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GENETIC EFFECTS ON BEEF TENDERNESS

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INTRODUCTION

Tenderness greatly affects consumers' beef purchasing decisions, and a significant portion of beef cuts are "unacceptable" in tenderness. Higher levels of marbling have been associated with improved tenderness and with reduced variation in tenderness of cooked beef. Moreover, postmortem aging of beef has long been known to improve beef tenderness. Finally, recent research has established a relationship between calpastatin, the inhibitor of calpain enzymes, and beef tenderness. Marbling, calpastatin activity, and tenderness are all influenced by the genotype of the animal. Genetic differences in tenderness, marbling and calpastatin activity have been found both among and within breeds of cattle (Shackelford et al., 1994). The objectives of this research were to quantify the variation in beef tenderness, marbling and calpastatin activity among progeny of 18 different sires representing two breeds; to ascertain whether tenderness improvement could be made through genetic selection; and to determine the efficacy of two gene probes in identifying superior and inferior genetics for beef tenderness.

METHODS

This project involved 392 progeny (both steers and heifers) resulting from random matings of 18 sires, representing two Continental European cattle breeds, to crossbred cows in two commercial herds. Sires representing each breed (10 Charolais sires and 8 Limousin sires) were selected from frequently used bloodlines known for superior growth, low birth weight, or superior marbling ability. The two participating cow herds were located in Colorado and Montana, where the calves (a total of 14 to 27 calves per sire) were raised until weaning. After weaning, all calves were fed at a commercial feedlot in Colorado. The cattle were slaughtered in four groups when visual evaluation and ultrasound scans indicated that they had attained approximately 1.1 cm external fat thickness. A number of live performance traits (gestation length, birth weight, weaning weight, yearling weight, feedlot average daily gain, slaughter weight) were recorded for each calf from birth to slaughter, and all routine carcass data (dressing percentage, hot carcass weight, fat thickness, rib eye area, kidney/pelvic/heart (KPH) fat percentage, carcass maturity, marbling score, incidence of dark cutting or PSE carcasses) were collected 24 hours after slaughter. Also, 24 hours after slaughter, longissimus muscle samples were obtained from each carcass for determination of: (a) 24-hour calpastatin activity; (b) shear force of cooked beef samples at six postmortem aging times (d1, d4, d7, d14, d21, d35); and (c) taste panel attributes of cooked beef at a single aging time (d14). All performance, carcass, sensory and shear force data were statistically analyzed using models which contained independent variables of birth/weaning location, gender, breed, and sire within breed. Adjusted fat thickness was included in the model as a covariate when evaluating dependent variables of feedlot average daily gain, slaughter weight, dressing percentage, hot carcass weight, rib eye area, KPH percentage, USDA yield grade, marbling, calpastatin activity, sensory traits and shear force. The presence or absence of dark, firm and dry lean (dark cutting beef) was also included as an independent variable when analyzing sensory traits and shear force. Frequency data were analyzed using chi-square tests.

RESULTS AND DISCUSSION

Sire within breed was a significant ($P < .05$) source of variation in gestation length, birth weight, 365-d weight, feedlot average daily gain, slaughter weight, dressing percentage, rib eye area, yield grade, marbling score, 24-h calpastatin activity, and shear force at all postmortem aging times, but did not affect ($P > .05$) 205-d weight, hot carcass weight, KPH fat percentage, or taste panel ratings for juiciness, flavor intensity and tenderness. The percentage of calves producing U.S. Choice carcasses ranged from 33% to 84% for Charolais sires, and from 21% to 54% for Limousin sires. The incidence of "dark-cutting" carcasses in the experimental population was 5%; however, the dark-cutting condition appeared to occur randomly among sires. There were three carcasses that exhibited pale, soft and exudative (PSE) beef, all produced by the same sire, suggesting that the PSE condition was genetic in origin.

Dark cutting carcasses were considerably tougher than normal carcasses, which were tougher then PSE carcasses ($P < .05$) (Figure 1). The incidence of "tough" loin steaks (those with shear force values above 3.9 kg) was 56% for dark cutting carcasses, 11% for normal carcasses, and 0% for PSE carcasses (across all aging times weighted according to current industry aging practices). Calpastatin activity at 24-h postmortem was 3.5 for dark cutting carcasses, 3.0 for normal carcasses, and 1.8 for PSE carcasses. Previous researchers have found positive correlations of early-postmortem muscle pH with shear force and with 24-h calpastatin activity (Whipple et al., 1990). Other research has shown that as pH decreases, calpastatin's ability to inhibit μ-calpain activity decreases in vitro (George et al., 1991). High calpastatin activity could be an explanation for the high shear force values in dark cutting beef observed in the present study.

Postmortem aging was very effective for improving tenderness of beef produced by progeny of all sires. Aging strip loin samples for 4, 7, 14, 21, and 35 days reduced shear force (from the baseline value at 1 day postmortem) by 10%, 19%, 28%, 33%, and 40%, respectively. Moreover, the incidence of "tough" loin steaks decreased from 58% at 1 day postmortem to 43%, 27%, 14%, 9%, and 3% at 4, 7, 14, 21, and 35 days postmortem, respectively. Tenderness variation among sires decreased only slightly during postmortem aging; however, tenderness variation among progeny within a sire decreased dramatically during postmortem aging. The ranking of sires according to tenderness (e.g., most tender to most tough) was similar at all aging times, indicating that sire differences in tenderness already were established by 1 day postmortem, and that sire groups differed very little in their response to postmortem aging (up to 35 days) (Figure 2). In addition, shear force measured at 1 day postmortem was closely correlated with shear force at day-4 ($r = .65$), day-7 ($r = .70$), day-14 ($r = .64$), day-21 ($r = .63$), and day-35 ($r = .57$), suggesting that day-1 shear force is a reasonably good indicator of shear force at other postmortem times.

Differences in marbling accounted for 5% and 34% of the variation in shear force among Charolais and Limousin sires, respectively. To determine if selection of sires with superior marbling ability would reduce the incidence of U.S. Standard carcasses and improve beef tenderness, progeny of the top 2 marbling sires in each breed were compared with progeny of all sires in each breed. In Charolais, progeny of all sires graded 51% Choice and 2% Standard, whereas progeny of the top 2 marbling sires graded 74% Choice and 0% Standard. In Limousin, progeny of all sires graded 38% Choice and 3% Standard, whereas progeny of the top 2 marbling sires graded 53% Choice and 0% Standard. Mean shear force values were 2.97 kg (all sires) vs. 2.91 kg (top 2 marbling sires) in Charolais,

and 3.28 kg (all sires) vs. 3.06 kg (top 2 marbling sires) in Limousin. These results suggest that selection for superior marbling would be effective for increasing the percentage of U.S. Choice carcasses and decreasing the percentage of U.S. Standard carcasses in both breeds, and would result in a slight improvement in tenderness in Limousin, but not in Charolais.

Differences in 24-h calpastatin activity accounted for 79% and 73% of the variation in shear force among Charolais and Limousin sires, respectively. Again, to determine if selection for lower calpastatin activity would improve beef tenderness, progeny of the top 2 calpastatin sires in each breed were compared with progeny of all sires in each breed. Mean shear force values were 2.97 kg (all sires) vs. 2.69 kg (top 2 calpastatin sires) in Charolais, and 3.28 kg (all sires) vs. 3.00 kg (top 2 calpastatin sires) in Limousin. Additionally, the incidence of "tough" loin steaks was 11% (all sires) vs. 4% (top 2 calpastatin sires) in Charolais, and 22% (all sires) vs. 10% (top 2 calpastatin sires) in Limousin. These results suggest that selection for low calpastatin activity would be effective for improving tenderness and reducing the frequency of tenderness problems in both breeds.

Blood samples were taken upon exsanguination and used to genotype animals for a *taqI* restriction fragment length polymorphism using a cDNA probe for the bovine calpastatin gene. CSSM18, a bovine microsatellite marker previously identified as being linked to the callipyge condition in sheep, was also scored for most (n=311) of the animals. Comparing progeny of different calpastatin genotypes, significant ($P < .05$) differences were found in shear force at 4, 7 and 35 days of postmortem aging, but not in calpastatin activity. These differences in shear force between genotypes, while statistically significant, were not great in magnitude. A "Likelihood-of-Distance" (LOD) analysis was conducted for the calpastatin and callipyge genotypes to determine if there was any linkage between them and genes affecting tenderness. Some of these LOD scores were statistically significant ($P < .05$) but were not consistent for shear force at different days postmortem and were not of the magnitude to indicate tight linkage of the gene probes with tenderness genes. The calpastatin gene probe was superior to the callipyge gene marker in identifying differences in tenderness; however, neither would be very useful in "screening" sires for toughness within this population of cattle.

CONCLUSIONS

Genetic differences exist in beef tenderness, and do not diminish during aging; however, aging decreases tenderness variation and improves tenderness regardless of genetics. Improvement in beef tenderness may be achieved by selecting breeding stock, via progeny testing, on the basis of 24-h calpastatin activity and/or shear force. Of the factors studied, the most rapid strategies for improving tenderness would be to ensure a minimum postmortem aging period and/or eliminate dark cutters from the steak and roast market.

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Figure 1. Effect of color/pH condition and postmortem aging time on shear force.

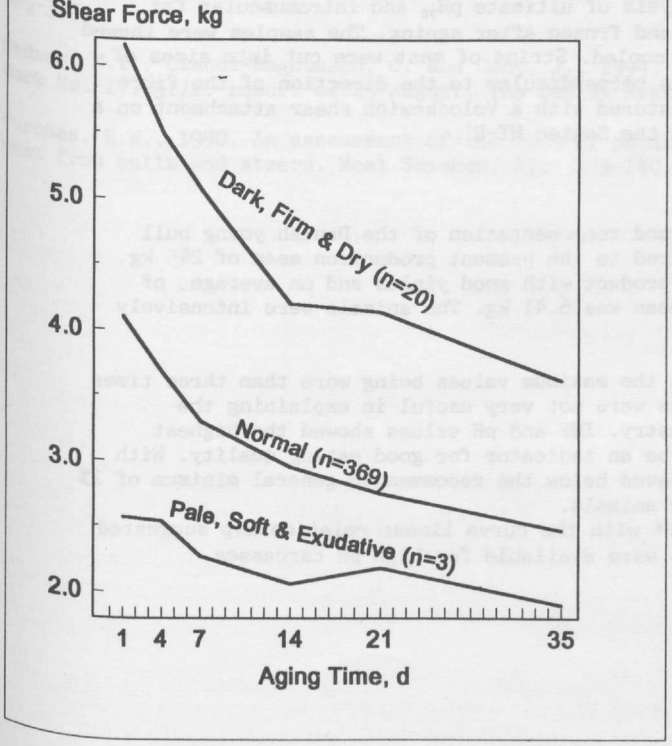

Figure 2. Effect of sire and postmortem aging time on shear force.