Implications of Selection for Residual Feed Intake in the Cowherd

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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). 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), and feedlot studies have demonstrated that a 10% improvement in average daily gain (ADG) improved profitability 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 production costs by at least $36 million annually.

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.

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, diet type, 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

Traditionally, the most common measure of feed efficiency in beef enterprises has been feed conversion ratio (FCR), also referred to as feed:gain (F:G). It is the ratio of feed intake to live-weight gain. A calf that consumes 15 pounds of feed per day and gains 3 pounds 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 high 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 or pens 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 greatly affect other phenotypic traits in cattle. It measures the variation in feed intake beyond that needed to support 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 average daily gain. Therefore, when cattle consume less feed than expected for their size and rate of gain, they have a negative RFI, which equates to a more desirable feed efficiency status as compared to cattle with more positive RFI values. One of the important findings in almost all of the studies to date show little or no correlated response in other important traits such as growth rate when selecting for RFI, so 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 days, after a 21-day 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 for 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 a difference of over 8.3 lb/day of feed savings in efficient versus inefficient animals. The savings in feed costs between low and high RFI animals could be as high as $92 (assuming 170 days on feed and $130/ton of feed).

Understanding the interactions 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 that was collected in the Feed Efficiency Facility (FEF) at the North Florida Research and Education Center in Marianna is shown with RFI and average daily gain (ADG) presented. There is a substantial representation of different gains and variation in RFI. Calves A and B both entered the FEF weighing 819 pounds and left weighing 1051. Their weights and gains (3.32 lbs/day) were identical. Based on their weight and performance numbers, the calves were expected to consume 24.32 pounds of feed/day. However, calf A's actual daily intake was 22.86 pounds and calf B's actual daily intake was 25.76 pounds for RFI's of -1.46 and +1.44, respectively, a difference of 2.90 pounds of feed consumed per day.

Over the course of the 70 day feeding period, calf A consumed 203 pounds less feed than calf B, yet performed exactly the same. Assuming similar diets and a similar rate of gain (3.32 pounds/day) it would take each calf 180 days to gain 600 pounds, but calf A would consume 522 pounds less feed. For 100 calves in a feedlot pen, this translates into 52,200 pounds less feed, and at $0.08/pound feed, this would result in a savings of $4,176 ($41.76 per calf). Assuming all other costs are equal, the resulting cost of gain in pen A would be $0.07/lb less than in pen B. Once again, this is a significant savings for the feeder.

Selecting for Residual Feed Intake

Genetic progress made by selecting for RFI is feasible only if the trait is somewhat heritable, or able to be successfully passed on to future generations. 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 (more efficient) had improved feed efficiencies in the feedlot compared to steers born to high RFI parents, with no accompanied change in performance of growth or carcass characteristics for the low or high progeny (Richardson et al., 1998). It was also reported that progeny of high RFI parents consumed 5% more feed per day than low RFI steers (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 (i.e., not direct selection). Cattle selected for divergent RFI lines over a five-year period showed average selection differentials of -0.70 and 0.86 lb/d per year for the low and high lines, 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 (FI) and feed conversion rate (FCR) changed significantly over the duration of the study, average daily gain (ADG) and 365-day body weight remained constant, indicating selection for RFI did not impact growth rate.

Selection for RFI in cattle can 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 (EPDs) 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 or exceeded *Bos taurus* genetics in most of the economic traits of importance with the exception of carcass quality traits (Cundiff, 2004). Previous studies have shown that this advantage can be tripled in tropically adapted cattle when studies are conducted in subtropical/tropical environments (Olson et al., 1991). This project will allow for the evaluation of tropically adapted breeds in a subtropical environment, thereby improving the ability of producers using these types of 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 nonlactating 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, when forage is limited small improvements in efficiency can make a large improvement in cowherd maintenance. 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.

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 (AOP) for 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) heifers (Shaffer et al., 2010); however, RFI had no effect on pregnancy or conception rates. Phenotypic correlations ($P < 0.05$) between RFI and ultrasounic 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) over a 113-d feeding test was calculated (Basarab et al., 2009). The average age at which heifers attained pubertal status were 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, it appears that RFI has no effect on overall pregnancy rates; however, 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 feed efficiency (RFI; Loyd et al., 2009). Although prepartum and postpartum body weight and body condition score did not differ by RFI group for either cows or heifers, efficient cows exhibited estrus sooner (42 ± 4.1 vs. 55 ± 3.7d), developed a corpus luteum (CL) sooner (40 ± 4.1 vs. 53 ± 3.7d), and exhibited estrus in conjunction with CL formation sooner (42 ± 4.1 vs. 54 ± 3.9d) 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 using RFI as a selection tool may result in a shorter postpartum 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 the Growing Heifer and the Lactating Cow

In our recent novel data, 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, the 3-year old cows reentered the Feed FEF with their calves for a second feed efficiency period (Phase II). For the heifer (Phase I; Table 2) and cow phases (Phase II; Table 3), upon arrival into the feed efficiency facility, females were allowed a 21-day (Phase I) or 14-day (Phase II) acclimation period before initiating a 70 d feed efficiency test. The diet for heifers was a forage-based growing diet (2.1 Mcal ME/kg DM) formulated to meet requirements to support growth rates of approximately 2.2 lb/d, whereas the diet for cows was a forage-based diet consisting of 86.7% Tifton 85 Bermudagrass silage, 12.4% dried distillers grains plus solubles, 0.7% range mineral, and 0.2% salt, suitable for lactating beef cows (NRC, 1996).

In phase II, the cows were milked to determine energy-corrected milk production on trial day 14 (day 28 ± 3.5 of lactation) and 70 (day 84 ± 3.5 of lactation) to more appropriately account for lactational differences when calculating RFI. In addition, cows were carcass ultrasounded for ribeye area (REA) and backfat thickness (BF) on trial day 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 sorted and placed 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, which were breed, ADG, MMW, milk production on day 14 and 70, and BF on day 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 (Table 2), Low, Medium, and High heifers had similar ages, body weights (BW), body condition scores (BCS), and ADG; 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. Intermediate heifers also consumed 1.9 lb/d less feed than the least efficient 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 significantly differed; therefore, the most efficient heifers subsequently became cows that were phenotypically similar, but consumed less feed than cows that were considered less efficient as heifers.

There have been relationships between RFI and carcass fat content reported in the literature, but they 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 another (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 seedstock 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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Table 1. Average forage intake (DMI) of cows with low and high residual feed intake (RFI; adapted from Meyer et al., 2008)

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

Table 2. Heifer performance characteristics for Low, Medium, and High RFI ranked heifers (Phase I)[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	0.27
Initial BW, lbs	561.2 ± 12.1	570.0 ± 13.2	571.8 ± 12.8	0.81
Final BW, lbs	676.1 ± 13.0	691.0 ± 14.1	690.4 ± 13.6	0.67
BCS	5.80 ± 0.06	5.85 ± 0.06	5.88 ± 0.06	0.62
ADG, lbs/d	1.78 ± 0.07	1.85 ± 0.07	1.80 ± 0.07	0.68
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	0.22
Initial BW, lbs	932.9 ± 17.4	925.5 ± 18.9	973.5 ± 18.5	0.15
Final BW, lbs	961.2 ± 18.5	958.8 ± 20.0	989.3 ± 19.6	0.47
BCS	4.4 ± 0.1	4.4 ± 0.1	4.4 ± 0.1	0.88
ADG, lbs/d	0.40 ± 0.13	0.53 ±0.13	0.37 ± 0.13	0.71
DMI, lbs/d	22.7 ± 0.90[x]	25.5 ± 0.97[y]	25.3 ± 0.95[y]	0.04
Cow RFI, lbs/d	-1.19 ± 0.62[x]	1.10 ± 0.68[y]	0.26 ± 0.64[xy]	0.05
d 14 ECM, lbs/d	11.92 ± 0.81	11.33 ± 0.90	12.94 ± 0.88	0.43
d 70 ECM, lbs/d	9.75 ± 0.73	10.27 ± 0.79	10.91 ± 0.77	0.55
d 0 REA, cm^2	30.46 ± 1.02	29.48 ± 1.11	30.75 ± 1.04	0.69
d 70 REA, cm^2	28.77 ± 0.97	30.32 ± 1.08	30.07 ± 1.01	0.51
d 0 BF, cm^2	0.25 ± 0.01	0.25 ± 0.01	0.28 ± 0.01	0.08
d 70 BF, cm^2	0.27 ± 0.01	0.25 ± 0.01	0.28 ± 0.01	0.26
d to calving	36.9 ± 4.4	35.0 ± 4.7	28.8 ± 4.7	0.44
d to first postpartum ovulation	75.7 ± 4.5	73.8 ± 4.5	76.0 ± 6.3	0.94

[a]ADG = average daily gain; BCS = body condition score; BF = backfat; 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 ($P < 0.05$).