loins), SBMC – soybean meal and corn (n = 15 paired loins), SC – sugar cane (n = 15 paired loins).

[2] Consumer tenderness, juiciness, flavor liking recorded on anchored 100 mm line scale, 0 = very tough, very dry, and dislike extremely of flavor and overall, 100 = very tender, very juicy and like extremely of flavor and overall.

[3] Consumer willingness to pay recorded on an anchored 100 mm line scale in Honduran Lempiras (L), range = L. 0/lb. to L. 400/lb. (USD 0/lb. to USD 17.50/lb., respectively).

[4] Pooled (largest) SE of least squares means.

[5] Observed significance levels for main effects of diet, enhancement and diet x enhancement.

values (23.2 to 34.9 kg) to more acceptable ones (14.7 to 17.9). Despite initial differences in shear force values between diets, all diets had similar shear force values post-enhancement. Additionally, all SSF values post-enhancement would be classified as "tender" according to Shackelford et al. (1999). The injection of sodium chloride and sodium tripolyphosphate created similar environments across all treatments (Baublits et al., 2005; Baublits et al., 2006a), which essentially equilibrated tenderness across diets. The results indicate that the enhancement of beef can be a viable option for improving tenderness and mitigating differences in SSF values in beef produced from varying finishing diets.

When focusing on non-enhanced samples, DDG, CON, and SBMC had lower ($P < 0.05$) shear values than all other finishing diets, while SORG steaks required the most ($P < 0.05$) force to shear, except for SC. The results suggest the alternative finishing diets had variable effects on tenderness compared to CON, and the results contradict the findings of others (Bowling et al., 1977; Schroeder et al., 1980, Dolezal et al., 1982; Larick et al., 1987), who found that grass finished beef typically requires a greater amount of force to shear than beef finished on grain. Moreover, Dolezal et al. (1982) found that shear force values can decrease with as little as 30 d of concentrate feeding and will continue to decrease as intensive feeding is prolonged, suggesting shear force differences should have existed in the current study. Although these studies suggest that grass-finishing of animals should lead to increased shear force values, their results have largely been tied to greater increases in marbling scores from grain-finishing. Sitz et al. (2005) found no differences in shear force values between Australian grass-finished steaks and U.S. grain-finished steaks with low marbling scores. It is possible that our experimental diets did not generate enough marbling to overcome other factors that impact tenderness compared to CON.

The inability for the experimental diets to result in lower SSF values may have been a result of differences in skeletal maturity that were observed in our study. As animals age, collagen found in their body will convert to insoluble tropocollagen and cause background toughening (Smith et al., 1987; Weston et al., 2002). Carcasses from both CON and SBMC had the lowest skeletal maturity scores. The low skeletal maturity scores of these 2 treatments would indicate younger carcasses that possessed lower amounts of tropocollagen bonds and limited background toughening, which would explain the low SSF values of these treatments. Shear force results indicated that PKM and PKMR may have been affected by background toughening, as the skeletal maturity of these treatments were greater ($P < 0.05$) than those of CON and SBMC, which possessed lower shear values ($P < 0.05$). Further analysis of SORG shows that this treatment possessed similar ($P > 0.05$) maturity scores compared to CON and SBMC, which had lower shear values ($P < 0.05$). No difference in skeletal maturity would suggest that the increased SSF values of SORG most likely occurred as a result of sarcomere shortening as opposed to increased background toughening. Sarcomere shortening can result in toughening caused at the myofibrillar level of meat (Cross, 1987; Warner et al., 2010). Myofibrillar toughening most likely occurred and resulted in increased shear values of SORG as it possessed much shorter sarcomeres ($P < 0.05$) than CON and SBMC.

In addition to tenderness differences caused by background and myofibrillar toughening, differences due to live animal growth may have occurred. Koohmaraie et al. (2002) stated that postnatal growth of muscle occurs through the process of muscle hypertrophy or increase in the cell size of the muscle. This growth most likely is a result of alterations to protein synthesis and decreased protein degradation. Compared to CON, all experimental diets had greater LW, HCW, and ribeye area, suggesting there was greater opportunity for muscle hypertrophy to occur in the experimental diets. While this growth may have been beneficial from a carcass yield perspective, it could have negatively impacted meat tenderness. For muscles that are susceptible to cold shortening, such as the *longissimus*, hypertrophic growth that results in decreased protein synthesis will lead to decreased meat tenderness (Koohmaraie et al., 2002), which could potentially explain differences in SSF values, in addition to the differences observed in sarcomere length and background toughening (due to advanced maturity).

Demographics of consumers

Consumer demographic data can be found in Table 6. A majority of the consumers that participated were in the 20 to 29-yr age category. A greater percentage of males participated in the consumer evaluation than females. The primary reported occupations of panelists were in the agricultural, forestry, fishing or hunting industry; however, this percentage was closely followed by wholesale and retail trade or restaurant and hotel workers. A majority of consumers lived in a household with 2 or 3 adults and 1 child. The majority of consumers consumed beef weekly. Additionally, the most commonly reported preferred degree of doneness for beef was very well done, which is in agreement with McDonald (2009) who stated that Central American consumers prefer beef cooked to a well-done

Table 6. Demographic characteristics of consumers (n = 288) who participated in consumer sensor panels in Honduras

Characteristic	Response	% of consumers
Age Group	< 20	15.09
	20 – 29	63.86
	30 – 39	17.19
	40 – 49	1.75
	50 – 59	1.05
	> 60	1.05
Gender	Male	62.19
	Female	37.81
Occupation	Agriculture, forestry, fishing, hunting	18.57
	Manufacturing	15.00
	Electricity, gas, and water	4.29
	Construction	6.07
	Wholesale and retail trade, restaurants and hotels	16.07
	Transportation, storage, and communications	6.07
	Financial intuitions, real estate, and services to companies	15.71
	Community, social, and personal services, security activities, building cleaning activities	9.64
	Hospital activities	2.86
	Student	2.50
	Not currently employed/retired	3.21
Beef Consumption	Daily	10.10
	Weekly	60.63
	Every other week	19.16
	Monthly	6.62
	Every other month	2.09
	2 – 3 times/year	1.05
	Never eat	0.35
Household Size (Adults)	1 person	7.09
	2 people	28.37
	3 people	24.47
	4 people	18.44
	5 people	8.87
	6 people	9.22
	7 people	1.42
	8 or more people	2.13
Household Size (Children)	1 child	36.71
	2 children	23.78
	3 children	23.43
	4 children	8.74
	5 children	5.24
	6 children	1.40
	7 children	0.35
	8 or more children	0.35
Preferred Beef Degree of Doneness	Rare	0
	Medium Rare	3.55
	Medium	15.96
	Well Done	16.31
	Very Well Done	64.18
Annual Household Income, Honduran L.[1]	< 110,000	37.23
	110,000 – 220,000	35.40
	220,000 – 330,000	15.69
	330,000 – 450,000	6.20
	> 450,000	5.47

(continued)

Table 6. (cont.)

Characteristic	Response	% of consumers
Level of Education	Non-high school graduate	7.09
	High school graduate	56.74
	Some college/technical school	18.44
	College graduate	15.25
	Post graduate	2.48
Country of Origin	Honduras	98.94
	Guatemala	0
	Nicaragua	0
	El Salvador	0.35
	Panama	0
	Columbia	0
	Ecuador	0
	Other	0.71

[1] Annual Household Income, Honduran L. equivalencies in USD: < 100,000 = < 5,000; 110,000 – 220,000 = 5,000 – 10,000; 220,000 – 330,000 = 10,000 – 15,000; 330,000 – 450,000 = 15,000 – 20,500; > 450,000 = > 20,500.

degree of doneness. Income level was predominantly reported between the two lowest income brackets. The most common education bracket that was selected by the consumers was a high school graduate. Nearly all consumers that participated in the current study originated from the country of Honduras (98.94%).

Consumer analysis

Consumer ratings for tenderness, juiciness, flavor liking, overall liking and willingness to pay for ENH and NE beef from all finishing diets can be found in Table 5. Diet and enhancement interacted ($P < 0.01$) to influence consumer tenderness, juiciness, flavor liking, overall liking, and willingness to pay.

Enhanced DDG was more tender ($P < 0.05$) than all other treatments except ENH-PKMR, while NE-SORG and NE-SC were less tender than all other treatments. The ENH beef from all experimental diets was more tender ($P < 0.01$) than NE beef from the corresponding diet. These results are in agreement with previous authors (Sheard et al., 1999; Vote et al., 2000; Baublits et al., 2005; Baublits et al., 2006a,b; Wicklund et al., 2006; Rose et al., 2010) who found that enhanced beef cuts will commonly be more tender than non-enhanced beef cuts. However, no difference in tenderness was detected ($P > 0.05$) between ENH and NE beef from the CON treatment. The lack of tenderness differences between ENH and NE for CON align with SSF results. The similarities in SSF between ENH and NE CON would suggest that consumers would not be able to detect a difference in tenderness. The effect of enhancement on ionization and water binding may have been minimized due to the high pH of this particular diet (Pearson, 1987; Kauffman and Marsh, 1987; Tarrant, 1981). The inability for enhancement to influence the tenderness of CON due to increased pH is further supported by the distribution of pH across this treatment. As previously stated, 73% of NE-CON samples had ultimate pH greater than 6.0. The percentage above 6.0 actually was reduced post-enhancement, leaving 59% of ENH-CON samples above a pH of 6.0. The differences in distribution suggested that enhancement of high pH beef with sodium tripolyphosphate may buffer the pH of the meat closer to the isoelectric point. Improving tenderness through enhancement in high pH beef may require the inclusion of a stronger alkaline substance than alkaline phosphates; however, the use of an alkaline ingredient may be unwarranted as high pH beef may be at an optimal pH for water retention without it.

When focusing on NE samples, CON was more tender ($P < 0.05$) than all other diets except PKMR, which was similar ($P > 0.05$) to CON. Previous research has shown grain feeding cattle resulted in meat that was more tender than grass-fed beef by panelists (Schroeder et al., 1980; Tatum et al., 1980; Dolezal et al., 1982). Moreover, Gomez (2016) found increased consumer tenderness ratings for Honduran grain and by-product-finished beef compared to Honduran grass-finished beef. The results contradict our findings; however, this may be related to the composition of carcasses found in our study.

Data suggest that CON samples would be in an ideal environment for a tender product, as carcasses had one of the lowest skeletal maturity scores coupled with loins with the greatest ($P < 0.05$) pH of all treatments.

The tenderness of CON would have benefited from these compositional components as they would have allowed for limited background toughening and increased water retention. In addition to increased water holding capacity, the high pH of CON may have resulted in more advanced protein degradation during the 21-d aging period compared to all other treatments. Yu and Lee (1986) determined that high pH beef benefits from advanced enzymatic breakdown of calpains, the protease that prefers a neutral pH for activation. Increased calpain activity could have resulted in increased proteolysis of the Z-line, tropomyosin, and troponin T and I (Yu and Lee, 1986; Giffee et al., 1987) in a large portion of CON samples, which could have resulted in increased tenderness scores by the consumer.

The findings of Savell et al. (1987) suggested that greater tenderness scores should have been found in DDG, PKM, PKMR, and SC compared to CON, as these samples possessed a greater amount of marbling; however, our results suggested that not only did the samples with a greater amount of marbling vary from control, but they varied between one another. These results are in agreement with the findings of Miller et al. (2001), and they indicated that multiple compositional components were influencing consumer tenderness scores. Furthermore, marbling may not have acted as a dominate driver of meat tenderness in our study, as O'Quinn et al. (2018) determined that no differences in tenderness occur between quality grades of steaks with low marbling scores (USDA Select and Standard). The sarcomere length of SORG indicated that consumers would most likely score these samples as being tougher because myofibrillar toughening had probably occurred. Although the sarcomere lengths of CON and SC were not statistically different ($P > 0.05$), tenderness sores indicated that SC may have suffered from myofibrillar toughening, as their sarcomere lengths were shorter than those described by Varcoe and Jones (1983). When compared to CON, the increased skeletal maturity scores of PKM most likely resulted in greater background toughening. Even though PKM possessed a greater amount of marbling and a higher percentage of chemical fat than CON, the increased background toughening could have resulted in a less tender product to the consumer.

Surprisingly, consumers did not find SBMC and CON similar in tenderness, which contradicts SSF results and similarities in skeletal maturity. Moreover, SBMC possessed a greater amount of marbling and a higher percentage of chemical fat that CON, which would have indicated the potential for a more tender product to the consumer (Savell et al., 1987). Further analysis of SBMC indicated that this treatment may have suffered in tenderness due to its low pH. The pH distribution of SBMC revealed that 45% of these samples had a pH below 5.4, which indicates that a large portion of samples were nearing the isoelectric point of meat (Wismer-Pedersen, 1987). The portion of the samples within this lower pH range would have possessed low water binding capability, especially when compared to the higher pH samples of CON. Moisture analysis of cooked samples further supports differences in water holding capacity, as CON possessed a significantly greater amount of moisture in the cooked product than SBMC. Differences in the amount of moisture retained post cooking between these cooked samples could have resulted in consumer tenderness differences noticed through the chewing process that was unexplainable by the myofibrillar tenderness measurement of SSF analysis.

When focusing on ENH samples, DDG was more tender ($P < 0.05$) than all other diets except PKMR, while SC was less tender ($P < 0.05$) than all other diets. Although PKMR was rated more tender ($P < 0.05$) than SBMC, no differences in tenderness were found from the remaining enhanced diets ($P > 0.05$). This reduction in variation between diets most likely resulted from the incorporation of various non-meat ingredients (Baublits et al., 2005; Baublits et al., 2006b); these alterations would allow for similarities in ionic strength and water binding capacity across treatments which could result in similar tenderness scores.

Although enhancement did not improve tenderness from both an objective and subjective perspective for the CON treatment, enhancement did improve consumer tenderness of every experimental diet. Furthermore, enhancement may be beneficial for mitigation of differences in meat tenderness between animals produced in traditional and non-traditional Honduran finishing systems as multiple diets, including DDG, PKM, PKMR, SORG, and SBMC, were less tender than CON before enhancement, but were similar or more tender than CON post-enhancement.

Consumers scored ENH meat from all diets juicier ($P < 0.01$) than their NE counterparts. These results are in agreement with multiple studies (Robbins et al., 2002; Baublits et al., 2005; Wicklund et al., 2006; Rose et al., 2010) that found enhanced meat was juicier than non-enhanced control. Increased juiciness scores can be linked to the alterations in the raw product, as enhancement can decrease the free water in meat through increased pH allowing for increased moisture (Robbins et al., 2002; Baublits et al., 2006a). Additionally, the effects of ENH on juiciness were still observed despite the high degree of doneness, which is in agreement with findings of Vote et al. (2000), who determined that enhancement with water binding ingredients can produce a juicier product than control even when cooked to 77°C.

Enhanced PKM was juicier (*P* < 0.05) than all other treatments except ENH-DDG and ENH-SORG, while NE-SORG was less juicy (*P* < 0.05) than all other treatments except NE-SC. When focusing on non-enhanced samples, CON had similar juiciness (*P* > 0.05) to DDG, PKM, and PKMR, while the remaining treatments were rated less juicy (*P* < 0.05) than CON. Contrary to our results, Bowling et al. (1977) found that beef from grain-finished cattle was juicier that grass-finished beef. Although our results suggest that alterations in diet alone did not consistently improve juiciness, similar ratings between CON, DDG, PKM, and PKMR are encouraging as Bueso (2015) determined that Honduran consumers rated grass-finished beef juicier than grain finished beef. Additionally, when the beef from the experimental diets in the current study were enhanced, 5 out of 6 diets had similar or superior juiciness than CON.

Consumers liked the flavor of ENH beef more (*P* < 0.05) compared to their NE counterparts. Stetzer et al. (2008) found that sodium chloride influenced the flavor characteristics of meat by increasing saltiness, acting as a flavor enhancer and increasing the perception of beef flavor intensity. Additionally, sodium tripolyphosphate possesses the ability to chelate iron which will result in decreased lipid oxidation products (Stetzer et al., 2008). Most likely the ENH samples benefited from the inclusion of these ingredients resulting in flavor that was preferred by the consumer. Although enhancement consistently increased flavor liking, selection of specific non-meat ingredients based on carcass quality attributes may further increase consumer scores. Holdstock et al. (2014) determined that as the pH of meat increases above 6.0, there will be an increased development of off flavors. As previously stated, sodium tripolyphosphate reduced the percentage of CON samples with a pH above 6.0. A reduction in the percentage of samples above this pH could have additionally reduced the presence of off flavors that would have been noticed by the consumer. Targeted enhancement of meat based on pH could add value to the consumer, and high pH beef, like CON, may benefit from the inclusion of acid-based ingredients, such as acid phosphates, opposed to alkaline ingredients.

All ENH treatments, except CON and SC, had greater flavor liking (*P* < 0.05) than the remaining treatment combinations. Consumers disliked the flavor of NE-SORG more (*P* < 0.05) than all other treatments except for NE-SC, which was rated similarly (*P* > 0.05). Among the non-enhanced samples, CON had similar (*P* > 0.05) flavor liking scores to multiple diets, including DDG, PKM, PKMR, and SBMC, but no diet had greater flavor liking than CON. These results are interesting as multiple studies (Sanudo et al., 1998; Oliver et al., 2006; Lobato et al., 2014) have determined that beef and lamb flavor liking was subject to traditional feeding practices of the region where meat was produced and the previous eating experience of the consumer. Their findings would suggest that Honduran consumers would prefer the flavor of traditional grass-finished beef, which is in agreement with the findings of Bueso (2015) who determined that Honduran consumers prefer the flavor of grass-finished beef compared to grain finished beef. Our results contradicted these findings and indicated that the flavor liking of several experimental diets were similar to CON. When beef was enhanced, the flavor liking of DDG, PKM, PKMR, SORG, and SBMC was preferred over CON and SC. Fortunately, these results show that the experimental diets in conjunction with enhancement can improve flavor liking while decreasing variation in flavor liking.

All enhanced steaks, except CON, had greater (*P* < 0.05) overall liking scores than their NE counterparts. In alignment with our results, Robbins et al. (2002) found consumers liked enhanced beef overall more than non-enhanced beef from high energy diets. Of all treatments, ENH-DDG, ENH-PKM, ENH-PKMR, ENH-SORG, and ENH-SBMC had similar and greater overall liking scores compared to the remaining treatment combinations (*P* < 0.05), while NE-SORG and NE-SC were liked less than all other treatments. Among the non-enhanced samples, DDG, PKM, PKMR, and SBMC had similar overall liking to CON, but no treatment had greater overall liking than CON. Although no experimental diet produced meat that was preferred to CON, similar overall liking scores are encouraging as Bueso (2015) determined Honduran consumers liked grass-finished beef more overall than grain-finished Honduran beef. These results indicate that when used in conjunction, enhancement and alternative diets can produce beef with greater overall liking according to Honduran consumers when compared to traditional non-enhanced grass-finished beef.

As seen in Table 5, results for consumer willingness to pay followed a similar trend to results for overall liking of the beef. Consumers were willing to pay more (*P* < 0.05) for each of the enhanced treatments compared to their NE counterparts, except CON. The ENH-PKMR did not differ (*P* > 0.05) from ENH-DDG, ENH-SBMC, and ENH-PKM and consumers were willing to pay more (*P* < 0.05) for these treatments compared to all other treatment combinations. Consumers were willing to pay less (*P* < 0.05) for NE-SORG than all other treatments except NE-SC. Between the non-enhanced samples, consumers were willing to pay a similar amount ($P > 0.05$) for PKMR, CON, DDG, PKM, and SBMC, while the remaining treatments were lower ($P < 0.05$). Killinger et al. (2004) reported that consumers were willing to pay more for grain-finished beef than grass-finished beef, which does not align with the current results as consumers were willing to pay a similar amount for CON beef as beef from four of the 6 experimental diets. Interestingly, the combined effects of diet and enhancement garnered greater value to the consumer and indicated that diet and enhancement should be used in conjunction to maximize value.

The consumer's perceived acceptability of tenderness, juiciness, flavor liking, and overall liking for ENH and NE beef from all from all finishing diets can be found in Table 7. Results show that diet and enhancement interacted ($P < 0.01$) to influence consumer acceptability of tenderness, juiciness and flavor, as well as the overall acceptability of each treatment. The percentage of consumers that found tenderness, juiciness, flavor liking and overall liking acceptable was similar for CON ($P > 0.05$) regardless of enhancement. These similar percentages would indicate that the enhancement of traditional grass-finished Honduran beef is not merited. A greater percentage of consumers found tenderness, flavor liking, and overall liking acceptable for ENH than NE for every experimental diet ($P < 0.05$); however, enhancement only improved juiciness acceptability for four of the 6 experimental diets.

Within non-enhanced samples, no diet resulted in a greater percentage of positive consumer tenderness, juiciness, flavor liking, and overall acceptability responses compared to CON ($P > 0.05$), with the exception that a greater percentage of consumers classified the juiciness of PKM acceptable ($P < 0.05$) compared to CON. A multinational study conducted by Realini et al. (2009) determined that consumers from multiple European countries rated beef from grass-finished cattle more acceptable than beef from concentrate-finished cattle. Findings of this study suggested that acceptability, like flavor liking, is subject to the regional preferences of the consumer, which would suggest that the Honduran consumer would find CON more acceptable than beef from the experimental diets. These findings were not represented in our study as DDG and PKMR resulted in a similar percentage of

Table 7. The main effects of diet and enhancement on the proportion of consumers (n = 288) that classified tenderness, juiciness, flavor liking of the 105 paired Honduran beef strip loins acceptable[1]

Treatment	Tenderness acceptability, %	Juiciness acceptability, %	Flavor acceptability, %	Overall acceptability, %
Enhanced				
CON	76.3^{cd}	78.6^{def}	63.2^{de}	68.2^{bc}
DDG	92.1^{a}	90.0^{ab}	85.1^{ab}	89.5^{a}
PKM	81.9^{bc}	91.4^{a}	87.6^{a}	89.4^{a}
PKMR	89.3^{ab}	82.9^{bcde}	87.7^{a}	89.9^{a}
SORG	82.0^{bc}	87.1^{abc}	85.8^{a}	86.0^{a}
SBMC	81.0^{bc}	86.6^{abcd}	86.2^{a}	85.5^{a}
SC	61.1^{e}	74.6^{efg}	76.1^{bc}	74.5^{b}
Non-Enhanced				
CON	77.9^{cd}	74.3^{efg}	61.8^{de}	70.7^{bc}
DDG	69.5^{de}	79.7^{cdef}	61.7^{de}	70.0^{bc}
PKM	63.7^{e}	86.1^{abcd}	65.6^{cde}	68.1^{bc}
PKMR	78.0^{cd}	73.4^{efg}	69.7^{cd}	74.3^{b}
SORG	48.1^{f}	55.6^{h}	47.5^{f}	54.2^{d}
SBMC	60.3^{e}	69.1^{fg}	62.9^{de}	61.5^{cd}
SC	39.8^{f}	68.9^{g}	56.9^{ef}	54.5^{d}
SEM[2]	4.4	4.5	4.7	4.8
P-value Diet[3]	< 0.01	< 0.01	< 0.01	< 0.01
P-value Enhancement[3]	< 0.01	< 0.01	< 0.01	< 0.01
P-value D × E[3]	< 0.01	< 0.01	< 0.01	< 0.01

[a-h] Within a column, least square means without a common superscript differ ($P < 0.05$) due to diet.

[1] CON – grass finished (n = 15 paired loins), DDG – distillers dry grain (n = 15 paired loins), PKM – palm kernel meal (n = 15 paired loins), PKMR – PKM replication (n = 15 paired loins), SORG – sorghum (n = 15 paired loins), SBMC – soybean meal and corn (n = 15 paired loins), SC – sugar cane (n = 15 paired loins).

[2] Pooled (largest) SE of least squares means.

[3] Observed significance levels for main effects of diet, enhancement and diet x enhancement.

positive responses for tenderness, juiciness, flavor liking, and overall acceptability ($P > 0.05$). The ability for DDG and PKMR to perform similarly to CON indicates that these experimental diets could be implemented without altering the odds for an unacceptable consumer eating experience. These results indicated that the combined effect of supplemental finishing diet and enhancement can result in a higher percentage of acceptable overall eating experiences for the consumer; however, consumer scores revealed that the use of experimental finishing diets alone was not a viable means of producing a more acceptable eating experience.

Table 8. Pearson's correlation coefficients for the relationships between consumer (n = 288) sensory scores and WTP for the non-enhanced and enhanced beef from all seven diets (n = 105 paired loins)

Trait	Overall liking	WTP	Tenderness	Juiciness
WTP	0.61*			
Tenderness	0.72*	0.50*		
Juiciness	0.64*	0.43*	0.66*	
Flavor Liking	0.84*	0.57*	0.60*	0.60*

*Correlation coefficients were significant ($P < 0.01$).

Correlations

Pearson correlation coefficients were determined to quantify the relationships between palatability traits, willingness to pay, and to overall liking (Table 8). Overall liking was strongly correlated ($P < 0.05$) to tenderness, juiciness, and flavor liking, with flavor liking exhibiting the strongest correlation ($r = 0.84$). The current results were not unexpected as the previous reports of beef eating quality for US consumers align with these coefficients (Hunt et al., 2014; Crownover et al., 2017). Similar results were reported by Crownover et al. (2017), as flavor liking was most strongly related to overall liking followed by tenderness and then lastly, juiciness. Individual palatability traits strongly correlated to each other ($r \geq 0.60$), indicating that individual improvements of these traits could influence the perception of another trait. Willingness to pay was associated ($P < 0.01$) with tenderness, juiciness and flavor liking, again with flavor liking showing the strongest relationship; however, the relationships between palatability traits to willingness to pay were weaker than the relationships between palatability traits and overall liking. These results indicate that consumer willingness to pay is most strongly related to the consumer's perception of the product overall as opposed to the perception of an individual trait. The findings suggest that implementations of value-based beef marketing systems should focus on the overall eating quality of a product instead of the merit of an individual palatability trait. Additionally, producers should implement production and processing strategies that result in a superior product overall to the consumer to garner greater value.

Conclusions

The results from this study indicated that the incorporation of experimental finishing diets and enhancement can influence eating quality. Although improvements in consumer eating quality did not occur with all experimental diets, diets with the inclusion of DDG or those with the highest percentage of PKM produced steaks that consumers rated similarly to CON for palatability traits, WTP, and acceptability of all palatability traits. These results are especially promising when held in conjunction with the influence that these diets had on live animal weight gain and hot carcass weight, which would increase edible red meat. Enhancement increased eating quality and WTP of beef from cattle finished on our experimental diets, but provided little to no improvement to overall liking of Honduran grass-finished beef. These results suggest that the Honduran beef industry may benefit from the enhancement of meat as it has the potential to overcome differences in eating quality caused by the diet of the live animal, allowing for more uniform products to the consumer. With all inputs considered, the results of this study would suggest that beef producers in Honduras would benefit from the implementation of the DDG, PKM, or PKMR based diets as they would lead to a greater amount of edible red meat, compared to CON, and beef from the cattle finished on these diets could be enhanced to maximize consumer eating quality.

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