Can We Select for RFI in Heifers?

L. Kriese-Anderson, Associate Professor[1]

[1]Extension Animal Scientist, Auburn University, Auburn AL

Introduction

Cow efficiency has been an important topic of conversation for many years. Ideas, from choosing cows that wean 50% of their weaning weight, using feed conversion ratio or dry matter intake, have been suggested as selection criteria. More recently, ideas of residual feed intake (RFI) or residual ADG have surfaced and some purebred breed associations have adopted these as a measure of efficiency.

However, for all the talk generated concerning efficiency the last 20 years, there is little to no evidence that American beef producers have selected for improved cow efficiency. For the most part, there is no such thing as an average 1100 pound commercial cow in the United States. The commercial cowherd may not be increasing in height, but they are increasing in weight. The continued use of larger EPD bulls, especially for weight and milk traits, have pushed the average commercial cow to larger weights with increased maintenance energy costs due to increased milk production. Matching cow genetics to the environment they produce in has not occurred in most regions of the United States.

The overall goal of a beef cattle producer should be to improve profitability. Because providing feed to animals is a major cost to producers, improving the efficiency of feed utilization would be of significant economic benefit. Efficient feeding programs are designed to provide cattle with the essential nutrients for maintenance and growth with minimal excesses and losses (Nkrumah et al., 2007).

Residual Feed Intake or RFI was first proposed by Koch et al. (1963) in growing beef cattle and is defined as the actual feed intake minus expected feed intake based on maintenance and production requirements. Expected feed intake is calculated by measuring daily feed intake, ADG and metabolic body weight on young, growing animals. RFI then becomes as the remaining residual not accounted for by measurable traits. By definition, RFI is phenotypically independent of its components, ADG and metabolic body weight, allowing for comparison between individuals differing in production during the measurement period. For example, in young animals a majority of their energy resources are devoted to growth and development. In mature cows, feed is utilized for maintenance and lactation. Using RFI as a measure of feed efficiency identifies animals that consume less feed than expected, putting selection pressure directly on feed intake. By incorporating measures of live weight and ADG, RFI tries to account for some of the underlying genetic variation in feed used for maintenance and growth. As a selection tool, the resulting progeny should be more efficient as slaughter animals and in the breeding herd (Arthur et al., 2001a). Therefore, improving feed efficiency using RFI would be beneficial at all levels of the production system. However, this improvement in feed efficiency cannot come with a decrease in reproductive traits.

Research to Date

Research examining the use of RFI as a selection tool began in the late 1990's in Australia. Studies indicate RFI is a moderately heritable trait (Table 1), with most estimates close to 0.40. This suggests if cattle are selected based on post-weaning measures of RFI, genetic progress can be achieved.

Table 1. Estimates of heritability for Residual Feed Intake (RFI)

Study	Breed	Sex	h^2
Koch et al., 1963	British	Both	0.28
Arthur et al., 2001a	Charolais	Bulls	0.39
Arthur et al., 2001b	Angus	Both	0.39
Schenkel et al., 2004	Multiple	Bulls	0.38
Lancaster et al., 2009	Brangus	Heifers	0.47
Crowley et al., 2010	Multiple	Bulls	0.45

The basic model for determining RFI is as follows:

$DMI= \beta_0 + \beta 1(ADG) + \beta_2(MMWT) + RFI$

Where:

DMI= average daily dry matter intake

β_0= regression intercept

β_1= partial regression coefficient of DMI on average daily gain (ADG)

β_2= partial regression coefficient of DMI on metabolic midweight (MMWT). MMWT is calculated as $(\text{Off-test Wt.} – (0.5*\text{ADG}*\text{Days on Feed}))^{0.75}$

RFI = residual feed intake

To be able to determine RFI on cattle, daily individual feed intake must be measured, and cattle must have ad libitum access to feed. Currently, cattle must have daily feed intake measured for 70 days. There are few farms who can measure individual feed intake on large groups of cattle on the farm and there are not very many facilities set up to measure feed intake. Generally, a facility must have GrowSafe® (GrowSafe Systems LTD, Airdrie, AB Canada) or Calan® (American Calan, Northwood, NH) technology. Beef Improvement Federation Guidelines (BIF, 2010) suggest animals be tested beginning no younger than 240 days of age and finish by 390 days of age.

Because of how RFI is calculated, the average RFI value of a contemporary group will be 0. Animals with a negative RFI value are more efficient because they eat less feed than expected based on their maintenance and production requirements. Animals with a positive RFI value are less efficient because they eat more feed than expected based on maintenance and production requirements. Animals with an RFI value around 0 are eating what is expected of them based on maintenance and production requirements.

Also due to the manner RFI is calculated the phenotypic correlations between RFI and ADG and RFI and metabolic body weight are 0. This suggests that regardless of the RFI value, ADG and body weight will be similar. This is one of the advantages of using RFI as a selection tool. Other tools, such as feed conversion rate, may end up selecting animals with increased growth rates, mature size, and maintenance requirements (Crews, 2005).

However, this does not necessarily mean genetic correlations between RFI and other economically relevant beef cattle traits are zero. Table 2 lists genetic correlations found from various studies. To date, RFI is genetically highly correlated with feed intake. Thus, selection for efficient animals, as determined by RFI, eat less. These same efficient animals will also be leaner. The genetic correlations between weight, ADG and RFI seem to be low. Several studies have shown more efficient heifers, based on RFI, do calve later and Crowley et al. (2011) estimated the genetic correlation between RFI and age at first calving in crossbred heifers to be -0.29.

Table 2. Genetic correlation estimates between Residual Feed Intake and other economically important traits in beef cattle.

Study	Breed	Sex	Trait	Genetic Correlation
Arthur et al., 2001a	Charolais	Bulls	Metabolic Weight	0.32
Arthur et al., 2001b	Angus	Bulls	Metabolic Weight	-0.21
Schenkel et al., 2004	Multiple	Bulls	Metabolic Weight	-0.17
Lancaster et al., 2009	Brangus	Heifers	Metabolic Weight	-0.33
Arthur et al., 2001a	Charolais	Bulls	ADG	-0.10
Schenkel et al., 2004	Multiple	Bulls	ADG	0.01
Arthur et al., 2001a	Charolais	Bulls	Feed Intake	0.79
Arthur et al., 2001b	Angus	Both	Feed Intake	0.69
Lancaster et al., 2009	Brangus	Heifers	Feed Intake	0.60
Schenkel et al., 2004	Multiple	Bulls	Feed Intake	0.81
Arthur et al., 2001b	Angus	Both	Ultrasound 12^{th} rib fat	0.17
Schenkel et al., 2004	Multiple	Bulls	Ultrasound 12^{th} rib fat	0.16
Lancaster et al., 2009	Brangus	Heifers	Ultrasound 12^{th} rib fat	0.36
Arthur et al., 2001b	Angus	Both	Ultrasound REA	0.09
Crowley, et al, 2011	Crossbred	Heifers	Age at first calving	-0.29

As much as efficiency is desired in the Unites Stated beef cowherd, reproduction is still the most economically important trait. Several studies have looked at RFI and subsequent reproduction in heifers. Preliminary studies suggest selecting for RFI may have some effect on reproductive performance. Feed intake trials are conducted post-weaning prior to selection decisions being made. Because there is a large variation in age at puberty, *Bos taurus* cattle tend to be at different stages of sexual development during this time and differences in physiological age may affect RFI results. It appears RFI testing tends to favor later maturing animals that don't have increased energy demands associated with sexual development and activity (Basarab et al., 2011). Therefore, prepubertal animals have lower feed intakes than those undergoing puberty and may be considered more efficient.

Basarab et al. (2011) analyzed the effects of feed efficiency associated with sexual development and activity by identifying when heifers reached puberty relative to the start of the testing period. Feed intake and feeding behaviors revealed heifers that attained puberty near the start of the test consumed more feed, spent more time at the bunk in feeding event duration and head-down behaviors, but removed their head from the bunk or went to the bunk less frequently than heifers reaching puberty near the end of the test. Additionally, pre-pubertal heifers had 4% to 7% improved feed efficiency given equal growth, body size, and body composition compared to post-pubertal heifers. These results suggest later maturing animals will be favored when predicting RFI from a mixture of pre- and post-pubertal animals.

Since later maturing animals tend to be more efficient at the time of testing, long term selection for efficient RFI heifers may affect herd reproductive performance, specifically age at puberty. However, some authors suggest a delay in puberty and conception may continue throughout the cow's lifetime, but will not affect herd fertility (Arthur et al, 2005b; Basarab et al., 2007). According to Crowley et al. (2011), a delay in onset of puberty is biologically possible because the partitioning of energy among animals differing in RFI may be altered. Efficient RFI heifers may partition more energy toward growth and away from reproductive function. Efficient RFI females tend to conceive later and calve later than high RFI females, most likely attributed to a delay in first estrus (Arthur et al., 2005b; Basarab et al., 2007; Donoghue et al., 2011). However, several studies report selection for post-weaning RFI does not have any effect on pregnancy rates, calving rates, and maternal productivity (Arthur et al., 2005; Basarab et al., 2007; Donoghue et al., 2011; Shaffer et al., 2011).

Auburn Residual Feed intake Heifer Study

Daily feed intake and performance measures of growth and body composition have been measured on 262 Brangus replacement heifers from two purebred Southeastern Brangus breeders. Heifers were delivered to the Auburn University Beef Cattle Evaluation Center (AUBEC) during 2014 and 2015. Table 3 provides the number of heifers and time of year daily feed intake was measured on these heifers.

Table 3. Number of heifers measured for daily feed intake and time of year

	Number of Heifers		
Trial	Farm 1	Farm 2	Birthdate Range
June to Sept 2014	34	39	Sept thru Nov 2013
Dec. 2014 to March 2015	28	51	Jan. thru April 2014
June to September 2015	46	0	Sept thru Oct 2014
July to October 2015	0	34	Sept thru Nov 2014
Sept to Dec 2015	30	0	Oct 2014 thru Jan 2015
Total	138	124	

AUBEC has eight pens, each containing 12 Calan® gates (American Calan, Northwood, NH) for a 96 head capacity. Each pen of heifers had indoor and outdoor access. Each pen was 20' x 30' inside and 60' x 300' outside. Two pens share an automatic water trough.

Heifers were transported post-weaning to the AUBEC on 18-wheel cattle trucks from their farm of origin. Upon arrival, heifers were randomly unloaded into one of the eight pens and given access to hay and water. Heifers were allowed to rest a minimum of 8 hours prior to processing. At processing, heifers were weighed and measured for hip height. Heifers were then placed in pens according to hip height and weight to minimize establishment of pecking order.

Heifers were trained to their individual Calan® gates during a 21 day acclimation period. Initially, heifers were fed 2% of their body weight of the diet in Table 4 which was formulated to be 2.47 Mcal ME/(kg DM) according to BIF Guidelines (BIF, 2010). Following the adaptation period, the heifers underwent a 70 day intake trial to measure daily feed intake and growth performance. Heifers were fed twice a day ad libitum amounts of the diet in Table 4. Heifers were fed such that one to two pounds of feed were left in their bunks at each feeding. Feed refusals were weighed and recorded each morning. Heifers were weighed and measured for hip height every 14 days. Carcass ultrasound measurements of 12th rib fat, longissimus dorsi area and percent intramuscular fat were taken by a UCG certified ultrasound technician within 7 days of the test completion.

Table 4. Diet ingredients and nutritional composition of diet fed to Brangus heifers

Ingredient (as fed)	Value, %
Cracked Corn	13.75
Soyhull pellets	20.00
Dried distillers grain	5.00
Corn gluten pellets	22.50
Cottonseed hull pellets	15.00
Alfalfa meal	5.00
Mineral	2.50
Potassium chloride	0.10
Cottonseed hulls	10.00
Molasses	6.00
Nutrient Analysis (DM)	
CP, %	13.40
NDF, %	44.10
NE_m	0.70
NE_g	1.42
ME, Mcal/kg DM	2.47

Residual feed intake was determined for each heifer that completed the 70 day feed intake trial by farm and trial. Heifers were given an RFI classification based on their RFI value. Heifers with an RFI value one standard deviation below the mean (mean = 0 in each case) were classified as low or efficient RFI heifers. Heifers with RFI values one standard deviation above the mean were classified as high or inefficient heifers. The heifers less than one standard deviation above or below the mean were classified as medium or average RFI heifers.

Heifers were sired by 45 different Brangus sires. There were 43 heifers classified as low or efficient RFI heifers, 186 classified as medium or average RFI heifers and 35 classified as high or inefficient RFI heifers. Table 5 contains simple averages of performance traits measured on the heifers. The data was additionally analyzed looking at farm of origin, RFI classification and sire for differences in on-test weight, off-test weight, ADG, and dry matter feed intake. To date, calving date records have been received on 53 of the heifers in the earliest trials. Calving data has also been analyzed looking for differences between RFI classification and calving date.

Table 5. Simple averages of performance traits by heifer RFI classification

	Heifer RFI Classification		
Trait	Low (Efficient), n=43	Medium, n=186	High (Inefficient), n=35
No. Sires Represented	22	40	17
On-Test Wt., lbs.	699	679	688
On-Test Ht., in.	46.4	45.5	45.9
Test ADG, lbs/day	3.02	3.11	2.97
Off-Test Wt., lbs.	913	899	899
Off-Test Ht., in.	49.3	48.5	48.7
Off-Test WDA	2.5	2.5	2.4
Final Frame Score	6.2	5.8	5.8
DM Feed Intake, lbs.	1422	1655	1948

As expected RFI values were significantly affected by RFI classification (Table 6). Remember RFI is the actual dry matter pounds of feed eaten minus the expected dry matter pound of feed per day. The medium RFI classified heifers ate what was expected. Low or efficient RFI heifers ate 3.66 lbs/day less than expected based on their size and growth, while high or inefficient heifers ate 3.96 lbs/day more based on their size and growth. RFI classification was not a significant source of variation for on-test or off-test weight. As expected, RFI classification was also not a significant source of variation for ADG. RFI classification was significant for dry matter feed intake. Low RFI heifers ate 459 and 240 pound less over the 70 day trial than the high and medium RFI heifers, respectively. The medium RFI classified heifers also ate 218 pound less than the high RFI classified heifers.

Table 6. Least Squares Means of performance traits by heifer RFI classification

	Heifer RFI Classification		
Trait	Low (Efficient), n=43	Medium, n=186	High (Inefficient), n=35
RFI, lbs feed/day	-3.66[a]	-0.02[b]	3.96[c]
On-Test Wt., lbs.	692	678	662
Test ADG, lbs/day	3.23	3.25	3.04
Off-Test Wt., lbs.	919	909	876
DM Feed Intake, lbs.	1455[c]	1696[b]	1914[a]

Rows with differing superscripts are significantly different (P<0.05)

Sire of the heifer was significant source of variation for all traits analyzed. This is expected since all the traits analyzed are moderately heritable. More heifer numbers are needed to find actual differences among sires. To date, most sires have heifers classified as low and medium or medium and high RFI heifers.

Also as expected farm and trial were significant sources of variation for all traits except RFI. Different management and feed resources affected the incoming weights on heifers. Farm 1 consistently had higher incoming weights leading to higher off-test weights. Additionally, because heifers from Farm 1 were heavier, they also ate more feed.

Current research suggests low classified RFI females calve later in the calving season than high classified RFI females. Because of the potential concerns between long-term selection for RFI and reproductive function, calving data from 53 heifers previously tested for RFI as heifers in 2014 was analyzed. There were no significant differences between age at first calving and RFI classification. High RFI classified heifers calved at 686 days of age (22.9 mo.), while medium and low classified heifers calved at (717 and 707 days of age; 23.9 and 23.5 mo., respectively). All heifers calved before two years of age and therefore, age at first calving does not appear to be of concern at this time in this study. However, calving age must continue to be monitored.

Conclusions

Residual feed intake is a moderately heritable trait independent of growth and size that can be placed in the set of tools to select beef cattle for efficiency. It is quite evident that efficient cattle eat significantly less leading to lower operational costs in the cowherd. However, feed intake, the critical component for measuring residual feed intake, is not easy to measure both due to time and facilities. Studies continue to show heifers can be selected for RFI without change in growth parameters. Studies able to incorporate female fertility have shown efficient RFI heifers calve later in the calving season. To date, this trend has not been seen in Brangus heifers measured at Auburn University. However, this must be continued to be monitored. Effective selection may be to select potential replacement heifers ±0.5 standard deviations from the mean and eliminate both tails of the distribution.

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