Characterization of topcross progenies from Hereford, Limousin, and Piedmontese sires[1]

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ABSTRACT: Breeds of larger mature size tend to grow more rapidly and be older when attaining a given level of fatness. Hereford, Limousin, and Piedmontese are of approximately equal mature size and yet may vary in body composition at a given degree of maturity. However, direct comparisons among these three breeds were not found. Therefore, the objective of this research was to compare Hereford, Limousin, and Piedmontese progenies for economically important traits. Crossbred cows were bred to Hereford (n = 23), Limousin (n = 24), or Piedmontese (n = 24) sires. Male calves were either left intact or castrated at approximately 2 mo of age. Calves remained with their dams until weaning at an average age of 179 d. Male calves were then individually fed a growing ration until they reached 386 kg and then fed a finishing ration either 90 or 132 d. They were then slaughtered at a commercial abattoir and carcass data were collected. Female calves were group-fed and used to examine nutritional effects on age at puberty. Data were analyzed using REML and linear contrasts among the breed-of-sire effects evaluated. Hereford-sired calves had shorter gestation periods and weighed less at birth than either Limousin- or Piedmontese-sired calves. Calving difficulty of Hereford- and Limousin-sired calves was less than that of Piedmontese-sired calves. Limousin-sired calves tended to grow more rapidly than Hereford-sired calves. By the finishing phase, Limousin- and Hereford-sired calves had greater average daily gains than Piedmontese-sired calves. Differences in dry matter intake among breeds of sire were relatively small. Differences in carcass weight, longissimus muscle area, fat depth, and percentage kidney, pelvic, and heart fat resulted in a clear stratification of USDA yield grade between breeds of sire. Differences in percentage primal cuts were similar to those for USDA yield grade. Hereford-sired calves had more marbling than progeny of Limousin or Piedmontese sires. However, the force necessary to shear cores from steaks of Piedmontese-sired calves was less than for progeny of Limousin or Hereford sires. Hereford- and Piedmontese-sired heifers were younger at puberty than Limousin-sired heifers. Within breeds of similar mature size and growth rate, ample variation exists in age at puberty and body composition at an approximately equal degree of maturity.

Key Words: Beef Cattle, Breed Differences, Carcass Composition, Growth, Puberty

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Introduction

Degree of maturity (the ratio of current size to mature size) accounts for substantial fractions of variation in both growth and body composition of livestock (Taylor, 1985). Thus, differences in growth and body composition among breeds varying in mature size are to be expected when expressed at age- or weight-constant

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end points. Breeds of larger mature size tend to grow more rapidly and be older when attaining a given level of fatness (Kempster and Southgate, 1984). However, contemporary comparisons among breeds of beef cattle having similar mature sizes are infrequent, especially beyond comparisons of Angus and Hereford.

Appropriate use of breed differences is a recommended strategy for matching biological types of beef cows with production environments and for producing beef products that are consistent with consumer desires relative to composition and palatability. In rotational crossing, using breeds of comparable characteristics such as birth weight, size, and lactation potential has been advised to avoid calf losses associated with dystocia, to stabilize nutrient requirements in the cow herd, and to control variability in product composition (Cundiff and Gregory, 1977). However, this restriction may be relaxed in exploiting breed resources in specialized roles (Cartwright et al., 1975).

Indirect evidence suggests that Hereford, Limousin, and Piedmontese are of approximately equal mature size and yet may vary in body composition at a given degree of maturity (Cundiff et al., 1993). Therefore, the objective of this research was to provide direct evidence of comparative performance for Hereford-, Limousin-, and Piedmontese-sired calves from birth to slaughter of male progeny at less than 2 yr of age and from birth to puberty of female progeny.

Materials and Methods

Crossbred females, ranging in age from 1 to 11 yr (average 3.8 yr), were bred randomly by AI for 3 yr to Hereford (n = 23), Limousin (n = 24), or Piedmontese (n = 24) sires. The crossbred cows were mainly ½ Red Angus, ¼ Charolais, and ¼ Tarentaise, but additional germplasm from Angus, Hereford, Simmental, Jersey, Shorthorn, Pinzgauer, and other breeds was also included. Calving date, birth weight, and calving difficulty score were recorded at birth. As part of a collaborative project, male calves were randomly assigned within sire to be left intact or castrated at approximately 2 mo of age. Calves remained with their dams until they were weaned at an average age of 179 d. During this time, all cows were managed together and grazed either improved, irrigated pastures or native rangeland. Weaning weights were adjusted to 180 d.

After weaning, male (bulls and steers) calves were placed into covered pens with individual electronic feeding gates (American Calan, Northwood, NH) with six animals per pen. Excess calves, beyond the capacity of the individual feeding facility, were fed in feedlot pens of approximately 25 animals. Bulls and steers were penned separately. Calves were fed once each morning. From weaning to 386 kg they were fed growing diets and thereafter were individually switched to finishing diets for 90 or 132 d. Diets differed in either level or degradability of protein. Effects of these dietary treatments on growth and carcass traits have been reported previously (Grings et al., 2001). Cattle were weighed unshrunk every 28 d except when they approached 386 kg, at which time they were weighed weekly to determine the appropriate time to switch diets. Weighing was done in the morning approximately 24 h after feeding.

Longissimus muscle area and backfat thickness were determined by ultrasound scanning within 10 d of completing the growing phase. Measurements were made by one of two trained technicians using an Aloka 500V realtime ultrasound unit (Corometrics Medical Systems, Wallingford, CT) equipped with a 17-cm scanning width, 3.5-MHz linear array transducer. The transducer was placed across the longissimus muscle between the 12th and 13th ribs. Images were recorded in a computer and later measured for longissimus muscle area and backfat thickness with the AUSKey 2.0 (Animal Ultrasound Systems, Howell, MI) computer software package by one of the two technicians.

Cattle were slaughtered at a commercial abattoir using standard industry procedures. Hot carcass weight was measured the day of slaughter and other carcass measures were taken after 48 h of storage at 2°C. Dressing percentage was calculated as 100 times the ratio of hot carcass weight to live weight taken 1 d before slaughter. Longissimus muscle area between the 12th and 13th sternal ribs was measured using a planar grid. Fat thickness over the longissimus muscle was taken at the 12th rib. The kidney, pelvic, and heart fat was estimated and recorded as a percentage of carcass weight. Marbling was evaluated by subjective comparison of the amount of fat within the longissimus muscle between the 12th and 13th ribs with photographic standards (National Live Stock and Meat Board, 1981). Primal cuts of one-half of the carcass were weighed and included chuck, rib, short loin, sirloin, and round. Meat tenderness was determined on the longissimus muscle taken at the 12th rib on the left side of the carcass. After aging for 14 d, steaks were flash-frozen and stored at −15°C for later analysis. Steaks were then thawed at 5°C for 40 to 48 h and cooked to a 70°C internal temperature. After cooling for a minimum of 2 h, five cores, 1.27 cm in diameter, were taken parallel to muscle fibers and Warner-Bratzler shear force was determined.

After weaning each year, female calves were used in experiments examining nutritional effects on age at puberty and subsequent breeding performance. In 1995, the 208 available heifers were blocked by breed of sire and randomly assigned within blocks to one of four treatments. The feeding protocol provided for either a controlled gain or a stair-step gain in which periods of high and low gain alternated. Trace mineral supplementation provided additional Cu, Zn, and Mn to one-half of the heifers. Additional details concerning this experiment can be found in Grings et al. (1999). In 1996, the 246 available heifers were stratified by breed of sire and within strata randomly assigned to diets containing either 1.9% or 4.4% fat. Safflower seeds provided the added fat. Further details concerning this experiment can be found in Lammoglia et al. (2000). Heifers were observed twice daily for estrual behavior. The occurrence of estrus was confirmed by the presence of a corpus luteum and serum progesterone concentration greater than 1 ng/mL 6 (1995) or 7 (1996) to 10 d after observing estrual behavior.

Pedigree data for the Hereford, Limousin, and Piedmontese sires were obtained from the respective breed associations or, in the case of Line 1 Hereford sires, from the research database of Fort Keogh Livestock and Range Research Laboratory (MacNeil et al., 1992). The pedigree information was at least three parental generations deep for all sires. All dams were assumed to be unrelated. This pedigree information was used in accounting for relationships among animals.

Data analyses were conducted using REML (Graser et al., 1987; Meyer, 1989) as implemented by Boldman et al. (1995). Each trait was analyzed separately and different models were used to analyze traits measured before and after weaning, although some effects were common to both models. To account for differences in breed of dam, both models included linear regression effects of proportion of maternal heterosis, Hereford, Charolais, Tarentaise, Simmental, Jersey, Shorthorn, Pinzgauer, and "other" germplasm of the dam. The effect of percentage Angus in the breed-of-dam was set to zero by elimination of the equation from the coefficient matrix. A discrete fixed effect for breed-of-sire was also included in both models. Finally, a random animal effect was common to all analyses. Analyses of gestation length, birth weight, calving difficulty incidence and score, gain from birth to weaning, and 180-d weight included additional discrete fixed effects for year-of-birth and age-of-dam by sex-of-calf subclasses, and an uncorrelated random effect associated with dams. Analyses of traits measured after weaning and on the carcass included a fixed effect for contemporary group composed of calves born in the same year, to the same age of dam, of similar sex condition (bull or steer), and subject to the same nutritional and managerial regimen. Convergence was determined by the variance of the simplex of parameter estimates being less than 10^{-10}. Global convergence was assumed when analyses with different starting values converged to similar parameter estimates and no further improvement in the log-likelihood was observed. The linear functions of breed-of-sire solutions for Hereford vs Limousin, Hereford vs Piedmontese, and Limousin vs Piedmontese were computed in the converged analyses.

Results and Discussion

Sampling of sires is a critical issue in breed evaluation. The Limousin and Piedmontese sires were sampled from their respective breeds without regard to preexisting genetic information. The average additive relationships among Limousin and Piedmontese sires were 0.9% and 8.2%, respectively. Seventeen of the Hereford sires used came from the Line 1 Hereford population of Fort Keogh Livestock and Range Research Laboratory. The remaining six Hereford sires included both horned and polled germplasm that was widely available for use in AI. The average additive relationship among the Hereford sires was 31.0%, which is approximately one-half the average additive relationship among contemporary Line 1 Hereford cattle (our unpublished observations). Line 1 has made a substantial genetic contribution to the U.S. Hereford population (Dickenson, 1984). However, to the extent that the sample of Hereford used here was not randomly drawn from the U.S. population, caution is advised in making broad inference characterizing Hereford.

Shown in Table 1 are numbers of observations, average levels of performance, and indicators of variability for the traits measured in this evaluation. Although the number of observations is sufficient to provide adequate power of the test for comparisons among the breeds of sire, they are hardly sufficient to precisely estimate heritability. This situation is most acute for postweaning and carcass traits. Heritability estimates are presented merely to provide an indication of the average level of variation among sires within breed in these data. Phenotypic CV for indicators of growth were from 11.1% for 180-d weight to 19.0% for average daily gain during the finishing period. For the carcass traits indicative of mass, the CV ranged from 5.3% for hot carcass weight to 6.1% for primal cut weight. Indicators of fatness were more variable, with CV from 13.4% for marbling score to 36.0% for fat depth.

Contrasts among the breed of sire solutions for calving traits are presented in Table 2. Hereford-sired calves had shorter gestation periods than either Limousin- or Piedmontese-sired calves, which were similar. Breed of sire effects on birth weight were similar to those on gestation length. However, calving difficulty was similar for Hereford- and Limousin-sired calves and less than for Piedmontese-sired calves. The results observed here for Hereford and Limousin are qualitatively similar to those observed in characterizations of these sire breeds in New Zealand (Baker and Carter, 1982) and at the U. S. Meat Animal Research Center (Cundiff et al., 1986). In slight contrast to the present results, Cundiff et al. (1998) found Piedmontese-sired calves had similar birth weight and incidence of calving difficulty, despite a longer gestation period, relative to the average of Hereford- and Angus-sired calves. Direct comparisons of calving traits expressed by Limousin- and Piedmontese-sired calves were not found. Collectively, the results indicate little cause for concern associated with incompatibility in calving traits among these breeds contraindicating their use in rotational crossbreeding programs. However, segregation of alternative alleles at the myostatin locus with major effects on birth weight and calving difficulty in F_2 Piedmontese crosses (Casas et al., 1999; R. E. Short and M. D. McNeil, unpublished observations) make Piedmontese

Table 1. Summary statistics describing topcross calves produced in evaluating Hereford, Limousin, and Piedmontese germplasm

Trait	n	Mean	SD	Heritability
Gestation length, d	1,070	286.7	6.45	0.37
Unassisted births, %	1,125	88.1	26.4	0.00
Calving difficulty[a]	1,125	1.2	0.52	0.01
Birth weight, kg	1,126	40.3	5.88	0.28
Preweaning gain, kg	1,049	172.8	21.82	0.09
180-d weight, kg	1,050	213.2	23.71	0.12
Backgrounding gain, kg/d	458	1.29	0.22	0.23
Days to 385 kg	458	330.1	38.58	0.29
Backgrounding DMI, kg/d	247	6.66	0.51	0.11
DM intake:gain	247	5.24	0.64	0.20
Longissimus muscle area, cm^2	445	69.7	6.61	0.08
Fat depth, mm	444	1.72	0.73	0.16
Finishing gain, kg/d	458	1.21	0.23	0.06
Finishing DMI, kg/d	247	8.67	0.90	0.33
DM intake:gain	247	6.90	1.35	0.14
Live wt at slaughter, kg	458	518.9	25.5	0.14
Age at slaughter, d	458	463.6	24.4	0.63
Hot carcass wt, kg	458	307.1	16.3	0.25
Dressing percentage	458	59.2	1.76	0.33
Longissimus muscle area, cm^2	458	85.2	7.53	0.02
Fat depth, mm	458	6.3	2.27	0.14
Kidney, pelvic, and heart fat, %	458	2.1	0.46	0.03
USDA yield grade	458	1.9	0.46	0.00
Primal cut wt, kg	458	162.3	9.98	0.30
% Primal cuts	458	53.8	1.60	0.15
Marbling score	458	5.0	0.67	0.29
Shear force, kg	458	3.6	0.73	0.16
Liver wt, kg	458	5.3	0.54	0.12
Age at puberty, d	454	378.6	46.4	0.36

[a]Degree of assistance required for delivery of normally presented live calf: 1 = unassisted, 2 = minor assistance, 3 = mechanical assistance, 4 = surgical assistance.

better suited to use as a terminal sire breed than in rotational crossing.

Differences among progeny of Hereford, Limousin, and Piedmontese sires in gain from birth to weaning were relatively small but became larger as the calves grew older. Limousin-sired calves tended to grow more rapidly than Hereford-sired calves. By the finishing phase, both Limousin- and Hereford-sired calves had greater average daily gains than Piedmontese-sired calves. Thus, Limousin-sired calves reached 386 kg at a younger age than Piedmontese-sired calves. Both Hereford- and Limousin-sired calves were heavier at slaughter than Piedmontese-sired calves. The similarity in growth rate of Hereford- and Limousin-sired calves seen here is consistent with earlier reports in the literature (Baker and Carter, 1982; Kempster and Southgate, 1984; Cundiff et al., 1986), as is the reduction in growth rate and final weight of Piedmontese-sired calves relative to Hereford-sired calves (Cundiff et al., 1996). Hoving-Bolink et al. (1999) found Piedmontese-sired calves also weighed less at slaughter than Limousin-sired calves, although the breed effect was confounded with one-half the individual heterosis being expressed by Piedmontese crosses and full individual heterosis being expressed by Limousin crosses.

Differences in dry matter intake among breeds of sire were relatively small. This may result because differences truly do not exist. However, measurement of individual feed intake may be subject to greater experimental error than other traits and the number of observations was substantially less than for other traits. Differences in dry matter required per unit of weight gain were consistent with differences in growth during the respective feeding periods. In experiments conducted in the United Kingdom (Kempster and Southgate, 1984) and at Clay Center, NE (Cundiff et al., 1986), Limousin-sired calves were less efficient in converting feed to live weight gain than Hereford-sired calves when carried to fat-constant end points. However, to weight- or age-constant end points Limousin-sired calves were more efficient than Hereford-sired calves (Cundiff et al., 1986). The end point used in the current study, while neither strictly age- nor weight-constant, more closely resembles a weight- (CV of slaughter weight = 4.9%) or age- (CV of age at slaughter = 5.3%) constant end point than a fat- (CV of fat depth = 36.0%) constant end point.

Live weight at slaughter was less for Piedmontese-sired calves than for either Limousin- or Hereford-sired calves, which were similar. However, due to differences in dressing percentage, Piedmontese- and Limousin-sired calves had similar carcass weights and were heavier than Hereford-sired calves. Longissimus muscle area was greater and fat depth less in Piedmontese-sired calves than in either Limousin- or Hereford-sired calves. Likewise, longissimus muscle area was greater and fat depth less in Limousin-sired calves than in Hereford-sired calves. Piedmontese-sired calves also had less internal fat than either Hereford- or Limousin-sired calves, which were similar. These differences in carcass traits resulted in a clear stratification of USDA yield grade between these breeds of sire. Differences in percentage of primal cuts mirrored differences in USDA yield grade. Even when carried to fat-constant end points in other trials, edible product yield from carcasses of Limousin-sired calves has exceeded that of Hereford-sired calves (Kempster and Southgate, 1984; Cundiff et al., 1986). Cundiff et al. (1996) also found offspring of Piedmontese sires to be leaner and to have greater longissimus muscle area at a constant age and to produce more retail product at a constant level of fatness than progeny of Hereford sires. In a direct comparison of Piedmontese- and Limousin-sired bulls and heifers, the progeny of Limousin sires had more subcutaneous and intramuscular fat than progeny of Piedmontese sires (Hoving-Bolink et al., 1999).

Hereford-sired calves had more marbling than progeny of either Limousin or Piedmontese sires, which were similar. However, the force required to shear cores from steaks of Piedmontese-sired calves was less than that needed for steaks from progeny of Limousin or Hereford sires. The force required to shear steaks from progeny of Hereford and Limousin sires was similar. Contrasts of Piedmontese progeny vs Limousin progeny (Hoving-Bolink et al., 1999), Piedmontese progeny vs Hereford progeny (Cundiff et al., 1996), and Limousin progeny vs Hereford progeny (Dikeman and Crouse, 1975) indicated similar tenderness of the longissimus muscle among these breeds of sire.

The liver may account for 20 to 25% of an animal's total energy expenditure (Ferrell, 1988). It is also readily obtainable and easily weighed at slaughter. Thus, liver weights are used here as an indicator of maintenance energy requirements. However, differences in body composition and associated differences in tissue requirements also complicate definitive inferences relative to maintenance requirements. A tendency for liver weight of Limousin-sired progeny to ex-

Table 2. Comparative performance of Hereford-, Limousin-, and Piedmontese-sired calves[a]

Trait	Contrast: Limousin – Hereford	Contrast: Piedmontese – Hereford	Contrast: Piedmontese – Limousin
Gestation length, d	3.60 ± 1.09	4.52 ± 1.18	0.92 ± 0.92
Unassisted births, %	–2.48 ± 2.07	–6.51 ± 2.08	–4.02 ± 1.91
Calving difficulty[b]	0.06 ± 0.04	0.14 ± 0.04	0.08 ± 0.04
Birth weight, kg	2.94 ± 0.89	1.98 ± 0.98	–0.96 ± 0.75
Preweaning gain, kg	2.79 ± 2.37	–0.50 ± 2.52	–3.28 ± 1.93
180-d weight, kg	5.59 ± 2.78	1.28 ± 2.98	–4.31 ± 2.27
Backgrounding gain, kg/d	0.05 ± 0.04	–0.08 ± 0.04	–0.12 ± 0.03
Days to 385 kg	–14.31 ± 7.70	1.92 ± 8.13	16.23 ± 6.21
Backgrounding DMI, kg/d	–0.14 ± 0.11	–0.06 ± 0.11	0.08 ± 0.10
DM intake:gain, kg/kg	–0.14 ± 0.14	0.34 ± 0.14	0.48 ± 0.12
Longissimus muscle area, cm^2	3.21 ± 1.04	8.17 ± 1.07	4.96 ± 0.88
Fat depth, mm	–0.44 ± 0.13	–0.89 ± 0.14	–0.45 ± 0.11
Finishing gain, kg/d	0.06 ± 0.03	–0.11 ± 0.04	–0.17 ± 0.03
Finishing DMI, kg/d	–0.39 ± 0.22	–0.14 ± 0.22	0.26 ± 0.19
DM intake:gain, kg/kg	–0.69 ± 0.28	0.45 ± 0.28	1.14 ± 0.26
Live wt at slaughter, kg	7.36 ± 4.39	–11.18 ± 4.58	–18.54 ± 3.62
Age at slaughter, d	–14.27 ± 5.97	4.19 ± 6.41	18.46 ± 4.86
Hot carcass wt, kg	9.49 ± 3.18	6.18 ± 3.35	–3.31 ± 2.57
Dressing percentage	1.00 ± 0.37	2.51 ± 0.39	1.51 ± 0.30
Longissimus muscle area, cm^2	6.33 ± 1.02	13.60 ± 1.03	7.26 ± 0.91
Fat depth, mm	–1.82 ± 0.39	–4.10 ± 0.41	–2.28 ± 0.32
Kidney, pelvic, and heart fat, %	0.05 ± 0.07	–0.27 ± 0.07	–0.31 ± 0.06
USDA yield grade	–0.44 ± 0.06	–1.11 ± 0.06	–0.67 ± 0.05
Primal cut wt, kg	7.79 ± 2.03	9.53 ± 2.15	1.74 ± 1.64
% Primal cuts	1.00 ± 0.28	2.18 ± 0.29	1.18 ± 0.23
Marbling score	–0.39 ± 0.14	–0.57 ± 0.14	–0.18 ± 0.11
Shear force, kg	0.00 ± 0.13	–0.34 ± 0.14	–0.33 ± 0.11
Liver wt, kg	0.18 ± 0.09	0.06 ± 0.09	–0.12 ± 0.07
Age at puberty, d	23.04 ± 9.26	–14.97 ± 9.82	–38.01 ± 7.79

[a]Effects of greater magnitude than approximately twice the standard error may be considered different from zero.

[b]Degree of assistance required for delivery of normally presented live calf: 1 = unassisted, 2 = minor assistance, 3 = mechanical assistance, 4 = surgical assistance.

ceed that of Hereford-sired progeny was noted. Otherwise, liver weights were similar for progenies of these breeds of sire.

Hereford- and Piedmontese-sired heifers were younger at attainment of puberty than Limousin-sired heifers. The differences observed between breeds in the present study are qualitatively similar to those observed previously (Cundiff et al., 1986, 1996). It is noteworthy that longissimus muscle area and percentage of primal cuts of F_2 50% Piedmontese steers and heifers without the Piedmontese mutation at the myostain locus were more similar to Hereford than to Limousin (R. E. Short and M. D. MacNeil, unpublished observations). Thus, the genetic relationship between leanness and age at puberty may result from the polygenic background, whereas the extreme leanness of Piedmontese results primarily from a mutation at the myostatin locus. However, the implied antagonism between leanness and age at puberty is not absolute. Dual-purpose breeds that have a history of selection for milk production reach puberty at a young age and yet they are also relatively lean (Gregory, et al., 1991, 1994).

Implications

Within breeds of similar mature size and growth rate, ample variation exists in body composition and age at puberty at an approximately equal degree of maturity. This contraindicates use of these breed resources in rotational crossbreeding systems. Limousin and Piedmontese germplasm may be best exploited as terminal sires without creating problems with excessive birth weight, calving difficulty, and resultant neonatal mortality in crosses with British breeds, such as Hereford.

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