Effects of Slaughter Age on Meat Tenderness and USDA Carcass Maturity Scores of Beef Females[1]

S. D. Shackelford[2], M. Koohmaraie, and T. L. Wheeler

Roman L. Hruska U.S. Meat Animal Research Center, ARS, USDA, Clay Center, NE 68933-0166

ABSTRACT: Two experiments were conducted to determine the effect of carcass maturity on meat palatability using concentrate-fed cattle of known history and to determine the relationship of chronological age to carcass maturity scores. Yearling heifers (n = 28) and 2-yr-old cows (n = 25) of similar breed groups were fed a high-energy-density diet for 90 d before slaughter. Longissimus muscle Instron peak load (Warner-Bratzler shear force) did not differ between age groups; but, fail elongation was higher for the 2-yr-old cows ($P < .05$). Overall tenderness ratings were lower for the 2-yr-old cows; however, the magnitude of the tenderness difference between age groups was small (.4 units on an 8-point scale). There was 10-fold more variation in tenderness within each age group than there was between age groups. Carcass maturity scores and chronological age were compared for heifers and cows (n = 249) ranging in age from 1.7 to 13.9 yr. Carcass maturity scores increased with increasing chronological age at a much faster rate than indicated by USDA. The following chronological age groups most accurately reflected the chronological age associated with each USDA carcass maturity class: A, 9 to 24 mo; B, 24 to 36 mo; C, 36 to 48 mo; D, 48 to 60 mo; E, > 60 mo. These results indicate that efforts to control variation in tenderness would be more effective if they targeted factors that have a greater effect on meat tenderness than does maturity class. Moreover, our results indicate that cows may grade lower at a given age than what USDA standards imply.

Key Words: Beef, Tenderness, Maturity, Age

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Introduction

Seven percent of concentrate-fed cattle slaughtered in the U.S. are B maturity (Lorenzen et al., 1993). A large proportion of B maturity carcasses result from young cows (heiferettes) that have been fed a high-energy-density diet for 60 to 120 d before slaughter. Although numerous experiments have associated increased carcass maturity with decreased meat palatability (Romans et al., 1965; Zinn et al., 1970; Berry et al., 1974; Carroll et al., 1976; Smith et al., 1982), the results of those experiments have been difficult to interpret because they involved comparison of different maturity classes using carcasses of unknown origin. It is likely that variation in maturity was confounded with preslaughter feeding regimen in those experiments. Miller et al. (1983) demonstrated that longissimus muscle tenderness did not differ between young (A and B) and old (C and D) maturity carcasses from steers that had been fed for 185 d on a high-energy-density diet. Moreover, meat tenderness can be improved by feeding aged cows concentrate for 60 d before slaughter (Miller et al., 1987). However, it is not known whether heiferette carcasses differ from those of concentrate-fed yearling beef in meat palatability. Thus, these experiments were conducted to determine the effect of carcass maturity on meat palatability using cattle of known history and to determine the relationship of chronological age to carcass maturity scores.

Materials and Methods

Experiment 1

Animals. Yearling heifers (n = 28) and 2-yr-old cows (n = 25) that had been culled due to reproductive failure (failure to conceive during the normal breeding season) were used for this experiment. All animals originated from the Roman L. Hruska U.S. Meat Animal Research Center (**MARC**). Breed

[1]Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of other products that may also be suitable.

[2]To whom all correspondence should be addressed.

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groups included purebreds (Angus [**A**], Charolais [**C**], Gelbvieh [**G**], and Hereford [**H**]) and composites (MARC I [1/4 C, 1/4 Braunvieh, 1/4 Limousin, 1/8 H, 1/8 A], MARC II [1/4 Simmental, 1/4 G, 1/4 H, 1/4 A], and MARC III [1/4 Red Poll, 1/4 H, 1/4 Pinzgauer, 1/4 A]).

At the initiation of the experiment, the yearling heifers were approximately 19 mo of age, whereas the 2-yr-old cows were approximately 31 mo of age. All of the 2-yr-old cows had reared one calf that had been weaned for approximately 1 mo before the initiation of the experiment.

Initially, cattle were allowed ad libitum access to a corn-corn silage-protein supplement diet that contained 2.7 Mcal of ME/kg of dry matter and 12.9% CP. The energy density of the diet was increased over a 28-d adjustment period, after which the cattle received a finishing diet (3.0 Mcal of ME/kg of dry matter and 11.5% CP) for an additional 62 d before slaughter. Cattle were implanted with Synovex-H® (Syntex Agribusiness, Des Moines, IA) 70 d before slaughter.

Carcass Handling. Cattle were slaughtered and processed commercially. The facility at which these cattle were slaughtered typically uses an electrical stimulation procedure; however, MARC personnel observed that the electrical stimulator was not in use when these cattle were processed. A spray-chilling system, which involved spraying carcasses with a fine mist of 2°C water for 30 s every 5 min, was used. Spray-chilling was terminated at approximately 12 h postmortem. At 28 h postmortem, carcasses were ribbed and USDA quality and yield grade were determined (USDA, 1989a). Skeletal, lean, and overall maturity and marbling score were independently evaluated by two expert carcass evaluators and values were averaged for computation of quality grade. Maturity scores were based on procedures outlined by Smith et al. (1988). Heat ring (1 = none, 2 = slightly two-toned, 3 = moderately two-toned, 4 = moderately two-toned and soft, 5 = moderately two-toned, very soft, and sunken ribeye, 6 = severely two-toned, 7 = severely two-toned, very soft, and sunken ribeye), lean color (1 = very light cherry red, 2 = cherry red, 3 = slightly dark, 4 = moderately dark, 5 = dark red, 6 = very dark red, 7 = black), lean texture (1 = very fine, 2 = fine, 3 = moderately fine, 4 = slightly fine, 5 = slightly coarse, 6 = coarse, 7 = very coarse), and lean firmness (1 = very firm, 2 = firm, 3 = moderately firm, 4 = slightly soft, 5 = soft, 6 = very soft, 7 = extremely soft) were evaluated by an expert carcass evaluator.

Meat Palatability Evaluations. The rib was removed from the right side of each carcass and transported to MARC. At 48 h postmortem, ribs were boned, the posterior end of the ribeye roll was faced, and three 2.54-cm-thick ribeye steaks were removed. The first (posterior) steak was assigned to Warner-Bratzler shear (**WBS**) force determination and the second and third steaks were assigned to trained sensory panel (**TSP**) analyses. Steaks were vacuum-packaged and aged (2°C) until 14 d postmortem, at which time TSP steaks were frozen at –30°C. Sensory steaks were stored (–30°C) for up to 6 mo before thawing (24 h at 4°C) and cooking. Shear steaks were cooked fresh (never frozen). For both WBS and TSP, steaks were broiled to an internal temperature of 40°C, turned, and broiled to a final internal temperature of 70°C. After cooking, WBS steaks were placed in polyvinylchloride bags and cooled for 24 h at 4°C before removal of six cores (diameter = 1.27 cm) parallel to the longitudinal orientation of the muscle fibers. Each core was sheared once with a WBS attachment using an Instron Universal Testing Machine (Instron Corp., Canton, MA). After cooking, TSP steaks were held in a warming oven at 70°C for up to 30 min before they were cubed and served. Each panelist received three cubes (1.3 cm × 1.3 cm × cooked steak thickness) from each carcass. Sensory panelists rated steaks for overall tenderness, juiciness, and beef flavor intensity on an 8-point scale (1 = extremely tough, dry, and bland and 8 = extremely tender, juicy, and intense). The eight-member sensory panel was selected and trained according to Cross et al. (1978) and was highly experienced (average experience level was 11 yr and the range was from 6 to 14 yr).

Statistical Analysis. To assess the effects of slaughter age on carcass and meat palatability traits, one-way ANOVA were conducted for a completely randomized design using the GLM procedure of SAS (1988). Additionally, carcasses were classified according to USDA maturity class and the effects of physiological maturity on meat palatability were assessed with one-way ANOVA.

Experiment 2

Animals. Heifers and cows (n = 249) ranging in age from 1.7 to 13.9 yr were removed from native bromegrass pasture and slaughtered at a commercial packing plant. After carcass washing, skeletal maturity of the hot carcasses was evaluated by two expert carcass evaluators.

Statistical Analysis. Carcasses were grouped into chronological age classes and one-way ANOVA were conducted for skeletal maturity and the frequency of skeletal maturity scores above C^{00}. Means were separated using the PDIFF procedure (a pairwise *t*-test) of SAS (1988). Additionally, frequency distributions were used to identify age groups that were more correctly associated with each USDA carcass maturity class.

Results and Discussion

Experiment 1

Carcass Traits. Skeletal, lean, and overall maturity scores indicated that yearling heifers were (P < .01) less physiologically mature than 2-yr-old cows (Table

Table 1. Effect of age on carcass characteristics and meat palatability of concentrate-fed beef females (Exp. 1)

	Age group			
Trait	Yearling heifers	2-yr-old cows	SEM	$P < F$
No. of observations	28	25	—	
Slaughter age, d	665.6	1,035.9	4.3	.001
Skeletal maturity[a]	180.2	278.2	9.2	.001
Lean maturity[a]	180.5	208.6	7.1	.01
Overall maturity[a]	179.5	249.7	7.7	.001
Marbling score[b]	426.1	427.4	14.3	.95
USDA Choice frequency, %	64.3	28.0	9.2	.01
Live wt, kg	562.3	643.5	11.8	.001
Hot carcass wt, kg	336.6	374.7	7.9	.001
Dressing percentage, %	59.8	58.1	.4	.01
Actual fat thickness, mm	7.8	9.7	.8	.11
Adjusted fat thickness, mm	7.2	8.7	.9	.24
Longissimus muscle area, cm^2	85.5	86.8	2.1	.65
Kidney, pelvic, and heart fat, %	2.3	2.1	.1	.23
USDA Yield grade	2.2	2.6	.1	.07
Heat ring score[c]	2.1	2.0	.1	.58
Lean color score[c]	3.9	4.1	.2	.59
Lean texture score[c]	1.9	1.8	.1	.93
Lean firmness score[c]	3.8	3.8	.2	.95
Sarcomere length, mm	1.7	1.7	.1	.73
Peak load, kg	6.0	6.1	.3	.83
Peak elongation, cm	2.1	2.1	.02	.59
Peak energy, cm-kg	2.2	2.3	.1	.64
Fail elongation, cm	2.9	3.0	.03	.01
Fail energy, cm-kg	5.1	5.5	.2	.26
Juiciness[d]	5.2	5.1	.1	.14
Ease of fragmentation[d]	5.0	4.7	.1	.03
Amount of connective tissue[d]	4.8	4.5	.1	.07
Overall tenderness[d]	5.0	4.6	.1	.03
Beef flavor intensity[d]	4.8	4.9	.1	.23
Off-flavor[e]	3.0	2.9	.1	.39

[a]100 = A^{00}, 200 = B^{00}, 300 = C^{00}.
[b]300 = $Slight^{00}$, 400 = $Small^{00}$, 500 = $Modest^{00}$.
[c]Heat ring scored as 1 = none, 2 = slightly two-toned, 3 = moderately two-toned, 4 = moderately two-toned and soft, 5 = moderately two-toned, very soft, and sunken ribeye, and 6 = severely two-toned, 7 = severely two-toned, very soft, and sunken ribeye. Lean color scored as 1 = very light cherry red, 2 = cherry red, 3 = slightly dark, 4 = moderately dark, 5 = dark red, 6 = very dark red, 7 = black. Lean texture scored as 1 = very fine, 2 = fine, 3 = moderately fine, 4 = slightly fine, 5 = slightly coarse, 6 = coarse, 7 = very coarse. Lean firmness scored as 1 = very firm, 2 = firm, 3 = moderately firm, 4 = slightly soft, 5 = soft, 6 = very soft, 7 = extremely soft.
[d]1 = extremely dry, extremely difficult, abundant, extremely tough, or extremely bland and 8 = extremely juicy, extremely easy, none, extremely tender, or extremely intense.
[e]1 = intense and 4 = none.

1). Although age groups did not differ in marbling score, quality grade distributions (Table 2) differed greatly between age groups because 28% of the cow carcasses were C-maturity. It was somewhat surprising that such a high percentage of the 2-yr-old cows were C-maturity because the maximum age in that group (35 mo) was considerably less than the minimum age (42 mo) associated with C-maturity (USDA, 1989b). Thus, we conducted Exp. 2 to determine the relationship between chronological age and physiological maturity.

Live and hot carcass weights were lower and dressing percentage was higher for yearling heifers. Actual and adjusted fat thickness, longissimus muscle area, and kidney, pelvic, and heart fat percentage did not differ between age groups. However, USDA yield grade tended ($P = .07$) to be lower for heifer carcasses. Subjective scores for heat ring, lean color, lean texture, and lean firmness did not differ between age groups.

Meat Palatability. Instron peak load (maximum amount of force required to shear the sample), peak energy (amount of energy required to reach the peak load), peak elongation (the distance that the crosshead travels before reaching the peak load), fail load (25% of peak load), and fail energy (amount energy required to reach the fail load) did not differ between age groups (Table 1); however, fail elongation (the distance that the crosshead travels before reaching the fail load) was higher for the 2-yr-old cows. Ease of

Table 2. Effect of age on quality grade percentage distribution (Exp. 1)

Quality grade	Yearling heifers	2-yr-old cows
Prime	0	4
Choice	64	24
Select	36	40
Standard	0	4
Commercial	0	16
Utility	0	12

fragmentation and overall tenderness ratings were lower for the 2-yr-old cows, but the age groups did not differ in juiciness, beef flavor intensity, or off-flavor. It is doubtful that the magnitude of the tenderness difference between age groups was large enough to justify the price discrimination in the marketplace against young, concentrate-fed cows relative to concentrate-fed yearlings. ANOVA indicated that there was considerably more (10-fold) variation in tenderness within each age group than there was between age groups.

Fail elongation and ease of fragmentation scores were lower for B-maturity carcasses than for A-maturity carcasses (Table 3; $P < .05$). Additionally, overall tenderness tended to be lower for B-maturity carcasses ($P = .06$). The magnitude of the difference in overall tenderness scores between A- and B-maturity carcasses was similar (.31 vs .38 units on an 8-point scale) for the present study compared with results of Smith et al. (1982). Thus, it seems that any confounding that may have existed between preslaughter feeding regimen and carcass maturity score in the study of Smith et al. (1982) had little effect on meat tenderness.

Whereas the relationship of fail elongation to overall tenderness ratings was low ($r^2 = .14$) compared with the relationship of peak load to overall tenderness ($r^2 = .49$), variation in fail elongation was completely independent of peak load ($R^2 = .00$). Therefore, these traits were almost completely additive in explaining variation in overall tenderness ratings. Thus, a two-variable regression equation that included peak load and fail elongation explained 62% (14 + 49 = 63) of the variation in overall tenderness. Harris and Shorthose (1991) indicated that shear force was not a good indicator of connective tissue toughness. Thus, it is possible that differences in connective tissue between age groups were large enough to be perceived by the sensory panel but too small to affect peak load.

Experiment 2

Carcass maturity was moderately related to chronological age ($r^2 = .60$). As we noted in Exp. 1, results of Exp. 2 (Table 4) conclusively demonstrated that carcass maturity scores increased with increased chronological age at a much faster rate than indicated by USDA (1989b). USDA grade standards indicate that cattle 72 to 96 mo of age would be expected to produce D-maturity carcasses. However, in this experiment, 96% of the cattle in this age range produced E-maturity carcasses (Table 5). In fact, there were cattle as young as 40 mo of age that produced E-maturity carcasses. Thus, we attempted to identify chronological age groups that were more correctly associated with the carcass maturity classes. In this study, there was a lower frequency of C-maturity (17.7%) carcasses than of B- (22.9%) and D- (24.1%) maturity carcasses, suggesting that the chronological

Table 3. Effect of carcass maturity on meat palatability of concentrate-fed beef females (Exp. 1)

	Overall maturity[a]			
Trait	A	B	SEM	*P* < *F*
No. of observations	26	20	—	—
Peak load, kg	5.87	6.16	.22	.35
Peak elongation, cm	2.05	2.09	.02	.15
Peak energy, cm-kg	2.20	2.23	.10	.85
Fail elongation, cm	2.93	3.02	.03	.04
Fail energy, cm-kg	5.05	5.45	.20	.14
Juiciness[b]	5.21	5.18	.09	.81
Ease of fragmentation[b]	5.03	4.70	.10	.02
Amount of connective tissue[b]	4.86	4.59	.12	.11
Overall tenderness[b]	4.99	4.68	.11	.06
Beef flavor intensity[b]	4.81	4.87	.06	.56
Off-flavor[c]	2.99	2.93	.05	.39

[a]Data for C-maturity carcasses is not presented because there were not enough C-maturity carcasses (n = 7) to compare with the other maturity groups.

[b]1 = extremely dry, extremely difficult, abundant, extremely tough, or extremely bland and 8 = extremely juicy, extremely easy, none, extremely tender, or extremely intense.

[c]1 = intense and 4 = none.

Table 4. Effect of chronological age group on carcass maturity (Exp. 2)

Age group, yr	Mean age, yr	n	Skeletal maturity score[a] Mean	Minimum	Maximum	Hard bone frequency, %[b]
1 to 2	1.9	7	185[h]	160	205	0[e]
2 to 3	2.9	73	280[g]	165	480	27[d]
3 to 4	3.9	59	398[f]	240	545	90[c]
4 to 5	4.9	43	465[e]	285	550	98[c]
5 to 6	5.9	15	507[d]	465	545	100[c]
6 to 7	6.9	14	539[cd]	500	590	100[c]
7 to 8	7.8	12	558[c]	495	590	100[c]
8 to 9	8.9	7	571[c]	525	590	100[c]
9 to 10	9.9	6	583[c]	550	590	100[c]
10 to 11	10.9	2	590[c]	590	590	100[c]
11 to 12	11.9	5	584[c]	565	590	100[c]
12 to 13	12.8	2	583[c]	575	590	100[c]
13 to 14	13.9	4	590[c]	590	590	100[c]

[a]100 = A^{00}, 200 = B^{00}, 300 = C^{00}, 400 = D^{00}, 500 = E^{00}.
[b]Carcasses score C^{00} or older.
[c,d,e,f,g,h]Means in the same column bearing a common superscript do not differ ($P > .05$).

age range associated with C-maturity was smaller than that associated with the other maturity classes. In fact, we could not identify any age group in which a majority of the carcasses were C-maturity. The frequency of C-maturity carcasses was greatest for the 36- to 48-mo age group; however, a higher proportion of carcasses in this age group were D- (45.8%) than were C- (39.0%) maturity. The following chronological age groups most accurately (Table 5) reflected the chronological age associated with each USDA carcass maturity class: A, 9 to 24 mo; B, 24 to 36 mo; C, 36 to 48 mo; D, 48 to 60 mo; E, > 60 mo. Perhaps producers could better decide how to manage and market cull cows if they were made aware of the probable distribution of carcass maturity classifications across various ages.

The discrepancy in maturity classification relative to chronological age found in this study indicates that changes in production practices may have altered the relationship between chronological age and physiological maturity. However, it is not clear what specific production practice may be responsible for this alteration. Obvious changes in U.S. beef production that have occurred over the last 30 yr include the infusion of continental European genetics and acceleration of production systems resulting in reduced slaughter

Table 5. Distribution (%) of carcass maturity scores within each current and proposed USDA chronological age group (Exp. 2)[a]

Skeletal maturity	n	Current USDA chronological age groups, mo: 9 to 30 (n = 7)	30 to 42 (n = 75)	42 to 72 (n = 113)	72 to 96 (n = 26)	> 96 (n = 28)
A	10	50.0	7.8	.0	.0	.0
B	57	50.0	59.7	6.3	.0	.0
C	44	.0	23.4	23.2	.0	.0
D	60	.0	7.8	47.3	3.8	.0
E	78	.0	1.3	23.2	96.2	100.0

Skeletal maturity	n	Proposed USDA chronological age groups, mo: 9 to 24 (n = 7)	24 to 36 n = 73)	36 to 48 (n = 59)	48 to 60 (n = 43)	> 60 (n = 67)
A	10	57.1	8.2	.0	.0	.0
B	57	42.9	64.4	10.2	2.3	.0
C	44	.0	21.9	39.0	11.6	.0
D	60	.0	5.5	45.8	53.5	9.0
E	78	.0	.0	5.1	32.6	91.0

[a]USDA (1989b) indicated that cattle 9 to 30 mo of age would be expected to produce A maturity carcasses, cattle 30 to 42 mo of age would be expected to produce B maturity carcasses, and so on.

ages. Continental European breeds are more variable in age at sexual maturity than British breeds (Gregory et al., 1991; Martin et al., 1992). Comparison of carcass maturity scores across breeds shows little difference among breeds at similar ages (Koch et al., 1976, 1979, 1982). Dikeman et al. (1985) indicated that, despite being 40 d younger at slaughter, steers reared under accelerated production systems had skeletal maturity scores similar to those of steers reared under conventional production systems. Most of the carcasses included in our experiment were from cows that had been pregnant at least once during their lifetime. Pregnancy increases carcass maturity (Bond et al., 1986; Waggoner et al., 1990) and, thus, may have contributed to the discrepancy in maturity classification relative to chronological age found in this study relative to those values reported by USDA (1989b). Moreover, the data reported in this experiment are based solely on skeletal maturity scores, whereas USDA's (1989b) classifications are based on overall maturity. For most carcasses from grain-fed cattle, lean and overall maturity scores are more youthful than skeletal maturity scores.

Implications

The elimination of carcasses from 2-yr-old, concentrate-fed cows from the block beef supply could slightly increase customer satisfaction. However, much more variation in tenderness exists within each chronological and physiological maturity group than between groups. Thus, efforts to control variation in tenderness would be more effective if they targeted factors that have a greater effect on meat tenderness than does maturity. Profit opportunities from feeding young cows (heiferettes) likely outweigh potential tenderness concerns.

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