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Maternal grandsire, granddam, and sire breed effects on growth and carcass traits of crossbred cattle

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Maternal grandsire, granddam, and sire breed effects on growth and carcass traits of crossbred cattle[1,2]

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ABSTRACT: Postweaning growth, feed efficiency, and carcass traits were analyzed on 1,422 animals obtained by mating F_1 cows to F_1 (Belgian Blue × British breeds) or Charolais sires. Cows were obtained from mating Hereford, Angus, and MARC III (¼ Hereford, ¼ Angus, ¼ Pinzgauer, and ¼ Red Poll) dams to Hereford or Angus (British breeds), Tuli, Boran, Brahman, or Belgian Blue sires. Breed groups were fed in replicated pens and slaughtered serially in each of 2 yr. Postweaning average daily gain; live weight; hot carcass weight; fat depth; longissimus area; estimated kidney, pelvic, and heart fat (percentage); percentage Choice; marbling score; USDA yield grade; retail product yield (percentage); retail product weight; fat yield (percentage); fat weight; bone yield (percentage); and bone weight were analyzed in this population. Quadratic regressions of pen mean weight on days fed and of cumulative ME consumption on days fed were used to estimate gain, ME consumption and efficiency (Mcal of ME/kg of gain) over time (0 to 200 d on feed), and weight (300 to 550 kg) intervals. Maternal grandsire breed was significant ($P < 0.01$) for all traits. Maternal granddam breed (Hereford, Angus, or MARC III) was significant ($P < 0.05$) only for fat depth, USDA yield grade, retail product yield, fat yield, fat weight, and bone yield. Sire breed was significant ($P < 0.05$) for live weight, hot carcass weight, longissimus area, and bone weight. Sex class was a significant ($P < 0.001$) source of variation for all traits except for percentage Choice, marbling score, retail product yield, and fat yield. Interactions between maternal grandsire and sire breed were nonexistent. Sire and grandsire breed effects can be optimized by selection and use of appropriate crossbreeding systems.

Key Words: Beef Cattle, Breeds, Carcass Composition, Growth

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Introduction

The five cycles of the Germplasm Evaluation (GPE) program at the U.S. Meat Animal Research Center (MARC) have characterized breeds representing several biological types of cattle. Results for postweaning growth feed efficiency and carcass and meat quality traits have been reviewed by Cundiff et al. (1981; 1984) and Koch et al. (1982b,c), for the first three cycles of the program. Results from more recent cycles have been reported by Wheeler et al. (1996; 1997; 2001). Evaluation of these traits is important in establishing the potential value of alternative germplasm resources in the beef industry.

In the GPE program, postweaning growth and feed efficiency are evaluated in F_1 animals obtained from breeds representing diverse biological types, while carcass traits are evaluated in F_1 steers. GPE Cycle V included three tropically adapted breeds (Tuli, Boran, and Brahman), two British breeds (Hereford and Angus), and Belgian Blue, which has a high frequency of double muscling. The objectives of this study were to assess the maternal grandsire, maternal granddam, and sire breed effect on these traits in male and female progeny of F_1 cows mated to Charolais and Belgian Blue × British breed sires.

Materials and Methods

Animals

Animals for this study were produced by F_1 cows from GPE Cycle V. Wheeler et al. (2001) described the mating

[1]Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the USDA and does not imply approval to the exclusion of other products that may be suitable.

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Table 1. Number of offspring produced by crossbred dam and sire breed in each year

	Sire				
	Charolais		Belgian Blue × British breed		
Dam[a]	1998	1999	1998	1999	Total
British × Hereford	8	9	6	6	29
British × Angus	24	23	23	23	93
British × MARC III	63	64	63	53	243
Brahman × Hereford	8	10	10	7	35
Brahman × Angus	16	16	18	14	64
Brahman × MARC III	34	34	29	32	129
Boran × Hereford	12	12	9	9	42
Boran × Angus	22	24	23	21	90
Boran × MARC III	34	32	31	23	120
Tuli × Hereford	12	9	9	10	40
Tuli × Angus	24	24	22	20	90
Tuli × MARC III	40	50	41	33	164
Belgian Blue × Angus	6	8	6	9	29
Belgian Blue × Hereford	29	23	17	24	93
Belgian Blue × MARC III	41	44	37	39	161
Total	373	382	344	323	1,422

[a]MARC III = ¼ Hereford, ¼ Angus, ¼ Pinzgauer, and ¼ Red Poll.

scheme used to produce these cows. Briefly, Hereford, Angus, and MARC III (¼ Hereford, ¼ Angus, ¼ Pinzgauer, and ¼ Red Poll) mature dams were mated by artificial insemination to Angus, Hereford, Tuli, Boran, Brahman, and Belgian Blue sires. No purebred Hereford or Angus matings were made to avoid confounding sire breed effects with heterosis effects. Hereford and Angus were treated as one breed group (British breeds). Females obtained from these crosses were mated to 28 Charolais, 9 Belgian Blue × MARC III, 8 Belgian Blue × Angus, or 1 Belgian Blue × Hereford sires during two consecutive years. All sires with Belgian Blue inheritance were treated as the same group (Belgian Blue × British breed) to evaluate the contribution of this breed. Matings were made by multisire natural service mounting within sire breed. Cows were run in four separate breeding pastures each year, two pastures containing Charolais bulls and two containing Belgian Blue × British breed bulls. Individual sires of progeny were not identified.

Offspring were born during spring of 1998 (n = 717) and 1999 (n = 705). Table 1 shows the number of animals born by breed group and year. Male calves were castrated within 24 h of birth. Calves were fed whole oats from mid-July or early August until weaning in early October. Calves were weaned in mid-October at an average age of 214 ± 18 d. Following an adjustment period of about 30 d, steers and heifers were randomly assigned to replicated pens and fed separately by sire breed for 247 ± 14 d. The growing diet fed from weaning until about 320 kg included corn silage, corn, and a urea-based liquid supplement containing about 2.7 Mcal of ME/kg of DM and 12.5% CP. The finishing diet fed from about 320 kg to slaughter contained about 3.05 Mcal of ME/kg of DM and 13.1% CP. Animals were slaughtered serially during the summers of 1999 and 2000 in a commercial beef processing plant. In 1999, steers were slaughtered on June 7 and July 19, and heifers were slaughtered on June 30 and August 10. In 2000, steers were slaughtered on June 5 and June 27, and heifers were slaughtered on June 20 and July 11.

Traits

Postweaning average daily gain (kg/d), live weight (kg), hot carcass weight (kg), fat thickness (cm), longissimus area (cm^2), estimated kidney, pelvic, and heart fat (percentage), percentage of carcasses classified as USDA Choice, marbling score, USDA yield grade (indicates the amount of usable meat from a carcass; a yield grade of 1 yields the highest percentage of retail product, 5 the lowest), retail product yield (percentage), retail product weight (kg), fat yield (percentage), fat weight (kg), bone yield (percentage), and bone weight (kg) were analyzed. Retail product, fat, and bone yields were estimated using prediction equations that included carcass grade traits (Shackelford et al., 1995).

Statistical Analysis

Data were analyzed with the MIXED model procedure of SAS (SAS Inst., Inc., Cary, NC). The model included the fixed effects of maternal grandsire breed (British breeds, Tuli, Boran, Brahman, and Belgian Blue), maternal granddam breed (Hereford, Angus, and MARC III), sire breed (Charolais and Belgian Blue × British breed), sex class (steers and heifers), year of birth (1998 and 1999), and all possible two-way interactions among these fixed effects. The random effect of maternal grandsire within breed was included in the model, which is the true error term for maternal grandsire breed. Hereford and Angus were treated as one group to estimate this effect. Fixed effects and their interactions were tested against the residual mean square. Age at weaning and days on feed were included in the model as covariates. Least squares differences and probability values for differences were estimated for significant effects. Probability values were nominal and do not correct for multiple testing.

Tests of sire breed using the residual error term rather than the more appropriate term of sire within breed (unfeasible because individual sires could not be identified with the use of multiple sires per pasture) were biased. Given that the studied traits have a moderate-to-high heritability (0.28 to 0.85), it was thought that the mean square for sire within breed, if estimable, was likely larger than the residual mean square. This concern prompted the use of previous estimates of heritability from reports involving the same traits on animals produced in the Germplasm Evaluation Program at MARC (Koch 1982a; Wheeler et al., 2001) to partition the residual mean square (expected value ~ σ^2_w + $k_1\,\sigma^2_s$, where k_1 ~ 0.978) into residual (σ^2_w) and sire (σ^2_s) components of variance. The expected mean squares for sire within breed group ($\sigma_w^2 + k_2\ \sigma_s^2$, where $k_2 \sim 30.9$), with 44 df, was then used to compute an approximate F test for sire breed. In all cases, the P-values were increased using the approximate sire within breed mean square with 44 df in the denominator, rather than those derived using the residual error with 1,396 df.

Efficiency of Growth (Pen Mean Analysis)

Cundiff et al. (1984) described the procedure used to estimate efficiency of growth. Weight curves were generated for each sex-breed group by linear and quadratic regression of pen means for weights taken at each 28-d period on days on feed. Cumulative ME intake per animal (megacalories) for each pen-sex-year-breed group also was linearly and quadratically regressed on days fed. These regressions were forced through the origin. Pen mean ME intake of steers and heifers in pens for intervals corresponding to weigh periods were used.

The regression of weight and cumulative megacalories of ME on days were used to estimate gain, megacalories of ME, and efficiency of live weight gain (Mcal/kg) during alternate intervals of time. The amount of ME consumed during the corresponding interval was estimated for each pen by subtracting the cumulative number of mega calories consumed from d 0 to the initial date (**Xi**) from the cumulative number of mega calories of ME consumed from d 0 to the final date (**Xf**). This procedure was used to estimate efficiency of live weight gain of steers and heifers in each pen over two intervals: (1) 0 to 200 d and (2) 300 to 550 kg live weight.

Daily maintenance energy was estimated from 0.77 × $BW^{0.75}$. The NE_m was predicted for each interval of evaluation by integrating a function similar to that used by Cundiff et al. (1984):

$$\int_{X_i}^{X_f} 0.77(B_0 + B_1X + B_2X^2)^{0.75}$$

where X_i denotes the approximate initial date, X_f denotes the final date, B_0 is the intercept, and B_1 and B_2 are linear and quadratic coefficients, respectively, for weight on days on feed X. Estimates of efficiency of live weight gain and its components for each pen were analyzed by ANOVA.

Results

Levels of significance, least squares means, and standard errors are reported in Tables 2 and 3 for the effects of maternal grandsire, maternal granddam, and sire breed and sex. Year was a significant ($P < 0.02$) source of variation for all traits except estimated kidney, pelvic, and heart fat, estimated retail product yield, estimated fat yield, and estimated fat weight.

Maternal Grandsire Effects

Grandsire breed effect was significant for all traits ($P < 0.001$). Animals with Boran and Tuli inheritance had similar performance for most traits. Those with Brahman maternal grandsire were significantly heavier at slaughter than Boran and Tuli. Animals with British-breed or Belgian Blue maternal grandsires had different performance than animals with Brahman, Boran, or Tuli maternal grandsires. Animals with Belgian Blue inheritance had carcasses with the lowest fat thickness, lowest fat yield, and lowest yield grade, and the greatest amount of retail product yield, retail product weight, longissimus area, highest bone yield, and heaviest bone weight. Animals with British-breed maternal grandsires had similar means as the animals with Belgian Blue maternal grandsires for live weight and hot carcass weight. Animals with British breed maternal grandsires also had the highest fat thickness, estimated kidney, heart, and pelvic fat percentage, percentage of USDA Choice carcasses, highest marbling score, heaviest fat weight, highest postweaning average daily gain, and the lowest retail product yield. Animals with British-breed or Belgian Blue maternal grandsires grew faster, gained more weight, and were either fatter or leaner, respectively, than animals with Brahman, Boran, or Tuli maternal grandsires.

Maternal Granddam Effects

Granddam breed effect was an important source of variation for fat thickness, yield grade, retail product yield, fat yield, fat weight, and bone yield. Animals with MARC III inheritance were leaner, had a lower amount of bone, and had a more favorable yield grade compared with animals with Hereford and Angus maternal granddams. Animals with Hereford maternal granddams were intermediate in retail product and fat yields when compared with animals with Angus and MARC III maternal granddams.

Sire Breed Effects

Sire breed effect was significant for postweaning average daily gain, live weight, hot carcass weight, longissimus muscle area, and bone weight. Animals by Charolais sires grew faster and were heavier than animals by Belgian Blue × British breed sires. However, animals by Belgian Blue × British breed sires had greater longissimus muscle area and less bone weight.

Sex Class Effects

Sex class was important for all traits except percentage USDA Choice carcasses, marbling score, retail product yield, and fat yield. Steers grew faster, were heavier, leaner, and had more bone compared with heifers.

Table 2. Levels of significance, least squares means, and standard errors for factors affecting live weight (LWT), hot carcass weight (HCW), fat depth (FAT), longissimus muscle area (LMA), estimated kidney, pelvic, and heart fat (KPH), percentage of carcass classified as Choice (CH), marbling (MA), and USDA yield grade (YG)

	Traits[e]							
Item	LWT, kg	HCW, kg	FAT, cm	LMA, cm^2	KPH, %	CH	MA[f]	YG
Maternal grandsire breed								
Significance	<0.0001	<0.0001	<0.0001	<0.0001	0.0008	<0.0001	<0.0001	<0.0001
Least squares means								
British breed	583 ± 4[a]	370 ± 2[a]	1.26 ± 0.03[a]	90 ± 0.7[a]	1.98 ± 0.02[a]	0.73 ± 0.04[a]	577 ± 7[a]	2.76 ± 0.05[a]
Brahman	558 ± 4[b]	358 ± 3[b]	1.07 ± 0.03[b]	89 ± 0.7[a]	1.89 ± 0.02[b]	0.37 ± 0.04[d]	507 ± 8[c]	2.50 ± 0.05[b]
Boran	530 ± 6[c]	340 ± 3[c]	1.13 ± 0.04[b]	88 ± 0.8[a]	1.92 ± 0.02[b]	0.46 ± 0.04[cd]	510 ± 9[bc]	2.45 ± 0.06[b]
Tuli	534 ± 5[c]	341 ± 3[c]	1.07 ± 0.04[b]	89 ± 0.7[a]	1.94 ± 0.02[ab]	0.57 ± 0.04[b]	535 ± 9[b]	2.40 ± 0.05[b]
Belgian Blue	574 ± 4[a]	373 ± 3[a]	0.93 ± 0.03[c]	95 ± 0.7[b]	1.88 ± 0.02[b]	0.5 ± 0.04[bc]	506 ± 8[c]	2.19 ± 0.05[c]
Maternal granddam breed								
Significance	0.13	0.45	0.0036	0.81	0.25	0.42	0.48	0.01
Least squares means								
Hereford	559 ± 4	358 ± 3	1.12 ± 0.03[a]	90 ± 0.7	1.93 ± 0.02	0.54 ± 0.04	525 ± 7	2.25 ± 0.05[a]
Angus	552 ± 3	356 ± 2	1.11 ± 0.02[a]	90 ± 0.5	1.93 ± 0.01	0.54 ± 0.02	532 ± 5	2.47 ± 0.03[a]
MARC III[g]	557 ± 2	355 ± 1	1.04 ± 0.02[b]	91 ± 0.3	1.91 ± 0.01	0.50 ± 0.02	524 ± 4	2.38 ± 0.03[a]
Sire breed								
Significance	0.00005	0.01	0.32	0.03	0.32	0.18	0.09	0.15
Least squares means								
Charolais	567 ± 4[a]	360 ± 4[a]	1.07 ± 0.05	89 ± 1[a]	1.93 ± 0.02	0.56 ± 0.05	537 ± 9	2.52 ± 0.08
Belgian Blue × British breed	545 ± 4[b]	352 ± 4[b]	1.12 ± 0.05	92 ± 1[b]	1.92 ± 0.02	0.49 ± 0.05	517 ± 9	2.39 ± 0.08
Sex								
Significance	<0.0001	<0.0001	0.001	0.0006	0.0009	0.61	0.29	<0.0001
Least squares means								
Female	521 ± 2[a]	336 ± 2[a]	1.13 ± 0.02[a]	91 ± 0.4[a]	1.94 ± 0.01[a]	0.53 ± 0.02	524 ± 4	2.28 ± 0.03[a]
Male	590 ± 3[b]	377 ± 2[b]	1.05 ± 0.02[b]	89 ± 0.4[b]	1.90 ± 0.01[b]	0.52 ± 0.02	530 ± 5	2.63 ± 0.03[b]

[a,b,c,d]Different letters within column differ ($P < 0.05$).
[e]Carcass traits were adjusted by including age at weaning and days on feed as covariates.
[f]MA: 400 = slight, 500 = $small^{00}$.
[g]MARC III = ¼ Hereford, ¼ Angus, ¼ Pinzgauer, and ¼ Red Poll.

Table 3. Levels of significance, least squares means, and standard errors for factors affecting retail product yield (RPYD), retail product weight (RPWT), fat yield (FATYD), fat weight (FATWT), bone yield (BONEYD), bone weight (BONEWT), and postweaning average daily gain (PWADG)

	Traits[e]						
Item	RPYD, %	RPWT, kg	FATYD, %	FATWT, kg	BONEYD, %	BONEWT, kg	PWADG, kg/d
Maternal grandsire breed							
Significance	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001
Least squares means							
British type	0.63 ± 0.003[a]	232 ± 2[a]	0.23 ± 0.003[a]	86 ± 1[a]	0.145 ± 0.0006[a]	54 ± 0.4[a]	1.4 ± 0.01[a]
Brahman	0.65 ± 0.003[b]	233 ± 2[a]	0.20 ± 0.004[b]	72 ± 1[b]	0.149 ± 0.0006[b]	53 ± 0.4[a]	1.2 ± 0.01[c]
Boran	0.65 ± 0.003[b]	221 ± 2[b]	0.21 ± 0.004[b]	70 ± 2[b]	0.148 ± 0.0007[b]	50 ± 0.5[b]	1.2 ± 0.02[c]
Tuli	0.65 ± 0.003[b]	220 ± 2[b]	0.21 ± 0.004[b]	71 ± 2[b]	0.149 ± 0.0007[b]	51 ± 0.5[b]	1.2 ± 0.01[c]
Belgian Blue	0.67 ± 0.003[c]	249 ± 2[c]	0.18 ± 0.004[c]	69 ± 2[b]	0.151 ± 0.0006[c]	56 ± 0.4[c]	1.3 ± 0.01[b]
Maternal granddam breed							
Significance	0.02	0.55	0.02	0.02	0.0036	0.54	0.3775
Least squares means							
Hereford	0.647 ± 0.003[a,b]	232 ± 2	0.21 ± 0.004[a,b]	79 ± 1[a]	0.149 ± 0.0006[a]	53 ± 0.4	1.3 ± 0.01
Angus	0.647 ± 0.002[a]	230 ± 1	0.21 ± 0.004[a]	75 ± 1[a]	0.148 ± 0.0004[a]	53 ± 0.2	1.3 ± 0.01
MARC III[fg]	0.653 ± 0.001[b]	231 ± 1	0.20 ± 0.002[b]	72 ± 1[b]	0.149 ± 0.0003[b]	53 ± 0.2	1.3 ± 0.01
Sire breed							
Significance	0.32	0.19	0.32	0.2	0.32	0.01	0.026
Least squares means							
Charolais	0.647 ± 0.004	233 ± 2	0.21 ± 0.004	75 ± 2	0.149 ± 0.004	53 ± 0.05[a]	1.30 ± 0.02[a]
Belgian Blue × British breed	0.651 ± 0.004	229 ± 2	0.20 ± 0.004	72 ± 2	0.148 ± 0.004	52 ± 0.05[b]	1.26 ± 0.02[b]
Sex							
Significance	0.4	<0.0001	0.19	<0.0001	0.0006	<0.0001	<0.0001
Least squares means							
Female	0.65 ± 0.002	217 ± 1[a]	0.21 ± 0.002	70 ± 1[a]	0.148 ± 0.0004[a]	49 ± 0.2[a]	1.2 ± 0.01[a]
Male	0.65 ± 0.002	244 ± 1[b]	0.20 ± 0.002	78 ± 1[b]	0.149 ± 0.0004[b]	56 ± 0.2[b]	1.4 ± 0.01[b]

[a,b,c,d]Different letters within column differ ($P < 0.05$).
[e]Carcass traits were adjusted by including age at weaning and days on feed as covariates.
[f,g]MARC III = ¼ Hereford, ¼ Angus, ¼ Pinzgauer, and ¼ Red Poll.

Table 4. Levels of significance, least squares means, and standard errors for the interaction of grandsire breed × sex, for yield grade and estimated fat weight

	Maternal grandsire breed × sex interaction[a]	
	YG	FATWT
Significance	0.02	0.04
Least squares means		
British × female	2.56 ± 0.06	179 ± 4
British × male	2.95 ± 0.06	199 ± 4
Brahman × female	2.37 ± 0.07	155 ± 4
Brahman × male	2.62 ± 0.07	163 ± 4
Tuli × female	2.36 ± 0.07	151 ± 5
Tuli × male	2.52 ± 0.07	158 ± 5
Boran × female	2.18 ± 0.06	146 ± 4
Boran × male	2.62 ± 0.07	168 ± 5
Belgian Blue × female	1.93 ± 0.06	142 ± 4
Belgian Blue × male	2.44 ± 0.07	164 ± 4

[a]YG = Yield grade; FATWT = Fat weight.

Interactions

The interaction between maternal grandsire breed and sex class was important ($P < 0.05$) for yield grade and fat weight (Table 4). In the interaction for yield grade, steers with Brahman and Boran inheritance had the same performance, whereas steers with Tuli inheritance had a lower yield grade. The performance was different for heifers; those with Brahman and Tuli inheritance had similar yield grades, whereas those with Boran inheritance had a lower yield grade. A similar pattern explains the interaction between maternal grandsire breed and sex for fat weight. These interactions were generated by differences in performance among combinations of breeds and sex, but in all cases steers had a higher yield grade and more fat thickness than heifers.

Feed Efficiency

Weight change and cumulative ME consumption patterns for each sex-breed group were based on linear and quadratic regression coefficients computed by pooling over pen-year subclasses, weighting each year equally within maternal grandsire breed groups (Table 5). Estimates of breed group means for feed efficiency (Mcal ME/kg of gain) and its components (final weight, weight gain, number of days, cumulative metabolizable energy consumption, and net energy for maintenance) are presented in Table 6. There was no difference between sire breeds (Charolais or F_1 Belgian Blue × British breeds) for a time and weight constant efficiency.

Table 5. Coefficients for linear and quadratic regressions of pen means for each sex within breed group for weight and cumulative metabolizable energy (ME) on days

		Weight, kg			ME, Mcal	
Sex	Breed[a]	b_0	b_1	b_2	b_1	b_2
Steers	Charolais	304	1.682	−0.0012	25.33	0.0125
	F_1	298	1.587	−0.0006	24.16	0.0181
Heifers	Charolais	275	1.422	−0.0003	14.08	0.0742
	F_1	276	1.489	−0.0007	13.89	0.0736

[a]F_1 = Belgian Blue × British breed.

Discussion

Maternal grandsire breed differences were similar to previous studies. Animals with British breed inheritance (maternal grandsires) were heavier and deposited more inter- and intramuscular fat than other breed groups. This was observed by Wheeler et al. (2001) when F_1 steers obtained from the cross of Hereford, Angus, and MARC III dams to British breeds, Tuli, Boran, Brahman, Piedmontese, and Belgian Blue sires were compared. Wheeler et al. (2001) found that animals sired by Brahman, Boran, and Tuli sires had a relative performance similar to that observed in the present study. For most traits, animals with inheritance from these maternal grandsire breeds had an intermediate performance when compared with animals with Belgian Blue and the British breed inheritance.

Differences between animals with Brahman and British breed grandsires have been previously reported. Koch et al. (1982b,c), Crouse et al. (1989), and Wheeler et al. (2001) compared Brahman-sired steers with Hereford-Angus cross steers; Paschal et al. (1995) compared Gray and Red Brahman with Angus. Consistent results with all these reports were observed in the present study for marbling and yield grade. Animals with Brahman inheritance had lower marbling and yield grade when compared with British breeds. Crouse et al. (1989) and Wheeler et al. (2001) showed that animals with British breed inheritance had heavier carcasses and a greater amount of fat thickness than Brahmans, which was similar with our results; however, Koch et al. (1982b,c) found no differences. Paschal et al. (1995) found that fat thickness was similar for animals with Brahman and British breed inheritance, but animals with Brahman inheritance had a heavier carcass weight when compared with animals with British breed inheritance. This difference could be attributed to the location of the studies in a temperate Nebraska environment vs. a subtropical Texas environment. More consistent results were observed when comparing the studies done at the U.S. Meat Animal Research Center (Koch et al., 1982b,c; Crouse et al., 1989; Wheeler et al., 2001) than when comparing these studies with other locations (Paschal et al., 1995).

Grandsire breed differences among Brahman, Boran, and Tuli were similar to those reported by Herring et al. (1996) and Wheeler et al. (2001). These studies have shown that carcasses of animals by Brahman sires were heavier when compared with animals by Boran and Tuli sires. Animals by Brahman sires had less estimated

Table 6. Breed group least squares means for feed efficiency and components of efficiency in different evaluation intervals

Breed group[a]	Weight, kg Initial	Weight, kg Final	Weight gain, kg	No. of days	ME, Mcal[b]	Feed efficiency, Mcal/kg	NE_m, Mcal
0 to 200 d							
Charolais	290	569	280	200	5,676	20.3	1461
F_1	287	567	281	200	5,640	20.1	1453
SEM	3	0.6	2	—	19	0.06	10
300 to 550 kg							
Charolais	300	550	250	177	5,141	17.14	1281
F_1	300	550	250	179	5,153	17.18	1295
SEM	—	—	—	0.1	13	0.04	5

[a]F_1 = Belgian Blue × British breed.
[b]Cumulative ME consumption.

kidney, heart, and pelvic fat than animals by Tuli, and the latter had less than animals by Boran. Animals by Boran sires had marbling similar to animals by Brahman or Tuli sires; however, animals by Brahman sires had significantly less marbling than animals with Tuli sires. Animals obtained from Brahman, Boran, and Tuli, had similar performance for fat thickness, longissimus area, and yield grade. Breed effect performance was similar among these breeds in the first and second generation of crossbreeding.

In the report by Wheeler et al. (2001), animals expressed differences of 0.5 of the direct genetic effects ($\mathbf{g_i}$) of breeds and none of the maternal genetic breed effects ($\mathbf{g_m}$), whereas animals in the current study expressed differences of 0.25 of the direct genetic effects of breeds and 0.5 of the differences in breed maternal genetic effects (assuming effects of paternal grandsire are negligible; Dickerson, 1973). It appears that breed differences of 0.5 g_i + 0.0 g_m were relatively similar to animals in the current study with breed differences of 0.25 g_i + 0.5 g_m. Thus, breed differences in g_i and g_m seemed to offset each other in the results from the two studies. As an example, the difference for live weight between animals by British breed and Brahman grandsires was 25 kg (583 – 558 kg, current study), whereas the difference in the previous generation was 41 kg (590 – 549 kg; Wheeler et al., 2001). If only direct genetic effects were acting on the trait, the difference would be approximately half of what was observed in the first generation (20 kg). The difference for live weight between animals with British breed and Brahman between the two generations is more than half because of the direct maternal effect.

Animals with Belgian Blue × British breed inheritance were more heavily muscled than any other group. This is consistent with segregation of the inactive form of myostatin within the breed (Casas et al., 1998). It has been shown that an inactivated myostatin allele segregating in double-muscled breeds is responsible for this condition in cattle (Kambadur et al., 1997; Smith et al., 1997). Animals with one copy of the inactive allele will have an average of 14% less fat, and 7% more lean (Casas et al., 1998), although animals with two copies of the inactive allele will have up to 30% more muscle tissue (Arthur, 1995).

The only significant differences ($P < 0.05$) between sire breeds were for postweaning average daily gain, live weight, hot carcass weight, longissimus area, and bone weight. Individuals sired by Charolais grew faster and were heavier than animals by Belgian Blue × British breed sires. Animals by Belgian Blue × British breed sires had more muscle mass because all Belgian Blue grandsires were double-muscled and expected to be homozygous for the gene coding for inactive myostatin. Each Belgian Blue × British breed sire was heterozygous at the myostatin locus and was expected to transmit the gene coding for inactive myostatin to one half its progeny.

Interactions between year and sex class were due to performance of animals with Tuli, Boran, and Brahman inheritance. Although interactions between these two factors for yield grade and fat weight were significant ($P < 0.05$), in both cases steers had a greater yield grade and fat weight than heifers within breed-cross. These interactions resulted because the performance between steers and heifers for animals with Brahman, Tuli, and Boran inheritance was different. Previous studies in which animals with Brahman, Boran, and Tuli are compared do not assess these interactions or are irrelevant (Herring et al., 1996).

Feed efficiency of cattle sired by Charolais or Belgian Blue × British breed was similar for both groups of crossbred animals. In previous feed efficiency studies, shifts in ranking among F_1 breed groups for feed efficiency to time and weight end points were observed. In Cycle III (Cundiff et al., 1984), Sahiwal-sired crosses were significantly lighter in initial and final weight and gained less than the remaining breeds evaluated in the cycle. The Sahiwal-sired crosses also tended to be less efficient than animals sired by other breeds. In Cycle II (Cundiff et al., 1981), Gelbvieh-, Main Anjou-, and Chianina-sired crosses had greater ADG than British breed crosses. Braunvieh-, Gelbvieh-, and Main Anjou-sired crosses were more efficient than British breed crosses in a weight constant interval. In Cycle I (Smith et al., 1976), Charolais-sired crosses were more efficient than British breed crosses to a constant time, but less efficient to fat constant endpoint. Limousin-, Charolais-, Simmental-, and South Devon-crosses were more efficient than British breed crosses on a weight constant interval. Observations from previous cycles suggest that the difference among breeds could be of considerable magnitude and are dependent on the interval of evaluation.

Implications

Differences in growth and carcass traits exist among maternal grandsire breeds. No single maternal grandsire breed excelled in every trait. Sire and maternal grandsire breed differences allow for the optimization of postweaning growth and carcass traits by incorporating these breeds in selection and crossbreeding schemes. In these data, interactions between maternal grandsire and sire breed were nonexistent.

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