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Palatability of Beef Strip Loin Steaks Representing Various Marbling and Maturity Levels from Grain-Fed Beef

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Abstract: This study compared palatability traits of beef strip loin steaks with varying marbling scores from young and mature grain-fed beef. Strip loins (*n* = 150) were selected from grain fed cattle representing ten treatments with the following USDA marbling scores: Slightly Abundant or greater (SLAB+), Moderate or Modest (MD/MT), Small (SM), Slight (SL), and Traces or Practically Devoid (TR/PD) from young "A" maturity carcasses (Y) and mature "C" or greater maturity carcasses (M). Subprimals were fabricated into 2.5-cm steaks at 21 d postmortem and stored frozen until further analysis. Consumer (*n* = 120) sensory panelists evaluated cooked steaks for tenderness, juiciness, flavor liking, and overall liking. Trained panelists (*n* = 15 sessions) evaluated each sample for initial and sustained juiciness, initial and sustained tenderness, flavor intensity, and off-flavor intensity. For all traits, consumer and trained panelists' scores generally decreased with decreasing marbling score, regardless of maturity. According to consumers, maturity had no effect on juiciness or flavor liking within each marbling score, except flavor liking of SLAB+ was greater ($P < 0.05$) for young than mature carcasses. Conversely, young carcasses had greater tenderness scores than mature within all marbling categories except SM, which translated to greater overall liking of MD/MT, SL, and TR/PD of young compared to their mature counterparts ($P < 0.05$). Trained panelists detected very few differences between young and mature samples within their respective marbling score; however, M-MD/MT had lower initial and sustained tenderness coupled with greater off-flavor intensity than Y-MD/MT ($P < 0.05$). Mature samples with SLAB+ and MD/MT marbling were rated greater than or equal to Y-SM for all traits, indicating the presence of marbling from feeding a grain diet prior to harvest may elicit a similar eating experience to young beef by offsetting negative palatability traits often associated with mature beef.

Keywords: beef palatability, consumer, marbling, maturity, trained sensory
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Introduction

Quality of beef is determined by considering the amount of intramuscular fat in the ribeye in relation to the physiological maturity of the animal from which the carcass was produced. It is well documented that as maturity increases, trained panelists have identified beef to be tougher and less desirable for overall palatability than beef from younger animals (Smith et al., 1982; Hilton et al., 1998).

Trained panelists have identified less variation in beef flavor and fewer off-flavors in beef from "A" maturity than beef from other maturity groups (Berry et al., 1980; Hilton et al., 1998; Bruce et al., 2005). Additionally, as animals increase in age, collagen matures, and crosslinks gradually stabilize to an insoluble form resulting in tougher meat (Lepetit, 2008). As a result, beef from older animals has been ranked with lower tenderness scores, correlating with greater shear force values than beef from young animals (Smith et al., 1982; Shackelford et al., 1995).

Palatability traits of beef from mature cattle can increase by feeding cull cows a high-energy ration prior to slaughter (Cranwell et al., 1996; Schnell et al., 1997), but the extent of improvement has not been examined across a full range of resulting marbling scores. Moreover, flavor desirability of grain fed beef has been positively correlated to consumer acceptance (Calkins and Hodgen, 2007; Stelzleni et al., 2007; Maughan et al., 2012). In addition, tenderness is altered with an increase in PUFA concentrations from grain-finished diets, by altering the sarcoplasmic reticulum membrane and thereby improving tenderness in postmortem muscle (Chao et al., 2015). Therefore, by feeding cull cows a high-energy diet, producers may capitalize on higher carcass weights, dressing percentages, and subprimal weights (Schnell et al., 1997), while increasing beef quality for consumers. Thus, the purpose of this study was to evaluate the influence of grain-finishing across a range of marbling scores on the sensory characteristics of beef strip steaks from young and mature beef carcasses.

Materials and Methods

Product selection

Beef strip loins (Institutional Meat Purchase Specifications #180; *n* = 15/treatment) were selected to equally represent 5 marbling groups [Slightly Abundant or greater (SLAB+), Moderate or Modest (MD/MT), Small (SM), Slight (SL), and Traces or Practically Devoid (TR/PD)] across 2 carcass types [young fed (Y; A maturity) and mature fed (M; C to E maturity)]. Mature fed-cattle that were 30 mo of age or older (determined by dentition) were segregated and marketed separately from fed-young cattle. Carcasses (both young and mature) were selected from a single commercial processing facility in Omaha, NE that identified all cattle as being commercially finished on a conventional grain-based diet (Gredell et al., 2018). According to cattle feeding surveys, feedyard rations in the Northern Plains, and specifically Nebraska, consist predominately of corn (high moisture, steam flaked, and/or dry rolled), wet or modified distillers grains, haw and straw, silage, and mineral (Asem-Hiablie et al., 2016; Birch and Brooks, 2015). Cattle in the Northern Plains (Nebraska, South Dakota, and North Dakota) are on finishing rations an average of 137 d (Asem-Hiablie et al., 2016). Regional mature fed-beef programs, sometimes referred to as "white-cow" programs due to high-concentrate rations, consisting of corn, soybeans, roughage, and supplement, being fed to cull cows that turn the fat color from yellow to white, generally last at least 120 to 140 d prior to slaughter (Miller, 2016). However, exact duration of finishing ration was not known for any cattle (young or mature) in the current study due to their selection from a commercial abattoir.

Carcass data were collected by trained personnel from Texas Tech University at the time of selection and included lean and skeletal maturity, ribeye area, fat thickness, hot carcass weight, percentage of kidney, pelvic and heart fat, and calculated USDA yield and quality grades (USDA, 2016). Subprimals were shipped to the Texas Tech University Gordon W. Davis Meat Laboratory (Lubbock, TX) under vacuum at 0 to 4°C and stored in the absence of light until 21 d postmortem.

Steak fabrication

All subprimals were cut into 2.5-cm thick steaks from anterior to posterior. The most anterior steak was designated for proximate analysis and the next 3 steaks were randomly assigned to either Warner-Bratzler shear force (WBSF) testing, consumer sensory panel analysis, or trained sensory panel analysis, with 1 steak from each subprimal assigned to each analysis. Steaks were then vacuum packaged, frozen (-10°C), and stored until subsequent analysis.

Color and pH analyses

One steak from each strip loin was tested for instrumental color, pH, and proximate analysis. Prior to analysis, samples were tempered in a single layer for 24 h until thawed at 2 to 4°C. Samples were removed from the vacuum package and allowed to bloom for 30 min. After blooming, a handheld spectrometer (Model 45/0-L Hunter MiniScan XE Plus; Hunter Associates Laboratory, Reston, VA) was used to determine L*, a*, and b* values for each sample using illuminant D65 and the 10 standard observer angles and 2.54 cm aperture. Once color was assessed, pH for each intact steak sample was determined using a pH probe (Model 13–620–285; Fisher Scientific, Pittsburgh, PA). The pH probe was rinsed using distilled water and dried between each pH measurement.

Proximate analysis

Before analysis, steaks were trimmed to remove all subcutaneous and intermuscular fat to assure only lean tissue and marbling were present prior to grinding through a commercial food grinder (Krups 150-Watt Grinder item #402–70; Krups, Sheldon, CT). Proximate analysis was conducted using an AOAC-approved (Official Method 2007.04; Anderson, 2007) near infrared spectrophotometer (FoodScan, FOSS NIRsystems, Inc., Laurel, MD). Values for fat, protein, and moisture percentage were determined for each strip loin.

Warner-Bratzler shear force

Warner-Bratzler shear force testing was performed in accordance to the American Meat Science Association (2015) procedures. Steaks were thawed for 24 h until the samples reached 2 to 4°C prior to testing. Upon thawing, steaks were weighed to the nearest 0.1g and raw temperature was recorded, assuring the steaks were between 2 and 4°C, by using a digital thermometer (Digi-Sense Type J; Cole-Parmer Instrument Company, Vernon Hills, IL). Steaks were cooked on a gas radiant broiler (model IRB-36; Imperial Commercial Cooking Equipment, Corona, CA). The final cooked temperature and weight were recorded following a 3-min rest period. All samples were chilled at 2 to 4°C for 24 h, prior to coring. Six 1.3-cm core samples were collected parallel to the muscle fibers from each steak and sheared perpendicular to the muscle fiber orientation using a WBSF analyzer (G-R Elec. Mfg., Manhattan, KS). The 6 values were averaged to determine 1 shear force value (kg) for each steak.

Consumer sensory panels

The Texas Tech University Institutional Review Board approved all procedures concerning human subjects used in this study.

Consumer panels were conducted at Texas Tech University in the Animal and Food Science Building. Five panels of 24 consumer panelists were recruited, resulting in a total of 120 panelists. Each consumer panelist received monetary compensation for his or her participation. Consumers that participated in the study were screened to prefer a medium degree of doneness (71°C) and eat beef on a regular basis and were only allowed to participate once. 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). Each ballot included an informational sheet about the project for the consumer, demographic survey, and 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.

Before cooking, steaks were thawed at 2 to 4°C for 24 h prior to each consumer panel. Upon thawing, steaks were weighed to the nearest 0.1g and raw temperature was recorded, assuring the steaks were between 2 and 4°C, by using a digital thermometer (Digi-Sense Type J). Steaks were cooked on a gas radiant broiler (Model IRB-36) to represent cooking methods used in the food service industry. Steaks were rested for a 3-min period after removal from the grill, with a target end-point temperature of 71°C. The final cooked temperature and weight were recorded. Each steak was cut into 8 equal parts relative to the size of the steak and served to the panelists. Consumers were served 1 sample from each treatment in a random order. Each sample was evaluated for tenderness, juiciness, flavor liking, and overall liking on a 100-mm, verbally anchored line-scales (0 = extremely dry/tough/dislike extremely; 100 = extremely juicy/tender/like extremely). Acceptability of tenderness, juiciness, flavor liking, and overall liking were also selected (yes/no) for each sample. Each panel session was approximately 1 h.

Trained sensory panels

Trained panelists were trained according to the American Meat Science Association (2015) sensory procedures and consistent with the methods outlined by Gredell et al. (2018) and Lucherk et al. (2016). Panelists were trained during 3 different sessions in the days leading up to the panels to evaluate differences in tenderness, juiciness, and flavor by feeding samples of varying marbling scores, maturity levels, and muscles. Panels and training sessions were conducted in a dark room under low intensity red lights to minimize potential bias related to the visual appearance of the sample.

Trained panelists (n = 7) participated in 15 panel sessions. All treatment samples were presented into a predetermined, balanced order so panelists would receive 1 sample from each treatment during each panel session. Two sample pieces measuring 1 cm^3 from each steak were served to each panelist. Similar to consumer panels, steaks were thawed at 2 to 4°C for 24 h prior to cooking. Cooking procedures for trained sensory panels were identical to those described for consumer panels. Trained panelists evaluated each sample for initial juiciness, sustained juiciness, initial tenderness, sustained tenderness, beef flavor, flavor intensity, and off-flavor intensity using 100-mm verbally anchored line scales (0 = extremely dry/tough/unbeef-like/bland and 100 = extremely juicy/tender/beef-like/intense). Each panel session was approximately 30 min.

Statistical analysis

Statistical analyses were conducted using the procedures of SAS (Version 9.3; SAS Inst. Inc., Cary, NC) as a completely randomized design, with treatment as the fixed effect. The treatment main effect was tested for significance using PROC GLIMMIX with

Table 1. Least squares means of subjective lean, skeletal, and overall maturities of beef carcasses from grain-finished, young (A maturity) and mature (C, D, and E maturity) carcasses with varying marbling degrees[1]

Treatment	Skeletal maturity[2]	Lean maturity[2]	Overall maturity[2]	Marbling score[3]	Preliminary fat thickness, cm	Adjusted fat thickness, cm	Ribeye area, cm[2]	Hot carcass weight, kg	Kidney, pelvic, and heart fat, %	Yield grade
Young										
SLAB+	156.7^{c}	161.3^{c}	158.0^{c}	803.3^{a}	1.6^{b}	1.7^{b}	86.0^{bc}	418.9^{bc}	2.1^{a}	3.8^{b}
MD/MT	161.3^{c}	159.3^{c}	161.3^{c}	564.0^{c}	1.4^{bcd}	1.5^{bcd}	87.9^{bc}	386.6^{cd}	2.0^{abc}	3.3^{cd}
SM	156.0^{c}	164.7^{c}	160.0^{c}	450.7^{d}	1.5^{bc}	1.7^{bc}	92.4^{ab}	411.5^{bc}	2.0^{ab}	3.4^{bcd}
SL	158.7^{c}	184.0^{a}	169.3^{c}	354.7^{e}	1.1^{de}	1.0^{ef}	90.6^{ab}	400.0^{bc}	1.9^{abc}	2.8^{e}
TR/PD	142.7^{c}	168.0^{bc}	152.7^{c}	226.0^{g}	0.5^{f}	0.6^{g}	93.2^{ab}	353.3^{d}	1.8^{bc}	1.8^{f}
Mature										
SLAB+	543.3^{a}	179.3^{ab}	431.3^{ab}	746.0^{b}	2.0^{a}	2.1^{a}	96.4^{a}	507.4^{a}	2.0^{ab}	4.5^{a}
MD/MT	496.0^{b}	172.0^{abc}	401.3^{b}	590.0^{c}	1.2^{cde}	1.3^{cde}	82.8^{c}	430.7^{b}	2.0^{ab}	3.7^{bc}
SM	558.7^{a}	178.0^{ab}	456.0^{a}	450.0^{d}	0.9^{e}	1.1^{ef}	87.8^{bc}	429.8^{b}	2.0^{abc}	3.2^{cde}
SL	552.7^{a}	173.0^{ab}	454.0^{a}	353.3^{e}	1.1^{de}	1.3^{de}	91.8^{ab}	430.1^{b}	1.9^{abc}	3.2^{cde}
TR/PD	550.7^{a}	182.0^{a}	452.7^{a}	266.7^{f}	0.9^{e}	1.0^{f}	72.3^{d}	354.8^{d}	1.7^{c}	3.2^{de}
SEM[4]	13.6	4.7	12.4	10.5	0.1	0.1	2.6	13.2	0.1	0.2
P-value	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

$^{a\text{–}g}$ Least squares means in the same column without a common superscript differ ($P < 0.05$).

[1]Marbling degrees: SLAB+ = ≥ slightly abundant^{00}; MD/MT = modest^{00} to moderate^{100}; SM = small^{00} to small^{100}; SL = slight^{00} to slight^{100}; TR/PD = practically devoid^{00} to traces^{100}.

[2]Maturity scores: 100: A, 400: D, 500: E.

[3]Marbling scores: 200: traces; 300: slight; 400: small; 500: modest; 600: moderate; 700: slightly abundant; 800: moderately abundant.

[4]Standard error (largest) of the least squares means.

α = 0.05 and the denominator degree of freedom were calculated using the Kenward-Roger method. For both trained and consumer sensory data, ratings for each sample were averaged across panelist before analysis and panel number was included in the model as a random effect. Acceptability data for each palatability trait were analyzed with a model that included a binomial error distribution. Consumer demographic information was summarized using PROC FREQ.

Results and Discussion

Carcass characteristics

Carcass characteristics are presented in Table 1. Skeletal maturity scores among young carcasses were similar ($P > 0.05$) and lesser ($P < 0.05$) than all mature carcasses, which were also similar to each other except M-MD/MT was lower than the other 4 mature marbling groups. Furthermore, lean maturity scores for young cattle with SM or greater marbling were more youthful ($P < 0.05$) than all mature carcasses except M-MD/MT. As a result, overall maturity for young carcasses was lower ($P < 0.05$) than mature carcasses, and M-MD/MT had lower ($P < 0.05$) overall maturity than M-SM, M-SL, and M-TR/PD. Beef from Y-SLAB+ had greater marbling scores ($P < 0.05$) than M-SLAB+, while Y-TR/PD had lower marbling scores than M-TR/PD ($P < 0.05$). Otherwise, marbling score did not differ between respective marbling groups between young and mature carcasses ($P > 0.05$).

Proximate analysis

The proximate composition of samples is shown in Table 2. An inverse relationship was evident that as USDA marbling scores increased from TR/PD to SLAB+, the percentage of fat also increased while moisture and protein percentages decreased ($P < 0.05$). Maturity did not have an effect on fat and moisture percentages, as seen by similar ($P > 0.05$) percentages for both components within each marbling score. Fat percentage decreased ($P < 0.05$) from Y-SLAB+ to Y-TR-PD, but Y-MD/MT and Y-SM had similar fat percentage ($P > 0.05$). Likewise, fat percentage decreased ($P < 0.05$) from M-SLAB+ to M-TR/PD, but M-SL did not differ from M-SM or M-TR/PD ($P > 0.05$). Protein percentage generally increased as fat percentage decreased ($P < 0.05$); however, there were protein similarities ($P > 0.05$) in several adjacent marbling scores. Unlike fat and moisture, protein percentage differed ($P < 0.05$) by maturity within certain marbling scores. Strip loins from young carcasses with MD/MT, SL, and TR/PD marbling scores had greater

Table 2. Least squares means for proximate analyses, color, pH, and Warner-Bratzler Shear Force (WBSF) of beef strip loin steaks from grain-finished, young (A maturity) and mature (C, D, and E maturity) carcasses with varying marbling degrees[1] (n = 15/treatment)

Treatment	Fat, %	Moisture, %	Protein, %	L*[3]	a*[4]	b*[5]	pH	WBSF, kg
Young[2]								
SLAB+	15.1^{a}	63.0^{f}	21.6^{d}	44.29^{a}	24.34^{ab}	21.26^{a}	5.58^{bc}	2.18^{bc}
MD/MT	8.2^{bc}	68.1^{de}	23.4^{b}	43.67^{a}	24.79^{ab}	21.39^{a}	5.51^{bc}	2.14^{c}
SM	6.9^{cd}	69.0^{cd}	23.5^{b}	41.05^{b}	24.42^{ab}	20.76^{ab}	5.58^{bc}	2.43^{bc}
SL	4.2^{f}	70.7^{b}	24.4^{a}	38.40^{cd}	26.75^{a}	21.51^{a}	5.64^{b}	2.63^{ab}
TR/PD	2.1^{g}	72.4^{a}	24.5^{a}	37.70^{cde}	24.77^{ab}	19.49^{bcd}	5.82^{a}	2.59^{abc}
Mature[2]								
SLAB+	13.9^{a}	63.7^{f}	21.2^{d}	41.10^{b}	19.76^{d}	18.87^{cd}	5.50^{c}	2.30^{bc}
MD/MT	8.6^{b}	67.5^{e}	22.8^{c}	39.36^{bc}	23.25^{bc}	20.59^{ab}	5.52^{bc}	2.33^{bc}
SM	6.1^{de}	69.0^{cd}	23.4^{b}	37.30^{cde}	23.14^{bc}	20.77^{ab}	5.49^{c}	2.89^{a}
SL	4.8^{ef}	70.2^{bc}	23.7^{b}	36.47^{de}	21.52^{bcd}	19.90^{abc}	5.52^{bc}	2.50^{abc}
TR/PD	3.4^{fg}	71.4^{ab}	23.5^{b}	35.46^{e}	20.16^{cd}	18.17^{d}	5.50^{c}	2.94^{a}
SEM[6]	0.5	0.5	0.2	0.88	1.17	0.61	0.05	0.17
P-value	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

$^{a–g}$ Least squares means in the same column without a common superscript differ (P < 0.05).

[1]SLAB+ = ≥ slightly abundant^{00}; MD/MT = modest^{00} to moderate^{100}; SM = small^{00} to small^{100}; SL = slight^{00} to slight^{100}; TR/PD = practically devoid^{00} to traces^{100}.

[2]Young: "A" overall USDA maturity cattle, Mature: "C" overall USDA maturity or greater.

[3]L*: Lightness (0 = black and 100 = white).

[4]a*: Redness (–60 = green and 60 = red).

[5]b*: Blueness (–60 = blue and 60 = yellow).

[6]SEM: Standard error (largest) of the least squares means.

(P < 0.05) protein percentage than their mature counterpart. These results were unsurprising as it has been shown that with a greater percentage of fat, resulting from greater marbling score, moisture and protein will decrease (Savell et al., 1986; Corbin et al., 2015).

Color and pH analyses

Results presented in Table 2 show objective color and pH measurements for all treatment groups. Treatment influenced (P < 0.01) all instrumental color traits, as well as pH. Samples from Y-SLAB+ and Y-MD/MT had greater L* values than all other treatments (P < 0.05). Interestingly, M-SLAB+, M-MD/MT and Y-SM had similar L* values (P < 0.05), potentially suggesting that feeding cull cows a high-energy diet prior to harvest improved lightness of steaks, which could offset negative reactions from consumers for dark lean color often associated with mature animals. There were no differences in a* values among steaks from young carcasses, suggesting similar redness of young steaks despite marbling differences. The M-TR/PD had lower (P < 0.05) b* values, indicating those samples were less yellow, than most other treatments, but did not differ (P > 0.05) from M-SLAB+ or Y-TR/PD. The Y-TR/PD had lower (P < 0.05) b* values than all other young treatments, except Y-SM, but there were no clear and consistent trends for b* values within steaks from mature carcasses. Highly marbled (SLAB+) beef from young cattle had higher L*, a*, and lower b* values compared to mature beef with a similar marbling score. Additionally, M-MD/MT and M-SM had lower L* values than Y-MD/MT and Y-SM, while M-SL and M-TR/PD had lower a* values when compared to young beef with similar marbling scores. Marbling score was similar between young and mature carcasses for MD/MT (564 and 590) and SM (451 and 450), respectively, yet there were differences in L* values between young and mature at these marbling levels. This would suggest lean color, not the marbling, was responsible for the difference in L* between young and mature carcasses with similar marbling scores. According to Patten et al. (2008), fed beef cull cows had lower L* values for longissimus muscle compared to young Select longissimus muscle, despite having greater marbling, suggesting advanced physiological maturity produced darker beef. These results support the current findings; however, Patten et al. (2008) failed to detect differences in a* or b* between longissimus muscle from fed beef cull cows and young Select longissimus muscle, but we found a* and b* were reduced for M-SLAB+ compared to its young counterpart as well as reduced a* values for M-TR/PD compared to Y-TR/PD. Otherwise redness and yellowness did not differ due to maturity within a marbling score, which is supported by previous results (Patten et al., 2008).

For analysis of pH, Y-TR/PD samples had the highest ($P < 0.05$) average pH value compared to all other treatments. There were no differences ($P > 0.05$) in pH between the remaining young maturity samples. Likewise, all mature treatments had similar pH ($P > 0.05$). Maturity did not appear to affect pH as pH was similar ($P > 0.05$) within all marbling scores, except TR/PD. Although minor differences were detected in pH, biological significance was likely minimal as all were below 5.8, aside from Y-TR/PD.

Warner-Bratzler shear force

Treatment influenced WBSF values ($P < 0.01$) as seen in Table 2. Shear force values generally increased as marbling decreased, regardless of maturity; however, several adjacent marbling scores had similar ($P > 0.05$) WBSF values. The strip loin steaks with TR/PD and SM marbling scores from mature carcasses had greater ($P < 0.05$) WBSF values than strip loin steaks with higher marbling scores (MD/MT and SLAB+), but M-SL had a similar ($P > 0.05$) WBSF values to all other mature shear force values. The Y-SL had greater ($P < 0.05$) WBSF values than Y-MD/MT, but was similar ($P > 0.05$) to WBSF values of all other young treatments. Within each marbling score, maturity largely had no effect ($P > 0.05$) on WBSF values except M-SM had greater ($P < 0.05$) WBSF values than Y-SM. These results align with previous reports where longissimus WBSF values did not differ between young and mature cattle with marbling scores ranging from TR/PD through MD/MT (Acheson et al., 2014; Semler et al., 2016; Gredell et al., 2018). However, previous reports have shown concentrate feeding of culls cows can reduce WBSF compared to non-fed cull cows (Cranwell et al., 1996), but not to the extent in which WBSF values were similar to young Select beef (Stelzleni et al., 2007). In fact, Schnell et al. (1997) reported WBSF was not influenced at all by feeding cull cows a high concentrate diet. It should be noted cull cows were typically fed 14 to 56 d on a high-concentrate diet; whereas, the cattle in the current study could have been on feed a longer period of time. Moreover, WBSF values in the current study were markedly lower than these previous results, possibly indicating differences in methodology, as well as a general population of cattle that are more tender than cattle used in research studies from the 1990s and early 2000s.

Consumer demographics

Demographic profiles of consumers that participated in sensory panels from Lubbock, TX are presented in Table 3. The majority of participating consumers were male compared female and identified as Caucasian/White most often, with the second most common ethnicity being Hispanic. These demographics slightly differ from the United States population as reported by the US Census Bureau which is 49% male and 51% female (2017). The majority of consumers were also married. Additionally, the participants in this study differed from the average American population in annual household income and education level. Approximately 43% of the participants reported an annual household income of at least $75,000 and had, at minimum, a college degree (51.7%) compared to the medium household income of the US population, $59,039, with 88% of the population obtaining a high school diploma (US Census Bureau, 2016, 2017). Throughout the last decade, the United States has remained within the top 5 countries in meat consumption with the average consumer eating 120 kg of red meat per year (Daniel et al., 2011). Therefore, it was no surprise that 97.5% of the participants eat beef at least once per week and 75.8% prefer beef flavor to all other meat types. Nearly one-half of the participants identified flavor as the most important palatability trait when eating beef, followed by tenderness and juiciness.

Consumer palatability ratings

Consumer sensory ratings for tenderness, juiciness, flavor liking, and overall liking are shown in Table 4 and acceptability classification can be found in Table 5. Treatment influenced tenderness, juiciness, flavor liking, and overall liking ($P < 0.01$). For all traits, consumer scores generally decreased with decreasing marbling score, regardless of maturity, but adjacent marbling scores were often similar. The positive relationship between marbling and increased consumer tenderness within A maturity beef has been firmly established in previously published literature (O'Quinn et al., 2012; Hunt et al., 2014; Corbin et al., 2015). Within young samples in the current study, SLAB+ and MD/MT were similar ($P > 0.05$) and were scored more tender ($P < 0.05$) than SM, SL, and TR/PD, which were also similar ($P > 0.05$) to each other. Within mature samples, SLAB+ and MD/MT were

Table 3. Demographic characteristics of consumers ($n = 120$) who participated in consumer sensory panels

Characteristic	Response	Consumers, %
Gender	Male	57.5
	Female	42.5
Household size	1 person	11.7
	2 people	14.2
	3 people	25.0
	4 people	25.0
	5 people	16.7
	6 people	6.7
	> 6 people	0.8
Marital Status	Single	30.0
	Married	69.2
Age	Under 20	13.3
	20–29	17.5
	30–39	25.8
	40–49	18.3
	50–59	17.5
	Over 60	7.5
Ethnic Origin	African-American	4.2
	Asian	0.8
	Caucasian/White	67.5
	Hispanic	27.5
Annual Household Income	Under $25,000	14.2
	$25,000- $34,999	5.8
	$35,000- $49,999	17.5
	$50,000- $74,999	19.2
	$75,000- $100,000	20.8
	> $100,000	22.5
Education Level	Non-high school graduate	2.5
	High school graduate	15.0
	Some college/Technical school	30.8
	College graduate	40.0
	Post graduate	11.7
Weekly beef consumption	None	2.5
	1 to 3 times	36.7
	4 to 6 times	47.5
	7 or more times	13.3
Most important palatability trait when eating beef	Flavor	48.3
	Juiciness	12.5
	Tenderness	39.2
Meat product preferred for flavor	Beef	75.8
	Chicken	10.8
	Fish	0.8
	Lamb	0.8
	Pork	3.3
	Shellfish	2.5
	Turkey	1.7
	Veal	0.0
	Venison	4.2

Table 4. Least squares means for consumer ($n = 120$) sensory ratings[1] of the palatability traits of beef strip loin steaks from grain-finished, young (A maturity) and mature (C, D, and E maturity) carcasses with varying marbling degrees[2]

Treatment	Tenderness	Juiciness	Flavor liking	Overall liking
Young				
SLAB+	70.9[a]	66.1[a]	63.3[a]	63.0[a]
MD/MT	66.7[ab]	58.6[abc]	61.9[ab]	62.7[a]
SM	54.4[cd]	50.4[bcd]	50.4[cde]	52.3[bc]
SL	58.2[c]	54.3[bcd]	51.1[cd]	55.6[ab]
TR/PD	53.6[cd]	50.7[cde]	46.2[cde]	50.1[c]
Mature				
SLAB+	59.6[bc]	62.3[ab]	52.1[cd]	57.4[ab]
MD/MT	55.9[c]	50.8[cde]	53.4[bc]	54.5[b]
SM	51.9[cd]	52.5[bcde]	51.1[cd]	53.4[bc]
SL	46.3[de]	46.0[de]	43.6[de]	45.9[cd]
TR/PD	42.5[e]	43.4[e]	41.6[e]	41.8[d]
SEM[3]	3.4	4.0	3.4	3.0
P-value	< 0.01	< 0.01	< 0.01	< 0.01

[a–e] Least squares means in the same column without a common superscript differ ($P < 0.05$).

[1]Sensory scores: 0 = extremely dry/tough/unbeef-like, dislike extremely; 100 = extremely juicy/tender/beef-like, like extremely.

[2]Marbling degrees: SLAB+ = ≥ slightly abundant^{00}; MD/MT = modest^{00} to moderate^{100}; SM = small^{00} to small^{100}; SL = slight^{00} to slight^{100}; TR/PD = practically devoid^{00} to traces^{100}.

[3]Standard error (largest) of the least squares means.

similarly ($P > 0.05$) scored more tender ($P < 0.05$) than SL and TR/PD, but SM did not differ ($P > 0.05$) from any of the other mature samples for tenderness. Tenderness acceptability followed a fairly similar trend as tenderness scores ($P < 0.01$; Table 5).

Consumers scored Y-SLAB+ greater ($P < 0.05$) for juiciness than all other young marbling scores except MD/MT, and M-SLAB+ was scored juicier ($P < 0.05$) than all other mature marbling scores except M-SM. Juiciness scores translated to greater ($P < 0.05$) juiciness acceptability for Y-SLAB+ compared to all other young treatments except Y-MD/MT, and a greater ($P < 0.05$) proportion of consumers that considered M-SLAB+ acceptable for juiciness compared to all other mature treatments except M-SM (Table 5).

Within young samples, SLAB+ and MD/MT were similar ($P > 0.05$) for flavor liking and were more liked ($P < 0.05$) than SM, SL, and TR/PD, which were also similar ($P > 0.05$) to each other. However, flavor acceptability of Y-SLAB+ was only greater ($P < 0.05$) than Y-TR/PD and similar ($P > 0.05$) to all other young samples. Within mature samples, TR/PD had lower ($P < 0.05$) flavor liking than all other marbling scores except M-SL. Flavor liking of M-SLAB+ did not differ

Table 5. Percentage of beef strip loin steaks from grain-finished, young (A maturity) and mature (C, D, and E maturity) carcasses with varying marbling degrees[1] that were classified as acceptable for juiciness, tenderness, flavor liking, and overall liking by consumer sensory panelists (n = 120)

Treatment	Tenderness	Juiciness	Flavor liking	Overall liking
Young				
SLAB+	93.3^{a}	84.2^{a}	80.8^{abc}	87.5^{a}
MD/MT	90.0^{a}	79.2^{abc}	81.7^{ab}	84.2^{ab}
SM	77.5^{bc}	67.0^{de}	70.6^{cde}	71.7^{cd}
SL	78.2^{bc}	72.8^{bcd}	73.1^{bcde}	77.5^{abc}
TR/PD	73.1^{cd}	69.1^{cde}	67.5^{de}	70.0^{cd}
Mature				
SLAB+	86.4^{ab}	80.8^{ab}	84.9^{a}	80.7^{abc}
MD/MT	78.3^{bc}	69.6^{cd}	78.2^{abcd}	75.6^{bc}
SM	74.0^{c}	70.3^{bcd}	73.3^{bcde}	76.5^{bc}
SL	61.7^{de}	63.1^{de}	63.3^{e}	62.5^{d}
TR/PD	57.1^{e}	56.6^{e}	62.2^{e}	62.2^{d}
SEM[2]	0.1	0.1	< 0.1	< 0.1
P-value	< 0.01	< 0.01	< 0.01	< 0.01

[a–e] Least squares means in the same column without a common superscript differ (P < 0.05).

[1]Marbling degrees: SLAB+ = ≥ slightly abundant^{00}; MD/MT = modest^{00} to moderate^{100}; SM = small^{00} to small^{100}; SL = slight^{00} to slight^{100}; TR/PD = practically devoid^{00} to traces^{100}..

[2]Standard error (largest) of the least squares means.

(P > 0.05) from any other mature marbling score except M-TR/PD. Despite the overwhelming lack of difference in flavor liking scores of mature samples, consumers found M-SLAB+ acceptable for flavor more often (P < 0.05) than all other mature marbling scores except M-MD/MT (P > 0.05). It should be noted that the cooking method (charbroiling) used for the current study could have prevented consumers from distinguishing flavor liking between each marbling score. Sepulveda (2018) found cooking beef strip loin steaks using a char broiler resulted in considerably greater flavor liking scores than steaks cooked on a clamshell grill, which is common in university research, a flat top gas grill, or salamander gas broiler. In addition, consumers did not distinguish flavor liking, regardless of cook method, between Prime and Top Choice or between Low Choice and Select (Sepulveda, 2018), which supports the current findings.

Consumers scored Y-SLAB+ and Y-MD/MT greater (P < 0.05) for overall liking compared to Y-SM and Y-TR/PD, but similar to Y-SL (P > 0.05). Overall acceptability of young samples followed the same trend. Similar to young samples, M-SLAB+ and M-MD/MT had greater (P < 0.05) overall liking scores than lower marbling scores (M-SL and M-TR/PD). Consequently, a greater (P < 0.05) proportion of consumers found the higher marbling scores (M-SLAB+, M-MD/MT, and M-SM) acceptable overall compared to the lower marbling scores (M-SL and M-TR/PD). Previous studies have found similar results that as marbling scores increase, overall palatability ratings also increase for consumers (O'Quinn et al., 2012; Hunt et al., 2014; Corbin et al., 2015).

According to consumers, maturity had no effect on juiciness or flavor liking within each marbling score, except flavor liking of SLAB+ was greater (P < 0.05) for young than mature strip loin steaks. Conversely, young carcasses had strip loin steaks with greater tenderness scores than mature within all marbling scores except SM, which translated to greater overall liking of MD/MT, SL, and TR/PD of young compared to their mature counterparts (P < 0.05). These findings contradict the similarity in WBSF values between marbling scores between young and mature carcasses. Similar shear force values for all marbling scores, except SM, would suggest tenderness should not have differed. Moreover, a WBSF value of 3.4 kg should result in 99% consumer acceptability for tenderness according to Miller et al. (2001). However, several studies in the past 10 yr have shown despite average WBSF values below 3.4 kg, tenderness acceptability still waivers and certainly has not achieved 99% consumer acceptability for tenderness (Igo et al., 2011; Garmyn et al., 2014; Hunt et al., 2014; Corbin et al., 2015; Ron et al., 2019). Girard et al. (2012) showed that correlation coefficients between soluble collagen content and connective tissue shear force was stronger than that of soluble collagen and peak shear force, and that myofibrillar shear force was not correlated at all with total or soluble collagen content. Therefore, the connective tissue component of muscle is better represented by the connective tissue shear force than myofibrillar shear force; however, shear force was not separated into connective tissue or myofibrillar components in the current study. According to Gredell et al. (2018), WBSF values or consumer tenderness scores did not differ between young fed and mature fed beef strip steaks with SL or TR/PD marbling. However, concentrations of heat soluble collagen was greater from young carcasses than mature fed carcasses, resulting in greater total collagen concentrations (Gredell et al., 2018). Potential variation in heat soluble collagen, which was not measured in the current study, could explain why no differences where observed in WBSF, but consumers found differences in tenderness due to maturity within marbling scores. Despite lower (P < 0.05) tenderness and flavor liking of Y-SLAB+ compared to M-SLAB+, overall liking did not differ (P > 0.05) between those

Table 6. Least squares means for trained sensory panelist ratings[1] of the palatability traits of beef strip loin steaks from grain-finished, young (A maturity) and mature (C, D, and E maturity) carcasses with varying marbling degrees[2]

Treatment	Initial juiciness	Sustained juiciness	Initial tenderness	Sustained tenderness	Beef flavor	Beef flavor intensity	Off flavor intensity
Young							
SLAB+	80.4[a]	81.2[a]	84.5[a]	85.2[a]	84.4[a]	78.3[a]	5.8[bc]
MD/MT	70.2[bc]	70.0[bc]	80.6[ab]	79.6[ab]	80.2[ab]	73.9[ab]	4.2[c]
SM	64.2[cd]	63.2[cde]	72.5[bc]	70.7[cdef]	80.0[abc]	73.1[abc]	6.1[bc]
SL	70.1[bc]	67.5[cd]	76.3[abc]	74.6[bcd]	77.5[bc]	71.0[bcd]	6.0[bc]
TR/PD	61.5[d]	57.3[e]	70.4[cd]	66.8[cdef]	75.1[cd]	67.0[cd]	11.0[abc]
Mature							
SLAB+	76.1[ab]	77.3[ab]	76.6[abc]	75.4[abc]	83.7[a]	78.6[a]	4.2[c]
MD/MT	68.9[bcd]	67.8[cd]	70.3[cd]	68.4[cdef]	77.7[bc]	72.6[abc]	13.2[ab]
SM	68.2[bcd]	65.6[cde]	68.0[cd]	64.8[def]	77.8[bc]	70.4[bcd]	7.4[bc]
SL	68.1[bcd]	67.7[cd]	68.5[cd]	64.4[ef]	77.6[bc]	70.9[bcd]	9.2[bc]
TR/PD	61.3[d]	59.5[de]	62.3[d]	58.6[f]	71.4[d]	66.3[d]	18.3[a]
SEM[3]	3.0	3.3	3.3	3.7	1.9	2.3	2.9
P-value	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

[a–f] Least squares means in the same column without a common superscript differ ($P < 0.05$).

[1]Sensory scores: 0 = extremely dry/tough/bland/unbeef-like/bland; 100 = extremely juicy/tender/beef-like/intense.

[2]Marbling degrees: SLAB+ = ≥ slightly abundant[00]; MD/MT = modest[00] to moderate[100]; SM = small[00] to small[100]; SL = slight[00] to slight[100]; TR/PD = practically devoid[00] to traces[100].

[3]SEM:Standard error (largest) of the least squares means.

2 treatments. Maturity had little effect on acceptability of all traits within each marbling score (Table 5); however, the most noticeable decrease in acceptability occurred for tenderness, as mature samples had a lower ($P < 0.05$) proportion of acceptable samples for tenderness for the MD/MT, SL, and TR/PD marbling scores compared to the proportion of young samples that were acceptable for tenderness within those marbling scores. Additionally, M-SL had lower ($P < 0.05$) overall acceptability than Y-SL, but no other differences in overall acceptability were observed between maturity within a marbling score ($P > 0.05$). Gredell et al. (2018) reported no differences in consumer tenderness, juiciness, flavor liking, and overall liking scores due to maturity when focusing on slight or lower marbling scores, suggesting enough marbling was present to offset any negative palatability issues related to advanced maturity. Although palatability scores were not different due to maturity, Gredell et al. (2018) did observe differences in the acceptability of each palatability trait due to maturity. Generally speaking, these findings demonstrate the importance of marbling in consumer acceptability ratings and even that as an animal increases in age, beef can recover and even surpass steaks of younger animals for certain palatability characteristics if marbling is present. However, it should be noted these results may not be expected of all mature fed beef programs and implications should be limited to beef produced from mature cattle fed for this particular program.

Trained panels

As seen in Table 6, trained panelists detected very few differences between young and mature samples within their respective marbling scores; however, M-MD/MT had lower initial and sustained tenderness coupled with greater off-flavor intensity than Y-MD/MT ($P < 0.05$). The M-SL also had lower sustained tenderness compared to Y-SL ($P < 0.05$). Previous researchers have also found trained panelists were unable to differentiate tenderness, juiciness, or flavor due to maturity between steaks from A maturity compared to B–D maturity representing 3 marbling categories ranging from slight to moderate (Acheson et al., 2014; Semler et al., 2016). Similarly and in support of the current findings, trained panelists could not detect differences in juiciness, tenderness, beef flavor, and beef flavor intensity between young beef and mature fed beef representing slight and lower marbling scores (Gredell et al., 2018). These results suggest USDA carcass maturity may not effectively identify differences in longissimus palatability when mature cattle were a fed high energy concentrate diet prior to harvest, despite previous results that indicate USDA maturity was capable of grouping carcasses based on differences in flavor, tenderness, and overall palatability (Smith et al., 1982; Hilton et al., 1998).

The Y-SLAB+ had distinctly greater ($P < 0.05$) initial and sustained juiciness than all other lower marbling scores from young carcasses. Initial juiciness of

M-SLAB+ was similar to all other treatments, except M-TR/PD. The M-SLAB+ had clearly elevated sustained juiciness compared to all other lower marbling scores from mature carcasses. Unlike previous reports (Garmyn et al., 2011; Acheson et al., 2014; Semler et al., 2016), panelists in the current study did not detect differences in juiciness due to marbling from slight to moderate, regardless of maturity.

The Y-SLAB+ and Y-MD/MT had similar and greater ($P < 0.05$) initial and sustained tenderness than Y-TR/PD. The M-SLAB+ was more tender ($P < 0.05$) initially compared to M-TR/PD, but after subsequent chews, M-SLAB+ was more tender ($P < 0.05$) than all other lower marbling scores from mature carcasses except M-MD/MT. Again previous reports (Garmyn et al., 2011; Acheson et al., 2014; Semler et al., 2016) have shown panelists can detect difference in tenderness due to marbling or quality grade, which contradicts the current findings.

Beef flavor of Y-SLAB+ was similar ($P > 0.05$) to Y-MD/MT and Y-SM; however, Y-SM did not differ from Y-SL or Y-TR/PD ($P > 0.05$). The M-SLAB+ had similar ($P > 0.05$) beef flavor to the 3 highest marbling scores from young carcasses and had more intense ($P < 0.05$) beef flavor compared to all other marbling scores from mature carcasses. Flavor intensity followed a similar trend for young samples, but M-SLAB+ and M-MD/MT had similar flavor intensity ($P > 0.05$). The M-TR/PD had greater off-flavor intensity compared to all other treatments except M-MD/MT and Y-TR/PD. With the exception of M-MD/MT, off-flavor intensity generally decreased as marbling score increased within both young and mature samples.

These results suggest there is potentially significant value in feeding cull cows prior to slaughter so that cull cows may provide a similar eating experience to that of young cattle.

CONCLUSION

For all traits, consumer scores generally decreased with decreasing marbling score, regardless of maturity, but adjacent marbling scores were often similar. Generally speaking, these findings reinforce the importance of marbling in consumer acceptability ratings and even that as an animal increases in age, beef can recover and even surpass steaks of younger animals for certain palatability characteristics if marbling is present. Trained panelists detected very few differences between young and mature samples within their respective marbling scores. These results add significance supporting the potential value of feeding cull cows prior to slaughter so that cull cows may provide strip loin steaks with similar eating experience to that of young cattle with comparable marbling scores. Moreover, results suggest USDA carcass maturity may not effectively identify differences in longissimus palatability when cull cows are grain fed to supply beef for this particular white cow program. Ultimately, presence of marbling as a result of feeding a high energy concentrate diet prior to harvest in mature beef may elicit a similar eating experience to young beef by offsetting negative palatability traits often associated with mature beef. However, it should be noted these results may not be expected of all mature fed beef programs and implications should be limited to beef produced from mature cattle fed for this particular white cow program.

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