The Importance of Feed Efficiency in the Cow Herd

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Introduction

The definition of efficiency is a ratio of outputs to inputs. Businesses use measures of efficiency to establish benchmarks and goals for production and finance, which may result in decisions that increase productivity without increasing costs of production. A well-run, profitable commodity business is usually operated more efficiently than its competitors. In the case of beef cattle, competition can arise from two sources: other producers who sell similar classes of cattle; and, other protein-producing species, such as pork and poultry, which compete with beef in the marketplace. Measuring efficiency across the entire integrated beef system is difficult due to the different classes of cattle (growing, finishing, breeding), breed differences, and how the different biological systems (nutrition, reproduction, lactation, basal metabolism) interact. There are measures of efficiency that can be used to optimize biological productivity and/or economical profitability in beef production enterprises. One of these is feed efficiency.

Applications of feed efficiency warrant consideration in the beef industry because 55 to 75% of the total costs associated with beef cattle production are feed costs (NRC, 2000; Arthur et al., 2001a; Basarab et al., 2002). For instance, a 5% improvement in feed efficiency could have an economic impact four times greater than a 5% increase in average daily weight gain (Basarab et al., 2002). In addition, feedlot studies have demonstrated that a 10% improvement in average daily gain (**ADG**) improved profitability by 18%; whereas, a 10% improvement in feed efficiency returned a 43% increase in profits (Fox et al., 2001). Thus, efforts aimed at improving the efficiency of feed/forage use will have a large impact on reducing input costs associated with beef production. For example, in Florida alone with approximately 1.83 million cattle on inventory, a 10% increase in feed/forage efficiency could reduce annual production costs by, at least, $36 million.

Although the depths of feed efficiency research have vastly expanded in the past decade, most research efforts have focused on growing/fed cattle. Until now, little data has been collected on the breeding herd, which consumes about 70% of the feed utilized throughout all beef production systems. In Florida, forage grazing females such as replacement heifers, young cows, and mature cows compose the predominant classes of cattle. Therefore, it is important for producers to better understand the implications feed efficiency has on the breeding herd.

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Determining Feed Efficiency

Due to complex biological processes and the relationship of feed intake to body size and production level, selecting cattle based on feed intake alone is rarely used. Instead, different measures or traits of feed efficiency have been used. Feed efficiency is a measure of how much saleable product is being produced for each unit of feed consumed. Factors that influence feed/forage efficiency include age, sex, type of diet, breed, production level, environmental temperature, growth promotants, physical activity, and many other management and environmental variables (NRC, 2000). These factors are important to consider when selecting cattle to evaluate for feed efficiency.

Feed Conversion Ratio

The most common measure of feed efficiency in beef enterprises has been feed conversion ratio (**FCR**), also referred to as feed:gain (**F:G**), which is the ratio of feed intake to live-weight gain. A calf that consumes 15 lb of feed per day and gains 3 lb of live-weight per day would have a FCR of 15 to 3, or 5:1, or simply 5. A calf with a low FCR consumes less feed per unit of gain compared to calves with a high FCR; therefore, it converts feed at a higher rate, is classified as more feed efficient, and is highly desirable for cattle owners and for feedlots that charge on a gain basis. Feed conversion ratio is most often used as a tool to evaluate groups of growing cattle to determine costs of production and break even prices in feeding operations. It is a moderately heritable trait (Crews, 2005) and cow/calf producers who have access to this data can potentially use this information as a marketing tool to promote the sale of their feeder calves. However, when applying this feed efficiency trait to their cow herd, beef producers should consider the relationship of FCR with mature body size. The highly negative correlation between FCR and growth rate (Koots et al., 1994), as well as the observed increase in mature cow size resulting from lean FCR selection (Mrode et al., 1990) indicates that selection for improved FCR may result in amplified cow maintenance requirements and higher feed costs.

Residual Feed Intake

Residual feed intake (**RFI**) is an alternative measure of feed efficiency that has not been shown to increase mature weights or to greatly affect other phenotypic traits in cattle. It measures the variation in feed intake beyond maintenance and growth requirements. It is calculated as the difference between actual feed intake and the feed an animal is expected to consume based on its body weight and ADG. Therefore, when cattle consume less feed than expected for their size and rate of gain, they are consider to have a negative RFI, which equates to a more desirable feed efficiency status as compared to cattle with more positive RFI values. One important finding consistent in almost all of the studies to this date is that no other important trait, such as growth rate, is affected when selecting for RFI. Therefore, calves with lower RFI values consume less feed for similar performance.

Residual feed intake is determined by placing a group of like-type or similar cattle on a feeding test for 70 d, after a 21-d adaptation period to the facilities and diet. The calculation of RFI requires collection of individual daily intake data and biweekly animal weights. However, facilities equipped to measure individual intakes are becoming more common and accessible for producers.

Reducing feed costs in beef cattle can significantly improve profitability of the production enterprise. Studies have shown differences in RFI values that range between -4.3 lb/d (the calf consumes 4.3 lb/d less than it is expected to) and 4.0 lb/d (the calf consumes 4.0 lb/d more than it is expected to). This represents an overall difference of 8.3 lb/d in feed in efficient versus inefficient animals. The savings in feed costs between low and high RFI animals could be as high as $92 (assuming 170 d on feed and $130/ton of feed).

Understanding the effects of feed efficiency or RFI on biological processes and management procedures is critical when utilizing RFI as a tool for beef cattle selection. Improvements in feed and forage efficiency by RFI will not only increase ranch profit through reduced input costs, but they can also reduce potential environment disruption due to lower methane emissions and nutrient excretions. This is especially critical when the cost of feed resources continues to increase, the availability of forages continues to decrease, and the concern for the cattle industry's environmental impact is at its highest.

Unlike FCR, RFI is phenotypically independent of the traits that are used to calculate it. As an example, a data set containing RFI and ADG values collected in the Feed Efficiency Facility (**FEF**) at the North Florida Research and Education Center in Marianna is shown. There is a substantial representation of different gains and variation in RFI. Calf A and B both entered the FEF weighing 819 lb and left weighing 1051 lb. In addition to their weights, ADG was also similar between calves (3.32 lb/day). Based on their weight and performance responses, both calves were expected to consume 24.32 lb of feed per day. However, calf A's actual daily intake was 22.86 lb vs. 25.76 lb for calf B, resulting in respective RFI of -1.46 and 1.44, and a difference of 2.90 lb of feed/calf/d.

Over the course of the 70 d feeding period, calf A consumed 203 lb less feed than did calf B, yet performed exactly the same. Assuming similar diets and a similar rate of gain (3.32 lb/day) it would take for each calf 180 d to gain 600 lb. However, calf A would consume 522 lb less feed. For 100 calves in a feedlot pen, this would add to a total of 52,200 lb less feed offered. Considering a feed cost of $0.08/lb, such reduction in feed expenditure would result in a savings of $4,176 ($41.76 per calf). Assuming that all other costs are equal, the cost of gain in pen A would be $0.07/lb less than in pen B.

Selecting for Residual Feed Intake

Genetic progress made by selecting for RFI is feasible only if the trait is heritable. A variety of studies have examined heritability estimates for RFI, and values range from

0.16 (Herd and Bishop, 2000) to 0.47 (Lancaster et al., 2009). Because most heritability estimates fall between these values, RFI has been termed moderately heritable. Therefore, selecting for RFI should reduce feed costs without affecting growth rate or mature size, while maintaining the ability to produce more efficient progeny. It has been demonstrated that divergent selection for RFI results in progeny that maintain efficiency. Angus steers born to parents selected for low RFI had improved feed efficiencies in the feedlot compared to steers born to high RFI parents, with no associated change in growth performance or carcass characteristics between the low and high RFI progeny (Richardson et al., 1998). It was also reported that the progeny of high RFI parents consumed 5% more feed per day than those generated from low RFI progenitors (Richardson et al., 2001). These results indicate that genetic selection for RFI is possible and lower RFI progeny may be economically superior to higher RFI counterparts.

Selection for feed efficiency in cattle has traditionally been accomplished by indirect procedures and various management strategies. Cattle selected for divergent RFI lines over a five-year period showed average selection differentials of -0.70 and 0.86 lb/d for the low and high RFI lineages, respectively. An annual divergence rate in RFI of 0.46 lb/d was achieved between the lines with a realized heritability of 0.33 (Arthur et al., 2001a). While RFI, feed intake and FCR changed significantly over the duration of the study, ADG and 365-d body weight remained constant, indicating that selection for RFI did not impact growth rate.

Selection for RFI in cattle is expected to have dramatic implications in the beef cattle industry. Low RFI cattle consume less feed and have lower maintenance requirements while growth appears to be unaffected. Generation of RFI expected progeny differences (**EPD**) will allow for the selection of more efficient animals. Recent research at the U.S. Meat Animal Research Center (**MARC**) in Clay Center, NE demonstrated that tropically adapted breeds (Brangus and Beefmaster) performed as well as or better than *Bos taurus* animals regarding most of the important economic traits, with the exception of carcass quality traits (Cundiff, 2004). Previous studies have shown that this advantage for tropically adapted cattle can be tripled when studies are conducted in subtropical/tropical environments (Olson et al., 1991). These projects allow for the evaluation of tropically adapted breeds in subtropical environments; thereby, improving the ability of producers that raise adapted cattle to compete in a global economy.

Residual Feed Intake and the Cowherd

Forage Utilization

Improving feed efficiency is not just relegated to growing cattle and some differences may be seen in mature cows. Although little work has been validated in lactating and non-lactating beef cows, two studies have indicated that selection for low RFI may have positive effects on future forage intake and reproductive efficiency. In non-lactating beef cows fed a forage-based diet, the most efficient cows (top third) consumed about 20% less forage than the least efficient cows (bottom third; Table 1; Meyer et al., 2008). Therefore, small increases in efficiency may lead to a large improvement in cowherd maintenance when forage is limited. Therefore, selection of replacement heifers based on efficiency could assist in the reduction of maintenance costs of the cowherd. However, little data is available that demonstrates the overall productivity of beef cattle operations that have selected for feed efficiency over several generations.

Table 1. Average dry matter intake (DMI) from forage by cows with low and high residual feed intake (RFI; adapted from Meyer et al., 2008)

Variable	Low RFI	High RFI
DMI, lbs/day		
Experiment 1	27.28	34.32
Experiment 2	27.50	31.02

Reproductive Efficiency

Reproductive efficiency is a key component to cow-calf enterprises because it is a primary determinant of profitability. Since nutritional status has been identified as an important mediator of reproductive events (Wiltbank et al., 1969; Day et al., 1986), differences in feed intake may affect the age of puberty in heifers, as well as the length of the anestrous period for cows.

It was recently reported that British-bred heifers (n = 137) with positive RFI values (inefficient) reached puberty 13 days earlier (P = 0.03) than negative (efficient) RFI heifers (Shaffer et al., 2010). However, RFI had no effect on pregnancy or conception rates. Phenotypic correlations (P < 0.05) between RFI and ultrasonic measures of subcutaneous rib (initial r = 0.19; final r = 0.27) and rump fat (initial r = 0.17; final r = 0.24) were sustained throughout the trial, indicating that more feed efficient heifers may have delayed attainment of reproductive maturity due to decreased fatness.

In crossbred beef heifers (n = 61) between 7.6 and 9.5 mo of age, RFI adjusted for backfat (**BF**) thickness over a 113-d feeding test was calculated (Basarab et al., 2009). The average age at which heifers attained pubertal status was similar between positive and negative RFI heifers. However, more inefficient RFI heifers tended (P = 0.09) to reach puberty by 12 (P = 0.09) and 13 (P = 0.06) mo of age compared with efficient heifers. These results are consistent with Shaffer et al. (2010) and indicate that puberty may be slightly delayed in more efficient heifers.

It has been reported that pregnancy rates for mature cows producing low, medium, or high RFI progeny (Basarab et al., 2007) and for mature cows divergently selected to produce low or high RFI calves (Arthur et al., 2005) are similar. However, in both of these studies, it was reported that cows producing more efficient progeny tended to calve later in the season than their counterparts. Therefore, although it appears that RFI has no effect on overall pregnancy rates, more efficient females may have slightly delayed attainment of pregnancy throughout their lifetime.

A recent study investigated the postpartum performance of Brahman first-calf heifers and multiparous cows which had been previously evaluated shortly after weaning for RFI (Loyd et al., 2009). Although prepartum and postpartum body weight and body condition (**BCS**) score did not differ by RFI group for either cows or heifers, efficient cows exhibited estrus (42 ± 4.1 vs. 55 ± 3.7 d) and developed a corpus luteum (**CL**) earlier (40 ± 4.1 vs. 53 ± 3.7 d) than inefficient cows. However, no difference was detected between efficient and inefficient heifers for estrus and/or CL formation. The authors concluded that selection for efficient cattle based on RFI may result in a shorter postpartum anestrus interval in multiparous Brahman cows.

With these results taken collectively, it is unclear whether or not more efficient females have a reproductive advantage or disadvantage over less efficient counterparts. Little is known about the relationship between feed efficiency and reproductive efficiency, demonstrating the need to continue this work.

Relationship Between Residual Feed Intake for Growing Heifers and Lactating Cows

In a recent study from our group, feed efficiency was measured in 74 replacement heifers (Phase I) of six breeds (n = 14 Angus; n = 11 Brahman; n = 22 Romosinuano; n = 10 Angus × Brahman; n = 9 Angus × Romosinuano; n = 8 Brahman × Romosinuano) using the GrowSafe System (GrowSafe Systems Ltd., Alberta, Canada) for individual feed intake collection. After Phase I, these females were retained until they gave birth to their second calf as 3-year old cows. Upon calving, 3-year old cows reentered the Feed Efficiency Facility with their calves for a second feed efficiency period (Phase II). For the heifer (Phase I) and cow phases (Phase II), females were allowed a 21-d or 14-d acclimation period before a 70-d feed efficiency test, respectively. Heifers were fed a forage-based growing diet (2.1 Mcal ME/kg DM) formulated to meet requirements to support growth rates of approximately 1 kg/d. Cows also received a forage-based diet consisting of 86.7% Tifton 85 Bermudagrass silage, 12.4% dried distillers grains, 0.7% range mineral, and 0.2% salt, suitable for lactating beef cows (NRC, 2000). In phase II, cows were milked to determine energy-corrected milk production on study d 14 (28 ± 3.5 d of lactation) and 70 (84 ± 3.5 d of lactation) to account for lactational differences when calculating RFI. In addition, cows had their carcasses scanned by ultrasonography for measurements of ribeye area (**REA**) and BF thickness on study d 0 and 70. The ADG for heifers and cows was calculated using the slope of the body weights collected weekly or biweekly, during the test. In phase I, RFI was calculated by accounting for breed differences and regressing dry matter intake (**DMI**) on ADG and mid-metabolic weight (**MMW**; weight halfway through the test raised to the 0.75 power) for each animal. Heifers were classified into Low (< 0.5 SD; n = 27), Medium (< 0.5 SD >; n = 23), and High (> 0.5 SD; n = 24) RFI groups, with more negative RFI values being most efficient (Low), intermediate RFI values being less efficient (Medium) and positive RFI values inefficient (High). In phase II, we incorporated traits that significantly affected cow DMI, such as breed, ADG, MMW, milk production on d 14 and 70, and BF thickness on d 70. Cow performance based on their RFI ranking as heifers (Low, Medium, and High) was assessed to determine how heifers of differing feed efficiency statuses performed subsequently as mature, lactating cows (Table 3).

Individual heifer RFI values ranged from -4.5 lb/d (most efficient) to 4.1 lb/d (least efficient) and individual cow RFI values ranged from -7.5 lb/d (most efficient) to 11.8 lb/d (least efficient). In Phase I, Low, Medium, and High heifers had similar ages, body weights (**BW**), BCS, and ADG (Table 2). However, those which were most efficient (Low) consumed 3 lb/d less than those which were intermediate (Medium) and 4.9 lb/d less than the least efficient (High) heifers. When cow performance was assessed based on heifer feed efficiency rank (Table 3), cows which were most efficient as heifers had significantly lower DMI than their counterparts and consumed 2.6 or 2.8 lb/d less than cows that were Medium and High heifers. Interestingly, DMI was the only parameter that differed between groups, and the most efficient heifers subsequently became cows that were phenotypically similar, but consumed less feed than cows that were considered less efficient as heifers.

Table 2. Heifer performance characteristics for Low, Medium, and High RFI ranked heifers (Phase I) during a 70-day feed efficiency test[a].

	RFI Classification[b]			
Trait	Low	Medium	High	*P*-value
No. of heifers	27	23	24	-
Initial age, d	294.7 ± 4.3	299.4 ± 4.7	288.8 ± 4.6	0.2716
Initial BW, lbs	561.2 ± 12.1	570.0 ± 13.2	571.8 ± 12.8	0.8121
Final BW, lbs	676.1 ± 13.0	691.0 ± 14.1	690.4 ± 13.6	0.6705
BCS	5.80 ± 0.06	5.85 ± 0.06	5.88 ± 0.06	0.6161
ADG, lbs/d	1.78 ± 0.07	1.85 ± 0.07	1.80 ± 0.07	0.6821
DMI, lbs/d	18.74 ± 0.51[x]	21.74 ± 0.55[y]	23.67 ± 0.53[z]	<0.0001
RFI, lbs/d	-2.27 ± 0.15[x]	0.20 ± 0.15[y]	2.35 ± 0.15[z]	<0.0001

[a]ADG = average daily gain; BCS = body condition score; BW = body weight; DMI = dry matter intake; RFI = residual feed intake.
[b]Heifers were sorted and placed into Low (< 0.5 SD), Medium (< 0.5 SD >), and High (> 0.5 SD) RFI groups based on their RFI values, with more negative values (Low) being efficient and positive values (High) inefficient.
[xyz] Significant differences of Least Squared Means within a row ($P < 0.05$).

Table 3. Cow performance, milk, and carcass ultrasound parameters (Phase II) based on heifer rankings considered as Low, Medium, and High feed efficiency categories[a].

	RFI Classification[b]			
Trait	Low	Medium	High	*P*-value
No. of cows	27	23	24	-
Initial age, d	1127.2 ± 6.7	1128.2 ± 7.2	1112.5 ± 7.1	0.2187
Initial BW, lbs	932.9 ± 17.4	925.5 ± 18.9	973.5 ± 18.5	0.1481
Final BW, lbs	961.2 ± 18.5	958.8 ± 20.0	989.3 ± 19.6	0.4686
BCS	4.4 ± 0.1	4.4 ± 0.1	4.4 ± 0.1	0.8813
ADG, lbs/d	0.40 ± 0.13	0.53 ±0.13	0.37 ± 0.13	0.7103
DMI, lbs/d	22.7 ± 0.90[x]	25.5 ± 0.97[y]	25.3 ± 0.95[y]	0.0426
Cow RFI, lbs/d	-1.19 ± 0.62[x]	1.10 ± 0.68[y]	0.26 ± 0.64[xy]	0.0468
ECM, lbs/d				
d 14	11.92 ± 0.81	11.33 ± 0.90	12.94 ± 0.88	0.4348
d 70	9.75 ± 0.73	10.27 ± 0.79	10.91 ± 0.77	0.5514
REA, cm^2				
d 0	30.46 ± 1.02	29.48 ± 1.11	30.75 ± 1.04	0.6867
d 70	28.77 ± 0.97	30.32 ± 1.08	30.07 ± 1.01	0.5056
BF, cm^2				
d 0	0.25 ± 0.01	0.25 ± 0.01	0.28 ± 0.01	0.0809
d 70	0.27 ± 0.01	0.25 ± 0.01	0.28 ± 0.01	0.2559
Days to calving	36.9 ± 4.4	35.0 ± 4.7	28.8 ± 4.7	0.4407
Days to first ovulation	75.7 ± 4.5	73.8 ± 4.5	76.0 ± 6.3	0.9446

[a]ADG = average daily gain; BCS = body condition score; BF = backfat thickness; DMI = dry matter intake; ECM = energy corrected milk; RFI = residual feed intake; REA = ribeye area.
[b]Heifers were sorted and placed into Low (<0.5 SD), Medium (<0.5 SD >), and High (>0.5 SD) efficiency groups based on their RFI values, with more negative values (Low) being efficient and positive values (High) inefficient.
[xy] Significant differences of Least Squared Means within a row ($P < 0.05$).

There have been relationships between RFI and carcass fat content described in the literature. Nevertheless, reports are inconsistent, with no relationship in some studies (Herd and Bishop, 2000; Arthur et al. 2001b; Richardson et al., 2001) and a moderate relationship in others (animals with improved efficiency were also leaner, Herring and Bertrand, 2002). Relationships between RFI and mature cow size are limiting, but Herd and Bishop (2000) presented preliminary evidence that selection for improved feed efficiency has little effect on mature cow size. In our study, there were no relationships observed between RFI in the growing phase for heifers and mature cow size, milk production, carcass composition, or reproductive parameters as mature cows. A strong correlation between RFI measured after weaning and RFI measured in mature breeding females has been previously reported (Archer et al., 2002); however, we did not observe this relationship. This is likely because the cows in our study were lactating while those in the previous study were not.

Conclusion

Feed efficiency is not a new measure, but it is one that is receiving more attention as feed costs have increased. Many seed producers and bull testing facilities have installed technology that allows for the determination of RFI and some breed associations have started the process of standardizing data collection and analysis and soon EPD's and Value Indices for feed efficiency will be reported. The use of DNA testing for feed efficiency is becoming more widely available. Producers who would like to include feed efficiency in their selection criterion will have several tools available to them. In addition, ongoing and future research efforts in RFI will likely clarify how RFI affects the entire efficiency of the breeding herd. Producers who understand and appropriately incorporate this type of information into their operation will have the means to make sound decisions to improve the efficiency and profitability of their enterprise.

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SESSION NOTES