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Effects of USDA carcass maturity on sensory attributes of beef produced by grain-finished steers and heifers classified as less than 30 months old using dentition[1]

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ABSTRACT: This study compared sensory properties of LM steaks from A maturity and B maturity or older carcasses that were produced by grain-finished steers and heifers classified as less than 30 mo old at the time of slaughter using dentition. Carcasses were selected to represent 2 maturity groups and 3 marbling categories within each maturity group, resulting in 6 maturity × marbling subclasses, each subclass consisting of 75 carcasses. Maturity groups consisted of carcasses classified by USDA graders as either A^{00} to A^{99} overall (A) maturity or B^{00} to C^{99} overall (B-C) maturity; marbling categories consisted of carcasses with instrument marbling scores of Slight (SL), Small (SM), or $Modest^{00}$ or greater (MT+). Carcasses were selected in pairs so that each carcass chosen to represent the B-C maturity group was paired with an A maturity carcass of the same sex and marbling score (±30 marbling units). Strip loin (LM) steaks were obtained from both sides of each carcass. After a 14-d aging period, 1 LM steak was measured for Warner-Bratzler shear force (WBSF) and slice shear force (SSF), whereas the other LM steak was used for sensory analysis by a trained descriptive attribute panel. No differences ($P > 0.05$) in WBSF, SSF, or sensory panel ratings for tenderness, juiciness, or flavor were detected between LM steaks from carcasses classified as A maturity and steaks from B-C maturity carcasses. However, marbling categories effectively stratified carcasses (MT+ > SM > SL) according to differences ($P < 0.0001$) in LM tenderness, juiciness, meaty/brothy flavor, and buttery/beef fat flavor. Increased marbling also was associated with lesser ($P < 0.01$) intensities of bloody/serumy and livery/organy flavors and reduced ($P < 0.01$) values for WBSF and SSF. Of the traits tested, only bloody/serumy flavor was affected ($P < 0.05$) by the maturity × marbling interaction. Interaction means showed that LM steaks from B-C maturity carcasses with SL marbling had a less intense bloody/serumy flavor than did steaks from A maturity carcasses with SL marbling. Results of this study suggest that, when applied to carcasses from grain-finished cattle whose dental ages are less than 30 mo old at the time of slaughter, USDA quality grades would be no less effective in identifying eating quality differences if the A and B-C maturity groups were combined and quality grades were assigned using only marbling.

Key words: beef, carcass, grading, maturity, quality, tenderness

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INTRODUCTION

The USDA beef quality grading system (USDA, 1997) involves the use of carcass indicators of physiological maturity (vertebral ossification, size and shape of the ribs, and color and texture of the LM at the 12th rib) to reflect age-associated differences in beef tenderness. The U.S. grade standards (USDA, 1997) recognize 5 maturity groups (A, B, C, D, and E), the youngest of which (A maturity) normally includes carcasses of cattle 9 to 30 mo old (USDA, 1996). Occasionally, however, cattle less than 30 mo old produce B maturity (or older) carcasses due to premature vertebral ossification, resulting in a reduction of final quality grade and decreased value in the U.S. beef trade (Tatum, 2011).

Another method of estimating bovine age or maturity is to determine an animal's dental age (Graham and Price, 1982). Currently, dentition is not used for USDA grading; however, since 2004, U.S. beef proces-

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sors have been required to segregate beef carcasses into 2 age groups (<30 mo and ≥30 mo) using documentation of actual age or dentition (FSIS, 2004).

Previous research has failed to demonstrate a consistent relationship between USDA carcass maturity and beef tenderness when comparisons among maturity groups are restricted to include only carcasses produced by grain-finished steers and heifers (Miller et al., 1983; Field et al., 1997). Correspondingly, it could be argued that carcasses from fed steers and heifers whose actual or dental ages are less than 30 mo at the time of slaughter should be considered A maturity for grading purposes, regardless of their carcass maturity characteristics, provided that beef derived from those carcasses provides the same eating experience as beef from carcasses classified as A maturity by USDA graders. This study was conducted to compare sensory properties of beef from A maturity and B maturity or older carcasses produced by grain-finished steers and heifers classified as less than 30 mo old at the time of slaughter using dentition.

MATERIALS AND METHODS

Institutional Animal Care and Use Committee approval was not obtained because no live animals were involved in this study. The experimental sample consisted of chilled beef carcasses (n = 450) selected at 2 commercial fed-beef processing plants located in Colorado and Nebraska.

Carcass Selection

Carcass selection began 13 August 2012 and concluded 6 November 2012. Sampling for the experiment was restricted to include only beef carcasses produced by cattle that had been classified as less than 30 mo old at the time of slaughter based on dentition. Carcasses were selected to represent 2 maturity groups and 3 marbling categories within each maturity group. Maturity groups (USDA, 1997) included A^{00} to A^{99} overall (**A**) maturity and B^{00} to C^{99} overall (**B-C**) maturity; marbling categories (USDA, 1997) included Slight (**SL**), Small (**SM**), and Modest^{00} or greater (**MT+**).

Carcasses were preselected based on a cursory assessment of carcass maturity characteristics and the official marbling score, which was determined using an online, USDA-approved instrument grading system (E+V Technology, Oranienburg, Germany). Preselected carcasses then were transferred to stationary rails for official maturity classification by USDA graders and further data collection by the research team. Carcasses were evaluated by USDA graders who determined official skeletal, lean, and overall maturity scores. Final selection of a carcass for inclusion in the study was based on the official overall maturity score and the instrument-based marbling score. Each carcass selected to represent the B-C maturity group was paired with an A maturity carcass of the same sex and marbling score (±30 marbling units). When possible, paired carcasses were selected from the same slaughter lot.

Colorado State University personnel recorded the following information for each selected carcass: HCW, subcutaneous fat thickness at the 12th rib, adjusted preliminary yield grade, estimated KPH fat percentage, and sex classification (heifer or steer). Instrument measurements of LM area were retrieved from the data archives at each plant and were used to calculate yield grade.

Within 1 h of carcass ribbing, L*, a*, and b* values were measured (Hunter Lab Miniscan, Model 45/O-S; Hunter Associates Laboratory Inc., Reston, VA) in triplicate on the exposed surface of the LM at the 12th to 13th rib interface. Objective color measurements obtained from the left and right sides of each carcass were averaged to obtain a single L* (0 = black and 100 = white), a* (negative number = green and positive number = red), and b* (negative number = blue and positive number = yellow) value for the carcass. The spectrophotometer (6-mm aperture and D-65 light source) was calibrated with black and white tiles and was operated in a 2°C cooler environment.

Of the carcasses eventually selected for the study, 252 (56%) were produced by heifers and 198 (44%) were produced by steers. Cattle type, carcass weight, and yield grade were allowed to vary randomly in the experimental sample. Carcasses with quality or dressing defects (i.e., blood splash, dark cutters, fat pulls, excessive trimming, etc.) were excluded from the study.

Longissimus Muscle Sampling and Postmortem Aging

After completion of carcass data collection, LM samples (4 cm thick) were removed from the 13th rib region of the left and right sides of each carcass to be used for shear force measurement and sensory evaluation. Samples were packaged in barrier bags and transported in ice-filled coolers to the Colorado State University Meat Laboratory. Upon arrival, all samples were individually vacuum packaged and aged at 2°C until the 14th day postmortem. On the 14th day postmortem, vacuum-packaged LM samples were frozen and stored at –20°C. All frozen LM sections subsequently were fabricated using a band saw (Model 400, AEW-Thurne; AEW Engineering Co. Ltd., Norwich, UK) to yield 1 steak (2.5 cm thick) per section. The LM steak from the right side of each carcass was designated for shear force measurements and the LM steak from the left side of each carcass was used for sensory analysis.

Shear Force Measurements

Steaks to be measured for shear force were stratified by maturity and marbling degree and randomly allocated to 3 blocks, each block consisting of 150 steaks. Blocks included equal numbers of steaks representing the 2 maturity levels and the 3 degrees of marbling within maturity level. Shear force measurements were obtained on 3 different days with all steaks in a block being measured for shear force on the same day.

Frozen steaks used for Warner-Bratzler shear force (**WBSF**) and slice shear force (**SSF**) were tempered for 36 to 48 h to ensure that raw internal steak temperatures were between 1 and 5°C. Steaks then were cooked on a convection conveyor oven (Model 1832-EL XTL OVENS; BOFC Inc., Wichita, KS) to attain a peak internal temperature of 71°C. A type K thermocouple thermometer (AccuTuff 340, model 34040; Cooper-Atkins Corporation, Middlefield, CT), placed in the geometric center of each steak, was used to measure peak internal temperature.

Warner-Bratzler shear force and SSF measurements were obtained from the same steak using procedures described by Lorenzen et al. (2010). Within 5 min of recording peak internal temperature, a 1-cm-thick, 5-cm-long slice was removed from the steak parallel to the muscle fibers and sheared perpendicular to the muscle fibers, using a universal testing machine (Instron Corp., Canton, MA) equipped with a flat, blunt-end blade (crosshead speed: 500 mm/min and load capacity: 100 kg), resulting in a single SSF measurement for each steak. The lateral portion (approximately one-third) of the LM steak was used for SSF measurement. The remaining portion of each steak was allowed to equilibrate to room temperature (22°C) and 4 to 6 cores (1.2 cm in diam.) were removed from each steak parallel to the muscle fibers. Each core was sheared once, perpendicular to the muscle fibers, using a universal testing machine (Instron Corp., Canton, MA) fitted with a Warner-Bratzler shear head (crosshead speed: 200 mm/min and load cell capacity: 100 kg). Peak shear force of each core was recorded, and the resulting values were averaged to obtain a single WBSF for each steak.

Sensory Analysis

Cooked LM samples from the left side of each carcass were used for sensory analysis to characterize descriptive sensory attributes. Steaks designated for sensory analysis were stratified by maturity level and degree of marbling within maturity level and randomly allocated to 37 complete blocks (12 steaks per block) and 1 partial block (6 steaks). Each block consisted of equal numbers of steaks representing the 2 maturity levels and the 3 degrees of marbling within maturity level. Two blocks were evaluated for sensory attributes on the same day (12 samples per session) with 5 h between sessions.

Panelists were trained, selected, and tested to determine their abilities to distinguish and rate differences in meat tenderness, juiciness, and flavor according to the procedures outlined by Adhikari et al. (2011) and Miller and Prusa (2010). The lexicon of descriptive attributes used for sensory training and analysis (AMSA, 1995; Adhikari et al., 2011) included tenderness, juiciness, and the following flavor descriptors: meaty/brothy (basic flavor and aroma of grilled or roasted beef; simulated by the flavor of beef broth), buttery/beef fat (flavor and aroma associated with cooked fat from grain-finished beef; often described as a buttery flavor), bloody/serumy (flavor and aroma associated with blood in beef cooked to a rare degree of doneness; sometimes described as a metallic taste), livery/organy (flavor and aroma associated with cooked beef liver or kidney), grassy (flavor and aroma of beef produced by grass-finished or short-fed cattle; often described as green or hay-like), and gamey (flavor and aroma associated with wild game meat).

Frozen steaks used for each panel session were tempered for 36 to 48 h to ensure that raw internal steak temperatures were between 1 and 5°C. Steaks were cooked on electric grills (model GGR64; Salton, Inc., Mt. Prospect, IL) that heated the steaks from both sides simultaneously to a target peak internal temperature of 71°C. A type K thermocouple thermometer (AccuTuff 340, model 34040; Cooper-Atkins Corporation, Middlefield, CT) placed in the geometric center of each steak was used to measure peak internal temperature. After cooking, steaks were cut into 1.3 by 1.3 by 1.3 cm cubes, placed in a glass bowl, wrapped in aluminum foil, and held in a warming oven at 70°C for a maximum of 30 min before being served to a 8-member trained descriptive attribute panel. Each panelist received 2 cubes from each steak. Panelists were seated in individual cubicles equipped with red incandescent light to mask color differences among samples. Each panelist was supplied with unsalted saltine crackers, distilled water, and unsweetened apple juice for palate cleansing between samples. Sensory attributes of each sample were quantified using 15-cm unstructured line scales anchored at both ends with descriptive terms. For each line scale, 0 denoted a very low intensity of that specific attribute, while 15 denoted a very high intensity of the attribute. Sensory testing was conducted for 19 d with a routine, 1-d retraining session conducted at midpoint. For each sample, individual panelists' scores were averaged to determine a single value for each sensory attribute.

Statistical Methods

All analyses used statistical procedures of SAS (SAS Inst. Inc, Cary NC). Preliminary data analysis showed that sex class did not affect ($P > 0.05$) carcass quality grade traits or any of the LM characteristics examined in this study. Therefore, data for heifers and steers were pooled for further analysis.

Least squares analyses were conducted using REML-based, mixed model procedures (PROC MIXED). Carcass quality grade traits (marbling score and scores for skeletal, lean, and overall maturity) and LM color measurements (L*, a*, and b*) were analyzed using a statistical model that included fixed effects of maturity group, marbling category, and maturity group × marbling category along with random effects of day of carcass selection and pair nested within marbling category × sex subclass. Sensory panel ratings and LM shear force measures were analyzed using statistical models that included fixed effects of maturity group, marbling category, and maturity group × marbling category and random effects of day of carcass selection, block, and pair nested within marbling category × sex subclass. Peak temperature of the steak after it was removed from the grill also was included in the model as a covariate.

Analyses conducted to determine probabilities of LM steaks meeting ASTM International standard specifications for shear force (ASTM, 2011), with the response variable coded as 1 and 0, were performed using PROC GLIMMIX. The statistical model used for these analyses included fixed effects of maturity group, marbling category, and maturity group × marbling category and random effects of day of carcass selection, block, and pair. Peak temperature of the steak after it was removed from the grill was used as a covariate.

For all analyses, denominator degrees of freedom were calculated using the Satterthwaite approximation. Least squares means were compared, using the PDIFF option of LSMEANS, when F-tests were significant. All comparisons were tested using a comparison-wise significance level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

Characteristics of Experimental Sample

Data presented in Tables 1 and 2 characterize the sample of beef carcasses selected for the experiment. Selection of carcasses in pairs, so that each B-C maturity carcass was paired with a matching A maturity carcass (same sex and marbling score within 30 units), resulted in equal distributions of steer and heifer carcasses within the 2 maturity groups (Table 1) and no difference ($P = 0.6271$) in mean marbling scores between maturity groups (Table 2). The number of steer and heifer carcasses selected to represent each marbling category was not strictly controlled (Table 1); however, marbling categories consisted of comparable ($P = 0.1054$) percentages of steer and heifer carcasses (SL: 51% steers and 49% heifers, SM: 43% steers and 57% heifers, and MT+: 39% steers and 61% heifers).

Table 1. Sample of steer and heifer carcasses ($n = 450$) selected to represent 2 maturity groups and 3 marbling categories

Marbling category	A maturity[1]		B-C maturity[2]	
	Steer	Heifer	Steer	Heifer
	Number of carcasses			
Slight	38	37	38	37
Small	32	43	32	43
Modest+[3]	29	46	29	46

[1]Carcasses exhibiting A^{00} to A^{99} overall (A) maturity characteristics.
[2]Carcasses exhibiting B^{00} to C^{99} overall (B-C) maturity characteristics.
[3]Modest+ = carcasses with $Modest^{00}$ or greater marbling scores.

By design, carcass maturity characteristics (skeletal, lean, and overall maturity scores) differed ($P < 0.0001$) for the 2 maturity groups but not ($P > 0.05$) among marbling categories (Table 2). Moreover, within both maturity groups, carcasses with SL, SM, and MT+ marbling all had very similar mean scores for skeletal, lean, and overall maturity (Table 2). Consequently, the interaction between maturity group and marbling category was not ($P > 0.05$) a significant source of variation in skeletal, lean, or overall maturity (Table 2).

Overall maturity scores ranged from A^{30} to A^{90} within the A maturity group and from B^{00} to C^{80} within the B-C maturity group. Of the carcasses chosen to represent the B-C maturity group, 70% were classified as B maturity and 30% were classified as C maturity, based on overall maturity scores assigned by USDA graders. The difference in overall maturity scores for A maturity vs. B-C maturity carcasses was due primarily to the more ($P < 0.0001$) advanced skeletal maturity characteristics of the B-C maturity carcasses (Table 2), although B-C maturity carcasses also exhibited more ($P < 0.0001$) mature lean characteristics (Table 2).

Color of the LM at the 12th rib is used as an indicator of physiological maturity (i.e., lean maturity) by USDA graders when assigning quality grades to beef carcasses (USDA, 1997). Previous studies have shown that as cattle mature, carcass lean tissue becomes progressively darker red in color (Tuma et al., 1963; Romans et al., 1965; Breidenstein et al., 1968). Objective LM color measurements, obtained shortly after each carcass was evaluated for maturity (Table 2), confirmed that B-C maturity carcasses had lower ($P = 0.0156$) L* values (darker-colored lean) and higher ($P = 0.0271$) a* values (redder-colored lean) than did A maturity carcass-

Table 2. United States Department of Agriculture quality grade traits and objective LM color measurements for beef carcasses selected to represent 2 maturity groups and 3 marbling categories

		USDA quality grade trait[1]				LM color measurement[2]		
Effect	*n*	Marbling score	Skeletal maturity score	Lean maturity score	Overall maturity score	L*	a*	b*
Maturity (MAT)		$P = 0.6271$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P = 0.0156$	$P = 0.0271$	$P = 0.3689$
A[3]	225	456	160	149	155	39.6	12.1	25.5
B-C[4]	225	458	281	160	241	38.8	12.4	25.2
SEM		4.4	3.1	2.0	2.7	0.84	0.27	0.48
Marbling (MARB)		$P < 0.0001$	$P = 0.6079$	$P = 0.5692$	$P = 0.8929$	$P = 0.1214$	$P = 0.0060$	$P = 0.0223$
Slight	150	362[c]	220	155	198	38.6	11.7[b]	24.6[b]
Small	150	442[b]	219	156	197	39.2	12.2[b]	25.2[b]
Modest+[5]	150	569[a]	223	153	199	39.8	12.9[a]	26.3[a]
SEM		5.0	3.6	2.8	3.2	0.86	0.33	0.58
MAT × MARB		$P = 0.8834$	$P = 0.6851$	$P = 0.5883$	$P = 0.8575$	$P = 0.6205$	$P = 0.5350$	$P = 0.7742$
A Slight	75	362	158	148	154	39.1	11.5	24.7
A Small	75	439	160	150	155	39.3	12.1	25.4
A Modest+	75	568	162	148	157	40.3	12.7	26.3
B-C Slight	75	361	282	161	242	38.2	11.9	24.4
B-C Small	75	444	277	162	239	39.0	12.2	25.0
B-C Modest+	75	570	283	157	241	39.3	13.2	26.3
SEM		6.0	4.6	3.2	4.1	0.90	0.38	0.63

[a–c]Means in the same column within an effect that do not share a common superscript letter differ ($P < 0.05$).

[1]Marbling scores were measured using USDA-approved grading instruments (Slight = 300 to 399, Small = 400 to 499, Modest = 500 to 599). Carcass maturity characteristics (USDA, 1997) were evaluated and scored by official USDA graders (A = 100 to 199 and B = 200 to 299).

[2]L*: 0 = black and 100 = white; a*: negative number = green and positive number = red; b*: negative number = blue and positive number = yellow.

[3]Carcasses exhibiting A^{00} to A^{99} overall (A) maturity characteristics.

[4]Carcasses exhibiting B^{00} to C^{99} overall (B-C) maturity characteristics.

[5]Modest+ = carcasses with $Modest^{00}$ or greater marbling scores.

es, which was consistent with lean maturity scores (B-C > A) assigned by USDA graders (Table 2).

Marbling category also was a significant source of variation in LM color measurements; however, in this case, LM color differences did not reflect among-class differences in lean maturity (Table 2). Carcasses representing the MT+ category had higher ($P < 0.05$) values for a* and b* (indicative of a more cherry red lean color in the LM at the 12th rib) compared with carcasses in the SL and SM categories (Table 2).

According to Moore et al. (2012), 9.9% of all carcasses surveyed in the 2011 National Beef Quality Audit were phenotypically classified as dairy type. However, because dairy steers are slaughtered at comparatively young ages (Eng, 2005), advanced physiological maturity characteristics occur infrequently in dairy-type carcasses. Consequently, only nondairy, beef-type carcasses were identified for use in the experimental sample.

Longissimus Muscle Sensory Properties and Shear Force Measurements

The use of physiological maturity to determine eligibility of a beef carcass for specific USDA quality grades (USDA, 1997) is based on the presumption that as cattle become older the beef they produce becomes tougher. Investigations involving cattle spanning wide ranges in chronological age have shown that increased animal age is associated with reduced beef tenderness (Hiner and Hankins, 1950; Tuma et al., 1963; Shorthose and Harris, 1990). However, when comparisons involve steers and heifers less than 30 mo old, age of the animal has been shown to have little effect on LM tenderness (Field et al., 1966; Arthaud et al., 1977; Bouton et al., 1978; Waggoner et al., 1990). An important question that has not been addressed in the scientific literature is whether or not advanced carcass maturity characteristics are associated with reduced beef tenderness among cattle whose dental ages are less than 30 mo.

Field et al. (1997) examined the relationship between LM tenderness and skeletal maturity characteristics (ranging from A to C) of carcasses produced by heifers of similar chronological ages (31 to 35 mo) slaughtered after 100 d of grain feeding and concluded that skeletal maturity was of limited value for predicting differences in LM tenderness (Field et al., 1997). Therefore, we hypothesized that advanced carcass maturity characteristics (B maturity or older), occurring among

Table 3. Least squares means comparing sensory attributes of LM steaks from carcasses representing 2 maturity groups and 3 marbling categories

		LM sensory attribute[1]							
Effect	n	Tenderness	Juiciness	Meaty/brothy flavor	Buttery/beef fat flavor	Bloody/serumy flavor	Livery/organy flavor	Grassy flavor	Gamey flavor
Maturity (MAT)		$P = 0.5301$	$P = 0.8490$	$P = 0.4499$	$P = 0.6446$	$P = 0.1270$	$P = 0.5903$	$P = 0.0743$	$P = 0.9347$
A[2]	225	8.14	7.51	8.01	5.73	1.22	0.32	0.16	0.07
B-C[3]	225	8.05	7.52	8.06	5.77	1.12	0.34	0.22	0.07
SEM		0.157	0.068	0.072	0.095	0.096	0.038	0.027	0.016
Marbling (MARB)		$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P = 0.0079$	$P < 0.001$	$P = 0.0744$	$P = 0.2878$
Slight	150	7.35[c]	7.01[c]	7.52[c]	4.97[c]	1.41[a]	0.43[a]	0.24	0.09
Small	150	8.08[b]	7.45[b]	8.07[b]	5.67[b]	1.18[b]	0.35[a]	0.19	0.08
Modest+[4]	150	8.85[a]	8.09[a]	8.51[a]	6.62[a]	0.92[c]	0.22[b]	0.14	0.05
SEM		0.175	0.076	0.080	0.107	0.103	0.045	0.032	0.023
MAT × MARB		$P = 0.2718$	$P = 0.5874$	$P = 0.3737$	$P = 0.9574$	$P = 0.0276$	$P = 0.3170$	$P = 0.8475$	$P = 0.1512$
A Slight	75	7.26	6.96	7.50	4.96	1.59[a]	0.39	0.22	0.09
A Small	75	8.13	7.49	7.99	5.66	1.18[bc]	0.38	0.16	0.10
A Modest+	75	9.02	8.09	8.54	6.58	0.89[d]	0.19	0.11	0.03
B-C Slight	75	7.43	7.07	7.53	4.98	1.23[b]	0.48	0.25	0.10
B-C Small	75	8.04	7.41	8.16	5.69	1.18[bc]	0.31	0.23	0.06
B-C Modest+	75	8.68	8.09	8.49	6.65	0.95[cd]	0.24	0.18	0.07
SEM		0.207	0.097	0.099	0.128	0.118	0.058	0.043	0.028

[a–c]Means in the same column within an effect that do not share a common superscript letter differ ($P < 0.05$).

[1]Scored using 15-cm unstructured line scales: 0 = extremely dry, extremely tough, or no presence of flavor; 15 = extremely juicy, extremely tender, or strong presence of flavor.

[2]Carcasses exhibiting A^{00} to A^{99} overall (A) maturity.

[3]Carcasses exhibiting B^{00} to C^{99} overall (B-C) maturity.

[4]Modest+ = carcasses with modest^{00} or greater marbling scores.

fed steers and heifers whose dental ages have been determined to be less than 30 mo, would not adversely affect beef tenderness, juiciness, or flavor.

Results showing the effects of maturity group on LM sensory attributes and shear force measurements are summarized in Tables 3 and 4. Sensory panelists were unable ($P > 0.05$) to detect any differences in tenderness, juiciness, or flavor between LM steaks from carcasses classified as A maturity and steaks from B-C maturity carcasses (Table 3). Moreover, neither WBSF nor SSF differed ($P > 0.05$) between maturity groups (Table 4).

According to current USDA grade standards (USDA, 1997) carcasses with the same marbling score may be assigned different quality grades if they differ in maturity classification. For example, among carcasses with a SM degree of marbling, those classified as A maturity are graded Choice, those classified as B maturity are graded Standard, and those classified as C maturity are graded Utility or Commercial (USDA, 1997). Implicit in this method of assigning quality grades to beef carcasses is the assumption that relationships between marbling and the eating qualities of beef are influenced by maturity or, in other words, that maturity and marbling interact to affect beef sensory attributes. The design of the current study included 3 marbling levels (SL, SM, and MT+) within each maturity group so that effects on LM sensory attributes and shear force could be examined.

In contrast to maturity classification, marbling categories effectively stratified carcasses (MT+ > SM > SL) according to differences ($P < 0.0001$) in LM tenderness, juiciness, meaty/brothy flavor, and buttery/beef fat flavor (Table 3). In addition, increased marbling was associated with lesser ($P < 0.01$) intensities of bloody/serumy and livery/organy flavors (Table 3) and reduced ($P < 0.01$) values for WBSF and SSF (Table 4). Of the traits presented in Tables 3 and 4, the only trait affected ($P < 0.05$) by the maturity × marbling interaction was bloody/serumy flavor (Table 3). Comparison of maturity × marbling subclass means for bloody/serumy flavor (Table 3) showed that LM steaks from B-C maturity carcasses with a SL degree of marbling had a less ($P < 0.05$) intense bloody/serumy flavor than did steaks from A maturity carcasses with SL marbling and that the decrease in bloody/serumy flavor intensity with increased marbling was greater within the A maturity group than within the B-C maturity group. Emerson et al. (2013) reported data for A maturity carcasses quantifying relationships between instrument marbling scores (Traces through Moderately Abundant) and LM sensory attributes and shear force. Differences in LM tenderness, juiciness, various

Table 4. Least squares means comparing Warner-Bratzler shear force (WBSF) and slice shear force (SSF) measurements of LM steaks from carcasses representing 2 maturity groups and 3 marbling categories

Effect	*n*	LM shear force measurement, kg: WBSF	LM shear force measurement, kg: SSF	Steaks meeting ASTM International specifications for "Certified Tender,"[1] %: WBSF specification	Steaks meeting ASTM International specifications for "Certified Tender,"[1] %: SSF specification
Maturity (MAT)		$P = 0.5915$	$P = 0.1139$	$P = 0.6712$	$P = 0.2356$
A[2]	225	4.18	18.05	66.4	74.6
B-C[3]	225	4.14	18.68	64.2	69.3
SEM		0.082	0.369	4.79	5.21
Marbling (MARB)		$P < 0.0001$	$P = 0.0018$	$P < 0.0001$	$P = 0.0003$
Slight	150	4.55[a]	20.03[a]	42.1[c]	57.4[b]
Small	150	4.17[b]	17.72[b]	65.2[b]	75.5[a]
Modest+[4]	150	3.75[c]	17.35[b]	83.1[a]	80.4[a]
SEM		0.095	0.464	5.45	6.37
MAT × MARB		$P = 0.4062$	$P = 0.0812$	$P = 0.4974$	$P = 0.1829$
A Slight	75	4.63	19.91	42.6	59.6
A Small	75	4.14	17.82	62.6	73.3
A Modest+	75	3.76	16.41	86.1	86.2
B-C Slight	75	4.47	20.15	41.5	55.1
B-C Small	75	4.19	17.61	67.6	77.6
B-C Modest+	75	3.75	18.28	79.6	72.9
SEM		0.112	0.579	6.87	7.65

[a–c]Means in the same column within an effect that do not share a common superscript letter differ ($P < 0.05$).

[1]Minimum tenderness threshold values required for classification as "Certified Tender": WBSF: 4.4 kg, SSF: 20 kg (ASTM International, 2011).

[2]Carcasses exhibiting A^{00} to A^{99} overall (A) maturity.

[3]Carcasses exhibiting B^{00} to C^{99} overall (B-C) maturity.

[4]Modest+ = carcasses with $Modest^{00}$ or greater marbling scores.

flavor characteristics, and shear force observed among marbling categories in the current study for A and B-C maturity carcasses were in close agreement with results reported by Emerson et al. (2013).

Data summarized in Tables 3 and 4 suggest that, when applied to carcasses from fed steers and heifers that have been classified as less than 30 mo old based on dentition, USDA quality grades would be no less effective in identifying eating quality differences if the A and B-C maturity groups were combined and USDA grades were assigned using only marbling. Hilton et al. (1998) compared sensory attributes and WBSF of LM steaks from A and B maturity carcasses across a broad range in marbling (Traces through Slightly Abundant) and found no differences in tenderness, juiciness, flavor, or WBSF as well as no interactions between maturity and marbling. Their findings also supported combining the A and B maturity groups into a single maturity classification (Hilton et al., 1998). Several others have reported no differences in sensory panel tenderness ratings or WBSF values for LM steaks from A and B maturity carcasses (Romans et al., 1965; Breidenstein et al., 1968; Covington et al., 1970; Norris et al., 1971; Berry et al., 1974; Tatum et al., 1980). In contrast, Smith et al. (1982, 1988) reported that LM steaks from A and B maturity carcasses differed in sensory tenderness and WBSF.

Implications of Results

According to results of the 2011 National Beef Quality Audit, 7.2% of the U.S. fed steer and heifer population produced carcasses that were classified as B maturity or older (Moore et al., 2012). O'Connor et al. (2007) reported official USDA maturity scores for more than 4,300 beef carcasses produced by cattle of known ages (11 to 30 mo) and found that cattle as young as 14 mo old produced carcasses classified as B maturity or older. Results of the present study indicate that A and B-C maturity carcasses have similar LM sensory attributes and shear force measurements when they originate from grain-finished cattle that have been classified as less than 30 mo old at the time of slaughter. These findings do not support the current grading concept of using skeletal and lean maturity characteristics to reflect age-associated tenderness differences in this subpopulation of cattle.

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