Tenderness Variation Among Loin Steaks from A and C Maturity Carcasses of Heifers Similar in Chronological Age

R. Field*,1, R. McCormick*, V. Balasubramanian*, D. Sanson*, J. Wise†, D. Hixon*, M. Riley*, and W. Russell*

*Department of Animal Science, University of Wyoming, Laramie, WY 82071 and †USDA Livestock and Meat Standardization Branch, AMS, Washington, DC 20090-6456

ABSTRACT: Fifty-two Angus × Gelbvieh rotationally crossed virgin, ovariectomized, or single-calf heifers were slaughtered after 100 d on a high-concentrate diet. Heifers from each treatment were approximately 31, 33, or 35 mo of age, and they produced 31 A, 5 B, and 16 C maturity carcasses. Because of the small number, B maturity carcasses were not included in this study. Number of A maturity carcasses decreased as age increased. No differences (P > .05) in slaughter weight, total weight gain, dressing percentage, longissimus muscle area, or kidney fat percentage existed between carcass maturity groups, but C maturity heifers had 3.56 mm more fat (P < .01) over the longissimus muscle than A maturity heifers. Marbling scores of slight79 and small0 for A and C maturity carcasses, respectively, did not differ (P > .05). The A and C maturity heifers had similar amounts of collagen and hydroxylysyl-pyridinium crosslinks in metacarpal bone cortex and in longissimus muscle. Neither means for panel tenderness nor Warner-Bratzler shear values differed (P > .05) between maturity groups. Coefficients of variation for tenderness were slightly higher in steaks from C maturity carcasses, but CV for shear values between A and C maturity groups were similar. Because inconsistent meat tenderness is a recognized problem in the beef industry, more research on tenderness variability within maturity and marbling groups is needed. This information, in addition to pooled SEM and differences between means, should aid in finding ways to reduce beef tenderness variability.

Key Words: Bovines, Maturity, Collagen, Tenderness, Age


Introduction

As chronological age increases, tenderness of beef decreases (Jeremiah, 1978; Smith et al., 1984; Shortshose and Harris, 1990), and this is one reason why A, B, C, D, and E maturity categories are part of the beef grading system (USDA, 1989). The maturity categories are based to a large extent on degree of bone calcification in the vertebral column. The A and B categories are reserved for Prime, Choice, and Standard grade carcasses, and the Select grade will soon be restricted to A maturity only (USDA, 1996). The highest grade a C maturity carcass can obtain is commercial and as such is sold for much less per kilogram than higher-grading carcasses from the A or B maturity categories. Two-year-old cattle that have calved produce a higher percentage of C maturity carcasses than virgin heifers, and virgin heifers produce a higher percentage of C maturity carcasses than ovariectomized heifers (Balasubramanian et al., 1995). Nevertheless, within virgin, ovariectomized, and single-calf heifers, A, B, and C maturity categories are present. The purpose of this study was to identify factors related to tenderness and tenderness variability in loin steaks from A and C maturity carcasses of heifers similar in chronological age.

Materials and Methods

Fifty-two Angus × Gelbvieh rotationally crossed virgin, ovariectomized, and single-calf heifers were studied. At 1 yr of age, they were assigned at random to slaughter age and treatment groups. After 18 heifers were bred and 18 were ovariectomized, all heifers grazed the same pastures and were supplemented when required during the winter. Pregnant heifers were separated from the other treatment groups approximately 2 mo before parturition and given supplemental feed until their calves were weaned. Virgin and ovariectomized heifers were
limit-fed during the nursing period for single-calf heifers so condition of all three treatment groups would be comparable. When calves were weaned on June 14 at approximately 120 d of age, single-calf heifers were pastured with ovariectomized and virgin heifers. Groups to be slaughtered at 31, 33, and 35 mo of age were removed from the pasture and started on feed July 15, September 15, and November 15, respectively. Virgin, ovariectomized, and single-calf heifers were fed in the same pen. Adjacent pens were used for the three age groups. Heifers from each age group and treatment were slaughtered after 100 d on feed. The diet included a receiving diet and four step-up diets fed 4 to 6 d with heifers moved up to the final diet by d 26 of the feeding period. The final diet was 39.33% rolled sorghum grain, 39.33% rolled corn, 8.95% dehydrated alfalfa, 8.25% molasses, and 4.15% protein supplement. The protein supplement included urea, soybean meal, limestone, salt, dicalcium phosphate, potassium chloride, trace mineral, Rumensin, and Tylosin (Rumensin and Tylosin were provided by Elanco Animal Health, Indianapolis, IN). The heifers produced 31 A, 5 B, and 16 C maturity carcasses, but the B maturity carcasses were not included in this study because the number was too small to furnish meaningful information.

Carcasses were evaluated for quality and yield grade characteristics by a representative from the USDA Livestock and Meat Standardization Branch approximately 48 h postmortem. The USDA representative assigned percentage scores for bone maturity (e.g., A<sup>80</sup>), and these scores, along with lean maturity, were used in determining overall carcass maturity (USDA, 1989). Roasts 10 cm thick were removed posterior to the 12<sup>th</sup> rib after 14 d of aging at 4°C. The roasts were frozen and stored at −20°C for 2 to 6 mo until biochemical, sensory, and Warner-Bratzler (WB) shear analyses could be completed.

Bone dust from sawing the metacarpal shaft cortex and a thin transverse slice of the longissimus muscle minus all epimysial tissue from each animal were dried to a constant weight in an oven at 100°C for 2 d. The dried muscle was ground using a mortar and pestle. Dried muscle and bone were hydrolyzed and used for determination of hydroxyproline (Woessner, 1961). Collagen concentration was calculated assuming that collagen weighed 7.25 times the measured weight of hydroxyproline (Eastoe and Leach, 1958). Hydroxylysylpyridinoline (HP) and lysylpyridinoline (LP) crosslink concentrations for bone, and HP concentration for intramuscular collagen were determined using a modification (Field et al., 1996) of the HPLC procedure developed by Eyre et al. (1984).

For WB shear force determination, 2.5-cm-thick steaks were cut from the roasts, thawed overnight at 4°C, and roasted at 177°C in a convection oven to an internal temperature of 74°C. Cooked steaks were then cooled, wrapped in freezer paper, and held at 4°C overnight before WB shear values were obtained on three cores 2.54 cm in diameter cut parallel to the muscle fibers. Each core was sheared three times. The average of nine shear values was used for subsequent analysis. Thirteenth rib roasts for sensory analysis were removed from the freezer at random, thawed at 4°C for 24 h, and then roasted to an internal temperature of 74°C in a 177°C convection oven. The internal temperature was monitored by thermocouples and a relay scanner. Samples were served warm to an eight-member, experienced sensory panel. Panelists evaluated tenderness using an unstructured 12-cm-long continuous line scale (0 = extremely tough; 12 = extremely tender) as outlined by the American Meat Science Association (AMSA, 1978). Evaluations were made on six steaks per session. All data were analyzed with one-way ANOVA using the GLM procedures of SAS (1985).

**Results and Discussion**

Numbers of A or C maturity carcasses within the 31-, 33- and 35-mo slaughter age groups were 13, 11, and 7 or 3, 6, and 7, for A and C maturity and age respectively. As age increased over the 31- to 35-mo range, number of A maturity carcasses decreased and number of C maturity carcasses increased. Therefore, Angus × Gelbvieh rotationally crossed heifers should be slaughtered at ages younger than 31-mo to avoid price discounts that accompany some B maturity and all C maturity carcasses. The reason for more C maturity carcasses in our study when compared with more B maturity carcasses in 30- and 31-mo-old heifers as noted by Waggoner et al. (1990) and Shackelford et al. (1995), respectively, may have been breed related. Angus × Gelbvieh rotationally crossed heifers in our study would be expected to mature sexually at an earlier age than Simmental-cross heifers in the Waggoner et al. (1990) study. The Shackelford et al. (1995) study included some Angus and Gelbvieh heifers along with Charolais, Herefords, and 12 composite breeds. Higher endogenous estrogen levels at an earlier age in our study may be responsible for greater ossification of bones. Ho et al. (1989) previously reported that bones of Finn cross ewe lambs fused earlier than bones of ewe lambs from later sexually maturing breeds. In addition to breed differences, many of the heifers in the current study were 2 to 4 mo older than those in the Waggoner et al. (1990) and Shackelford et al. (1995) studies, and it is clear that a few months difference in age can significantly influence carcass maturity scores.

Heifers producing C maturity carcasses on the average were 32 d older (P < .01) than those producing A maturity carcasses (Table 1). Initial feedlot weights, slaughter weights, and hot carcass...
weights tended to be heavier for C maturity animals, but neither weight differences nor differences in weight gain during the 100-d feeding period were significant (P > .05). Greater (P < .01) actual and adjusted fat depths for C maturity carcasses, compared with A maturity carcasses, indicate that fat deposition and bone maturation in animals of similar chronological age may occur simultaneously. Percentage kidney, pelvic, and heart fat (KPH), and marbling followed the same trends as those for fat depth, but differences between maturity groups were not significant (P > .05). Standard errors of the means for marbling of A and C maturity carcasses were .14 and .20, respectively, indicating that almost all carcasses possessed slight or small amounts of marbling. Lean maturity scores were almost identical for A and C maturity carcasses of heifers fed alike and slaughtered at approximately the same chronological age. Therefore, differences in endogenous estrogen levels that are probably responsible for differences in bone maturity scores (Klindt and Crouse, 1990; Turner et al., 1994) are not associated with differences in lean maturity. Bone maturity scores in all anatomical locations were older for C maturity carcasses than for A maturity carcasses; the greatest difference was in the thoracic region. Metacarpal bone weights and lengths were not different (P > .05) between maturity groups but weight of bones from C maturity heifers tended to be lighter, indicating that their bones may have stopped growing earlier than those from animals producing A maturity carcasses. Earlier bone maturation in C maturity heifers could be related to their greater fat depths because nutrients no longer required for bone growth would be available to increase fat deposition.

Collagen characteristics of bone from A and C maturity carcasses were similar (Table 2). Lack of differences in collagen percentage supports the previous work of Field et al. (1974), who found similar hydroxyproline levels in bone from cattle 2 to 96 mo of age. The lack of differences (P > .05) in HP and LP crosslinks agrees with work of Eyre et al. (1988), who found HP in human bone reached a maximum by 10 to 15 yr and then remained essentially constant throughout life. Interpreting the results of the crosslinking analyses on bone is complicated by the continual resorption and deposition of new collagen that occurs throughout life. Hence, recently synthesized collagen, which is rich in immature crosslinks, will be present in mature bones. The chemical pathway of crosslinking in bone collagen also seems to be arrested to some degree at the stage of reducible bonds by the mineralization process (Eyre, 1987). This effect of mineralization on the collagen fibrils helps to further explain why crosslink concentrations in cortex of bones from A and C maturity heifer carcasses were similar. Ash and moisture percentages in bone cortex also were similar for A and C maturity carcasses. Field et al. (1974) reported an increase in ash and dry matter of whole bovine bone from a 2 to 96 mo of age, but these differences were not present in bone cortex of A and C maturity heifer carcasses in the present study.
Neither collagen percentage nor HP concentration in muscle varied between A and C maturity carcasses from animals similar in chronological age. Even though meat from young and old animals differs only slightly in muscle collagen content (Bosselmann et al., 1995), the content of HP increases with advancing age (Eyre, 1987; McCormick, 1994). Nevertheless, the relationship between HP in bone and HP in muscle was $r = -0.13$ for the 52 heifers. An even lower $r$ value of $0.04$ was found between overall bone maturity scores and HP in muscle. Because these $r$ values were not significant ($P > 0.05$), we concluded that the collagen maturation process in bone and muscle occurred independently and that within the age of cattle in this study, maturation of collagen in muscle was not related to bone maturity. Perhaps crosslinking of collagen in muscle is more easily changed with age, diet, or other factors than is crosslinking in bone because of the mineralization process in bone.

Panel tenderness scores tended to be lower and WB shear values higher when loin steaks from C maturity carcasses were compared with those from A maturity carcasses (Table 2), but the differences were not significant ($P > 0.05$). Shackelford et al. (1995) found that longissimus muscles from yearling heifers were similar in shear force to those from 2-yr-old cows, but mean panel tenderness scores were slightly lower for the 2-yr-old cows. In contrast, Waggoner et al. (1990) reported longissimus muscles from 2-yr-old nonpregnant heifers were similar in panel tenderness to those from 2-yr-old cows, but muscles from 1- or 2-yr-old virgin heifers had slightly lower shear force values. We compared longissimus muscles from A and C maturity carcasses from virgin, single-calf, and ovariec- tomed heifers. Under these conditions, neither bone maturity nor collagen characteristics were related to panel tenderness or shear values.

Percentage incidences of loin steaks in specific Warner-Batzler shear and panel tenderness categories within overall maturity scores are found in Tables 3 and 4, respectively. In Table 3, SD and CV for Warner-Batzler shear values of the A and C maturity groups were similar, but for panel tenderness (Table 4) SD and CV were slightly higher for loin steaks from C maturity carcasses. Smith et al. (1984) used tables similar to Tables 3 and 4 to show that nearly 50% of the loin steaks from B maturity carcasses with slight marbling and over 30% of loin steaks from B maturity carcasses with small marbling were less than satisfactory. The recent beef grade change (USDA, 1996) centered on variability in tenderness and used the data of Smith et al. (1984) to justify the change. Other justifications were based on projected increased demand for beef that is more uniform in tenderness and on an increased price for Choice and Select because fewer carcasses would be eligible for these grades. Data in Table 4 tend to support the grade change because steaks from more mature carcasses were more variable in tenderness.

However, steaks from B and C maturity carcasses are not always more variable in tenderness compared to those from A maturity carcasses. Data on variation in sensory evaluation and Warner-Batzler shear values for longissimus muscle by maturity groups are listed in Table 5. In most cases, SD and CV are similar to those in Tables 3 and 4. Only in the data of Smith et al. (1982) are CV appreciably higher in older maturity groups. References on longissimus muscle for all groups of animals under 30 mo of age (A maturity) were not included in Table 5 because means for loin steaks from these cattle are usually similar in tenderness and shear force (USDA, 1975; Carroll et al., 1976). Standard deviation or CV for shear values and panel tenderness for A maturity cattle (Smith et al., 1984; Jones and Tatum, 1994; Shackelford et al., 1994; Wheeler et al., 1994) are also similar to those for B and C maturity cattle in Table 5. We calculated
from data of Wheeler et al. (1994) that 15 to 17-mo-old Bos taurus cattle managed and fed alike and possessing slight, small, or modest amounts of marbling had CV for shear values of 28, 29, and 28%, respectively. Smith et al. (1984) selected longissimus steaks from A maturity carcasses of unknown history and reported CV for shear values of 22, 23, and 26% for slight, small, and modest amounts of marbling, respectively. In another study (Jones and Tatum, 1994), A maturity carcasses varying from traces to moderately abundant marbling had CV of 22 and 34% for muscle fiber tenderness and shear force, respectively. Coefficients of variation of 25 and 14% for shear force and panel tenderness of calf-fed steers were reported by Shackelford et al. (1994). Overall, the literature on variation in panel tenderness and shear values supports the findings of Morgan et al. (1991) showing that inconsistent meat tenderness is a major defect in the current beef production system. However, only a small portion of the researchers studying tenderness differences report variability within maturity groups. Numerous studies comparing means for

### Table 5. Literature on variation in panel tenderness and(or) Warner-Bratzler shear values of longissimus muscle by maturity groups

<table>
<thead>
<tr>
<th>Reference</th>
<th>Beef carcass maturity or equivalent age group&lt;sup&gt;ab&lt;/sup&gt;</th>
<th>A, n = 31</th>
<th>B, n = 31</th>
<th>C, n = 16</th>
<th>A, n = 31</th>
<th>B, n = 31</th>
<th>C, n = 16</th>
<th>A, n = 31</th>
<th>B, n = 31</th>
<th>C, n = 16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Romans et al. (1965)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Panel tenderness</td>
<td>3.4 ± 0.7</td>
<td>3.3 ± 0.9</td>
<td>3.9 ± 0.8</td>
<td>3.4 ± 0.7</td>
<td>3.3 ± 0.9</td>
<td>3.9 ± 0.8</td>
<td>3.4 ± 0.7</td>
<td>3.3 ± 0.9</td>
<td>3.9 ± 0.8</td>
</tr>
<tr>
<td></td>
<td>WB shear, kg</td>
<td>7.0 ± 1.5</td>
<td>7.1 ± 1.3</td>
<td>7.2 ± 1.5</td>
<td>7.0 ± 1.5</td>
<td>7.1 ± 1.3</td>
<td>7.2 ± 1.5</td>
<td>7.0 ± 1.5</td>
<td>7.1 ± 1.3</td>
<td>7.2 ± 1.5</td>
</tr>
<tr>
<td>Covington et al. (1970)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>WB shear, kg</td>
<td>8.2 ± 1.7</td>
<td>8.1 ± 1.3</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<tr>
<td>Norris et al. (1971)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>Panel tenderness</td>
<td>5.4 ± 0.9</td>
<td>5.7 ± 0.3</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<tr>
<td></td>
<td>WB shear, kg</td>
<td>2.5 ± 0.7</td>
<td>2.4 ± 0.4</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<tr>
<td>Cross et al. (1973)&lt;sup&gt;e&lt;/sup&gt;</td>
<td>Panel tenderness</td>
<td>5.5 ± 1.0</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>5.2 ± 0.9</td>
<td>18</td>
<td>—</td>
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<td>—</td>
</tr>
<tr>
<td></td>
<td>WB shear, kg</td>
<td>5.3 ± 1.5</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>5.9 ± 1.3</td>
<td>21</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Regan et al. (1976)&lt;sup&gt;f&lt;/sup&gt;</td>
<td>Panel tenderness</td>
<td>4.8 ± 1.4</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>4.6 ± 1.5</td>
<td>33</td>
<td>—</td>
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<td>—</td>
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<tr>
<td></td>
<td>WB shear, kg</td>
<td>6.3 ± 1.5</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>8.0 ± 2.1</td>
<td>26</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Smith et al. (1982)</td>
<td>WB shear, kg</td>
<td>3.6 ± 1.1</td>
<td>3.9 ± 1.4</td>
<td>4.2 ± 1.6</td>
<td>3.6 ± 1.1</td>
<td>3.9 ± 1.4</td>
<td>4.2 ± 1.6</td>
<td>3.6 ± 1.1</td>
<td>3.9 ± 1.4</td>
<td>4.2 ± 1.6</td>
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</table>

<sup>a</sup>Three 2.54-cm-diameter cores from loin steaks in the 13th rib region were sheared three times each.

<sup>b</sup>Evaluated by an experienced sensory panel using a 12-point continuous scale: 0 = extremely tough; 12 = extremely tender.
tenderness or shear values of maturity groups were left out of Table 5 because no measure of variability within group was included.

In the future, researchers are encouraged to publish measures of tenderness variability within groups in addition to publishing pooled SEM or simply testing differences between means. An alternate procedure for reporting variability would be to report the percentage of beef top loin steaks with shear force values higher than 4.6 or 3.9 kg (Shackelford et al., 1991). According to their data, steaks having shear force values of less than 4.6 kg should have a 50% chance of being rated slightly tender or higher, and steaks having a shear force value less than 3.9 kg should have a 68% chance of being rated slightly tender or higher. If the beef industry is successful in decreasing variation in tenderness, these same shear values should have greater confidence levels.

**Implications**

Heifers of a narrow age range produced carcasses ranging from A to C maturity, but differences in bone maturity are not related to collagen percentage, hydroxylysylpyridinoline crosslinks, panel tenderness, or shear values. Therefore, differences in bone maturity are of limited value in predicting eating quality. More direct measures of beef tenderness are needed to reduce variability because much variability in tenderness exists within maturity groups even when animals similar in chronological age are studied. Publishing measures of tenderness variability within groups or treatments will give decision makers more information to use in reducing inconsistency in beef tenderness.

**Literature Cited**


