Influence of genotype and diet on steer performance, manure odor, and carriage of pathogenic and other fecal bacteria. I. Animal performance[1]

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ABSTRACT: Although Brahman crosses constitute a large portion of US beef cattle, little information is available on their response to diverse feed resources compared with *Bos taurus* steers. Thus, the objectives were to evaluate genotype and diet effects on steer performance during the growing period and subsequent response to a high grain diet during the finishing period. Fifty-one steers [0 (15), ¼ (20), ½ (7), and ¾ Brahman (9), with the remaining proportion being MARC III] were allotted to 8 pens. Beginning on December 2, steers were individually fed chopped bromegrass hay (n = 26; DM = 85%, CP = 9.5%, ME = 2.19 Mcal/kg) or a corn silage-based diet (n = 25; DM = 51%, CP = 11.9%, ME = 2.75 Mcal/kg) for 119 d. All steers were then fed a high corn diet (DM = 79%, CP = 11.7%, ME = 3.08 Mcal/kg) to a target BW of 560 kg (176 d). Data were analyzed by ANOVA, with genotype, growing diet, and the 2-way interaction included. The interaction was not significant ($P > 0.25$). The MARC III and ½ Brahman steers weighed more ($P < 0.01$) than ¼ or ¾ Brahman steers initially and at the end of the growing period. Weight of bromegrass-fed (325 kg) steers was less than that of corn silage-fed (384 kg) steers at the end of the growing period. Steer ADG and intake of DM, CP, and ME were less ($P = 0.087$ to 0.001) for ¼ and ¾ Brahman than for 0 or ½ Brahman steers during growing, finishing, and total, but efficiency of gain did not differ ($P >$ 0.10). Carcass weight, marbling score, quality grade ($P < 0.05$), and kidney fat ($P = 0.06$) differed among genotypes. Daily DMI (6.91 vs. 7.06 kg) was similar, but CP (0.66 vs. 0.84 kg) and ME (15.2 vs. 19.4 Mcal) intake of bromegrass fed was less ($P = 0.001$) than those of corn silage-fed steers. Values for DMI/gain (22.3 vs. 7.43 kg/kg), CP intake/gain (2.13 vs. 0.88 kg/kg), and ME intake/gain (48.8 vs. 20.4 Mcal/kg) were greater ($P < 0.001$) in bromegrass-fed than corn silage-fed steers. Over the total study, ADG was lower (0.96 vs. 1.01 kg), and DMI (7.82 vs. 7.19 kg), DMI/gain (8.21 vs. 7.10 kg/kg), and ME intake/gain (22.6 vs. 20.9 Mcal/kg) were greater ($P < 0.05$) in bromegrass-fed than in corn silage-fed steers. Carcass weight, dressing percent, adjusted backfat, and yield grade ($P < 0.05$) were greater for corn silage-fed than for bromegrass-fed steers. Feed intake and performance, but not efficiency, differed among these genotypes. Compensatory performance during finishing was insufficient to overcome reduced performance during the growing period.

Key words: beef cattle, *Bos indicus*, compensation, efficiency

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INTRODUCTION

Several researchers have suggested that *Bos indicus* cattle utilize low-quality forage diets more efficiently than *Bos taurus* cattle (Ashton, 1962; Kaurue et al., 1972). Improved performance on low-quality forage diets may result from lower maintenance requirements of *Bos indicus* compared with *Bos taurus* in nutritionally restrictive environments (Frisch and Vercoe, 1977) or greater intake relative to maintenance requirements, rather than improved utilization of low-quality diets per se. In contrast, when high-quality forage (Moran, 1976) or forage-grain mixtures (Ledger et al., 1970; O'Donovan et al., 1978) were fed, *Bos taurus* cattle consumed more feed relative to their maintenance requirements, gained weight faster, and were more efficient than *Bos indicus* cattle. Similarly, Beaver et al. (1989) reported that Angus steers consumed more feed and gained faster, but had similar diet digestibility and feed efficiency compared with Brangus steers when fed a high concentrate diet. Krehbiel et al. (2000) observed

[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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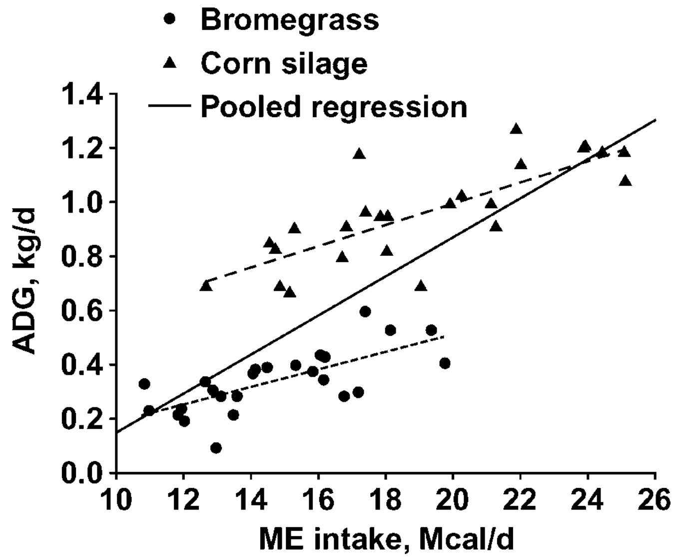

Figure 1. Relationships between ADG and daily ME intake (DMEI) for steers fed bromegrass hay (– – – ●; ADG = –0.14 ± 0.10 + [0.032 ± 0.007 × DMEI], R^2 = 0.50) or corn silage (——— ▲; ADG = 0.21 ± 0.13 + [0.039 ± 0.006 × DMEI], R^2 = 0.61) during the growing period, as well as the pooled regression (—; ADG = –0.57 ± 0.14 + [0.072 ± 0.008 × DMEI], R^2 = 0.62).

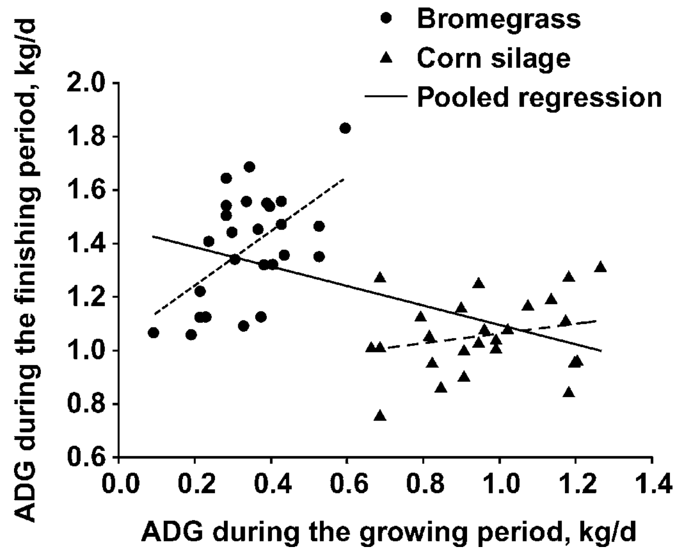

Figure 2. Relationships between rate of gain during the finishing period (ADG2) and rate of gain during the growing period (ADG1) for steers fed bromegrass hay (– – – ●; ADG2 = 1.05 ± 0.11 + [1.00 ± 0.31 × ADG1], R^2 = 0.31) or corn silage (——— ▲; ADG2 = 0.87 ± 0.15 + [0.19 ± 0.15 × ADG1], R^2 = 0.06) during the growing period, as well as the pooled regression (—; ADG2 = 1.46 ± 0.06 – [0.36 ± 0.09 × ADG2], R^2 = 0.26).

little effect of 50% *Bos indicus* influence on utilization of a high-grain diet. To our knowledge, compensatory gain responses of *Bos indicus* crossbred steers have not been directly compared with those of *Bos taurus* crossbred steers after moderate levels of dietary limitation of growth. Results from the cited studies have been used to suggest a diet by genotype interaction on feed utilization and animal performance, but are not conclusive.

Objectives of the current study were to: 1) evaluate diet × genotype interactions in terms of feed intake, feed utilization, and performance of steers fed ground bromegrass hay or corn silage-corn diet, and 2) evaluate effects of diet during the growing period on compensatory responses during the finishing period. Additional objectives are addressed in the companion papers (Berry et al., 2006; Miller et al., 2006).

MATERIALS AND METHODS

All animal procedures were reviewed and approved by the US Meat Animal Research Center Animal Care and Use Committee.

Fifty-one steers consisting of 15 MARC III (¼ Angus, ¼ Hereford, ¼ Red Poll, and ¼ Pinzgauer), 20 ¼ Brahman × ¾ MARC III (produced by artificial insemination of ½ Brahman × ½ MARC III cows to MARC III sires), 7 ½ Brahman × ½ MARC III (produced by artificial insemination of MARC III cows to Brahman sires), and 9 ¾ Brahman × ¼ MARC III (produced by artificial mating of ½ Brahman × ½ MARC III cows to Brahman sires) steers from the US Meat Animal Research Center (**MARC**) cattle populations were used for the study.

Upon weaning, the steers were transported to an intensive cattle confinement area followed by a 28-d adjustment period. The steers were then moved to 1 of 8 pens in a facility equipped with Calan-Broadbent electronic headgates (American Calan, Inc., Northwood, NH). The feeding facility consisted of pens that were approximately 9 × 9 m, with a concrete floor, and approximately one-third under a barn open to the south. Thus, the animals were partially protected from winter weather conditions. Approximately equal numbers of steers of each breed cross were represented in each pen. Steers were trained to use the individual headgates during the ensuing 28 d. During the 56 d postweaning period, the steers were fed a 50:50 blend of the chopped bromegrass hay and the corn silage-based diet (Table 1) to appetite and were weighed at weaning and at 28 and 56 d postweaning.

At the end of the adaptation period (December 2), the steers were weighed, and 7, 11, 3, and 5 of the 0, ¼, ½, and ¾ Brahman steers, respectively, were fed bromegrass, and 8, 9, 4, and 4 of the 0, ¼, ½, and ¾ Brahman steers, respectively, were fed corn silage individually to appetite (4 pens of steers on each diet). The bromegrass diet was chosen as a moderate-quality forage that might be available as a backgrounding diet and was intended to nutritionally limit ADG to about 0.3 to 0.4 kg/d. The corn silage diet was designed as a growing ration and was intended to result in ADG of approximately 1.0 kg/d. Trace mineral salt was provided in

Table 1. Diet formulations (as-fed)

Ingredient	Diet: Bromegrass hay	Corn silage	Finishing
Bromegrass hay, ground	100.00	0.00	0.00
Corn silage	0.00	87.02	23.94
Corn, ground	0.00	8.86	70.44
Soybean meal	0.00	3.35	4.63
Vitamin A, D, and E supplement[1]	0.00	0.415	0.008
Trace mineral supplement[2]	0.00	0.243	0.007
Salt	0.00	0.063	0.065
Urea	0.00	0.059	0.319
Limestone	0.00	0.00	0.574
Monensin premix[3]	0.00	0.00	0.014
Nutrient content (as concentration on a DM basis)			
DM, %	88.64	42.14	76.60
CP, %	9.50	11.92	13.35
ME, Mcal/kg	2.19	2.75	3.08
NE_m	1.27	1.66	2.07
NE_g	0.64	1.07	1.41
Ca, %	0.30	0.40	0.33
P, %	0.35	0.26	0.32

[1]The supplement provided 8,800,000 IU of vitamin A; 880,000 IU of vitamin D; and 880 ppm of vitamin E per kilogram.
[2]Trace mineral premix contained 13% Ca, 12% Zn, 8% Mn, 10% Fe, 1.5% Cu, 0.2% I, and 0.1% Co.
[3]Rumensin 80 (Elanco Animal Health, Indianapolis, IN).

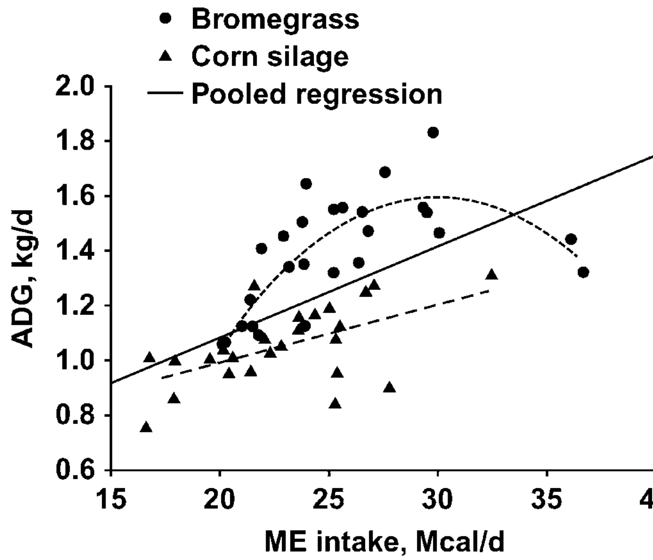

Figure 3. Relationships between ADG and daily ME intake (DMEI) during the finishing period for steers that had received bromegrass hay (– – – ●; ADG = –3.32 ± 0.84 + [0.327 ± 0.062 × DMEI] – [0.0054 ± 0.0011 × DMEI^2], R^2 = 0.64) or corn silage (——— ▲; ADG = 0.57 ± 0.15 + [0.021 ± 0.007 × DMEI], R^2 = 0.32) during the growing period, as well as the pooled regression (—; ADG = 0.42 ± 0.17 + [0.033 ± 0.007 × DMEI], R^2 = 0.33).

each pen. The growing period lasted 119 d. Steers were weighed at the beginning, end, and at 14-d intervals during the growing period. All steers were then switched, over a 2-wk "step-up" interval, to the high-concentrate diet, and were individually fed ad libitum to achieve a final target weight of 560 kg. Steers were weighed at 14-d intervals until slaughtered.

Steers were fed once daily throughout the study. Samples of each diet were taken daily, frozen, and composited over each 14-d interval. Weight and samples of unconsumed feed were taken at weekly intervals and composited for each 14-d interval. Composite feed and ort samples were subsequently analyzed for DM (oven drying at 70°C to constant weight), carbon and nitrogen (model CN 2000; Leco Corp., St. Joseph, MI), and gross energy (adiabatic bomb calorimeter). Dietary ME and NE values, as well as Ca and P concentrations, were calculated from tabular values for dietary ingredients (NRC, 1996).

All steers were slaughtered, upon achieving the target weight, at the MARC abattoir. Carcass data, including HCW, cold carcass weight, LM area, fat thickness at the 12th rib, adjusted fat thickness, percentage KPH, marbling score, quality grade, and yield grade were recorded by trained MARC personnel.

Steer weight or cumulative feed intake was regressed on days on feed for each animal for the growing and finishing periods. Those regressions were then used to calculate initial BW, BW at the end of the growing period, final BW, rate of gain, total DMI, and daily DMI of each steer during each period. Metabolizable energy intake was calculated by the use of DMI and tabular values for dietary ME concentration for each diet (Table 1). Data were analyzed by ANOVA and individual steer was the experimental unit. The statistical model included steer breed cross (or genotype), grower diet, and the 2-way interaction (Snedecor and Cochran, 1973). Means were compared by Student's *t*-test if the *F*-test was significant. Residual ADG for the growing period, finishing period, and total study was derived from the regression of ADG on daily ME intake and beginning BW for the respective feeding periods with all animals included. Similarly, residual ME intake was derived as residuals from the regression of daily ME intake on ADG and beginning BW for the respective feeding periods, with all animals included. These approaches were similar to those reported by Koch et al. (1963) and discussed by Pitchford (2004).

RESULTS AND DISCUSSION

The breed group (proportion Brahman) × diet interaction was not a significant ($P > 0.25$) source of variation for any trait evaluated; thus, least squares means are presented for the main effects of proportion Brahman and diet. Initial BW of ½ Brahman steers was greater ($P < 0.05$) than weights of other steers (Table 2). At the end of the 119-d growing period, ½ Brahman steers were heaviest ($P < 0.05$), MARC III steers were intermediate and not different from ¾ Brahman, and ¼ Brahman were lightest and not different from the ¾ Brahman. The ADG of MARC III and ½ Brahman steers

Table 2. Weight and performance of steers during the growing period

Trait	Proportion Brahman[1] 0	¼	½	¾	Growing period diet[2] Bromegrass	Corn silage	Mean	RSD[3]	Probability[4] B	GD	B × GD
No. of animals	15	20	7	9	26	25					
Initial wt, kg	273[a]	255[a]	321[b]	274[c]	288	274	273	39	0.006	0.25	0.92
Ending wt, kg	361[b]	325[a]	411[c]	339[ab]	330	388	350	48	0.002	0.0003	0.89
ADG, wt	0.74[b]	0.59[a]	0.75[b]	0.55[a]	0.35	0.96	0.64	0.14	0.005	0.0001	0.36
Daily DMI, kg	7.32[bc]	6.17[a]	7.95[c]	6.58[ab]	6.95	7.06	6.84	109	0.002	0.73	0.90
Daily CP intake, kg	0.79[bc]	0.66[a]	0.86[c]	0.71[ab]	0.66	0.84	0.73	0.12	0.002	0.0001	0.73
Daily ME intake, Mcal	18.1[bc]	15.2[a]	19.7[c]	16.2[ab]	15.2	19.4	16.9	2.72	0.002	0.0001	0.72
Total ME intake, Mcal	2,155[bc]	1,813[a]	2,345[c]	1,931[ab]	1,811	2,312	2,008	324	0.002	0.0001	0.72
DMI/gain, kg/kg	13.2	13.9	13.2	19.2	22.3	7.43	14.8	6.72	0.17	0.0001	0.31
CP intake/gain, kg/kg	1.34	1.41	1.35	1.93	2.13	0.88	1.50	0.64	0.16	0.0001	0.34
ME intake/gain, Mcal/kg	30.8	32.5	31.0	44.3	48.8	20.4	34.3	14.8	0.16	0.0001	0.34
Residual ADG[5]	–0.023	0.031	0.021	–0.033	–0.083	0.081	0	0.145	0.62	0.001	0.90
Residual ME intake[6]	0.46	–0.44	–0.03	–0.13	0.182	–0.121	0	1.54	0.42	0.53	0.80

[a–c]Means within a row with different superscripts differ, $P < 0.05$.

[1]Steers were 0, ¼, ½, or ¾ Brahman, with the remaining proportion from MARC III (¼ Angus, Hereford, Red Poll, Pinzgauer).

[2]The bromegrass diet consisted of coarse ground bromegrass hay, and the corn silage diet consisted of primarily corn silage (Table 1). These diets were fed ad libitum during the 119-d growing period.

[3]RSD = residual standard deviation.

[4]Probability that means differed due to proportion Brahman (B), growing period diet (GD), or the 2-way interaction (B × GD).

[5]Residual ADG was derived from regression of ADG on daily ME intake (DMEI) and initial BW (IWT), with all animals included. The resulting regression was: ADG = 0.071 (± 01.43) + [0.094 (± 0.007) × DMEI] – [0.0037 (± 0.0006) × IWT], $R^2 = 0.78$.

[6]Residual ME intake was derived from regression of DMEI on ADG and IWT with all animals included. The resulting equation was: DMEI = 0.433 (± 1.44) + [8.35 (± 0364) × ADG] + [0.041 (± 0.005) × IWT], $R^2 = 0.84$.

Table 3. Weight and performance of steers during the finishing period

Trait	Proportion Brahman[1]				Growing period diet[2]		Mean	RSD[3]	Probability[4]		
	0	¼	½	¾	Bromegrass	Corn silage			B	GD	B × GD
Beginning weight, kg	361[b]	325[a]	411[c]	339[a,b]	330	388	350	48	0.002	0.003	0.89
Final weight, kg	563	550	575	566	562	565	560	26	0.11	0.70	0.85
Days on feed	155[a]	196[b]	134[a]	199[b]	170	172	176	42	0.002	0.90	0.93
ADG, wt	1.32	1.18	1.21	1.16	1.40	1.04	1.22	0.17	0.087	0.001	0.70
Daily DMI, kg	8.44[b]	7.73[ab]	8.41[b]	6.82[a]	8.46	7.24	7.87	1.21	0.015	0.002	0.26
Daily CP intake, kg	0.97[b]	0.86[ab]	0.96[b]	0.78[a]	0.95	0.83	0.89	0.12	0.002	0.005	0.12
Daily ME intake, Mcal	26.0[b]	23.8[ab]	25.9[b]	21.0[a]	26.1	22.3	24.3	3.7	0.015	0.002	0.26
Total ME intake, Mcal	3,967[a]	4,528[b]	3,503[a]	4,127[ab]	4,323	3,720	4,147	758	0.02	0.17	0.24
DMI/gain, kg/kg	6.54	6.64	7.12	5.94	6.10	7.02	6.55	1.00	0.14	0.004	0.43
CP intake/gain, kg/kg	0.75	0.74	0.82	0.68	0.68	0.81	0.74	0.11	0.12	0.001	0.33
ME intake/gain, Mcal/kg	20.1	20.5	21.9	18.3	18.8	21.6	20.2	3.07	0.14	0.004	0.43
Residual ADG[5]	0.043	–0.052	–0.006	0.047	0.087	–0.071	0	0.170	0.33	0.004	0.52
Residual ME intake[6]	0.47	0.56	0.37	–2.33	0.39	–0.86	0	3.02	0.11	0.19	0.15

[a–c]Means within a row with different superscripts differ, $P < 0.05$.
[1]Steers were 0, ¼, ½, or ¾ Brahman, with the remaining proportion from MARC III (¼ Angus, Hereford, Red Poll, Pinzgauer).
[2]The bromegrass diet consisted of coarse ground bromegrass hay and the corn silage diet consisted of primarily corn silage (Table 1). These diets were fed ad libitum during the 119-d growing period. All steers were fed the high concentrate diet (Table 1) ad libitum during the finishing period.
[3]RSD = residual standard deviation.
[4]Probability that means differed due to proportion Brahman (B), growing period diet (GD), or the 2-way interaction (B × GD).
[5]Residual ADG was derived from regression of ADG on daily ME intake (DMEI) and beginning BW (SWT) with all animals included (n = 51). The resulting regression was: ADG = 0.70 (± 0.20) + [0.038 (± 0.0066) × DMEI] − [0.00112 (± 0.00046) × SWT], $R^2 = 0.41$.
[6]Residual ME intake was derived from regression of DMEI on ADG and SWT with all animals included (n = 51). The resulting equation was: DMEI = 3.10 (± 3.68) + [10.64 (± 1.88) × ADG] + [0.0232 (± 0.0075) × SWT], $R^2 = 0.45$.

was similar and greater ($P < 0.05$) than ADG of ¼ and ¾ Brahman steers. Daily DM, CP, and ME intake followed similar patterns among genotypes. However, neither DMI/gain (kg/kg), CP intake/gain (kg/kg), ME intake/gain (Mcal/kg), residual ADG, nor residual ME intake differed ($P > 0.16$) among steer breed groups. Because no breed cross by diet interaction was observed, we conclude that steers having 0, ¼, ½, and ¾ Brahman breeding responded to the different diets similarly. Thus, these results do not support previous suggestions that *Bos indicus* crosses utilize low-quality forages better than *Bos taurus* cattle (Ashton, 1962; Kaurue et al., 1972). These data are consistent with reports indicating that *Bos indicus* steers consume less feed (Beaver et al., 1989; Huffman et al., 1990), gain more slowly (Rogerson et al., 1968; Adams et al., 1982), but have similar feed conversion (Boyles and Riley, 1991) to *Bos taurus* steers. Feed consumption and ADG of ½ Brahman steers was similar to that of MARC III steers, but greater than ¼ and ¾ Brahman steers, consistent with the expected greater level of heterosis for these traits in the ½ Brahman steers (Dickerson, 1973; Koger et al., 1975).

Initial BW was similar for steers fed bromegrass hay and corn silage during the growing period, but steers fed corn silage gained BW faster and weighed more ($P < 0.0001$) at the end of the growing period. Daily DMI was similar ($P = 0.63$) between the 2 diets, but CP and ME intake was greater ($P < 0.0001$) for corn silage-fed steers. The DMI/gain, CP intake/gain, ME intake/gain, and residual ADG values improved with ($P < 0.001$) corn silage compared with bromegrass hay, but no difference ($P = 0.59$) in residual ME intake was detected. Intercepts of linear relationships between ADG (kg/d) and ME intake (Mcal/d, Figure 1) differed (–0.136 ± 0.098 vs. 0.213 ± 0.125; $P < 0.04$) between steers fed bromegrass hay and those fed the corn silage diet, but slopes of the relationships were similar (0.032 ± 0.007 vs. 0.039 ± 0.006, $P = 0.49$). We interpret these relationships to suggest that ADG of corn silage-fed steers was greater than ADG of bromegrass hay-fed steers at the same ME intake. Conversely, steers fed bromegrass hay required 5.3 Mcal of ME/d more to achieve the same rate of gain as steers fed the corn silage diet. This observation suggests that either maintenance needs were lower for corn silage-fed steers or nutrients from the corn silage diet were utilized more efficiently than those from bromegrass hay, or both. The ratios of CP/ME intakes were similar for the bromegrass hay (43.4 g/Mcal) and corn silage (43.3 g/Mcal) diets suggesting the protein to energy ratio or protein availability was not causing the differences. Numerous other potential explanations exist. The data presented in Figure 1 also demonstrated that use of the pooled regression does not adequately describe the data. In this situation, use of residuals from the pooled regression is inappropriate. Results shown in Figure 1 also show why no differences ($P > 0.40$) were detected in residual ME intake (Table 1) due to breed, diet, or the interactions. Similar problems with residual analysis were described in some detail by Darlington and Smulders (2001).

All steers were fed the same high-concentrate diet to appetite during the finishing phase of the study. Beginning weight for the finishing period (ending

Table 4. Weight and performance of steers over the entire study

Trait	Proportion Brahman[1]				Growing period diet[2]		Mean	RSD[3]	Probability[4]		
	0	¼	½	¾	Bromegrass	Corn silage			B	GD	B × GD
Initial weight, kg	273[a]	255[a]	321[b]	274[a]	288	274	273	39	0.006	0.25	0.92
Final weight, kg	563	550	575	566	562	565	560	26	0.11	0.70	0.85
Days on feed	274[a]	315[b]	253[a]	318[b]	289	291	295	42	0.002	0.90	0.93
ADG, wt	1.06[b]	0.95[a]	1.00[ab]	0.93[a]	0.96	1.01	0.99	0.10	0.004	0.08	0.78
Daily DMI, kg	7.97[b]	7.13[a]	8.21[b]	6.73[a]	7.82	7.19	7.46	1.02	0.006	0.05	0.62
Daily CP intake, kg	0.89[b]	0.78[a]	0.91[b]	0.75[a]	0.83	0.84	0.83	0.10	0.001	0.68	0.45
Daily ME intake, Mcal	22.5[b]	20.4[a]	23.1[b]	19.2[a]	21.5	21.2	21.2	2.75	0.010	0.72	0.48
Total ME intake, Mcal	6,123	6,341	5,848	6,058	6,134	6,051	6,155	711	0.43	0.71	0.26
DMI/gain, kg/kg	7.52	7.54	8.25	7.32	8.21	7.10	7.60	0.97	0.27	0.0005	0.66
CP intake/gain, kg/kg	0.84	0.83	0.92	0.81	0.87	0.83	0.84	0.09	0.15	0.17	0.49
ME intake/gain, Mcal/kg	21.3	21.6	23.2	20.8	22.6	20.9	21.6	2.68	0.37	0.05	0.64
Residual ADG[5]	0.048	−0.023	−0.022	−0.13	−0.034	0.028	0	0.091	0.12	0.03	0.87
Residual ME intake[6]	0.37	0.18	0.35	−1.31	0.20	−0.40	0	2.12	0.26	0.36	0.28

[a,b]Means within a row with different superscripts differ, $P < 0.05$.

[1]Steers were 0, ¼, ½, or ¾ Brahman, with the remaining proportion from MARC III (¼ Angus, Hereford, Red Poll, Pinzgauer).

[2]The bromegrass diet consisted of coarse ground bromegrass hay and the corn silage diet consisted of primarily corn silage (Table 1). These diets were fed ad libitum during the 119-d growing period. All steers were fed the high concentrate diet (Table 1) ad libitum during the finishing period.

[3]RSD = residual standard deviation.

[4]Probability that means differed due to proportion Brahman (B), growing period diet (GD), or the 2-way interaction (B × GD).

[5]Residual ADG was derived from regression of ADG on daily ME intake (DMEI) and initial BW (IWT) with all animals included (n = 51). The resulting regression was: ADG = 0.51 (± 0.11) + [0.0233 (± 0.005) × ADG] − [0.00007 (± 0.00037) × IWT], $R^2 = 0.35$.

[6]Residual ME intake was derived from regression of DMEI on ADG and IWT with all animals included (n = 51). The resulting equation was: DMEI = 1.80 (± 2.93) + [12.24 (± 2.80) × ADG] + [0.027 (± 0.0075) × IWT], $R^2 = 0.48$.

weight for the growing period) differed due to proportion Brahman and diet during the growing period (Table 3), but as defined by the experimental protocol, final BW was not different due to breed group, previous diet, or the 2-way interaction. However, there were fewer ($P = 0.002$) days on feed during the finishing period for MARC III (155 d) and ½ Brahman (134 d) steers than for ¼ (196 d) or ¾ (199 d) Brahman steers, reflecting differences in beginning weight and a trend ($P = 0.096$) for differences in rate of gain. Daily DM, CP, and ME intakes by MARC III and ½ Brahman steers were greater than daily intakes by ¼ or ¾ Brahman steers. However, because of the greater time required to achieve the target final weight, total ME intakes during the finishing period were 3,928, 4,530, 3,503, and 4,127 Mcal for 0, ¼, ½, and ¾ Brahman steers ($P = 0.016$), respectively. Neither DMI/gain, CP intake/gain, ME intake/gain, nor residual ADG differed ($P > 0.12$) among breed groups indicating that even with the substantial differences in feed intake and days on feed, estimates of feed conversion did not differ substantially among the breed groups. Residual ME intake tended ($P = 0.11$) to differ among breed groups, primarily because ¾ Brahman had lower residual ME intake than the other groups. This result is consistent with other measures of efficiency in that the ¾ Brahman had lower feed intake, grew slower, and required more days on feed to reach slaughter weight, and yet had numerically lower DM, CP, or ME consumption per kilogram of gain than other groups of steers.

Steers that had been fed bromegrass hay during the growing period weighed less at the beginning of the finishing period than those fed corn silage, but final weights (by design; $P = 0.66$) and days on feed ($P = 0.99$) were similar. Rate of gain by steers that had been fed bromegrass hay was nearly 40% greater ($P < 0.0001$) during the finishing period than rate of gain of steers that had been fed corn silage. The greater rate of gain reflected, in part, greater ($P < 0.01$) daily intake of DM, CP, and ME. Measures of feed conversion (DMI/gain, CP intake/gain, ME intake/gain, and residual ADG) were improved ($P < 0.01$) for steers that had been fed bromegrass hay during the growing period compared with those that had received the corn silage diet. No effects of previous diet or breed cross ($P = 0.11$) on residual ME intake was detected.

Relationships between rate of gain during the growing and finishing periods (Figure 2) show that when all animals are included, greater rate of gain during the growing period (**ADG1**) was associated ($P < 0.001$) with lower rate of gain (**ADG2**) during the finishing period (ADG2 = 1.45 − 0.36 × ADG1, $R^2 = 0.26$). These results are consistent with conventional thinking (Carstens, 1995), in that greater rates of gain during the growing period are associated with lower subsequent performance. However, when evaluated within dietary treatment group, rate of gain during the finishing period was positively associated ($P = 0.02$) with rate of gain during the growing period. These observations suggest that animals that had greater rates of gain compared with contemporaries fed the same diet continued to perform at a greater level after being switched to the high-concentrate diet.

Table 5. Influence of breed composition and diet during the growing period on carcass characteristics of steers slaughtered at similar final weights

Trait	Proportion Brahman[1]				Growing period diet[2]		Mean	RSD[3]	Probability[4]		
	0	¼	½	¾	Bromegrass	Corn silage			B	GD	B × GD
Final wt, kg	564	550	575	566	562	565	560	26	0.11	0.70	0.85
Carcass wt, kg	340[a]	338[a]	359[b]	349[ab]	340	353	343	15	0.02	0.01	0.50
Dressing percent	60.4	61.6	62.3	61.6	61.5	62.4	61.3	1.9	0.13	0.002	0.85
Marbling score[5]	470[bc]	490[c]	390[ab]	364[a]	444	413	450	95	0.006	0.29	0.69
Quality grade[6]	16.2[b]	16.2[b]	15.0[ab]	14.3[a]	15.7	15.2	15.7	1.3	0.002	0.19	0.92
Fat thickness,[7] cm	1.01	1.50	1.29	1.44	1.17	1.44	1.31	0.72	0.25	0.22	0.82
Adjusted fat thickness,[8] cm	0.88	1.30	1.10	1.35	0.96	1.35	1.15	0.60	0.17	0.04	0.59
LM area, cm^2	80.3	74.4	78.4	76.0	77.3	77.2	76.9	7.1	0.11	0.95	0.62
KPH, %	3.13	2.76	3.23	2.15	2.65	2.98	2.80	0.91	0.06	0.24	0.72
Yield grade	2.86	3.45	3.38	3.29	3.00	3.49	3.23	0.82	0.21	0.05	0.54

[a–c]Means within a row with different superscripts differ, $P < 0.05$.
[1]Steers were 0, ¼, ½, or ¾ Brahman, with the remaining proportion from MARC III (¼ Angus, Hereford, Red Poll, Pinzgauer).
[2]The bromegrass diet consisted of coarse ground bromegrass hay and the corn silage diet consisted of primarily corn silage (Table 1). These diets were fed ad libitum during the 119-d growing period. All steers were fed the high concentrate diet (Table 1) ad libitum during the finishing period.
[3]RSD = residual standard deviations.
[4]Probability that means differed due to proportion Brahman (B), growing period diet (GD), or the 2-way interaction (B × GD).
[5]Small = 400, modest = 500, etc.
[6]High select = 15, low choice = 16, etc.
[7]Fat thickness at the 12th rib.
[8]Fat thickness subjectively adjusted for overall visual appearance of fatness.

Relationships between ADG and ME intake during the finishing period for steers that had received bromegrass hay or corn silage during the growing period, as well as the pooled regression, are presented in Figure 3. The regressions for steers previously fed corn silage and the pooled regression did not deviate from linearity, but the relationship between ADG and daily ME intake for steers fed bromegrass hay during the growing period was nonlinear (quadratic, $P < 0.005$). The nonlinearity appeared to be largely attributable to 2 steers that had very high intakes (11.9 and 11.7 kg of DMI daily) with approximately average rates of gain (1.32 and 1.44 kg/d). However, removal of the 2 "outliers" resulted in a very similar regression ($ADG = -3.42 + 0.336 \times DMEI - 0.0056 \times DMEI^2$, $R^2 = 0.64$), where DMEI = daily ME intake. The ADG of steers previously fed bromegrass hay (1.32 ± 0.03) or corn silage (1.08 ± 0.03) adjusted to mean daily ME intake differed ($P < 0.0001$). Furthermore, maximum gain (1.63 kg/d) was achieved at 30.3 Mcal of ME intake per day in steers previously fed bromegrass. At the same ME intake, steers that had been fed corn silage gained 1.21 kg/d. These results indicate that ME consumed was used more efficiently for live weight gain by steers previously fed bromegrass hay. These observations are consistent with previous observations (Carstens, 1995) and show that part of the compensatory gain response is due to improved efficiency of feed utilization.

Over the entire study, days on feed were less ($P < 0.01$) for MARC III and ½ Brahman steers than for ¼ or ¾ Brahman steers (Table 4), and rate of gain was greatest for MARC III, intermediate for ½ Brahman, and least for ¼ and ¾ Brahman steers. Although daily feed intake (DM, CP, or ME) differed ($P < 0.01$) among breed groups, total ME intake was not different ($P = 0.41$). Consistent with the latter observation, none of the measures of efficiency of feed utilization differed ($P > 0.10$) among breed groups.

Initial BW, final BW, and days on feed for the entire study of steers fed bromegrass hay during the growing period were similar to those of steers fed corn silage, but rate of gain tended ($P = 0.07$) to be lower and daily DMI tended ($P = 0.06$) to be greater. The daily CP and ME intakes and total ME intake during the entire study of the 2 groups were similar ($P > 0.50$), but DMI/gain ($P < 0.001$), ME intake/gain ($P = 0.05$), and residual ADG ($P = 0.03$) favored steers fed corn silage during the growing period. No differences in CP intake/gain ($P = 0.17$) or residual ME intake ($P = 0.36$) were detected.

Even though final live BW did not differ ($P > 0.10$) due to breed group, growing period diet, or the interaction, carcass weight differed (Table 5) due to both breed group ($P = 0.02$) and growing period diet ($P = 0.01$). Dressing percent did not differ among breed groups ($P = 0.13$), but was greater ($P = 0.002$) for steers fed corn silage during the growing period than for steers fed bromegrass hay reflecting, in part, differences in DMI and presumably, gut fill, during the finishing period. Marbling score and quality grade was lower ($P < 0.01$) for ½ and ¾ Brahman than for MARC III or ¼ Brahman steers. Percentage KPH tended to differ ($P = 0.06$) among breed groups, with ¾ Brahman having the least, ¼ Brahman intermediate, and ½ Brahman and MARC III having the greatest amount. Neither fat thickness at the 12th rib, LM area, nor yield grade differed ($P > 0.17$) among breed groups. Influence of proportion Brahman on carcass characteristics was consistent with observations reported by Crouse et al. (1989). Growing period diet did not have significant affects ($P > 0.20$) on marbling score, quality grade, fat thickness, LM area, or KPH, although adjusted fat thickness ($P = 0.04$) and yield grade ($P = 0.05$) were greater in steers that had consumed the corn silage diet during the growing period.

IMPLICATIONS

Differences in numerous traits among breed crosses were observed in this study. Those differences reflected, in part, lower feed intake, lower performance, and reduced carcass quality characteristics of Brahman compared with MARC III steers. Many of these genotypic differences appeared to be negated by the high level of heterosis of the ½ Brahman steers. No evidence was observed to support suggestions that Brahman crossbred steers respond to varying diet quality differently than *Bos taurus* steers. Performance and feed utilization was reduced in steers grown on bromegrass hay, but compensation was observed when they were switched to a high-concentrate diet, compared with those that were grown on a corn silage diet. However, when evaluated over the total system, compensatory responses were insufficient to totally overcome reduced performance during the growing period.

LITERATURE CITED

Adams, N. J., G. C. Smith, and Z. L. Carpenter. 1982. Performance, carcass and palatability characteristics of Longhorn and other types of cattle. Meat Sci. 7:67–79.

Ashton, G. C. 1962. Comparative nitrogen digestibility in Brahman, Brahman × Shorthorn, Africander × Hereford and Hereford steers. J. Agric. Sci. 58:333–341.

Beaver, E. D., J. E. Williams, S. J. Miller, D. L. Hancock, S. M. Hannah, and D. L. O'Conner. 1989. Influence of breed and diet on growth, nutrient digestibility, body composition and plasma hormones of Brangus and Angus steers. J. Anim. Sci. 67:2415–2425.

Berry, E. D., J. E. Wells, S. L. Archibeque, C. L. Ferrell, H. C. Freetly, and D. N. Miller. 2006. Influence of genotype and diet on steer performance, manure odor, and carriage of pathogenic and other fecal bacteria. II. Pathogen and other fecal bacteria. J. Anim. Sci. 84:2523–2532.

Boyles, S. L., and J. G. Riley. 1991. Feedlot performance of Brahman × Angus versus Angus steers during cold weather. J. Anim. Sci. 69:2677–2684.

Carstens, G. E. 1995. Compensatory growth in beef cattle. Pages 70–84 in Proc. Symp. Intake by Feedlot Cattle. Oklahoma Agric. Exp. Sta. P-942, Stillwater.

Crouse, J. D., L. V. Cundiff, R. M. Koch, M. Koohmaraie, and S. C. Seideman. 1989. Comparisons of *Bos indicus* and *Bos taurus* inheritance for carcass beef characteristics and meat palatability. J. Anim. Sci. 67:2661–2668.

Darlington, R. B., and T. V. Smulders. 2001. Problems with residual analysis. Anim. Behav. 62:599–602.

Dickerson, G. E. 1973. Inbreeding and heterosis in animals. Pages 54–77 in Proc. Anim. Breed. Genetics Symp. in honor of Dr. J. L. Lush. Am. Soc. Anim. Sci., Savoy, IL.

Frisch, J. E., and J. E. Vercoe. 1977. Food intake, eating rate, weight gains, metabolic rate and efficiency of feed utilization in *Bos taurus* and *Bos indicus* crossbred cattle. Anim. Prod. 25:343–358.

Huffman, R. D., S. E. Williams, D. D. Hargrove, D. D. Johnson, and T. T. Marshall. 1990. Effect of percentage Brahman and Angus breeding, age-season of feeding and slaughter end point on feedlot performance and carcass characteristics of steers. J. Anim. Sci. 68:2243–2252.

Kaurue, C. N., J. L. Evans, and A. D. Tillman. 1972. Metabolism of nitrogen in Boran and Hereford-Boran crossbred steers. J. Anim. Sci. 35:1025–1030.

Koch, R. M., L. A. Swiger, D. Chambers, and K. E. Gregory. 1963. Efficiency of feed use in cattle. J. Anim. Sci. 22:486–494.

Koger, M., F. M. Peacock, W. G. Kirk, and J. R. Crockett. 1975. Heterosis effects on weaning performance of Brahman-Shorthorn calves. J. Anim. Sci. 40:826–833.

Krehbiel, C. R., K. K. Kreikemeier, and C. L. Ferrell. 2000. Influence of *Bos indicus* crossbreeding and cattle age on apparent utilization of a high grain diet. J. Anim. Sci. 78:1641–1647.

Ledger, H. P., A. Rogerson, and G. H. Freeman. 1970. Further studies on the voluntary food intake of *Bos indicus* and *Bos taurus* and crossbred cattle. Anim. Prod. 12:426–431.

Miller, D. N., E. D. Berry, J. E. Wells, C. L. Ferrell, and H. C. Freetly. 2006. Influence of genotype and diet on steer performance, manure odor, and carriage of pathogenic and other fecal bacteria. III. Odorous compound production. J. Anim. Sci. 84:2533–2545.

Moran, J. B. 1976. The grazing feed intake of Hereford and Brahman cross cattle in a cool temperate environment. J. Agric. Sci. 86:131–134.

NRC. 1996. Nutrient Requirements of Beef Cattle. National Academy of Science, National Academy Press, Washington, DC.

O'Donovan, P. B., A. Gebrewolde, B. Kebede, and E. S. Galal. 1978. Fattening studies with cross-bred (European × Zebu) bulls. 1. Performance on diets of native hay and concentrate. J. Agric. Sci. 90:425–429.

Pitchford, W. S. 2004. Genetic improvement of feed efficiency of beef cattle: What lessons can be learnt from other species. Aust. J. Exp. Agric. 44:371–382.

Rogerson, A., H. P. Ledger, and G. H. Freeman. 1968. Food intake and live weight gain comparisons of *Bos indicus* and *Bos taurus* steers on a high plane of nutrition. Anim. Prod. 10:373–380.

Snedecor, G. W., and W. G. Cochran. 1973. Statistical Methods. 6th ed. Iowa State Univ. Press, Ames.