

# Effect of breed composition on phenotypic residual feed intake and growth in Angus, Brahman, and Angus × Brahman crossbred cattle

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**ABSTRACT:** The influence of additive and nonadditive genetic effects and temperament on 4 postweaning feed intake and growth traits was evaluated in a group of 581 bull, heifer, and steer calves born in 3 Florida herds in 2006 and 2007. Calves had breed compositions ranging from 100% Angus (A) to 100% Brahman (B). They were randomly allocated to 24 pens each year by herd (Brooksville, Gainesville, Marianna, FL), sire group (A, 3/4 A 1/4 B, Brangus, 1/2 A 1/2 B, 1/4 A 3/4 B, and B), and sex (bull, heifer, and steer) in a GrowSafe automated feeding facility at Marianna. Calves were fed a concentrate diet during the 21-d adjustment and the 70-d trial periods. Individual feed intakes were recorded daily, and BW, chute scores, and exit velocities were recorded every 2 wk. Traits were phenotypic daily residual feed intake (RFI), mean daily feed intake (DFI), mean daily feed conversion ratio (FCR), and postweaning BW gain. Phenotypic RFI was computed as the difference between actual and expected feed intakes. Calves were assigned to 3 RFI groups: high (RFI greater than 0.9 kg of DM/d),

low (RFI less than  $-0.9$  kg of DM/d), and medium (RFI between mean  $\pm 0.9$  kg of DM/d; SD = 1.8 kg of DM/d). The mixed model included the fixed effects of contemporary group (herd-year-pen), RFI group (except when trait was RFI), age of dam, sex of calf, age of calf, B fraction of calf, heterozygosity of calf, mean chute score, and mean exit velocity. Brahman fraction and heterozygosity of calf were nested within sex of calf for RFI and within RFI group for DFI, FCR, and postweaning BW gain. Random effects were sire and residual. Feed efficiency tended to improve (decreased RFI) as the B fraction increased. However, calves required larger amounts of feed per kilogram of BW gain (larger FCR) as the B fraction increased. Postweaning BW gain tended to decrease as the B fraction increased. Temperament traits were unimportant for all traits except exit velocity for DFI, suggesting perhaps a lack of variation for temperament traits in this herd, or that calves became accustomed to the level of handling pre- and postweaning, thus decreasing behavioral differences among them.

**Key words:** calf, feed intake, multibreed, temperament

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## INTRODUCTION

In an era of dwindling resources and escalating costs of production, efficiency of feed utilization has become an essential component of beef cattle production systems. Particular attention has been devoted to phenotypic daily residual feed intake (RFI; Koch et al., 1963), defined as the difference between the actual feed intake of an animal and the expected feed intake over a

time period. For growing cattle, expected feed intake is usually computed as a regression of intake on ADG and metabolic midweight (Archer et al., 1997; Arthur et al., 2001a,b; Nkrumah et al., 2004, 2007). This makes RFI phenotypically independent of ADG and metabolic midweight by design (Kennedy et al., 1993; Crews, 2005). Largely because of this property, RFI has become the preferred measure of efficiency of feed utilization. Research on RFI and postweaning growth in beef cattle has been concentrated in temperate regions and has used either purebred (Archer et al., 1997; Arthur et al., 2001a,b; Schenkel et al., 2004) or crossbred (Basarab et al., 2003; Nkrumah et al., 2004, 2007) *Bos taurus* cattle. Breed has been found to affect both growth and

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RFI (Nkrumah et al., 2004; Schenkel et al., 2004), and temperament scores have been associated with growth in beef cattle (Burrow and Dillon, 1997; Voisinet et al., 1997). Studies involving RFI and its association with breed composition, postweaning growth, and temperament using *B. taurus* and *Bos indicus* cattle in subtropical and tropical environments may yield substantially different results from those obtained for *B. taurus* breeds in temperate regions. Thus, the objectives of this research were to assess the effect of breed composition and indicators of temperament [chute score (**CS**) and exit velocity (**EV**)] on RFI, daily feed intake (**DFI**), feed conversion ratio (**FCR**), and postweaning growth, and to estimate genetic parameters for these traits in a group of bulls, heifers, and steers ranging from 100% Angus (**A**) to 100% Brahman (**B**).

## MATERIALS AND METHODS

Research protocols were approved by the University of Florida Institutional Animal Care and Use Committee.

### *Animals and Preconditioning*

Animals ( $n = 581$ ) were from 3 Florida herds of beef cattle located in Brooksville ( $n = 100$ ), Gainesville ( $n = 388$ ), and Marianna ( $n = 93$ ), Florida. Calves were born in 2006 ( $n = 330$ ) and 2007 ( $n = 251$ ). Established standards for animal care and use were followed. There were 31 bulls, 317 heifers, and 233 steers from 6 breed groups: A ( $n = 153$ ), 3/4 A 1/4 B ( $n = 66$ ), Brangus (5/8A 3/8 B;  $n = 107$ ), 1/2 A 1/2 B ( $n = 115$ ), 1/4 A 3/4 B ( $n = 49$ ), and B ( $n = 91$ ). Calves from the 3 locations were born between December and March and were weaned in August or early September in 2006 and 2007. After weaning, calves grazed on bahiagrass (*Paspalum notatum*) pastures and received a preconditioning diet for 3 to 6 wk in preparation for their feed intake trial at the Feed Efficiency Facility of the Institute of Food and Agricultural Sciences of the University of Florida (**IFEF**), equipped with GrowSafe technology (GrowSafe Systems Ltd., Airdrie, Alberta, Canada), in Marianna. Heifers from Brooksville received a preconditioning cottonseed- and soybean meal-based ration (1.8 kg/d; 14% CP; 488 Pellet Medicated Weaning Ration, Lakeland Animal Nutrition, Lakeland, FL), bahiagrass hay, and a free-choice mineral (Brooksville Research Mineral, Lakeland Animal Nutrition). Calves from Gainesville were fed concentrate (1.6 kg to 3.6 kg/d; 14.0% CP; 488 Pellet Medicated Weaning Ration, Lakeland Animal Nutrition; and soyhull pellets), bahiagrass hay, and a free-choice mineral (UF University Special Hi-Cu Mineral, University of Florida, Animal Science Department, Gainesville). Calves from Marianna were given 2.5 kg of a mixed feed (75% soyhull pellets and 25% corn gluten pellets; 15.1% CP). They also had access to free-choice Tifton 85 bermudagrass hay and a complete mineral (Southern States, Marianna, FL). Subsequently, calves

were moved to the IFEF in September (Gainesville and Marianna) and October (Brooksville).

### *Management, Nutrition, and Data Collection at the IFEF*

Calves were randomly allocated to 24 pens at the IFEF within herd (Brooksville, Gainesville, and Marianna) by sire group [A, 3/4 A 1/4 B, Brangus (5/8 A 3/8 B), 1/2 A 1/2 B, 1/4 A 3/4 B, and B] by sex (bull, heifer, and steer) subclass in 2006 and in 2007. The IFEF has 24 pens (108 m<sup>2</sup>/pen) equipped with 2 GrowSafe feed nodes in each pen. Calves were identified with passive, half-duplex, transponder ear tags (Allflex USA Inc., Dallas-Fort Worth, TX) before entering the IFEF facility. The mean stocking rate was 16.9 calves per pen. Each pen had 2 GrowSafe nodes; thus, the mean stocking rate per node was 8.5 calves per GrowSafe node, and the range was from 7.5 to 10 calves per GrowSafe node. Animals were fed a concentrate diet ad libitum twice daily. The 2006 concentrate diet was composed of whole corn, soybean hulls, corn gluten feed, cottonseed hulls, and a protein, vitamin, and mineral supplement (FRM, Bainbridge, GA). The 2007 diet had greater fiber content (chopped bermudagrass instead of soybean hull pellets). The concentrate had a DM, CP, NE<sub>m</sub>, and NE<sub>g</sub> of 91.2%, 17.3%, 1.7 mcal/kg of DM, and 1.2 mcal/kg of DM in 2006, and 90.0%, 14.1%, 1.5 mcal/kg of DM, and 0.9 mcal/kg of DM in 2007. The pretrial adjustment period was 21 d, and the trial period lasted 70 d. GrowSafe software recorded individual feed intake in real time. Body weights and temperament traits were taken every 2 wk.

### *Traits*

Traits were phenotypic RFI, mean DFI, mean daily FCR, and postweaning BW gain (**PWG**). All intake traits were converted to a DM basis before analyses.

Individual feed disappearance and node attendance data were recorded using GrowSafe Data Acquisition software (GrowSafe Systems Ltd.) and DFI were compiled using the Process Intakes routine. Individual DFI data were excluded from the analysis because of equipment failure or when the proportion of daily feed assigned to individual animals (leakage) at any feeding station was less than 94% for a given day. Individual pens constituted a feeding station (2 GrowSafe nodes). A total of 3,220 feeding station days were produced during the study, with 19 and 28 d excluded from the data set in 2006 and 2007, respectively. The GrowSafe system accounted for  $99.53 \pm 1.49\%$  (range = 75.12 to 100%) of the feed delivered to the nodes being assigned to individual animals, showing the software to be robust. Feed disappearance when comparing feed delivery equipment with the GrowSafe system (2006 only) was within 98.52% agreement between the 2 weighing systems, indicating highly accurate data. Animals with individual means for feed intake 3 SD below or above

the sample mean were considered outliers and were removed from the analysis.

Phenotypic daily RFI was computed as the difference between actual average DFI and expected DFI (Koch et al., 1963; Archer et al., 1997; Arthur et al., 2001a,b) during the 70-d postweaning feeding trial. Expected DFI was estimated as a linear regression of average DFI on ADG and metabolic midweight. Thus, expected DFI was computed across all pens, years, breed groups, and sexes of calves. The proportion of the variation for average DFI explained by this model (i.e.,  $R^2$  value) was 30%. This  $R^2$  value computed across subclasses (pens, years, breed groups, and sexes of calves) was less than 50% of  $R^2$  values estimated within subclasses (steers within years: Basarab et al., 2003; bulls within test groups: Schenkel et al., 2004). The smaller  $R^2$  value obtained here was likely because the regression of DFI on ADG and metabolic midweight was done across pens, years, breed groups, and sexes of calves. Average daily gain was computed as the regression of calf BW on test day, using BW taken every 2 wk at the IFEF. Midweight was computed as the sum of the regression estimate for initial BW plus the regression estimate for ADG times 35 d. Metabolic midweight was equal to the estimated midweight to the power of 0.75.

Total DFI was the sum of all measurements of feed intake for each animal measured by the GrowSafe system for a given day, and DFI was the average DFI over the 70-d trial period. Mean daily FCR was computed as the ratio of DFI to ADG. Postweaning BW gain was computed as the difference between the BW of each calf at the end and at the beginning of the 70-d trial.

Mean CS was the average of the 6 CS measured every 2 wk (1 = docile; 2 = restless; 3 = nervous; 4 = flighty; 5 = aggressive; 6 = very aggressive; Beef Improvement Federation, 2002) during the 70-d trial period. Similarly, mean EV was the average of the 6 EV (velocity out of the chute in meters per second; Burrow and Dillon, 1997; Curley et al., 2006) measurements taken every 2 wk at the IFEF.

### Statistical Analysis

Calves were assigned to 3 groups according to their RFI values (Nkrumah et al., 2004). The RFI groups were high (calf RFI > mean + 0.5 SD), medium (calf RFI between mean  $\pm$  0.5 SD; SD = 1.8 kg), and low (calf RFI < mean - 0.5 SD). Feed efficiency increases from high to medium to low RFI groups; thus, calves in the low RFI group were the most efficient and calves in the high RFI group were the least efficient. Allocation of calves to low, medium, and high RFI groups was done using the complete data set. Numbers of calves per RFI group appeared to depend on their breed composition. Thus, a log-linear analysis (Stokes et al., 2000; Agresti, 2002) of calf frequencies per breed group by RFI group was conducted to test the hypothesis of independence between breed group and RFI group. Computations

were performed using the CATMOD procedure (SAS Inst. Inc., Cary, NC).

Traits were analyzed individually using mixed models. Fixed effects were contemporary group (herd-year-pen; herd = Brooksville, Gainesville, and Marianna; year = 2006 and 2007; pen = 1 to 24), RFI group (except when trait was RFI), age of dam (1 = 3 yr, 2 = 4 yr, and 3 = 5 yr and older), sex of calf (1 = bull, 2 = heifer, and 3 = steer), age of calf, B fraction of calf, heterozygosity of calf (i.e., probability of A and B alleles at 1 locus in the calf), mean CS, and mean EV. Brahman fraction and heterozygosity of calf were nested within sex of calf for RFI, and within RFI group for the other traits. Preliminary models for DFI, FCR, and PWG contained the B fraction and heterozygosity nested within sex of calf and within RFI group. The B fraction and heterozygosity nested within sex of calf were nonsignificant for these traits and thus were dropped from the final models. Random effects were sire and residual. Sires effects were assumed to have a mean of zero, a common variance of  $\sigma_s^2$ , and to be uncorrelated. Similarly, residual effects were assumed to have a mean of zero, a common variance of  $\sigma_e^2$ , and to be uncorrelated. Mixed model analyses were carried out using the MIXED procedure of SAS.

Sex of calf least squares means for RFI and for differences between sexes for the 6 breed groups defined here were computed using the expected B fraction of each group (0.0 for A, 0.25 for 3/4 A 1/4 B, 0.375 for Brangus, 0.5 for 1/2 A 1/2 B, 0.75 for 1/4 A 3/4 B, and 1.0 for B) and the expected heterosis of each group (0.0 for A, 0.5 for 3/4 A 1/4 B, 0.469 for Brangus, 1.0 for 1/2 A 1/2 B, 0.5 for 1/4 A 3/4 B, and 0.0 for B). Similarly, RFI group least squares means for DFI, FCR, and PWG, and differences between RFI groups for the 6 breed groups were computed using the expected B fractions and heterosis for each breed group. Bonferroni *t*-tests were used to compare pairs of least squares means.

Restricted maximum likelihood estimates of heritabilities for, and genetic and phenotypic correlations among, RFI, DFI, FCR, and PWG were obtained using ASREML (Gilmour et al., 1999). Genetic parameters were estimated using 2-trait analyses (RFI-DFI, RFI-FCR, RFI-PWG, DFI-FCR, DFI-PWG, and FCR-PWG) because of the small size of the data set (655 calves with records). The same model was used for all traits. Fixed effects were contemporary group, age of dam, sex of calf, age of calf, B fraction of calf nested within sex of calf, heterozygosity of calf nested within sex of calf, mean CS, and mean EV. Random effects were calf and residual. Calf effects were assumed to have a mean of zero, and variance equal to the relationship matrix times (direct product) the  $2 \times 2$  variance-covariance matrix of additive genetic effects for each pair of traits analyzed. For example, the elements of the additive genetic variance-covariance matrix for the analysis of RFI and DFI were **addvar**(RFI),

**Table 1.** Numbers of calves, means, and SD per breed group of calf by residual feed intake group and total

Breed group	RFI group <sup>1</sup>	N	Trait <sup>2</sup>							
			RFI, kg of DM/d		DFI, kg of DM/d		FCR, kg of DM·d <sup>-1</sup> / kg of BW gain·d <sup>-1</sup>		PWG, kg	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD
Angus	High	30	2.34	1.14	11.72	1.38	10.43	2.39	81.61	23.79
Angus	Medium	72	-0.10	0.50	9.45	1.11	7.36	1.56	95.16	22.70
Angus	Low	51	-1.70	0.83	7.61	1.39	6.81	2.53	84.38	29.28
3/4 A 1/4 B <sup>3</sup>	High	22	2.33	1.33	12.38	1.13	9.69	2.81	94.55	21.60
3/4 A 1/4 B	Medium	33	-0.02	0.45	9.93	1.34	7.16	1.45	101.79	21.99
3/4 A 1/4 B	Low	11	-2.34	1.80	7.79	2.15	6.49	2.17	89.59	22.38
Brangus	High	20	2.95	1.88	12.54	2.00	10.08	2.09	89.41	19.96
Brangus	Medium	63	-0.11	0.58	9.80	0.97	6.93	1.21	103.41	20.66
Brangus	Low	24	-1.58	0.57	8.23	1.12	6.14	0.99	95.91	22.65
1/2 A 1/2 B	High	37	2.42	1.34	12.26	1.51	11.05	2.51	82.80	23.94
1/2 A 1/2 B	Medium	44	-0.13	0.56	9.70	1.36	7.77	2.21	94.41	27.25
1/2 A 1/2 B	Low	34	-1.92	0.64	7.61	1.07	6.70	1.36	84.30	18.38
1/4 A 3/4 B	High	14	2.51	1.10	11.52	1.22	10.96	2.05	76.98	16.08
1/4 A 3/4 B	Medium	27	-0.16	0.44	9.52	1.00	7.41	1.22	94.07	14.52
1/4 A 3/4 B	Low	8	-1.35	0.25	8.20	0.67	6.86	0.76	86.70	14.75
Brahman	High	21	2.24	1.01	10.93	1.39	11.24	2.31	69.65	17.84
Brahman	Medium	23	-0.04	0.58	8.57	1.02	9.53	2.75	69.84	25.62
Brahman	Low	47	-2.21	0.89	6.36	1.28	6.94	1.73	70.54	25.6
Total	High	144	2.45	1.32	11.94	0.13	10.60	0.20	82.78	1.87
Total	Medium	262	-0.10	0.52	9.56	0.07	7.50	0.11	95.52	1.49
Total	Low	175	-1.89	0.89	7.40	0.11	6.71	0.14	82.66	1.94
Total	Total	581	-0.01	1.83	9.50	0.09	8.03	0.10	88.49	1.04

<sup>1</sup>High = RFI > mean + 0.5 SD; medium = RFI between mean ± 0.5 SD; low = RFI < mean - 0.5 SD; SD = 1.8 kg.

<sup>2</sup>RFI = residual feed intake; DFI = mean daily feed intake; FCR = mean daily feed conversion ratio; PWG = postweaning BW gain.

<sup>3</sup>A = Angus; B = Brahman.

**addcov**(RFI, DFI), **addcov**(DFI, RFI), and **addvar**(DFI), where **addvar** is additive genetic variance, and **addcov** is additive genetic covariance. The relationship matrix included 655 calves with records and all known ancestors. The total number of animals in the relationship matrix was 1,712 (655 calves, 71 sires of calves, 464 dams of calves, and 522 other ancestors). Residual effects were assumed to have a mean of zero, a common variance of  $\sigma_e^2$ , and to be uncorrelated.

## RESULTS AND DISCUSSION

### Description of Data

Table 1 contains a description of the data (number of calves, mean, SD) by trait for each breed group of calf × RFI group subclass and for the complete data set. A total of 144 calves were allocated to the high RFI group, 262 calves to the medium RFI group, and 175 calves to the low RFI group. Numbers of calves per breed group ranged from 14 (1/4 A 3/4 B) to 37 (1/2 A 1/2 B) for the high RFI group, from 23 (B) to 72 (A) for the medium RFI group, and from 8 (1/4 A 3/4 B) to 51 (A) for the low RFI group. The log-linear analysis of calf frequencies per breed group × RFI group yielded a highly significant likelihood ratio ( $P < 0.0001$ ), indicating that frequencies of calves per breed group × RFI group categories were not independent. Brahman

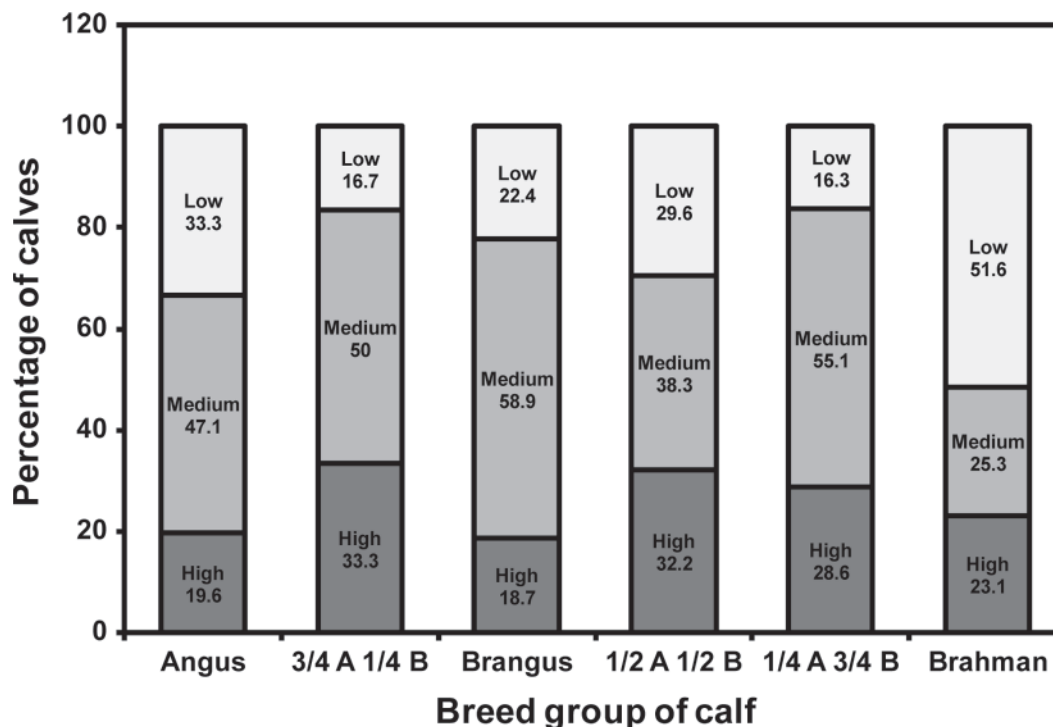
had a greater proportion of calves in the low RFI group (51.6%; Figure 1) than did other breed groups (16.3 to 33.3%; Figure 1). Greater fractions of calves in the medium RFI group existed in Brangus (58.9%) and 1/4 A 3/4 B (55.1%) than in other breed groups, with B having the least percentages (25.3%; Figure 1). Brangus (18.7%), A (19.6%), and B (23.1%) had smaller percentages of calves in the high RFI group than did the remaining 3 crossbred groups (28.6% to 32.2%).

Mean RFI was similar across breed groups for the high (from 2.24 kg for B to 2.95 kg for Brangus), medium (from -0.16 kg for 1/4 A 3/4 B to -0.02 for 3/4 A 1/4 B), and low RFI groups (from -2.34 kg for 3/4 A 1/4 B to -1.35 kg for 1/4 A 3/4 B). Mean DFI and mean FCR decreased from the high to the low RFI group for all breed groups of calves (mean DFI of 11.94, 9.56, and 7.40 kg, and mean FCR of 10.60, 7.50, and 6.71 kg of feed/kg of BW gain for the high, medium, and low RFI groups for the complete data set). Means for PWG tended to be greater for the medium RFI group than for the high and low RFI groups, and averaged 82.78 kg for the high RFI group, 95.52 kg for the medium RFI group, and 82.66 kg for the low RFI group over the complete data set.

### Daily RFI

Daily RFI was affected by contemporary group ( $P < 0.0001$ ), sex of calf ( $P < 0.003$ ), and B fraction of calf





**Figure 1.** Percentage of calves by breed group of calf and residual feed intake (RFI) group. High RFI group = RFI > mean + 0.5 SD; medium RFI group = RFI between mean ± 0.5 SD; low RFI group = RFI < mean - 0.5 SD; SD = 1.8 kg; A = Angus; B = Brahman.

nested within sex of calf ( $P < 0.0001$ ; Table 2). Age of dam, age of calf, heterosis of calf within sex of calf, mean CS, and mean EV were not important sources of variation.

Among sex of calf effects, only heifers differed from steers ( $1.24 \pm 0.36$  kg of DM/d;  $P < 0.0006$ ), indicating that heifers were less efficient than steers. Comparison with estimates from other studies was not possible because published RFI studies used either male calves (bulls, steers, or both; Arthur et al., 2001b; Nkrumah et al., 2004; Schenkel et al., 2004; Wang et al., 2006) or bulls and heifers, but they did not report sex differences for RFI (Archer et al., 1997; Arthur et al., 2001a). Differences between bulls and steers were non-significant, likely because of the small number of bulls

in the data set. Nkrumah et al. (2004) found bulls to be more efficient than steers in a group of crossbred cattle composed of various *B. taurus* breeds including A, Charolais, Galloway, Hereford, and Holstein.

Regression estimates for B breed effects nested within sex of calf were nonsignificant for bulls and steers but were negative ( $-1.29 \pm 0.28$  kg of DM/d;  $P < 0.0001$ ) for heifers. Because B effects were expressed as deviations from A, this indicates that feed efficiency improved (decreased RFI) as the B fraction increased from A to B. The B regression estimate for bulls was also negative, albeit nonsignificant ( $P < 0.25$ ). Perhaps a similar trend would have been found had more bulls been represented in this data set. Comparable studies were unavailable; however, Nkrumah et al. (2004)

**Table 2.** Significance values (*F*-test) for fixed effects

Effect	Trait <sup>1</sup>			
	RFI	DFI	FCR	PWG
Herd-year-pen	<0.0001	<0.0002	<0.0001	<0.0001
Age of dam	0.41	0.12	0.65	0.28
Sex of calf	0.003	<0.0001	<0.0001	<0.0001
Age of calf	0.06	0.01	0.0004	0.04
RFI group		<0.0001	0.78	0.09
Brahman fraction nested within sex of calf	<0.0001			
Heterosis nested within sex of calf	0.24			
Brahman fraction nested within RFI group		0.0009	0.0073	0.0004
Heterosis nested within RFI group		0.0002	0.22	0.20
Mean chute score	0.39	0.42	0.11	0.33
Mean exit velocity	0.89	0.0012	0.34	0.31

<sup>1</sup>RFI = residual feed intake; DFI = mean daily feed intake; FCR = mean daily feed conversion ratio; PWG = postweaning BW gain. Empty cells indicate effects that were not modeled for the respective traits.

**Table 3.** Differences between sex of calf least squares means for residual feed intake<sup>1</sup>

Breed group	Bulls – heifers	Bulls – steers	Heifers – steers
Angus	-0.23 ± 1.52 (1.0)	1.01 ± 1.52 (1.0)	1.24 ± 0.36 (0.002)
3/4 A 1/4 B <sup>2</sup>	-1.41 ± 0.51 (0.02)	-0.55 ± 0.49 (0.81)	0.86 ± 0.17 (<0.0001)
Brangus	-1.46 ± 0.39 (0.0008)	-0.77 ± 0.37 (0.12)	0.69 ± 0.15 (<0.0001)
1/2 A 1/2 B	-3.00 ± 1.63 (0.34)	-2.12 ± 1.65 (0.61)	0.48 ± 0.38 (0.64)
1/4 A 3/4 B	-1.84 ± 0.69 (0.03)	-1.68 ± 0.69 (0.05)	0.16 ± 0.21 (1.0)
Brahman	-1.07 ± 2.38 (1.0)	-1.24 ± 2.38 (1.0)	-0.18 ± 0.35 (1.0)
All	-1.34 ± 0.55 (0.05)	-0.73 ± 0.53 (0.51)	0.61 ± 0.14 (0.0001)

<sup>1</sup>Least squares means differences in kilograms of DM per day; numbers in parentheses refer to levels of probability as determined by a Bonferroni *t*-test.

<sup>2</sup>A = Angus; B = Brahman.

found nonsignificant differences among *B. taurus* crossbred cattle sired by A, Charolais, and University of Alberta crossbred bulls. Schenkel et al. (2004) reported RFI differences between Limousin, A, Simmental, Hereford, and Blonde d'Aquitaine and Charolais bulls ranging from 0.07 kg/d (as fed; Hereford – Charolais) to 0.55 kg/d (as fed; A – Charolais). Significance values were not reported in Schenkel et al. (2004). When deviated from A, these breed differences ranged from -0.38 kg/d (as fed; Simmental – A) to -1.08 kg/d (as fed; Blonde d'Aquitaine – A). Estimates of breed differences were smaller than the regression estimates here for both bulls (-2.14 ± 1.86 kg of DM/d; *P* < 0.25) and heifers (-1.29 ± 0.28 kg of DM/d; *P* < 0.0001). Although the data set here is small, these results may be an indication that breed differences for RFI may be larger between B and *B. taurus* breeds than among *B. taurus* breeds.

Table 3 presents least squares means of RFI differences between sexes for the 6 breed groups in this study. Least squares means differences between bulls and heifers were negative within and across breed groups, indicating that bulls were more efficient than heifers, but were significant within only 3 breed groups: 3/4 A 1/4 B (-1.41 ± 0.51 kg of DM/d; *P* < 0.02), Brangus (-1.46 ± 0.39 kg of DM/d; *P* < 0.0008), and 1/4 A 3/4 B (-1.84 ± 0.69 kg of DM/d; *P* < 0.03), and overall (-1.34 ± 0.55 kg of DM/d; *P* < 0.05). Least squares means differences between bulls and steers within breed groups were mostly negative and nonsignificant, except for 1/4 A 3/4 B (-1.68 ± 0.69 kg of DM/d; *P* < 0.05). Contrarily, differences between heifers and steers were positive (heifers were less efficient than steers) for all breed groups, except for B, and were significant for A (1.24 ± 0.36 kg of DM/d; *P* < 0.002), 3/4 A 1/4 B (0.86 ± 0.17 kg of DM/d; *P* < 0.0001), and Brangus (0.69 ± 0.15 kg of DM/d; *P* < 0.0001). Heifers were also less efficient overall (0.61 ± 0.14 kg of DM/d; *P* < 0.0001).

### Mean DFI and Mean FCR

Most effects in the model significantly affected DFI: contemporary group, sex of calf, age of calf, RFI group, B fraction nested within RFI group, heterosis nested

within RFI group, and mean EV (*P*-values ranging from 0.01 to 0.0001; Table 2). Only contemporary group, sex of calf, age of calf, and B fraction nested within RFI group were significant for FCR (Table 2).

Bulls consumed more feed per day (0.78 ± 0.27 kg of DM/d; *P* < 0.004) but required less feed per kilogram of BW gain (-1.14 ± 0.40 kg of DM·d<sup>-1</sup>/kg of BW gain·d<sup>-1</sup>; *P* < 0.004) than steers. On the other hand, heifers consumed slightly less feed per day (-0.51 ± 0.11 kg of DM/d; *P* < 0.0001) but required more feed per kilogram of BW gain (1.14 ± 0.17 kg of DM·d<sup>-1</sup>/kg of BW gain·d<sup>-1</sup>; *P* < 0.0001) than steers. Differences in DFI were greater between calves in the high and low RFI groups (3.96 ± 0.33 kg of DM/d; *P* < 0.0001) than between calves in the medium and low RFI groups (1.55 ± 0.28 kg of DM/d; *P* < 0.0001). However, only calves in the high RFI group required more feed per kilogram of BW gain (1.71 ± 0.48 kg of DM·d<sup>-1</sup>/kg of BW gain·d<sup>-1</sup>; *P* < 0.004). Although calves in the medium RFI group tended to consume more feed than those in the low RFI group, the difference was not significant.

Regression estimates of DFI on the B fraction of calves were negative and significant for all RFI groups (high: -0.97 ± 0.38 kg of DM/d; *P* < 0.01; medium: -0.90 ± 0.33 kg of DM/d; *P* < 0.007; low: -0.99 ± 0.31 kg of DM/d; *P* < 0.001), indicating that DFI decreased as the B fraction of calves increased. Conversely, regression estimates of heterosis effects for DFI were positive for all RFI groups and were significant for the high (1.01 ± 0.35 kg of DM/d; *P* < 0.004) and medium (1.09 ± 0.32 kg of DM/d; *P* < 0.0009) RFI groups. Heterosis estimates suggest that nonadditive effects would increase feed consumption in crossbred animals. Regression estimates for FCR were positive for B breed effects nested within RFI groups and were significant only for B breed effects in the high (1.41 ± 0.52 kg of DM·d<sup>-1</sup>/kg of BW gain·d<sup>-1</sup>; *P* < 0.008) and medium (1.29 ± 0.47 kg of DM·d<sup>-1</sup>/kg of BW gain·d<sup>-1</sup>; *P* < 0.007) groups. These estimates suggest that calves with a greater B fraction required more feed per kilogram of BW gain (less efficient). Heterosis effects were positive and nearly significant for the high RFI group (0.92 ± 0.51 kg of DM·d<sup>-1</sup>/kg of BW gain·d<sup>-1</sup>; *P* < 0.07), suggesting that crossbred calves in the high RFI group

**Table 4.** Differences between residual feed intake (RFI) group least squares means for daily feed intake<sup>1</sup>

Breed group	High – medium RFI group	High – low RFI group	Medium – low RFI group
Angus	2.41 ± 0.30	3.96 ± 0.33	1.55 ± 0.28
3/4 A 1/4 B <sup>2</sup>	2.36 ± 0.17	4.14 ± 0.20	1.79 ± 0.15
Brangus	2.36 ± 0.15	4.14 ± 0.18	1.78 ± 0.13
1/2 A 1/2 B	2.31 ± 0.31	4.33 ± 0.35	2.03 ± 0.32
1/4 A 3/4 B	2.32 ± 0.19	4.15 ± 0.22	1.83 ± 0.19
Brahman	2.34 ± 0.33	3.98 ± 0.33	1.63 ± 0.31
All	2.35 ± 0.14	4.11 ± 0.17	1.75 ± 0.13

<sup>1</sup>Least squares means differences in kilograms of DM per day (Bonferroni *t*-test); *P* < 0.0001 for all differences.

<sup>2</sup>A = Angus; B = Brahman.

tended to require more feed per kilogram of BW gain than calves (less efficient) in the low RFI group.

Analyses failed to detect strong associations between temperament measures and feed efficiency traits. Mean CS regression estimates for DFI and FCR were non-significant. The regression of FCR on mean EV was nonsignificant. Only the regression estimate of DFI on mean EV was negative ( $-0.29 \pm 0.09$  kg of DM/d; *P* < 0.001), suggesting that calves that consumed more feed were slower out of the chute, perhaps indicating a more docile temperament (Curley et al., 2006).

Pairwise differences between DFI least squares means for the high, medium, and low RFI groups (Table 4) were all positive (*P* < 0.0001), indicating that calves in the high RFI group consumed more feed than those in the medium RFI group, which in turn consumed more feed than calves in the low RFI group. Differences within breed groups were above 2.3 kg of DM/d between the high and medium RFI groups, 3.9 kg of DM/d and above between the high and low RFI groups, and above 1.5 kg of DM/d between the medium and low RFI groups. These values were similar to the overall least squares differences between the high and medium ( $2.35 \pm 0.14$  kg of DM/d; *P* < 0.0001), high and low ( $4.11 \pm 0.17$  kg of DM/d; *P* < 0.0001), and medium and low RFI groups ( $1.75 \pm 0.13$  kg of DM/d; *P* < 0.0001).

Similarly, least squares estimates of pairwise differences for FCR between the high, medium, and low RFI groups were positive for all breed groups, suggesting a decreasing level of feed efficiency between the 3 RFI groups. Least squares means differences for FCR between the high and medium RFI groups were less for purebred groups than for crossbred groups, and ranged from  $1.24 \pm 0.43$  kg of DM·d<sup>-1</sup>/kg of BW gain·d<sup>-1</sup> (*P* < 0.01) for A to  $2.67 \pm 0.45$  kg of DM·d<sup>-1</sup>/kg of BW gain·d<sup>-1</sup> (*P* < 0.0001) for 1/2 A 1/2 B. Differences between FCR least squares means for the high and low RFI calf groups ranged from  $1.71 \pm 0.48$  kg of DM·d<sup>-1</sup>/kg of BW gain·d<sup>-1</sup> (*P* < 0.001) for A to  $3.14 \pm 0.51$  kg of DM·d<sup>-1</sup>/kg of BW gain·d<sup>-1</sup> (*P* < 0.0001) for 1/2 A 1/2 B, and B had the second largest difference ( $2.78 \pm 0.49$ ; *P* < 0.0001). Differences between FCR least squares means of the medium and low RFI groups were smaller than differences between the high and medium, and high and low RFI groups, and were significant only for Brangus ( $0.60 \pm 0.20$  kg of DM·d<sup>-1</sup>/kg of BW

gain·d<sup>-1</sup>; *P* < 0.007), 1/4 A 3/4 B ( $0.94 \pm 0.27$  kg of DM·d<sup>-1</sup>/kg of BW gain·d<sup>-1</sup>; *P* < 0.002), and B ( $1.40 \pm 0.46$  kg of DM·d<sup>-1</sup>/kg of BW gain·d<sup>-1</sup>; *P* < 0.008). The pattern of differences among RFI groups suggests that calves with greater B fractions needed more feed per kilogram of BW gain, and thus were less efficient in terms of FCR than A calves.

### PWG

Factors affecting PWG (Table 2) were contemporary group (*P* < 0.0001), sex of calf (*P* < 0.0001), age of calf (*P* < 0.04), and B fraction within sex of calf (*P* < 0.0004). Age of dam was unimportant for PWG. As expected, bulls had greater PWG ( $20.00 \pm 4.28$  kg; *P* < 0.0001) than steers, and heifers had less PWG ( $-17.02 \pm 1.79$  kg; *P* < 0.0001) than steers.

Estimates of RFI group differences for PWG were significant only for the high vs. low groups ( $11.25 \pm 5.29$  kg; *P* < 0.03), indicating that less efficient calves gained more BW during the 70-d trial. To achieve these BW gains, less efficient calves in the high RFI group consumed more feed than those in the more efficient low RFI group ( $1.71 \pm 0.48$  kg of DM/d; *P* < 0.0004).

Brahman breed effects for PWG within RFI group were all negative, indicating that PWG decreased as the fraction of B in calves increased. Estimates of B regression effects decreased in absolute value from the high ( $-18.81 \pm 5.98$  kg; *P* < 0.005) to the medium ( $-16.18 \pm 5.28$  kg; *P* < 0.002) to the low ( $-14.82 \pm 4.85$  kg; *P* < 0.002) RFI group. Thus, there were smaller PWG differences between B and A among more efficient calves.

Heterosis estimates within RFI group for PWG were all positive but were significant only for the medium RFI group ( $10.59 \pm 5.88$  kg; *P* < 0.04). Regression estimates of PWG on mean CS and on mean EV were non-significant, indicating that neither temperament measurement was associated with PWG in these cattle.

Estimates of differences between least squares means for PWG of the high and medium RFI groups were all nonsignificant. Least squares means differences between the high and low RFI groups tended to decrease as the fraction of B in calves increased. However, differences between the high and low RFI groups were important only for 3/4 A 1/4 B ( $10.18 \pm 3.14$  kg; *P* <

**Table 5.** Estimates of heritabilities (diagonal) for, and genetic correlations (above diagonal) and phenotypic correlations (below diagonal) among residual feed intake (RFI), mean daily feed intake (DFI), mean feed conversion ratio (FCR), and postweaning BW gain (PWG)

Item	RFI	DFI	FCR	PWG
RFI	0.19 ± 0.11	0.73 ± 0.13	0.09 ± 0.38	0.58 ± 0.28
DFI	0.89 ± 0.01	0.42 ± 0.13	-0.05 ± 0.31	0.88 ± 0.12
FCR	0.55 ± 0.03	0.37 ± 0.04	0.24 ± 0.11	-0.50 ± 0.23
PWG	0.15 ± 0.04	0.41 ± 0.04	-0.57 ± 0.03	0.40 ± 0.13

0.0004), Brangus ( $9.97 \pm 2.79$  kg;  $P < 0.001$ ), and 1/4 A 3/4 B ( $9.19 \pm 3.55$  kg;  $P < 0.03$ ). These results suggest that differences in PWG between the high and low RFI groups may be more evident in calves with greater A than B fractions. A somewhat different pattern existed for the medium vs. low RFI groups. Least squares means differences between the medium and low RFI groups for PWG were smaller and nonsignificant for A and B (about 6 kg) but were larger and significant for the other 4 breed groups ( $10.26 \pm 2.43$  kg,  $P < 0.0001$  for 3/4 A 1/4 B;  $9.89 \pm 2.11$  kg,  $P < 0.0001$  for Brangus;  $13.17 \pm 5.10$  kg,  $P < 0.03$  for 1/2 A 1/2 B; and  $9.58 \pm 3.55$  kg,  $P < 0.004$  for 1/4 A 3/4 B), perhaps suggesting a larger amount of variation for PWG among calves in crossbred groups. Considering all calves in the data set, PWG differences were significant between the high and low RFI groups ( $9.55 \pm 2.65$  kg,  $P < 0.0006$ ) and between the medium and low RFI groups ( $9.24 \pm 2.00$  kg;  $P < 0.0001$ ).

### Heritabilities, Genetic Correlations, and Phenotypic Correlations

Table 5 shows REML estimates of heritabilities on the diagonal, genetic correlations above the diagonal, and phenotypic correlations below the diagonal. Heritability estimates from different pairwise analyses involving a given trait were similar. Thus, the estimate of heritability for RFI reported here is from the RFI-DFI analysis, and the heritabilities for DFI, FCR, and PWG are those from the RFI-DFI, RFI-FCR, and RFI-PWG analyses. These parameter estimates should be viewed with caution because of the small number of animals with records in the data set. The heritability estimate for RFI ( $0.19 \pm 0.11$ ) was less than that estimated by Arthur et al. (2001a) in Australia ( $0.39 \pm 0.03$ ; 1,180 A bulls and heifers; 15 mo of age), Arthur et al. (2001b) in France ( $0.39 \pm 0.04$ ; 792 Charolais bulls; 9 mo of age), and Schenkel et al. (2004) in Canada ( $0.38 \pm 0.07$ ;  $0.07 =$  average SE of 10 pairwise analyses; 2,284 Charolais, Limousin, Simmental, Hereford, A, and Blonde d'Aquitaine bulls; 9 mo of age). Numbers of animals in these 3 studies were larger than here. The heritability estimate for RFI may increase as the numbers of records from the B-A population in Florida increase and additional genetic variation from the B-A population in Florida is accounted for. However, the estimate of heri-

tability obtained here suggests that selection for RFI is feasible in Florida, although it would be advisable to substantially increase the number of calves evaluated for RFI at feed efficiency facilities each year.

The heritability estimate was  $0.42 \pm 0.13$  for DFI and  $0.24 \pm 0.11$  for FCR. The estimate of heritability for DFI was comparable with those obtained for A in Australia ( $0.39 \pm 0.03$ ; Arthur et al., 2001a), for Charolais in France ( $0.48 \pm 0.04$ ; Arthur et al., 2001b), and for 6 *B. taurus* breeds in Canada ( $0.44 \pm 0.06$ ;  $0.06 =$  average SE of 10 pairwise analyses; Schenkel et al., 2004). The estimate of heritability for FCR was similar to the estimate obtained in Australia ( $0.29 \pm 0.04$ ; Arthur et al., 2001a) but was less than estimated from France ( $0.46 \pm 0.04$ ; Arthur et al., 2001b) and Canada ( $0.37 \pm 0.06$ ; Schenkel et al., 2004).

The heritability estimate for PWG was moderate ( $0.40 \pm 0.13$ ). This estimate is within the range of parameters reported for cattle of *B. indicus* × *B. taurus* ancestry (Kriese et al., 1991; Davis, 1993), and was similar to estimates of heritability of postweaning ADG in feed efficiency studies (Arthur et al., 2001a,b; Schenkel et al., 2004).

Estimates of genetic correlations (Table 5) were positive between RFI and DFI ( $0.73 \pm 0.13$ ) and between RFI and PWG ( $0.58 \pm 0.28$ ), indicating that less efficient calves based on RFI had greater BW gains during the 70-d postweaning trial. The genetic correlation between RFI and FCR was close to zero ( $0.09 \pm 0.38$ ). The genetic correlation estimate between RFI and DFI was similar to, and the one between RFI and FCR was much smaller than, those obtained in feed efficiency studies with *B. taurus* cattle (Arthur et al., 2001a,b; Schenkel et al., 2004). The positive genetic correlation between RFI and PWG disagreed with the low and negative (Arthur et al., 2001b) and the near zero (Schenkel et al., 2004) estimates of genetic correlations reported between RFI and ADG. The positive estimate of genetic correlation between RFI and PWG here suggests that selection for more efficient animals (i.e., animals with reduced RFI) will reduce PWG, which may be economically undesirable. However, this estimate may change substantially as additional RFI and PWG from the A-B multibreed population of Florida is collected in future years.

Estimates of genetic correlations were near zero between DFI and FCR ( $-0.05 \pm 0.31$ ), were positive be-



tween DFI and PWG ( $0.88 \pm 0.12$ ), and were negative between FCR and PWG ( $-0.50 \pm 0.23$ ). These genetic correlation estimates indicate that calves that consumed more feed during the 70-d trial gained more BW and required approximately the same amount of feed per kilogram of BW gain. Estimates of genetic correlations between DFI and FCR were less than, and those between DFI and PWG and between FCR and PWG were in agreement with, values obtained with *B. taurus* breeds (Arthur et al., 2001b; Schenkel et al., 2004).

Phenotypic correlations had the same sign as genotypic correlations, except for the correlation between DFI and FCR (positive phenotypic, negative genotypic; Table 5). Estimates agreed with those reported by Arthur et al. (2001a,b) and Schenkel et al. (2004), except for the greater value between RFI and PWG ( $0.15 \pm 0.04$ ). The Pearson partial correlation coefficient (correlation coefficient corrected for contemporary group, sex of calf, B fraction of calf, and heterosis of calf) between RFI and PWG was zero, suggesting that the low positive value of the phenotypic correlation obtained here may be a computational issue. Perhaps with a larger data set the phenotypic correlation computed would also approach zero.

### Conclusion

This study found significant B breed effects nested within sex of calf for RFI. These B effects differed depending on the sex of the calf (negative and nonsignificant for bulls, negative and significant for heifers, and positive and nonsignificant for steers). Additional data will be required to clarify these sex differences, particularly the estimate obtained for steers. Nevertheless, results here indicated that B cattle tended to be more efficient than A cattle for postweaning growth under subtropical conditions in Florida.

Brahman breed effects nested within RFI groups were negative for DFI, indicating that as the fraction B of calves increased, they tended to consume less feed. In contrast, B estimates for FCR were positive, suggesting that as the B fraction increased, the amount of feed needed per kilogram of BW gain increased, making calves with a greater B fraction less efficient than calves with greater A fractions. Last, B estimates for PWG were all negative, indicating a decrease in PWG as the fraction of B in calves increased. As indicated above, results for FCR contradicted results for RFI. This is another aspect that will need to be reevaluated as new data are collected in Florida.

Heritabilities for all traits were reasonable. Similarly, estimates of genetic and phenotypic correlations seemed reasonable, considering the size and complexity of the multibreed data set used here. Estimates of genetic parameters here confirm that genetic variability existed and that selection for RFI would be feasible in the Florida A-B multibreed population. However, feed efficiency data need to continue to be collected in increasing numbers per year to compute accurate populational

genetic parameters for multiple traits. Considering the high cost of obtaining feed efficiency information, it would seem reasonable to link feed efficiency facilities across the Southern region to improve the accuracy of genetic evaluation of animals, particularly sires, to increase the rate of progress attributable to selection.

Heterosis was not a significant factor for RFI, FCR, or PWG, but it increased DFI. The *P*-values for RFI and FCR were less than 0.22 (Table 2); thus, their heterosis estimates may differ substantially in a different data set. Again, a larger data set would be needed to clarify the role of heterosis for feed efficiency traits in the Florida cattle population.

Temperament was not an important factor for any of the traits, with the exception of EV for DFI, where animals that consumed more feed exited the chute more slowly. This may be an indication of better temperament, or it may simply suggest that animals that ate more were more sluggish coming out of the chute. Further, calves from the 3 locations were worked though the chute frequently both before and during their stay at IFEF. Perhaps calves became accustomed to this level of management, and consequently behavioral differences among calves decreased, and so did the potential impact of temperament on feed efficiency and BW gain traits. Temperament traits will continue to be collected and reevaluated with larger accumulated data sets in Florida.

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