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Effect of breed composition on phenotypic residual feed intake and growth in Angus, Brahman, and Angus x 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), sire group (A, ¾ A ¼ B, Brangus, ½ A ½ B, ¼ A ¾ B, and B), and sex (bull, heifer, and steer) in a GrowSafe automated feeding facility at Marianna, FL. Calves were fed a concentrate diet during the 21-d adjustment and the 70-d trial periods. Individual feed intakes were recorded daily, and weights, chute scores, and exit velocities every 2 wk. Traits were phenotypic daily residual feed intake (**RFI)**, mean daily feed intake (**DFI**), mean daily feed conversion ratio (**FCR**), and postweaning gain (**PWG**). Phenotypic daily residual feed intake was computed as the difference between actual and expected feed intakes. Calves were assigned to 3 RFI groups: high (RFI > 0.9 kg DM/d), low (RFI < -0.9 kg DM/d), and medium (RFI between mean ± 0.9 kg DM/d; SD = 1.8 kg 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 (CS), and mean exit velocity (EV). Brahman fraction and heterozygosity of calf were nested within sex of calf for RFI, and within RFI group for DFI, FCR, and PWG. Random effects were sire and residual. Feed efficiency tended to improve (lower RFI) as B fraction increased. However, calves required larger amounts of feed per kg gain (larger FCR) as B fraction increased. Postweaning gain tended to decrease as 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: cattle, feed intake, multibreed, temperament

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 an animal's actual feed intake and expected feed intake over a

time period. For growing cattle, expected feed intake is usually computed as a regression of

intake on average daily gain and metabolic mid-weight (Archer et al., 1997; Arthur et al., 2001a,

b; Nkrumah et al., 2004, 2007). This makes RFI phenotypically independent of average daily

gain and metabolic mid-weight 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 utilized 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

was found to affect both growth and RFI (Nkrumah et al., 2004; Schenkel et al., 2004), and

temperament scores have been associated with growth in beef cattle (Voisinet et al., 1997;

Burrow and Dillon, 1997). Studies involving RFI and its association with breed composition,

postweaning growth, and temperament using *Bos taurus* and *Bos indicus* cattle in subtropical and

tropical environments may yield substantially different results from those obtained for *Bos 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 and exit velocity) on RFI, daily feed intake, feed conversion ratio, 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

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). Calves were born in 2006 (n = 330) and 2007 (n = 251). Established standards for animal care and use were followed. Research protocols were approved by the University of Florida Institutional Animal Care and Use Committee (IACUC number D477). There were 31 bulls, 317 heifers, and 233 steers from 6 breed groups: A (n = 153), ¾ A ¼ B (n = 66), Brangus (5/8A 3/8 B; n = 107), ½ A ½ B (n = 115), ¼ A ¾ B (n = 49), and B (n = 91). Calves from the 3 locations were born from December to March and 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, Florida. Heifers from Brooksville received a preconditioning cottonseed/soybean meal-based ration (1.8 kg per day; 14% CP; 488 Pellet Medicated Weaning Ration, Lakeland, Florida), bahiagrass hay, and a

free choice mineral (Brooksville Research Mineral, Lakeland Animal Nutrition, Lakeland,

Florida). Calves from Gainesville were fed concentrate (1.6 kg to 3.6 kg per day; 14.0% CP; 488

Pellet, Medicated Weaning Ration, Lakeland Animal Nutrition, Lakeland, Florida; and soy hull

pellets), bahiagrass hay, and free choice mineral (UF University Special Hi-Cu Mineral,

University of Florida, Animal Science Department, Gainesville, Florida). 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, Florida). Subsequently, calves were moved to the IFEF in

September (Gainesville and Marianna) and October (Brooksville).

Management, Nutrition, and Data Collection at the Feed Efficiency Facility

Calves were randomly allocated to 24 pens at the IFEF within herd (Brooksville,

Gainesville, and Marianna) by sire group (A, ¾ A ¼ B, Brangus (5/8 A 3/8 B), ½ A ½ B, ¼ A ¾

B, and B) by sex (bull, heifer, and steer) subclass in 2006 and in 2007. The IFEF has 24 pens

(108 m^2/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) prior to

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 a higher fiber content (chopped bermudagrass instead of soybean hull

pellets). The concentrate had a DM, CP, NEm, and NEg of 91.2%,17.3%, 1.7 mcal/kg DM, and

1.2 mcal/kg DM in 2006, and 90.0%,14.1%, 1.5 mcal/kg DM, and 0.9 mcal/kg DM in 2007. The

pre-trial adjustment period was 21 d, and the trial period lasted 70 d. GrowSafe software

recorded individual feed intake in real-time. Weights and temperament traits were taken every 2

wk.

Traits

Traits were phenotypic daily residual feed intake (**RFI**), mean daily feed intake (**DFI**),

mean daily feed conversion ratio (**FCR**), and postweaning gain (**PWG**). All intake traits were

converted to dry matter basis before analyses.

Individual feed disappearance and node attendance data were recorded using GrowSafe

Data Acquisition software (GrowSafe Systems, Ltd., Airdrie, Alberta, Canada) and daily feed

intakes were compiled using the Process Intakes routine. Individual daily feed intake data were

excluded from the analysis due to equipment failure or if 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 d and 28 d excluded from the dataset 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 to 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 removed from the analysis.

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

Total daily feed intake 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 daily feed intake over the 70-d trial period. Mean daily feed conversion ratio was computed as the ratio of DFI to average daily gain. Postweaning gain was computed as the difference between the weight of each calf at the end and at the beginning of the 70-d trial.

Mean chute score was the average of the 6 chute scores measured every 2 wk (CS; 1 = docile; 2 = restless; 3 = nervous; 4 = flighty; 5 = aggressive; 6 = very aggressive; BIF, 2002) during the 70-d trial period. Similarly, mean exit velocity was the average of the 6 exit velocity

(EV; velocity out of the chute in m/sec; Burrow and Dillon, 1997; Curley et al., 2006) measurements taken every 2 wk at 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 ± 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 are the most efficient and calves in the high RFI group are the least efficient. Allocation of calves to low, medium, and high RFI groups was done using the complete dataset. 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 procedure CATMOD of SAS (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 B fraction and heterozygosity nested within sex of calf and within RFI group. Brahman fraction and heterozygosity nested within sex of calf were non-significant for these traits, and thus were

dropped from the final models. Random effects were sire and residual. Sires effects were assumed to have mean zero, common variance σ_s^2, and to be uncorrelated. Similarly, residual effects were assumed to have mean zero, common variance σ_e^2, and uncorrelated. Mixed model analyses were carried out using SAS Proc MIXED.

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 ¾ A ¼ B, 0.375 for Brangus, 0.5 for ½ A ½ B, 0.75 for ¼ A ¾ B, and 1.0 for B), and the expected heterosis of each group (0.0 for A, 0.5 for ¾ A ¼ B, 0.469 for Brangus, 1.0 for ½ A ½ B, 0.5 for ¼ A ¾ 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) due to the small size of the dataset (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 chute score, and mean exit velocity. Random effects were calf and residual. Calf effects were assumed to have mean zero, and variance equal to the relationship matrix times (direct product) the 2×2 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), addcov(RFI,

DFI), addcov(DFI, RFI), and addvar(DFI), where addvar = additive genetic variance, and addcov = 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 mean zero, common variance σ_e^2, and 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 by RFI group subclass and for the complete dataset. A total of 144 calves were allocated to the high, 262 calves to the medium, and 175 calves to the low RFI groups. Numbers of calves per breed group ranged from 14 (¼ A ¾ B) to 37 (½ A ½ B) for the high RFI group, from 23 (B) to 72 (A) for the medium RFI group, and from 8 (¼ A ¾ B) to 51 (A) for the low RFI group. The log-linear analysis of calf frequencies per breed group by RFI group yielded a highly significant likelihood ratio (P < 0.0001), indicating that frequencies of calves per breed group by RFI group categories were not independent. Brahman had a higher proportion of calves in the low RFI group (51.6%; Figure 1) than other breed groups (16.3 to 33.3%; Figure 1). Higher fractions of calves in the medium RFI group existed in Brangus (58.9%) and ¼ A ¾ B (55.1%) than in other breed groups, Brahman having the lowest percentages (25.3%; Figure 1). Brangus (18.7%), A (19.6%), and B (23.1%) had lower percentage of calves in the high RFI group than the remaining 3 crossbred groups (28.6% to 32.2%).

Mean RFI was similar across breed groups for high (from 2.24 kg for B to 2.95 kg for Brangus), medium (from -0.16 kg for ¼ A ¾ B to -0.02 for ¾ A ¼ B), and low RFI groups (from

-2.34 kg for ¾ A ¼ B to -1.35 kg for ¼ A ¾ B). Mean DFI and mean FCR decreased from high to low RFI groups for all breed groups of calves (mean DFI of 11.94 kg, 9.56 kg, and 7.40 kg, and mean FCR of 10.60, 7.50, and 6.71 kg feed per kg gain for high, medium, and low RFI groups for the complete dataset). Means for PWG tended to be higher for medium than for high and low RFI groups, and averaged 82.78 kg for high, 95.52 kg for medium, and 82.66 kg for low RFI groups over the complete dataset.

Daily Residual Feed Intake

Daily residual feed intake was affected by contemporary group ($P < 0.0001$), sex of calf ($P < 0.003$), and B fraction of calf nested within sex of calf ($P < 0.0001$; Table 2). Age of dam, age of calf, heterosis of calf within sex of calf, mean chute score, and mean exit velocity were not important sources of variation.

Among sex of calf effects, only heifers differed from steers (1.24 ± 0.36 kg DM/d; $P < 0.0006$), indicating that heifers were less efficient than steers. Comparison with estimates from other studies was not possible because published residual feed intake 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 due to the small number of bulls in the dataset. Nkrumah et al. (2004) found bulls to be more efficient than steers in a group of crossbred cattle composed of various *Bos taurus* breeds including Angus, Charolais, Galloway, Hereford, and Holstein.

Regression estimates for Brahman breed effects nested within sex of calf were non-significant for bulls and steers, but were negative (-1.29 ± 0.28 kg DM/d; $P < 0.0001$) for heifers.

Because B effects were expressed as deviations from A, this indicates that feed efficiency improved (lower RFI) as the B fraction increased from A to B. The B regression estimate for bulls was also negative, albeit non-significant (P < 0.25). Perhaps a similar trend would have been found had more bulls been represented in this dataset. Comparable studies were unavailable; however, Nkrumah et al. (2004) found non-significant differences among *Bos taurus* crossbred cattle sired by Angus, Charolais, and University of Alberta crossbred bulls. Schenkel et al. (2004) reported RFI differences between Limousin, Angus, Simmental, Hereford, and Blonde d'Aquitaine and Charolais bulls ranging from 0.07 kg as fed/d (Hereford minus Charolais) to 0.55 kg as fed/d (Angus minus Charolais). Significance values were not reported in Schenkel et al. (2004). When deviated from Angus, these breed differences ranged from -0.38 kg as fed/d (Simmental minus Angus) to -1.08 kg as fed/d (Blonde d'Aquitaine minus Angus). Estimates of breed differences were smaller than the regression estimate here for both bulls (-2.14 ± 1.86 kg DM/d; P < 0.25) and heifers (-1.29 ± 0.28 kg DM/d; P < 0.0001). Although the dataset here is small, these results may be an indication that breed differences for RFI may be larger between Brahman and *Bos taurus* breeds than among *Bos 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: ¾ A ¼ B (-1.41 ± 0.51 kg DM/d; P < 0.02), Brangus (-1.46 ± 0.39 kg DM/d; P < 0.0008), and ¼ A ¾ B (-1.84 ± 0.69 kg DM/d; P < 0.03), and overall (-1.34 ± 0.55 kg DM/d; P < 0.05). Least squares means differences between bulls and steers within breed groups were mostly negative and non-significant, except for ¼ A ¾ B (-1.68 ± 0.69 kg 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 significant for A (1.24 ± 0.36 kg DM/d; P < 0.002), ¾ A ¼ B (0.86 ± 0.17 kg DM/d; P < 0.0001), and Brangus (0.69 ± 0.15 kg DM/d; P < 0.0001). Heifers were also less efficient overall (0.61 ± 0.14 kg DM/d; P < 0.0001).

Mean Daily Feed Intake and Mean Feed Conversion Ratio

Most effects in the model significantly affected DFI: contemporary group, sex of calf, age of calf, RFI group, Brahman fraction nested within RFI group, heterosis nested within RFI group, and mean exit velocity (P values ranging from 0.01 to 0.0001; Table 2). Only contemporary group, sex of calf, age of calf, and Brahman fraction nested within RFI group were significant for FCR (Table 2).

Bulls consumed more feed per day (0.78 ± 0.27 kg DM/d; P < 0.004), but required less feed per kg of weight gain (-1.14 ± 0.40 kg DM*d^{-1}/kg gain*d^{-1}; P < 0.004) than steers. On the other hand, heifers consumed slightly less feed per day (-0.51 ± 0.11 kg DM/d; P < 0.0001), but required more feed per kg of gain (1.14 ± 0.17 kg DM*d^{-1}/kg gain*d^{-1}; P < 0.0001) than steers. Differences in DFI were greater between calves in the high and low RFI groups (3.96 ± 0.33 kg DM/d; P < 0.0001) than between calves in the medium and low RFI groups (1.55 ± 0.28 kg DM/d; P < 0.0001). However, only calves in the high RFI group required more feed per kg of gain (1.71 ± 0.48 kg DM*d^{-1}/kg gain*d^{-1}; 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 B fraction of calves were negative and significant for all RFI groups (high: -0.97 ± 0.38 kg DM/d; P < 0.01; medium: -0.90 ± 0.33 kg DM/d; P < 0.007; low: -0.99 ± 0.31 kg DM/d; P < 0.001), indicating that DFI decreased as B fraction of calf increased. Conversely, regression estimates of heterosis effects for DFI were positive for all RFI

groups, and significant for high (1.01 ± 0.35 kg DM/d; P < 0.004) and medium (1.09 ± 0.32 kg 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 significant only for B breed effects in the high (1.41 ± 0.52 kg DM*d^{-1}/kg gain*d^{-1}; P < 0.008) and medium (1.29 ± 0.47 kg DM*d^{-1}/kg gain*d^{-1}; P < 0.007) groups. These estimates suggest that calves with a higher B fraction required more feed per kg gain (lower efficiency). Heterosis effects were positive and nearly significant for the high RFI group (0.92 ± 0.51 kg DM*d^{-1}/kg gain*d^{-1}; P < 0.07), suggesting that crossbred calves in the high RFI group tended to require more feed per kg gain than calves (less efficient) in the low RFI group.

Analyses failed to detect strong associations between temperament measures and feed efficiency traits. Mean chute score regression estimates for DFI and FCR were non-significant. The regression of FCR on mean exit velocity was non-significant. Only the regression estimate of DFI on mean exit velocity was negative (-0.29 ± 0.09 kg 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 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 DM/d between high and medium RFI groups, 3.9 kg DM/d and above between high and low RFI groups, and above 1.5 kg DM/d between medium and low RFI groups. These values were similar to the overall least squares differences between high and medium (2.35 ± 0.14 kg DM/d;

P < 0.0001), high and low (4.11 ± 0.17 kg DM/d; P < 0.0001), and medium and low RFI groups (1.75 ± 0.13 kg DM/d; P < 0.0001).

Similarly, least squares estimates of pairwise differences for FCR between 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 high and medium RFI groups were lower for purebred groups than for crossbred groups, and ranged from 1.24 ± 0.43 kg DM*d^{-1}/kg gain*d^{-1}; P < 0.01 for A to 2.67 ± 0.45 kg DM*d^{-1}/kg gain*d^{-1}; P < 0.0001 for ½ A ½ B. Differences between FCR least squares means for high and low RFI calf groups ranged from 1.71 ± 0.48 kg DM*d^{-1}/kg gain*d^{-1}; P < 0.001 for A to 3.14 ± 0.51 kg DM*d^{-1}/kg gain*d^{-1}; P < 0.0001 for ½ A ½ B, and B had the second largest difference (2.78 ± 0,49; P < 0.0001). Differences between FCR least squares means of medium and low RFI groups were smaller than differences between high and medium, and high and low RFI groups, and significant only for Brangus (0.60 ± 0.20 kg DM*d^{-1}/kg gain*d^{-1}; P < 0.007), ¼ A ¾ B (0.94 ± 0.27 kg DM*d^{-1}/kg gain*d^{-1}; P < 0.002) and B (1.40 ± 0.46 kg DM*d^{-1}/kg gain*d^{-1}; P < 0.008). The pattern of differences among RFI groups suggests that calves with greater B fractions needed more feed per kg of weight gain, and thus were less efficient in terms of FCR than A calves.

Postweaning Gain

Factors affecting PWG (Table 2) were contemporary group (P < 0.0001), sex of calf (P < 0.0001), age of calf (< 0.04), and B fraction within sex of calf (P < 0.0004).

Age of dam was unimportant for PWG. As expected, bulls had higher PWG (20.00 ± 4.28 kg; P < 0.0001) than steers, and heifers had lower PWG (-17.02 ± 1.79 kg; P < 0.0001) than steers.

Estimates of RFI group differences for PWG were only significant for high vs. low groups (11.25 ± 5.29 kg; P < 0.03), indicating that less efficient calves gained more weight during the 70-d trial. To achieve these weight gains, less efficient calves in the high RFI group consumed more feed than those in the more efficient low RFI group (1.71 ± 0.48 kg 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 high (-18.81 ± 5.98 kg; P < 0.005) to medium (-16.18 ± 5.28 kg; P < 0.002) to low (-14.82 ± 4.85 kg; P < 0.002) RFI groups. 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 significant only for the medium RFI group (10.59 ± 5.88 kg; P < 0.04). Regression estimates of PWG on mean chute score, and on mean exit velocity 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 non-significant. Least squares means differences between high and low RFI groups tended to decrease as the fraction of B in calves increased. However, differences between high and low RFI groups were important only for ¾ A ¼ B (10.18 ± 3.14 kg; P < 0.0004), Brangus (9.97 ± 2.79 kg; P < 0.001), and ¼ A ¾ B (9.19 ± 3.55 kg; P < 0.03). These results suggest that differences in PWG between high and low RFI groups may be more evident

in calves with greater A than B fractions. A somewhat different pattern existed for medium vs. low RFI groups. Least squares means differences between medium and low RFI groups for PWG were smaller and non-significant for A and B (about 6 kg), but larger and significant for the other 4 breed groups (10.26 ± 2.43 kg, P < 0.0001 for ¾ A ¼ B; 9.89 ± 2.11 kg, P < 0.0001 for Brangus, 13.17 ± 5.10 kg, P < 0.03 for ½ A ½ B, and 9.58 ± 3.55 kg, P < 0.004 for ¼ A ¾ B), perhaps suggesting a larger amount of variation for PWG among calves in crossbred groups. Considering all calves in the dataset, PWG differences were significant between high and low RFI groups (9.55 ± 2.65 kg, P < 0.0006) and between medium and low RFI groups (9.24 ± 2.00 kg; P < 0.0001).

Heritabilities, Genetic Correlations, and Phenotypic Correlations

Table 5 shows restricted maximum likelihood 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 dataset. The heritability estimate for RFI (0.19 ± 0.11) was lower than that estimated by Arthur et al. (2001a) in Australia (0.39 ± 0.03; 1,180 Angus bulls and heifers; 15 mo age), Arthur et al. (2001b) in France (0.39 ± 0.04; 792 Charolais bulls; 9 mo age), and Schenkel et al. (2004) in Canada (0.38 ± 0.07; 0.07 = average SE of 10 pairwise analyses; 2,284 Charolais, Limousin, Simmental, Hereford, Angus, and Blonde d'Aquitaine bulls; 9 mo age). Numbers of animals in these 3 studies were larger than here. The heritability estimate for

RFI may increase as numbers of records from the Brahman-Angus population in Florida increase and additional genetic variation from the Brahman-Angus population in Florida is accounted for. However, the estimate of heritability 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 ± 0.13 for DFI and 0.24 ± 0.11 for FCR. The estimate of heritability for DFI was comparable to those obtained for Angus in Australia (0.39 ± 0.03; Arthur et al., 2001a), for Charolais in France (0.48 ± 0.04; Arthur et al., 2001b), and for 6 *Bos taurus* breeds in Canada (0.44 ± 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 ± 0.04; Arthur et al., 2001a), but lower than estimated from France (0.46 ± 0.04; Arthur et al., 2001b), and Canada (0.37 ± 0.06; Schenkel et al., 2004).

The heritability estimate for PWG was moderate (0.40 ± 0.13). This estimate is within the range of parameters reported for cattle of *Bos indicus* x *Bos taurus* ancestry (Kriese et al., 1991; Davis, 1993), and was similar to estimates of heritability of postweaning average daily gain 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 ± 0.13), and RFI and PWG (0.58 ± 0.28), indicating that less efficient calves based on RFI had higher weight gains during the 70-d postweaning trial. The genetic correlation between RFI and FCR was close to zero (0.09 ± 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 *Bos taurus* cattle (Arthur et al., 2001a,b; Schenkel et al., 2004). The positive genetic correlation between RFI and PWG was in disagreement with the low and

negative (Arthur et al., 2001b) and near zero (Schenkel et al., 2004) estimates of genetic correlations reported between RFI and average daily gain. The positive estimate of genetic correlation between RFI and PWG here suggests that selection for more efficient animals (i.e., animals with lower RFI) will reduce PWG, which may be economically undesirable. However, this estimate may change substantially as additional RFI and PWG from the Angus-Brahman multibreed population of Florida is collected in future years.

Estimates of genetic correlations were near zero between DFI and FCR (-0.05 ± 0.31), positive between DFI and PWG (0.88 ± 0.12), and negative between FCR and PWG (-0.50 ± 0.23). These genetic correlation estimates indicate that calves that consumed more feed during the 70-d trial gained more weight and required approximately the same amount of feed per kg of weight gain. Estimates of genetic correlations between DFI and FCR were lower than, and those between DFI and PWG, and FCR and PWG were in agreement with, values obtained with *Bos 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 higher value between RFI and PWG (0.15 ± 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 dataset the phenotypic correlation computed would also approach zero.

Final Remarks

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 non-significant for bulls, negative and significant for heifers, and positive and non-significant for steers). Additional data will be required to clarify these sex differences, particularly the estimate obtained for steers. Still, 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. Contrarily, B estimates for FCR were positive, suggesting that as the B fraction increased, the amount of feed needed per kg of weight gain increased, making calves with greater B fraction less efficient than calves with greater A fractions. Lastly, 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 dataset used here. Estimates of genetic parameters here confirm that genetic variability existed and that selection for RFI would be feasible in the Florida Angus-Brahman 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 due 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 dataset. Again, a larger dataset 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 weight gain traits. Temperament traits will continue to be collected and reevaluated with larger accumulated datasets in Florida.

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

			Trait[1]							
			RFI, kg DM/d		DFI, kg DM/d		FCR, kg DM*d^{-1}/kg gain*d^{-1}		PWG, kg	
Breed group	RFI group[2]	N	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	Med	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
¾ A ¼ B	High	22	2.33	1.33	12.38	1.13	9.69	2.81	94.55	21.60
¾ A ¼ B	Med	33	-0.02	0.45	9.93	1.34	7.16	1.45	101.79	21.99
¾ A ¼ 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	Med	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
½ A ½ B	High	37	2.42	1.34	12.26	1.51	11.05	2.51	82.80	23.94
½ A ½ B	Med	44	-0.13	0.56	9.70	1.36	7.77	2.21	94.41	27.25
½ A ½ B	Low	34	-1.92	0.64	7.61	1.07	6.70	1.36	84.30	18.38
¼ A ¾ B	High	14	2.51	1.10	11.52	1.22	10.96	2.05	76.98	16.08
¼ A ¾ B	Med	27	-0.16	0.44	9.52	1.00	7.41	1.22	94.07	14.52
¼ A ¾ 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	Med	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	Med	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

[1]RFI = residual feed intake; DFI = mean daily feed intake; FCR = mean daily feed conversion ratio; PWG = postweaning gain.

[2] High = RFI > mean + 0.5 SD; Medium = RFI between mean ± 0.5 SD; Low = RFI < mean - 0.5 SD; SD = 1.8 kg.

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

Effect	Trait[1]			
	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

[1]RFI = residual feed intake; DFI = mean daily feed intake; FCR = mean daily feed conversion ratio; PWG = postweaning 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[1]

Breed group	Bulls minus heifers	Bulls minus steers	Heifers minus steers
Angus	-0.23 ± 1.52 (1.0)	1.01 ± 1.52 (1.0)	1.24 ± 0.36 (0.002)
¾ A ¼ B	-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)
½ A ½ B	-3.00 ± 1.63 (0.34)	-2.12 ± 1.65 (0.61)	0.48 ± 0.38 (0.64)
¼ A ¾ 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)

[1]Least squares means differences in kg DM/d; Numbers in parentheses refer to levels of probability as determined by Bonferroni t-test.

Table 4. Differences between residual feed intake group least squares means for daily feed intake[1]

Breed group	High minus medium RFI group	High minus low RFI group	Medium minus low RFI group
Angus	2.41 ± 0.30	3.96 ± 0.33	1.55 ± 0.28
¾ A ¼ B	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
½ A ½ B	2.31 ± 0.31	4.33 ± 0.35	2.03 ± 0.32
¼ A ¾ 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

[1]Least squares means differences in kg DM/d; Bonferroni t-test; $P < 0.0001$ for all differences.

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 gain (PWG)

	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

Figure 1. Percentage of calves by breed group of calf and residual feed intake 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.