Growth and Feed Efficiency

Utilization of *Bos indicus* Cattle in Florida Beef Enterprises

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Introduction

Climatic conditions in Florida dictate the use of animals that are adapted to subtropical environments. Crosses between *Bos indicus* and *Bos taurus* genetics come closer to meeting the needs of Florida cattle producers than any other combination of breeds. Whether or not to include germplasm from *Bos indicus* influenced breeds determines, to a great extent, how productive cattle perform in Florida. Often producers struggle with what percentage of *Bos indicus* genetics is needed to maintain superior maternal performance in their herds while meeting industry standards for carcass traits. Lately many producers have infused large quantities of Angus genetics into cowherds to improve carcass traits. This has reduced hybrid vigor and compromised performance traits such as adaptability, fertility, longevity, pre- and post-weaning gain, calf survival, and milking ability, while carcass quality has remained stagnant at the national level. This should lead producers to ask the question "Is my operation producing at optimum levels with the genetics currently in my cowherd?"

Genetic Tools to Improve Cowherd Productivity

There are two basic ways to genetically impact a herd of cattle. The first approach is to select superior cattle to serve as parents. This approach capitalizes on the additive genetic effects, or more commonly called, breeding values. This is simply the portion or percentage of a trait that is passed from parents to offspring. That is to say, additive genetic effects are heritable. The most common way to utilize additive genetic effects is through the use of expected progeny differences (EPDs) as they are estimates of one-half the breeding value and are a summation of all of the genetic effects within the animal for a given trait. Expected progeny differences give us the best estimate of an animal's ability to pass a given trait to their offspring.

The second source of genetic change is the result of non-additive genetic effects. Non-additive effects are those traits that are not passed on from parents to offspring, but are the result of epistatic and dominance effects. Epistatic effects are the interaction of genes at different loci. Dominance effects are the interaction of paired genes at the same locus. When summed these interactions result in the heterosis seen in crossbred cattle. Origin of animals (Table 1) have a large effect on how much heterosis is expressed when crosses are made. For example, animals from British (*Bos taurus*) derived breeds when crossed with Continental breeds will not express as much heterosis as when crossed with breeds of Indian or African (*Bos indicus)* origins. Table 2 shows the differences that would be expected when intermating *Bos taurus* breeds or mating *Bos taurus* with *Bos indicus* breeds. Notice that for almost all of the traits listed, *Bos taurus* crossed with the *Bos indicus* increased productivity approximately ten percent. This is primarily due to dominance effects as each gene from the different breeds used in the mating has dissimilar alleles at each locus across the entire genome.

Selection of which breeds and how much of each breed to incorporate into progeny has a large impact on dominance (or heterosis) effects that affect phenotype. Both additive and non-additive genetic effects can have a significant impact on a particular phenotype; therefore, it is important that both are considered during breed selection. Due to their different modes of inheritance, different tactics must be employed to capture the benefits of each.

Crossbreeding-Optimizing Heterosis

Crossbreeding can be a very effective tool to improve reproductive and weaning rates in beef cattle. Tables 3 and 4 summarize heterotic differences in various growth and reproductive traits. Notice that there are major production differences as expressed in heterosis by how divergent the original breeds used to make the crosses are (Table 2). Using information in Table 2, producers can increase their weaning weights and feedlot productivity by using a well planned crossbreeding program that incorporates *Bos indicus* germplasm. Note that the major increase in weaning weight is from maternal heterosis. Producers failing to use crossbred cows limit productivity in their herd. This includes calf survivability, cow fertility, and increased growth rate which results in more pounds of calf weaned per cow exposed. Other considerations that should be taken into account include matching the genetics of the cowherd with environmental conditions where the cows will perform. Selection of superior seedstock is a must. Crossbreeding cannot overcome poor genetics due to improper selection. The focus of this paper will address growth and feed efficiency in *Bos indicus* influenced cattle.

Growth Traits

Cattle growth traits include birth weight, weaning weight, yearling weight, post-weaning gain, and where available, slaughter weight. Growth traits are important as almost all cattle are marketed on a weight basis. Cattle that grow faster under the same production system will return a greater profit to the enterprise. Crossbred *Bos indicus* cows have been shown to be the most productive cows in subtropical environments. This is especially true when production is measured by pounds of weaning weight produced per cow exposed. Cows with up to 50% *Bos indicus* genetics can be used in a systematic crossbreeding system. When these cows are bred to *Bos taurus* bulls, the resulting offspring will qualify for most branded beef programs (≤ 1/4 *Bos indicus* genetics).

Data will be cited from the UF Beef Research Unit Angus-Brahman multibreed herd, USDA ARS Brooksville herd, NFREC Beef Unit, Texas A&M University Ranch to Rail South, TAMU Beef Unit, and commercial operations.

Birth weight

Birth weights are important in overall beef cattle production as future production of the cow and calf can be compromised in females experiencing calving difficulties. Calf birth weight is the largest factor leading to dystocia in beef cattle. Most calf losses occur during parturition or within four days of calving. Using the appropriate sires and breeds will determine the extent of calving problems within a cattle herd.

Most crossbreeding studies estimate heterosis for birth weight at approximately three percent (Tables 3 and 4). So on average, crossbred calves will weigh more at birth. If the average birth weight in a herd of cows is 80 lb, then crossbreeding would add 2.4 lb to the average. In mature cows this would be negligible causing little if any increase in calving problems. However, caution must be exercised when mating *Bos indicus* males to *Bos taurus* females as this can lead to extremely high birth weights and increased losses at calving. Riley et al., (2007a) showed a large increase in birth weights when Brahman bulls were mated to Angus and Romosinuano cows (Table 5). Other researchers have previously shown the same results. The difference in birth weight was greatest in male calves. The reciprocal mating (Angus and Romosinuano bulls mated to Brahman females) led to reduced birth weights and fewer calving problems. Therefore, cattle producers should design breeding programs to capitalize on this difference. For example, if a producer wanted to produce Angus-Brahman cross animals to use as replacements, Angus bulls should be purchased to mate to Brahman cows rather than Brahman bulls mated to Angus cows.

Weaning weight

Cattle producers are paid by the pounds of beef that their enterprise produces. Utilizing *Bos indicus* germplasm in cattle raised in subtropical/tropical environments has a dramatic affect on weaning weights. Notice in Figure 1, calves with at least 3/16 to 3/8

Bos indicus breeding had greater weaning weights than those with lesser amounts. Calves from cows with ≥3/8 *Bos indicus* genetics exceeded the weaning weights of those that were of *Bos taurus* decent. Calves resulting from Charolais bulls bred to Brangus cows were the heaviest while the purebred Brangus calves were the next heaviest class. Similar results were obtained when Charolais bulls were naturally mated to various types of purebred and crossbred cows (Table 6). All cows were managed in a single herd in central Texas and data was collected over a three-year period. Weaning weights were adjusted to 205 days and age of dam. Records from first-calf heifers were excluded. The difference in the Hereford versus the Brahman X Hereford cows (211 lb of extra weaning weight per cow exposed) points out the advantage of using crossbred cows, especially *Bos indicus* X *Bos taurus* breed types.

Brahman cows produced heavier calves when mated to Brahman, Angus, or Romosinuano bulls than when the reciprocal matings were made (Table 5; Riley et al., 2007a). This advantage is captured in the F-1 cow. However, it does not appear to matter whether the F-1 was produced through mating *Bos taurus* males to *Bos indicus* females or vice versa. Olson et al., 1991, compared different crossbred cattle in Nebraska and Florida. The study showed that *Bos indicus* X *Bos taurus* cows weaned calves approximately equal in weaning weight per cow exposed in Florida and Nebraska, but weaned 62 and 34 more pounds in comparison to *Bos taurus* X *Bos taurus* cattle in Florida and Nebraska, respectively. The Zebu productivity advantage in Florida was up to three-times greater than that experienced in Nebraska. Crossbreeding would have a dramatic impact on a beef cattle enterprise as this production advantage is repeated every year.

In a large commercial operation where a three breed rotation cross has been employed for several years, part of the cows were placed in a terminal crossbreeding program to increase weaning weight and marketability of the calves. The crossbreed cattle were 5/8 *Bos taurus* and 3/8 *Bos indicus* breeding. Table 7 summarizes weaning weights in the various crosses. Notice that there was very little difference between the crossbred calves and terminal cross calves for weaning weight performance. This data was for one year and could change from year to year.

Using the proceeding data, it is clear that *Bos indicus* genetics need to be incorporated into the cowherd to optimize pounds of calf weaned per cow exposed. It would appear that cows should have between 1/4 to 1/2 *Bos indicus* genetics to capitalize on maternal heterosis. The percent of *Bos indicus* influence would depend on production conditions cows are expected to perform in. Cattle in Northwest Florida would need less *Bos indicus* influence than cattle in South Florida.

Yearling weight/post-weaning gain

Table 8 summarizes how the Charolais calves produced from the *Bos indicus* influenced cows (Table 6) performed in the feedlot and at the packing plant. Note that the calves performed extremely well in the feedlot. All of the cattle graded high select or better, no “out” cattle, and all carcasses were yield graded 3 or better. All of these calves had at least 1/4 *Bos indicus* genetics. Granted, the Charolais bulls were selected for high levels of intramuscular fat as determined by ultrasonic imaging while maintaining optimum growth levels. Crossing Charolais bulls to this set of F-1 cows maximized heterosis in the cowherd as well as in feedlot. Carcass data shows that these animals performed above industry averages. It is important to note that the feedlot operator returned each year and paid a premium to purchase these calves.

Data collected from the Texas A&M University (TAMU) Ranch to Rail South program helps us to further understand how “eared” cattle perform in the feedlot and packing plant (see Table 9; Paschal et al., 2006). Cattle with up to 50% *Bos indicus* influence showed no significant difference in average daily gain compared to cattle with no *Bos indicus* influence. However, as the percent *Bos indicus* genetics increased; final weight, USDA quality grade, ribeye area and carcass weight declined. There was no difference in animals with *Bos indicus* breeding for overall marbling score and quality grade, but the marbling and quality grade of the non-*Bos indicus* cattle was higher (Low Choice versus High Select). Cattle with 100% *Bos indicus* genetics had lower average daily gains, higher cost of gains and less days on feed due to higher initial weights. These cattle also had the lowest medicine costs, the highest marketing margins, lowest feeding margins and highest net return. Part of the reason for the high net return was due to severe discounts when these animals were valued as feeder calves (Table 9; Paschal et al., 2006).

Data from the BRU Angus-Brahman multibreed herd also showed that as the percent of *Bos indicus* breeding increased average daily gain decreases (Table 10). Previous data from this same herd showed that slaughter weights for the crossbred steers were heavier on average than straightbred Angus and Brahman. Results also showed that crossbred steers with a high percent Brahman breeding will tend to be heavier than crossbred steers with low percent Brahman and straightbred Brahman steers. However, the Angus/Brahman crossbreeding average (interaction between Angus and Brahman) was 40 lb over the intrabreed Angus and Brahman interactions (Elzo et al., 2002). This was a result of the crossbred cattle performing at higher levels for weaning weight and post-weaning gain.

This data points out that purebred breeders of 100% *Bos indicus* genetics need to place more emphasis on post-weaning gain and carcass characteristics. Data presented at the 2002 UF/IFAS Florida Beef Cattle Short demonstrate that there is sufficient variation in *Bos indicus* populations to make genetic progress in these traits (Elzo et al., 2002). Other data not presented in this paper also confirms there is sufficient variation in *Bos indicus* influenced genetics for improvement in the traits that are deficient in these cattle types. Progressive operators can find seedstock producers that are addressing these problems and create crossbreeding programs that will optimize production while producing an acceptable product for the consumer.

Feed Efficiency

Compared to other animal protein sources, (pork and broiler chicken) little feed efficiency research has been conducted in beef cattle. It's been estimated that only six percent of the total dietary energy expended in beef production is used for protein deposition, while swine and poultry are more efficient at 14 and 21%, respectively. Some of this disadvantage is overcome as a beef cow's diet is composed largely of forages high in fiber that monogastric species cannot utilize. However, if beef is to remain competitive with these other sources of high quality protein, selection for feed efficient seedstock will be necessary.

Genetic research in beef cattle has focused on growth and more recently carcass traits while genetic variation that controls feed/forage efficiency has gone unexplored. With feed and forage accounting for the single largest expense for most beef cattle production systems, one would think that more research in beef cattle feed efficiency would have been conducted. One of the greatest detriments to feed efficiency research is the cost and resources needed to conduct this type of research. With advent of systems that eliminate much of the tedious labor involved in data collection, feed efficiency has become the focus of several researchers as its potential economic impact is beginning to be realized by the beef industry.

Feed conversion ratio

Typically live weight gain and dry matter intake are used to measure ratio based feed efficiency traits such as feed conversion ratio **(FCR)**. While FCR is useful in comparing the effects of environment, diet composition, and management practices on animal performance in growing animals, it has little value as an efficiency trait for genetic improvement. One of the major problems in selecting for feed efficiency using FCR is the genetic antagonisms with other traits. As post-weaning FCR is reduced, genetic merit in growth and mature size are increased. This leads to cows that are large and expensive to maintain. Carcass size also becomes a problem, as larger cattle have to be finished at heavier weights leading to cattle that are too large for the production system. Although moderately heritable, feed:gain ratio (FCR) is negatively correlated with post-weaning average daily gain, yearling body weight and mature cow size. As mentioned earlier, selection for improved FCR will indirectly increase genetic merit for growth and increase mature cow size which leads to increased feed costs to maintain the cowherd.

Feed conversion ratio is a gross measure of efficiency and makes no effort to partition feed intake requirements into maintenance and growth requirements. Archer et al. (2002) found that the genetic correlation between FCR measured in heifers (post-weaning) and then as mature cows was only 0.20% while feed intake and average daily gain of heifers was highly correlated to feed intake ($r_g = 0.94$) and average daily gain ($r_g = 0.72$) as mature cows. Feed conversion ratio calculated post-weaning would be a poor predictor of cow efficiency and selecting for improved FCR would probably increase maintenance costs in the cowherd.

Although FCR is heritable, recent data shows little difference between breed types, but large differences within breeds. Feed conversion ratio in Angus cattle was similar to Brahman cattle as well as each cross made between the breeds (Figure 2; Elzo et al., 2007). Riley et al., (2007b) showed the same results with Angus, Brahman and Romosinuano heifers. This would be expected as FCR is a gross measure of feed efficiency. However, Coleman et al., (2007) showed feed to gain data in which Brahman steers were more efficient in comparison to Angus and Romosinuano steers (Tables 11 and 12). Further studies need to be conducted to investigate FCR differences within breed types.

Residual feed intake

To overcome the problem of FCR being correlated to the component traits of average daily gain and mature cow size, a method using an animal's weight and growth rate in a linear regression procedure was devised to estimate feed efficiency in beef cattle. The procedure partitions feed input into maintenance and growth components. An animal's expected feed intake over a given period of time is calculated using linear regression equations. The regression equation generates predicted or expected feed consumption values based on the animals body weight and growth requirements. Summing the predicted feed intake **(PFI)** (calculated through linear regression) with the actual feed intake (**AFI)** produces a residual feed intake **(RFI)** value. Negative values represent more efficiency animals as they consumed less than was predicted by the equation.

To help understand RFI, let's take a simple example. This example has been simplified to help understand how RFI would work in a real life situation realizing that in experimental studies, regression analysis will be used to calculate RFI. If a steer averaged 1,000 lb over the last 120 days on feed and average daily gain was 3.9 lb/day, using a common feedlot ration, the steer would have a predicted average feed intake of 32 lb/day (NRC, 1996). If actual intake was 28 lb/day, then this would result in 4 lb/day less feed intake than expected. The RFI would be -4 lb/day. The opposite would be true of an animal that consumed more than predicted. Negative RFI values represent animal that are more efficient, while positive value represent less efficient animals.

RFI appears to be phenotypically independent of the production traits used to compute predicted intake as well as limited relationships with other important traits. This allows producers the opportunity to select for efficient cattle without a correlated response in fertility, growth and carcass traits. Carstens and Tedeshi (2006; Table 13) demonstrated that low RFI versus high RFI cattle, had equivalent growth rates in growing and finishing animals while ultrasound body composition was the same in growing animals but differed in finishing animals. Feed efficiency traits in low and high RFI groups were different ($P<0.01$) in cattle fed either a growing or finishing ration. This illustrates the ability to select for efficient cattle using RFI without adversely affecting other traits of economic importance.

Research results from the Meat Animal Research Center **(MARC)** Germplasm Evaluation Program looked at efficiency using live weight gained per unit of metabolizable energy consumed for alternative intervals and endpoints in Angus, Beefmaster, Brangus, Bonsmara, Hereford and Romosinuano cattle. Breed of sire differences were significant for efficiency of postweaning live weight gain for all intervals and endpoints (Table 14). Efficiency of gain was significantly greater for Angus and Hereford than Romosinuano or Bonsmara for every interval evaluated. Angus and Hereford sired steers did not differ significantly for efficiency of gain for any interval evaluated. Beefmaster and Brangus sired steers did not differ in efficiency of gain for any interval evaluated. Beefmaster sired steers did not differ significantly for efficiency of gain from Angus or Hereford sired steers in any interval except to the marbling endpoint. Angus were significantly more efficient than Beefmaster to the marbling endpoint. Brangus were intermediate in efficiency of live weight gain to the British (Angus and Hereford) and Tropically adapted (Romosinuano and Bonsmara) sire breeds for all intervals evaluated. Brangus did not differ significantly from Beefmaster, Hereford, or Angus in any interval evaluated except that Angus were more efficient than Brangus to all fatness endpoints (marbling, fat thickness, and fat trim). Beefmaster and Brangus sired steers were significantly more efficient than Bonsmara sired steers to live weight, fatness, and retail product weight endpoints. However to a time endpoint (186 days), Brangus did not differ significantly from Romosinuano or Bonsmara, and Beefmasters did not differ significantly from Romosinuano. Romosinuano did not differ from Bonsmara for feed efficiency for any interval evaluated, except for the marbling endpoint, to which efficiency of gain was greater for Romosinuano than Bonsmara sired steers. Previous results have indicated that efficiency of postweaning gain is greater for steer progeny of *Bos taurus* sire breeds (e.g., Angus and Hereford) than for those of tropically adapted *Bos indicus* sire breeds (Brahman, Nellore, and Sahiwal) when the postweaning period includes winter months (December through March), as in this study (from Wheeler et al., 2006). In summary, *Bos indicus* influenced sire breeds are comparable to Angus and Hereford breeds in several of the traits evaluated. Beefmaster steers were the same as Angus and Hereford breeds for all traits except marbling. Had this study been performed during summer conditions or in a warmer locale, the *Bos indicus* influenced cattle may have experienced greater performance.

Recent research conducted at the UF/IFAS Feed Efficiency Facility in Marianna has produced some very interesting results regarding breed differences for RFI. Data for individual feed intake, feeding behavior, and disposition was collected on animals of Angus, Brangus, Brahman, Romosinuano and Charolais breeding. Data collected on the BRU Angus-Brahman multibreed herd **(ABH)** as well as Brooksville herd **(BH)** showed significant difference between the various crosses and their percent *Bos indicus* breeding. This data will be presented in graphical form.

Simple means of RFI for cattle from the ABH (Figure 3) and BH (Figure 4) showed the same basic results. Angus was the least efficient purebred breed with Romosinuano intermediate and Brahman far superior to the rest. Residual feed intake values were intermediate in the crossbred cattle with exception of the 3/4 Brahman cattle in the ABH. This is probably due to the low numbers of individuals represented in this class of cattle. Although RFI values are clearly defined in the purebred breeds in the BH, data from the crossbred animals shows no real pattern. This is due to the small number of animals represented in each crossbred group. Further investigation is needed to give clarification of the crossbred data.

Animals were assigned to high (animal RFI > mean + 0.5 standard deviation; less efficient), medium (animal RFI between mean ± 0.5 standard deviation) or low (animal RFI < mean – 0.5 Standard Deviation; more efficient) RFI groups in order to investigate relationship between RFI and other traits of interest. For example, if the standard deviation was 0.80, then animals with values equal to or greater than 0.40 would be classified in the high RFI group. Animal with values equal to or less than -0.40 would classified in the low RFI group while animal with values from 0.39 to -0.39 would be classified in the medium RFI group. Animals were also classified according the percent of *Bos taurus* genetics present in their pedigree.

Assigning animals to RFI group further illustrated the advantage of the purebred Brahman calves in comparison to all other breeds and crosses between the breeds of interest. Notice that the number of calves (Figures 5 and 6) as well as the percentage (Figures 7 and 8) of Brahman calves classified in the low RFI group (more efficient) exceeds any other breed or combination of breeds in both the ABH and BH. While this data is preliminary, we feel that further studies will corroborate these results as more data is included in the analysis.

In the ABH, phenotypic RFI was analyzed using a homoscedastic mixed linear model. Fixed effects were pen, age of dam, sex of calf, initial age, initial weight, Brahman fraction of calf, and probability of Angus and Brahman alleles at 1 locus in the calf. Random effects were sire and residual. Important effects were sex (P<0.002; Males had lower RFI than females), initial weight (P<0.02), and Brahman fraction (P<0.02; Brahman had lower RFI than Angus). High and medium RFI group estimates were higher (P<0.001) for daily feed intake and feed conversion ratio, and lower (P<0.001) for average daily gain and final weight than those of the low RFI group (Elzo et al., 2007).

In the BH, Brahman heifers had the most favorable (P<0.05) RFI (–2.38 ± 0.55 lb) of all groups which ranged from 0.132 ± 0.374 (Romosinuano) to 1.01 ± 0.44 lb (Angus). Brahman ADG (1.84 ± 0.13 lb) was less than (P<0.05) that of Angus heifers (2.33 ± 0.11 kg). Means for ADG of crossbred heifers were 1.89 ± 0.18 (Romosinuano/Brahman), 2.38 ± 0.22 lb (Brahman/Angus), and 2.42 ± 0.20 lb (Romosinuano/ Angus). No breed effect was detected for FCR (P=0.31; Riley et al., 2007b).

As expected, males were more efficient that females. Figure 9a shows that bulls were the most efficient, followed by steers at intermediate and heifers being the least efficient when least square means were adjusted for fixed effects in the model. Unadjusted simple means for RFI (Figure 12b) were the same across all breeds and genders. Final weights were heavier and RFI was lower in low RFI groups when compared to the other RFI groups using least square means (Figure 10). This was true for all breed types. Residual feed intake was lowest for the 3/4 Angus 1/4 Brahman crossbred calves classified in the low RFI group. One individual in this group was extremely efficient and tended to lower the overall average of this group. It should be noted that all breed groups had individual animals that were very efficient allowing for RFI selection to take place in all classes of animals. The large number of Brahman calves with low RFI values would make selection easier than in Angus cattle where there were fewer individuals to select from.

Daily feed intake was lowest in the low RFI group and was highest in the high RFI group (Figure 11). Daily feed intake was highest in Angus cattle and decreased in a linear fashion as the percentage of Brahman genetics increased (Figure 11). Final weight was highest in animals with a greater percentage of Angus genetics and decreased as percentage of Brahman genetics increased (Figure 11). However, this was due in part to the younger age and lower initial weight of the Brahman influenced calves. Predicted final weight showed the same trend with the actual final weights in Angus influenced calves being the heaviest and lightest in the Brahman influenced cattle. Predicted RFI also showed the same results as the actual data with Brahman cattle being the most efficient and RFI increasing (in a linear manner) as the percent of Angus genetics increased in the calves (Figure 12).

For animals to optimize feed resources, they need to efficiently convert feed to lean tissue and do it in a timely manner (minimal level of average daily gain). Figure 16 charts average daily gain with RFI. Animals that are the most efficient with the highest gains are located in the lower right hand quadrant of the graph. Utilization of these animals as seedstock would allow for selection of both traits simultaneously.

Although there is considerable variation for average daily gain within the trial, there were an equal number of slow and fast gaining calves with low and high RFI values. Two animals (687 versus 6163) highlighted in Figure 13 had similar gains (3.96 versus 3.97 lb/day). However, animal 687 consumed 3.6 lb more feed on an actual basis. When RFI values are compared, 6163 consumed 7.8 lb less feed. The actual difference fails to correct for the differences in body weight. Animal 687 weighed 219 lb less than animal 6163. Residual feed intake is calculated to adjust for maintenance requirements based on animal body weight and growth. In other words, if the two animal's body weights were equal, 687 would have required 7.8 lb more feed to achieve the same gain as 6163.

Water intake

The capability to measure water intake has led to some interesting results in cattle that participated in trials in the UF/IFAS Feed Efficiency Facility. Data from 126 Angus bulls demonstrates that feed efficiency in young growing animals is linear related ($R^2 = 1.0$) to water consumption as more efficient animals consume less water than less efficient animals (Figure 14;

Hansen et al., 2007). Later trials with animals of various genetic makeup verified that efficient animals consume less water and females consume less water than males (Figure 15). Using this preliminary data as a basis, prediction equations could be developed using water intake to predict feed intake and vice versa.

Research data was further broken down into water intake as influenced by breed type. Figure 16 demonstrates that crossbred and *Bos indicus* influenced cattle consume less water than the other breeds represented. This was especially true of the crossbred animals with Romosinuano dams. Figure 17 shows a linear relationship between the percentage of *Bos indicus* genetics with water intake. As the percentage of *Bos indicus* genetics increases, water intake decreases. However, when water consumption is evaluated in terms of liter of water per kilogram of gain, crossbred animals appear to be the most efficient (Figure 18).

Summary

Often producers are somewhat reluctant to use *Bos indicus* germplasm in their enterprise due to discounts received for *Bos indicus* influenced cattle when they enter commerce. Producers can avoid these discounts if they have production records on how their cattle have preformed in the past. Also, producers must have a well developed plan prior to mating which includes where and how to market the cattle. Considering the advantages of the *Bos indicus* influenced crossbred cow, it would behoove cattle producers in Florida to investigate methods to incorporate these genetics into their cattle enterprises. Most branded beef programs will allow cattle with up to 1/4 *Bos indicus* genetics to participate in their programs as long their specifications are met. This would allow for cows that are up to 50 % *Bos indicus* influenced in their genetic background to be used in a crossbreeding program.

Bos indicus cattle appear to have greater feed efficiency (RFI) than the *Bos taurus* breeds evaluated in the studies to date. Further studies need to be conducted to determine if this difference in efficiency is maintained through the animal's productive life. If *Bos indicus* influenced cows maintain this efficiency advantage when in production, this would have a significant effect on reducing maintenance costs within the cowherd.

Breeders of *Bos indicus* influenced seedstock need to insure that areas of concern (tenderness, marbling, etc.) are addressed so that commercial cattle producers will be willing to use their genetics. Producers of quality cattle will continue to have markets for their cattle, but more verification of prior performance will be necessary.

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Table 1. Classification and country of origin of beef cattle breeds.

Breed[1]	Breed classification	Country of origin	% *Bos indicus*
Angus	British	Scotland	0
Beefmaster	American	United States	50
Belgian Blue	Continental	Belgian	0
Braford	American	United States	37.5
Brahman	Specialty	United States	100
Brangus	American	United States	37.5
Braunvieh	Continental	Switzerland	0
Brown Swiss	Dairy	Switzerland	0
Charolais	Continental	France	0
Chianina	Continental	Italy	0
Galloway	British	Scotland	0
Gelbvieh	Continental	Germany	0
Gir	Specialty	India	100
Guzerat	Specialty	India	100
Hereford	British	England	0
Holstein	Dairy	Netherlands	0
Jersey	Dairy	England	0
Limousin	Continental	France	0
Maine Anjou	Continental	France	0
Nellore	Specialty	India	100
Piedmontese	Continental	Italy	0
Red Angus	British	Scotland	0
Romosinuano	Specialty	Columbia	0
Saler	Continental	France	0
Santa Gertrudis	American	United States	37.5
Simbrah	American	United States	37.5
Simmental	Continental	Switzerland	0
Shorthorn	British	England	0
Tarentaise	Continental	France	0
Tuli	Specialty (Sanga)	Zimbabwa	~0
Wagyu	Specialty	Japan	0

[1]Breeds in bold represent 11 largest beef breeds by registration in United States.

Table 2. Average heterosis in the economically important beef traits when crossing divergent breed types of cattle[1].

Trait	*Bos taurus* X *Bos taurus* %	*Bos indicus* X *Bos taurus* %
Individual heterosis	(Calf performance)	
Birth weight	2.4	11.1
Weaning weight	3.9	12.6
Post-weaning gain	2.6	13.4
Maternal heterosis	(Cow performance)	
Calving rate	3.7	13.4
Calf survival	1.5	5.1
Birth weight	1.8	5.8
Weaning weight	3.9	16.0

[1]Adapted from Cundiff, 1989.

Table 3. Individual units and percentage of heterosis by trait.[1]

Trait	Heterosis Units	%
Calving rate, %	3.2	4.4
Survival to weaning, %	1.4	1.9
Birth weight, lb	1.7	2.4
Weaning weight, lb	16.3	3.8
Yearling weight, lb	29.1	3.8
Average daily gain, lb/day	0.08	2.6

[1]Cundiff and Gregory, 1999.

Table 4. Maternal units and percentage of heterosis by trait[1].

Trait	Heterosis Units	%
Calving rate, %	3.5	3.7
Survival to weaning	0.8	1.5
Birth weight, lb	1.6	1.8
Weaning weight, lb	18.0	3.9
Longevity, years	1.36	16.2
Lifetime productivity		
Number of calves	0.97	17.0
Cumulative weaning weight, lb	600	25.3

[1]Cundiff and Gregory, 1999.

Table 5. Birth and weaning weights for Romosinuano, Angus, and Brahman calves in a three breed diallel.[1]

Breed type	Birth weight			Weaning weight			
	No[2]	Male	Female	No[2]	Male	Female	Ave
Romosinuano	117/122	68.4	62.7	98/113	461	427	443
Brahman	67/63	70.1	64.6	56/56	523	484	504
Angus	69/60	66.4	62.5	49/54	435	422	428
Romosinuano/Brahman	58/59	64.5	66.2	50/56	530	517	523
Brahman/Romosinuano	84/92	84.3	74.1	82/90	533	495	513
Romosinuano/Angus	66/64	68.2	63.4	61/61	456	427	442
Angus/Romosinuano	95/83	72.2	68.4	88/81	514	475	495
Brahman/Angus	55/66	86.0	73.5	45/65	517	479	494
Angus/Brahman	63/54	67.8	69.5	58/52	568	543	556

[1]Adapted from Riley et al., 2007a.
[2]Number of birth and weaning records males and females, respectively.

Table 6. Percent pregnant, average weaning weight and weaning weight per cow exposed in females of various percentages of *Bos indicus* breeding.[1]

Cow type[2]	Number of records	% pregnant	Average wean wt	Weaning weight/ cow exposed	*Bos Indicus* %
Hereford	52	82	492	389	0
Angus	68	84	498	413	0
Brahman	48	79	549	434	100
3/4 Angus	63	86	523	439	0
Brahman X Hereford	230	97	619	601	50
Angus X Brahman	93	96	612	587	50

[1]Hansen, unpublished data.
[2]Cows were exposed to Charolais bulls.

Table 7. Average weaning weights on a large commercial operation using various breeds and crossbreeding systems.

Sire type	Head	Average weaning weight, lb	% *Bos indicus*
Angus	4,749	481	18.75
Charolais	3,960	515	18.75
Terminal cross total	8,709	497	18.75
Cross-bred (3 Breed Rotation)	13,701	514	37.50
Total	22,410	508	30.20

Table 8. Charolais crossbred calves post-weaning performance.

Item	Performance	Value/Cost
Pay weight	707 lb	$692.00
Average daily gain	4.04 lb	$49.41/cwt
Hot carcass weight	823 lb	$905.30
Dressing %	64.20%	--
Percent choice	58%	--
Percent select	42%	--
Outs	0%	--
Yield grade 1 & 2	82%	--
Yield grade 3	18%	--
% *Bos indicus*	25%	--

Table 9. Least-squares means for TAMU Ranch to Rail-South by percent *Bos indicus* from 1992-2002. [1]

Characteristic	% *Bos indicus*				
Bos indicus (%)	0	25	37.5	50	100
Average *Bos indicus* (%)	0	0.20	0.36	0.49	100
No. head	845	3,851	1,752	1,526	258
In weight (lb)	585[a]	602[b]	592[a]	599[b]	658[c]
Out weight (lb)	1,190[c]	1,185[c]	1,199[d]	1,170[b]	1,124[a]
Medicine cost ($/hd)	7.04[e]	4.95[c]	5.95[d]	4.04[b]	0.35[a]
Days on feed	202[d]	196[c]	198[c]	191[b]	167[a]
ADG (lb/d)	3.01[b]	2.99[b]	3.09[b]	3.01[b]	2.88[a]
Total cost of gain ($/cwt)	58.06[b]	58.28[b]	56.73[a]	57.53[b]	62.17[c]
Carcass weight (lb)	761[cd]	756[c]	761[d]	746[b]	715[a]
Dressing (%)	63.6[b]	63.6[b]	63.2[a]	63.5[b]	63.3[ab]
Fat thickness (in)	0.35[a]	0.39[b]	0.45[c]	0.44[c]	0.34[a]
Ribeye area (in^2)	14.6[e]	14.2[d]	13.6[c]	13.4[b]	12.8[a]
REA/cwt carcass (in^2/cwt)	1.93[c]	1.89[b]	1.79[a]	1.80[a]	1.80[a]
Kidney, pelvic and heart fat (%)	2.10	2.20	2.30	2.20	2.00
USDA yield grade	2.1[a]	2.3[b]	2.7[d]	2.7[d]	2.5[c]
USDA quality grade	Se 87[d]	Se 79[c]	Se 74[b]	Se 71[ab]	Se 66[a]
Net return ($/hd)	70.06[a]	77.03[a]	80.91[a]	76.82[a]	118.10[b]
Marketing margin ($/hd)	7.01[a]	13.08[bc]	11.46[b]	15.72[c]	78.27[a]
Feeding margin ($/hd)	69.09[c]	64.21[b]	69.41[c]	61.14[b]	39.94[a]
Shear force (lb)*	5.92[ab]	5.74[a]	6.49[b]	6.44[b]	6.64[b]

[a,b,c]Means within a row with different superscripts differ $P<0.05$.
[d]There were 54, 181, 106, 70, and 9 animals per breed type respectively.
[1]Paschal et al., 2006

Table 10. Average daily gain (ADG) and residual feed intake in the UF/IFAS Beef Research Unit Angus-Brahman multibreed herd.

Item	Angus	3/4 Angus	Brangus	1/2 Angus	3/4 Brahman	Brahman
Number	33	29	40	44	24	30
ADG (lb/d)	3.21	3.33	3.27	2.98	2.93	2.7
RFI	0.356	0.148	0.183	0.097	0.402	-1.244

Table 11. Growth and feed efficiency traits in Angus (A), Romosinuano (R), Brahman (B) purebred, and cross beef cattle.[1]

Trait	AA	AB	AR	BB	BA	BR	RR	RA	RB	SE[2]
Initial wt, lb	882	983	975	860	970	953	840	862	854	13
Final wt, lb	1,162	1,241	1,278	1,152	1,316	1,296	1,137	1,168	1,109	22.9
ADG, lb	2.22	2.02	2.38	2.27	2.71	2.71	2.38	2.42	1.98	0.132
Feed/gain	9.3	10.2	8.9	8.7	7.8	7.4	8.4	8.5	10.1	0.55
RFI, lb[3]	0.18	0.29	0.46	-0.81	-0.40	-0.57	-0.26	0.44	-0.86	0.35

[1]Coleman et al., 2007.
[2]Standard error.
[3]Residual feed intake.

Table 12. Heterosis and direct effects for Angus (A), Brahman (B), and Romosinuano (R).[1]

	Direct			Heterosis		
Trait	A	B	R	A-B	A-R	B-R
Initial wt, lb	43**	19^{+}	-62**	48**	26**	24**
Final wt, lb	16	61**	-77**	55**	33**	26**
ADG, lb	-0.21^{+}	0.31**	-0.10	0.06	0.05	0.01
DMI/lb body wt	-1.00	-0.25	1.25†	-1.39**	-.48	-1.44**
Feed/gain	2.16*	-2.73**	0.57	0.09	0.10	-0.01
Residual feed intake	0.48†	-0.44†	-0.05	0.11	0.23	-0.08

[1]Coleman, et al., 2007.
†P<0.10 *P<0.05 **P<0.01.

Table 13. Characterization of performance, ultrasound composition, and feeding efficiency traits in growing and finishing animals with low and high residual feed intake.[1,2]

	Growing studies				Finishing studies			
Traits	Low RFI	High RFI	SE[3]	P-value	Low RFI	High RFI	SE	P-value
Number	155	156			93	87		
Growth traits								
Initial wt, lb	611	611	7.12	0.99	721	793	12.8	0.56
Final wt, lb	780	780	8.35	0.98	1,142	1,150	15.9	0.32
ADG, lb/d	2.34	2.34	0.04	0.90	3.11	3.13	0.09	0.38
Feed efficiency traits								
DMI[4], lb/d	19.2	23.4	0.26	<0.01	18.6	23.4	0.37	<0.01
RFI[5]	-2.03	2.09	0.11	<0.01	-2.25	2.36	0.018	<0.01
Partial efficiency for growth[6]	0.26	0.18	0.004	<0.01	0.31	0.21	0.01	<0.01
Feed/gain	8.44	10.28	0.15	<0.01	6.05	7.63	0.13	<0.01
Ultrasound/carcass traits								
12th rib fat, in	0.20	0.21	0.01	0.20	0.40	0.56	0.2	<0.01
Ribeye area, in^2	10.17	10.20	0.12	0.65	12.25	11.84	0.15	<0.05

[1]Carstens and Tedeschi, 2006.
[2]Animals with low and high RFI were <0.50 and > 0.50 standard deviation from average RFI, respectively (RFI SD was 1.80 and 1.96 lb/d for growing and finishing studies respectively).
[3]Standard error.
[4]Dry matter intake.
[5]Residual feed intake.
[6]ADG/DMI for growth.

Table 14. Sire breed means for estimates of efficiency (live weight gain/unit metabolizable energy consumed, lb/Mcal) for alternative intervals and endpoints.[1]

Sire breed	Time, 186 days	Weight 649-1,190 lb	Marbling, Small 00	Fat Thickness, 0.39 in	Fat Trim, 24.6%	Retail Product, 467 lb
Angus	0.1319	0.1363	0.1389	0.1366	0.1364	0.1322
Hereford	0.1313	0.1350	0.1332	0.1330	0.1315	0.1311
Brangus	0.1282	0.1326	0.1277	0.1282	0.1276	0.1307
Beefmaster	0.1319	0.1364	0.1297	0.1346	0.1333	0.1340
Bonsmara	0.1226	0.1223	0.1204	0.1208	0.1210	0.1218
Romosinuano	0.1278	0.1260	0.1269	0.1254	0.1252	0.1266
LSD<0.05	0.0058	0.0066	0.0061	0.0066	0.0066	0.0062

[1]Wheeler et al., 2006.

Figure 1. Weaning weights in calves with varying percentages of *Bos indicus* genetics. Sire breed listed first.

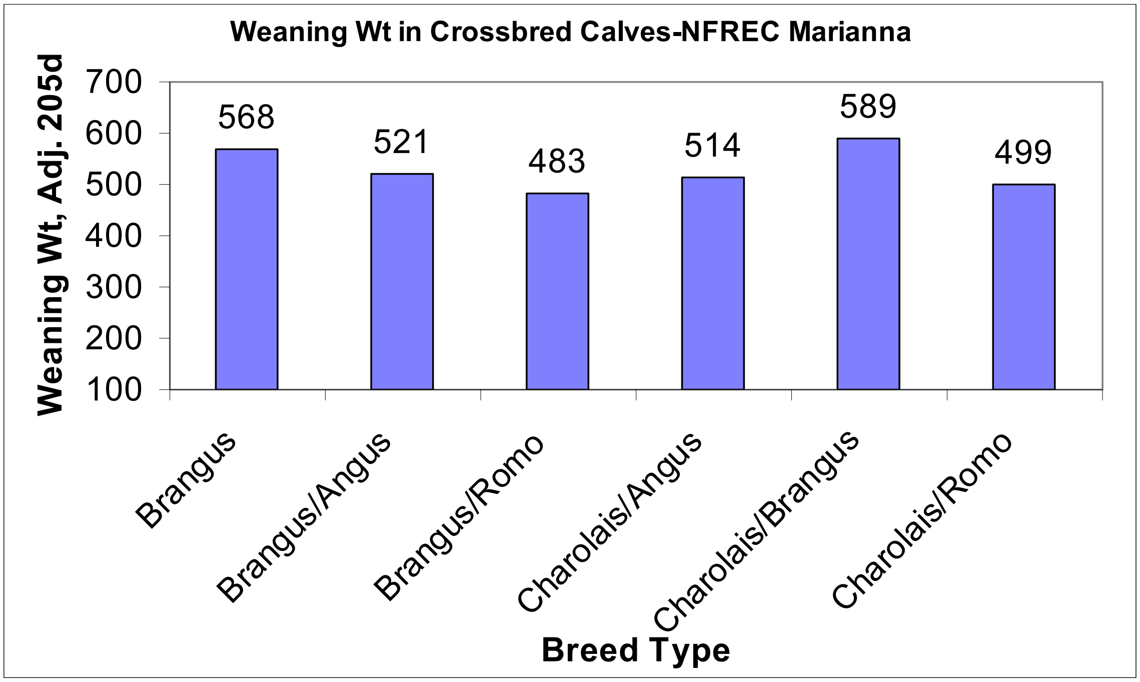


Figure 2. Feed conversion ratio by RFI group and gender in the UF/IFAS Beef Research Unit Angus-Brahman multibreed herd.

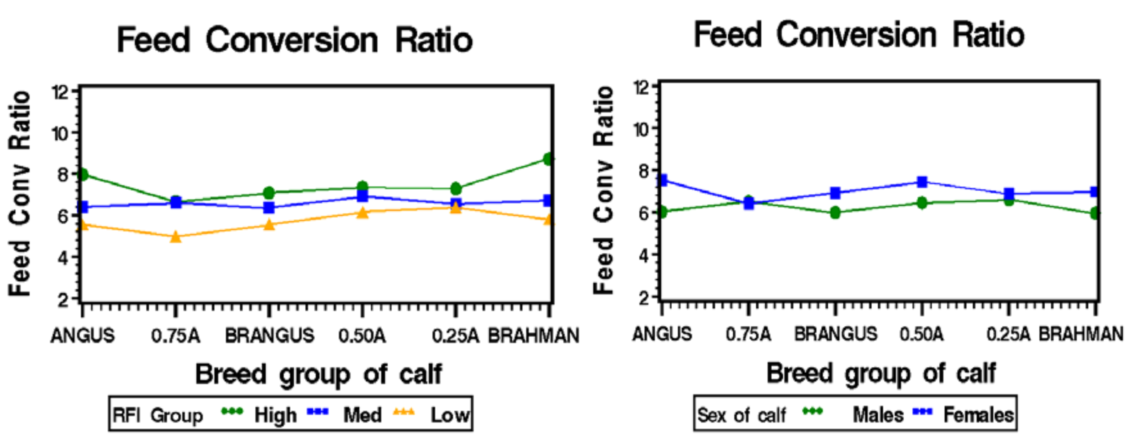


Figure 3. Residual feed intake by breed type in the UF/IFAS Beef Research Unit Angus-Brahman multibreed herd.

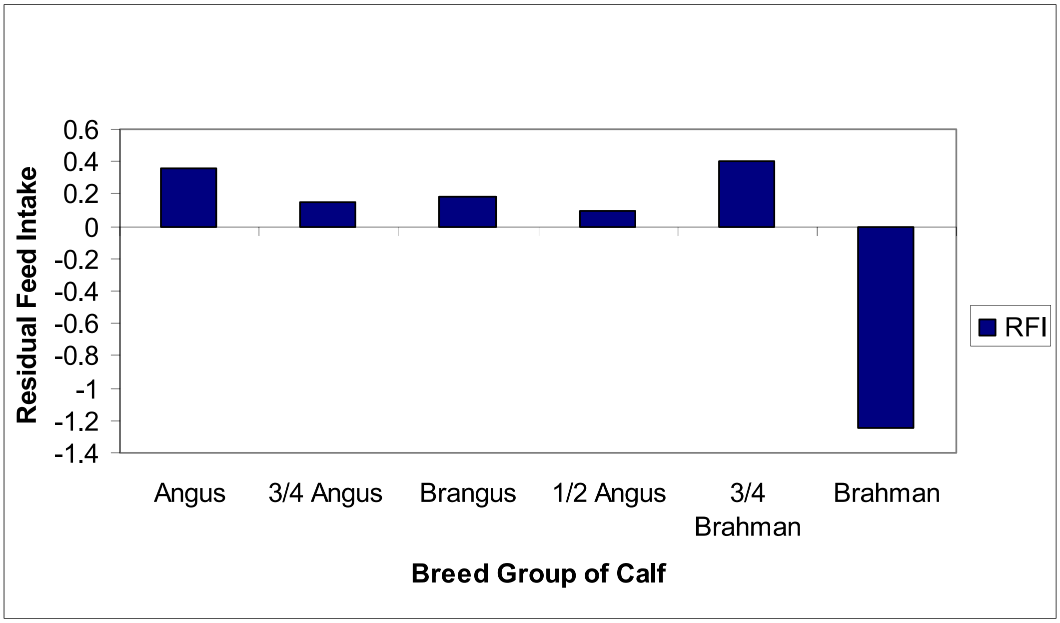


Figure 4. Residual feed intake in Romosinuano, Angus, and Brahman calves in a three breed diallel.

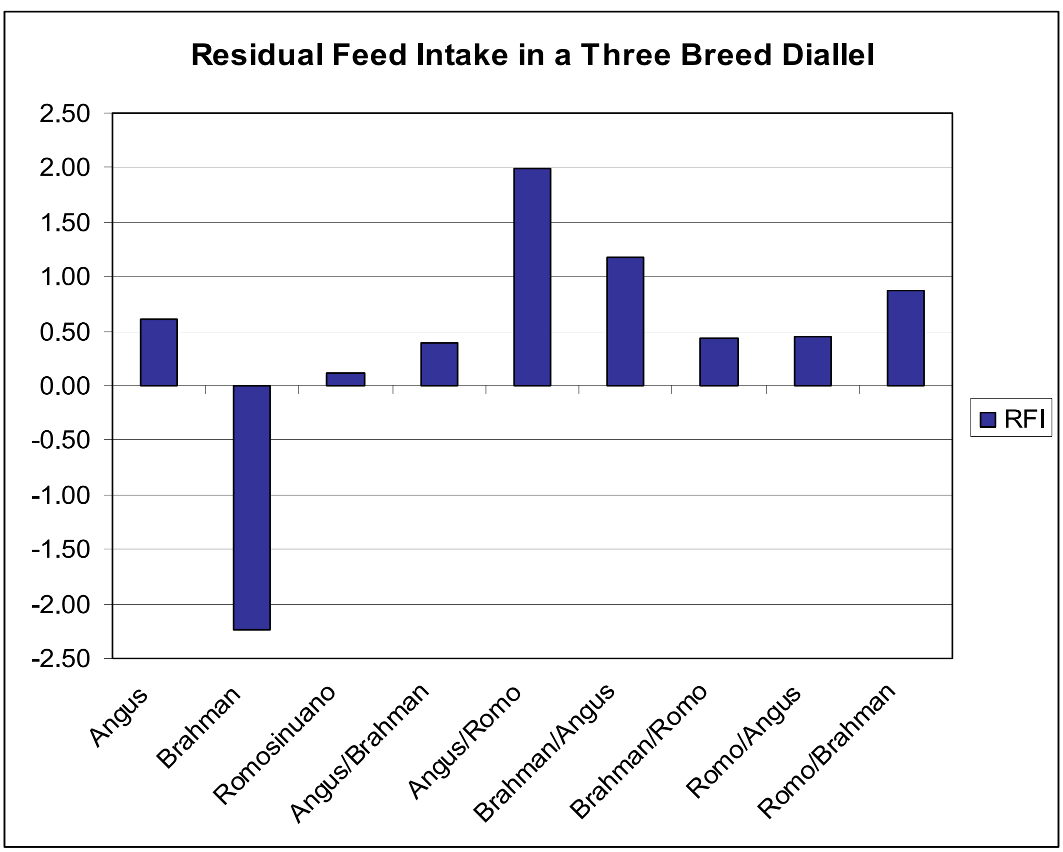


Figure 5. Number of calves by residual feed intake group within breed type in the UF/IFAS Beef Research Unit Angus-Brahman multibreed herd (Elzo et al., 2007).

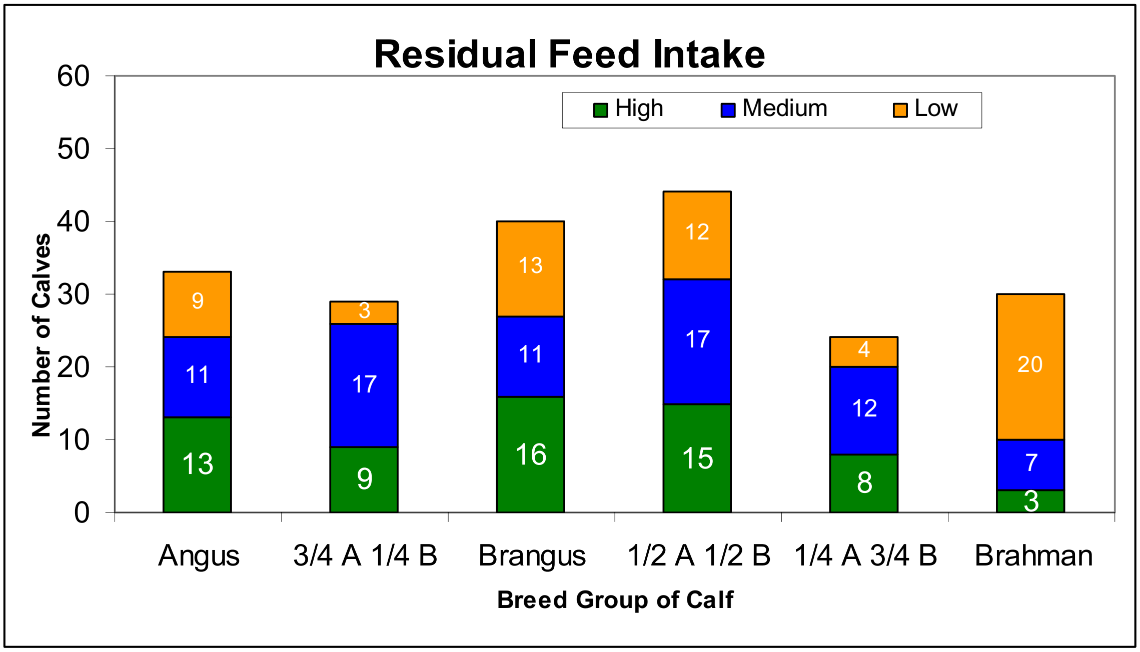


Figure 6. Number of calves by residual feed intake group within breed type in a three breed diallel (Riley et al., 2007b).

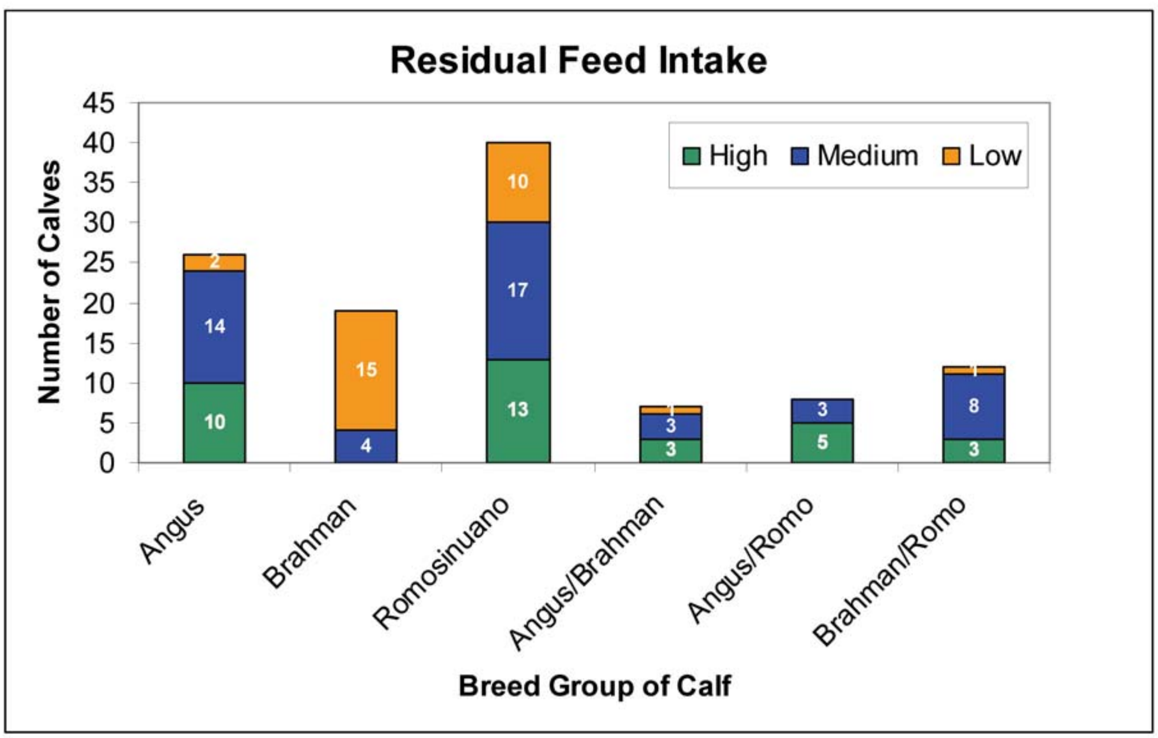


Figure 7. Percentage of calves by residual feed intake group within breed type in the UF/IFAS Beef Research Unit Angus-Brahman multibreed herd (Elzo et al., 2007).

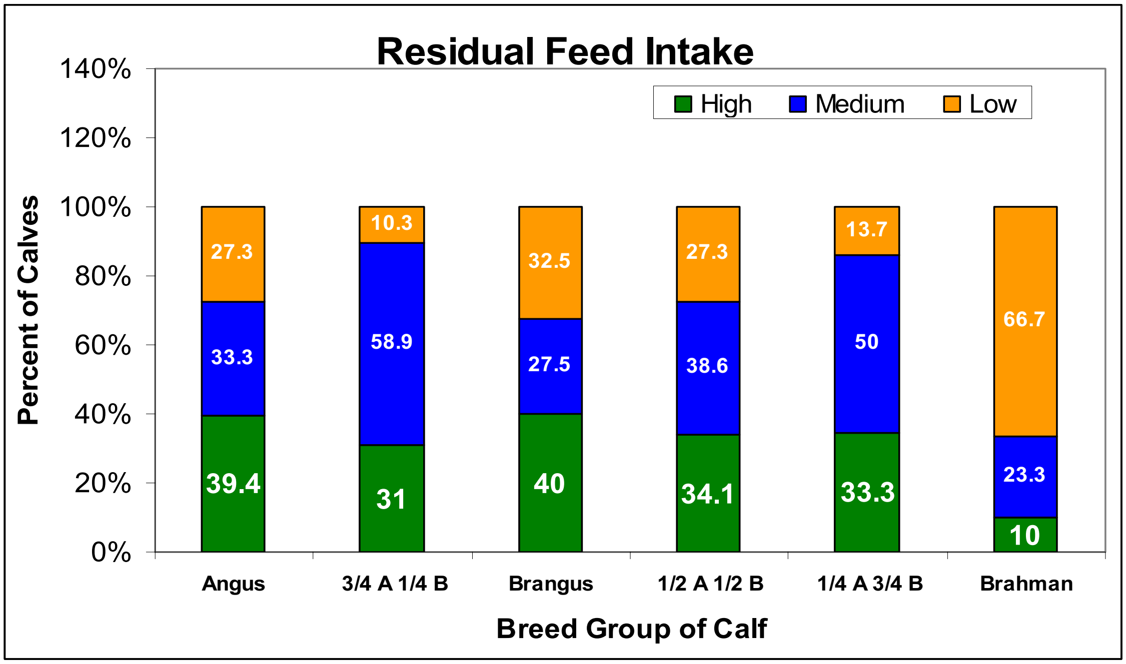


Figure 8. Percent of calves by residual feed intake group within breed type in a three breed diallel (Riley et al., 2007b).

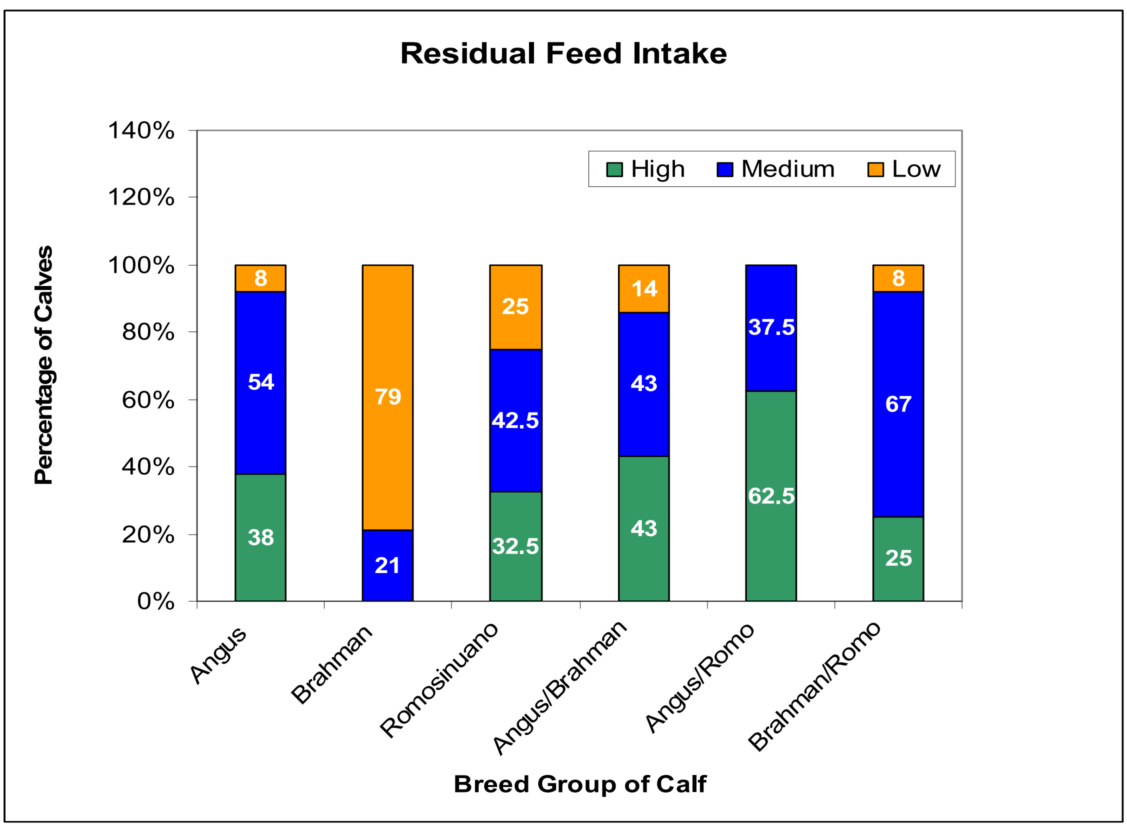


Figure 9. Residual feed intake least square means adjusted for gender and simple RFI means by gender in an Angus-Brahman multibreed herd.

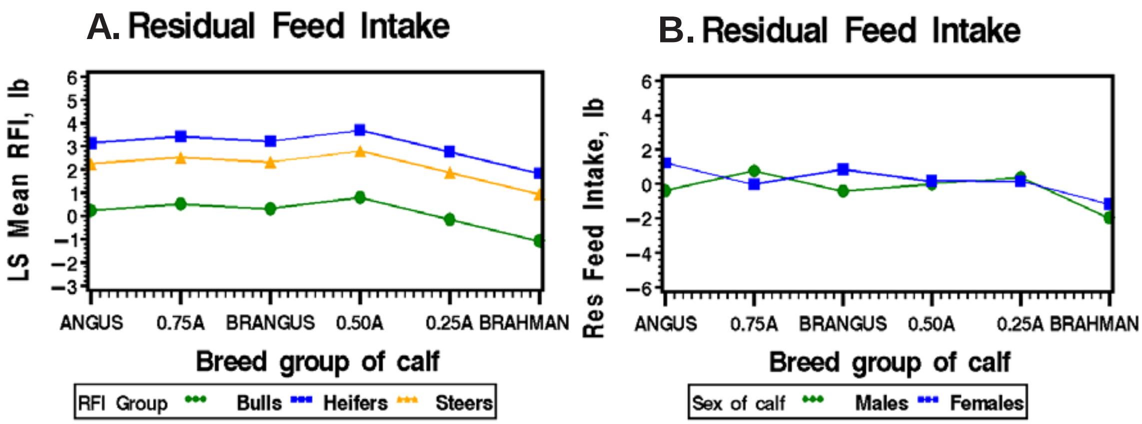


Figure 10. Adjusted least square means for final weight and residual feed intake in the UF/IFAS Beef Research Unit Angus-Brahman multibreed herd.

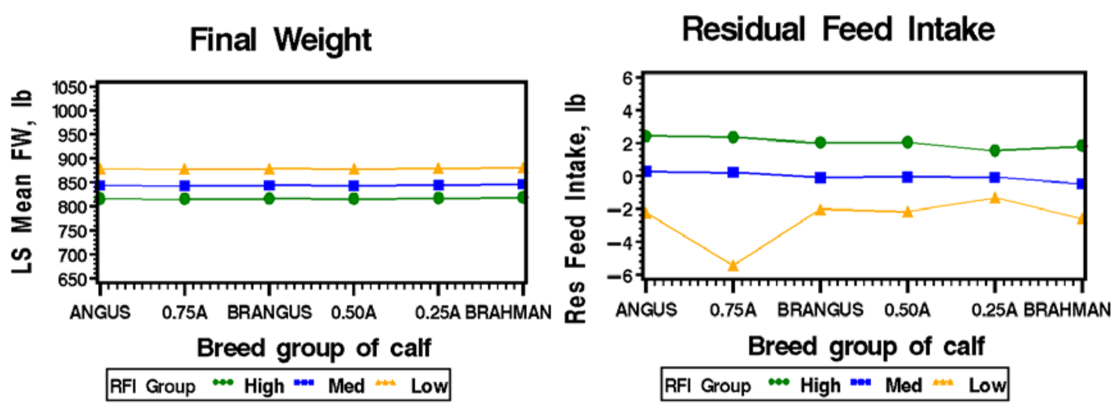


Figure 11. Daily feed intake and final weight as influenced by RFI group and breed type of calf.

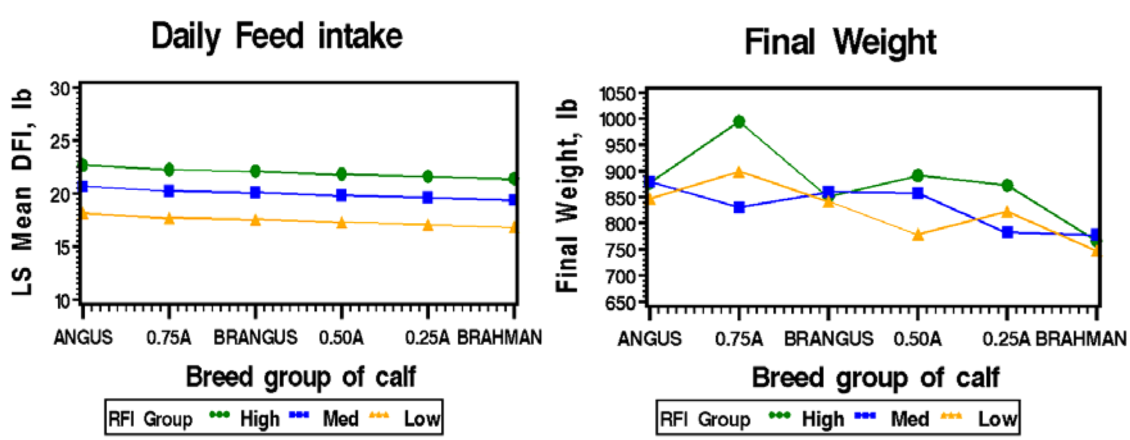


Figure 12. Predicted final weight and residual feed intake as affected by RFI group and breed type.

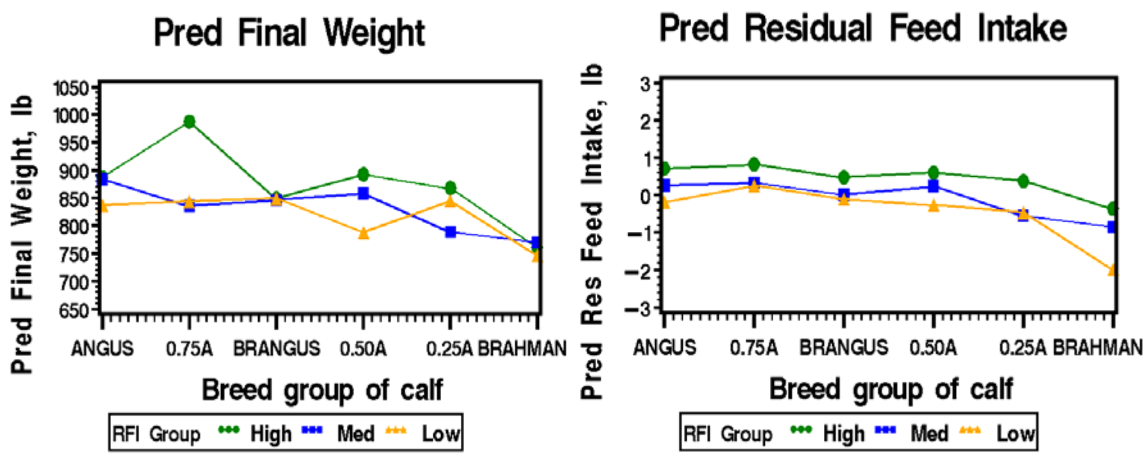


Figure 13. Relationship between residual feed intake and average daily gain in calves of varying percentages of *Bos indicus* genetics.

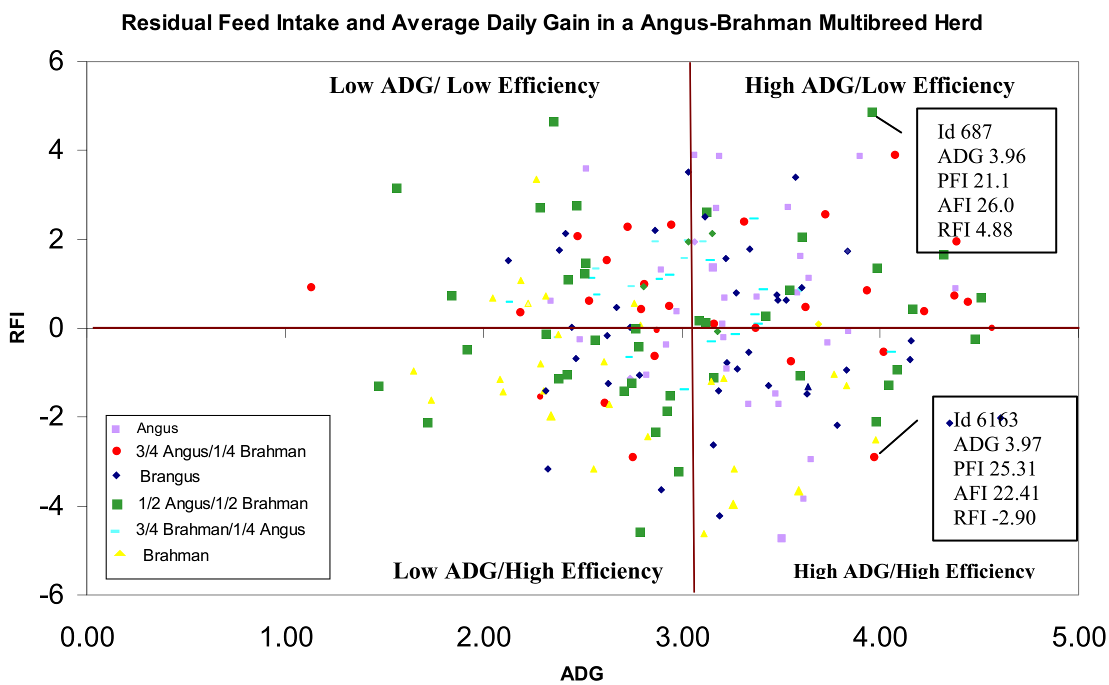


Figure 14. Water intake in young angus bulls classified by RFI group.

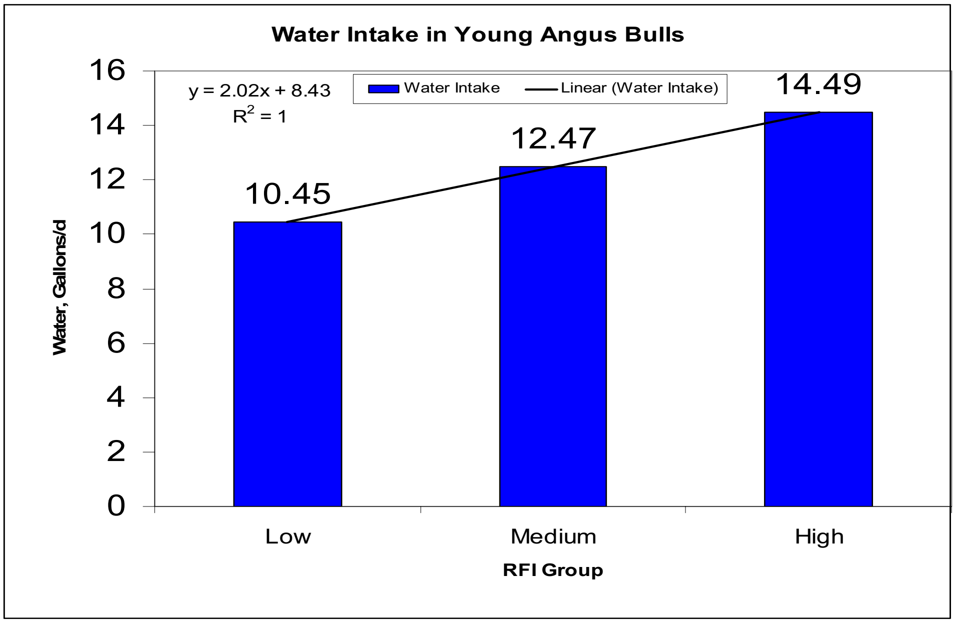


Figure 15. Water intake in male and female calves of various breed types classified by RFI group.

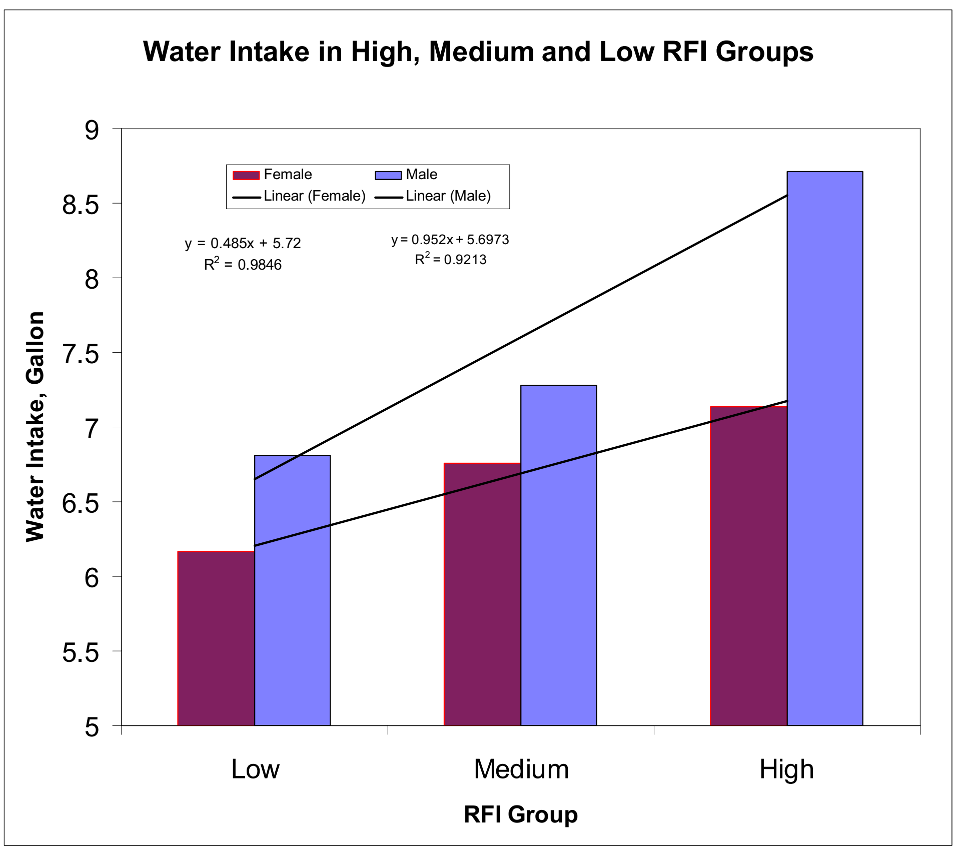


Figure 16. Water intake in growing calves of various percentage of *Bos taurus* breeding.

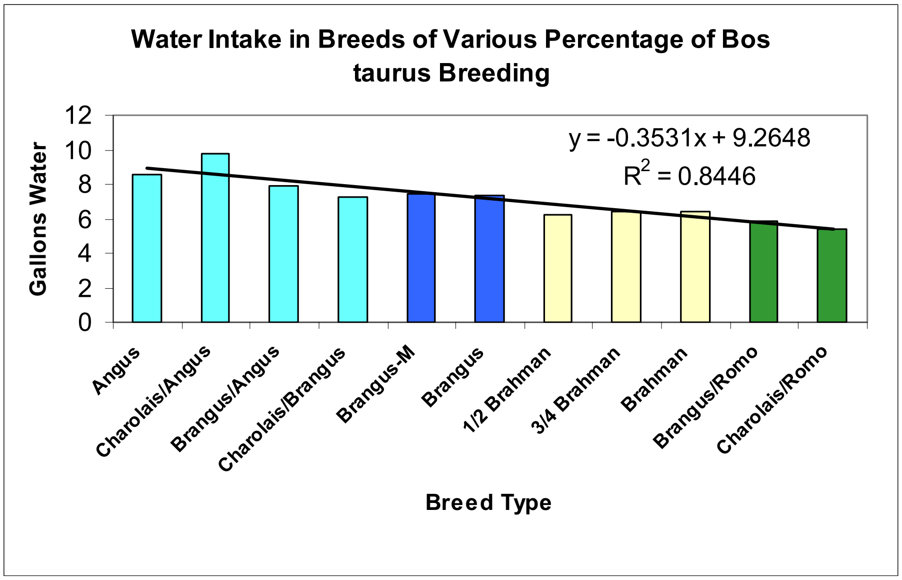


Figure 17. Water utilization in growing calves of various percentage of *Bos taurus* breeding.

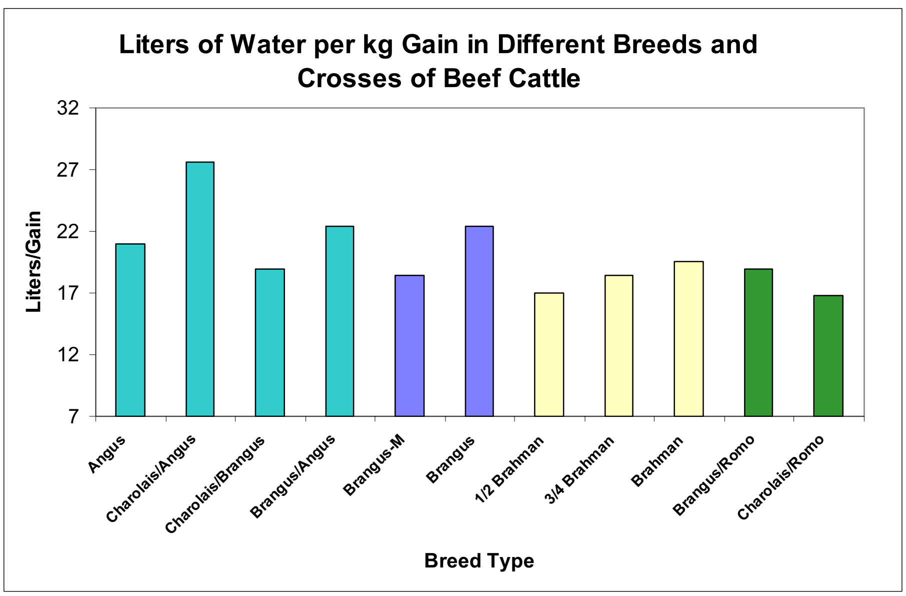
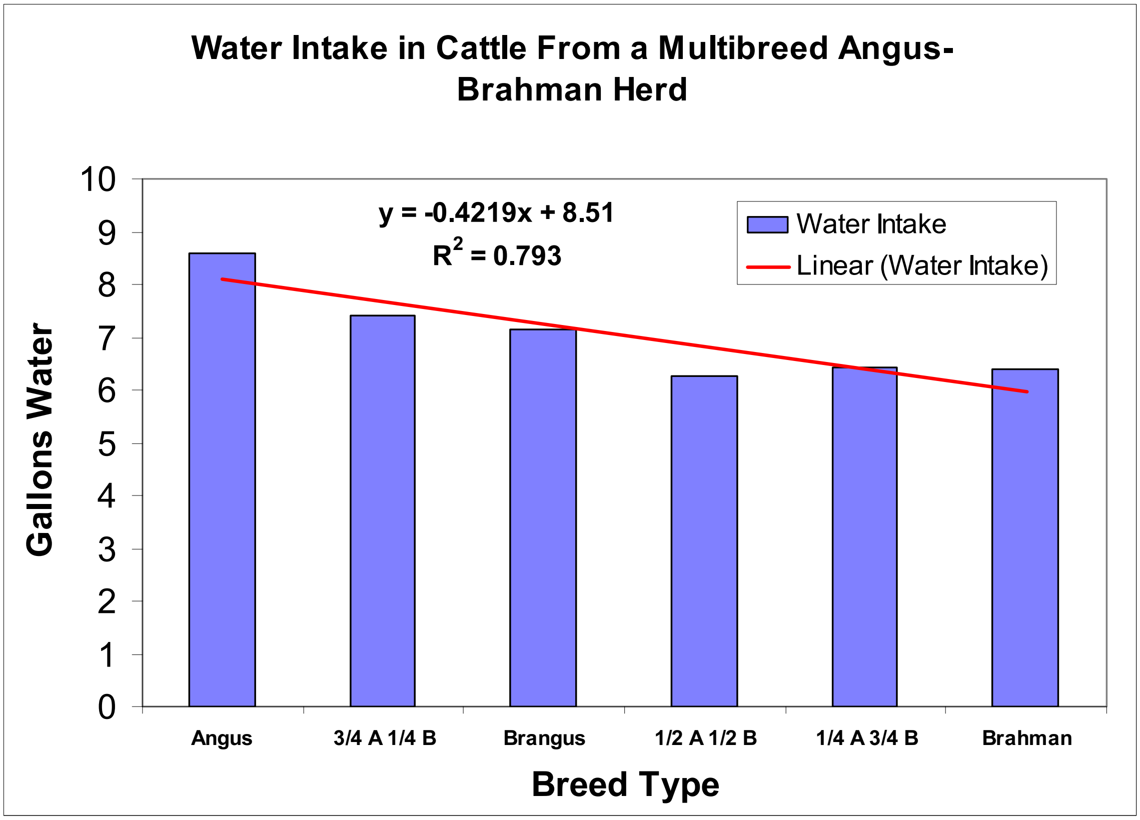


Figure 18. Water intake in the UF/IFAS Beef Research Unit Angus-Brahman multibreed herd.



Notes: