Impact of Selection for Residual Feed Intake on Forage Intake by Beef Cows and Feed Efficiency of Progeny

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Introduction

Use of residual feed intake (RFI) analysis to assess efficiency differences among cattle was first published by Koch et al (1963). Gain was regressed on intake and body weight with resulting regression coefficients used to compute expected gain for each animal based upon group average performance. This approach was adapted to compute RFI whereby intakes of animals in a test group are regressed against their body weight and daily gain. Regression coefficients for body weight and gain are then used to compute an expected intake for each animal, and difference between intake and expected intake reported as RFI. RFI is argued as a superior measurement of feed efficiency compared to feed conversion ratio (feed to gain ratio; FCR) because it is not confounded by gain. Residual feed intake is believed to provide a measure of metabolic efficiency. Feed conversion ratio, while correlated to RFI, is improved by both greater metabolic efficiency and improved growth rate. Thus using FCR as selection criteria would select for greater growth rate, and in turn increase frame score/mature weight. Animals with a negative RFI are believed to be more efficient at using consumed energy for maintenance and growth functions. Our goal in animal selection is to identify and propagate animals near biological maximum for efficiency of consumed energy use, and RFI provides a phenotype for that purpose. But how much progress can be expected when selection pressure for RFI is applied?

Intake among calves similar in body weight and daily gain will vary by 40%. Consequently range in metabolic efficiency among individuals within a population is substantial. Heritability of efficiency has been shown to be moderate (~0.4), similar to growth and carcass traits, meaning that substantial progress can be made through genetic selection. Richardson and Herd (2004) segmented biological mechanisms contributing to energy expenditure between RFI phenotypes. Components measured were body protein and lipid difference (5%), feeding behavior (2%), activity level (10%), digestion (10%), and metabolic functions (73%). The primary difference between efficient and inefficient animals was due to post-absorptive functions, assumedly cellular metabolism. Currently we believe that the basis for metabolic efficiency differences among animals resides in energy metabolism, more specifically in mitochondrial respiration. Mitochondrial respiration and RFI differ in magnitude similarly between efficient and inefficient animals (Golden et al., 2008).

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Because RFI is independent of growth, caution must be used in using RFI as selection criteria in an unbalanced or single-trait selection approach. It is possible to select for efficient genetics with poor growth ability. With this stated, however, I believe selection criteria should include efficiency if at all possible. Contrasting the one-third most efficient against the one-third least efficient calves can reduce feed costs 20% or more. Selecting heifers with negative RFI compared to positive RFI improved their progeny FCR by 11%. Selecting efficient sires compared to inefficient sires improved progeny FCR by 14%. The one-third most efficient cows consumed 20% less forage when nonlactating and 12% less forage when milking compared to the one-third least efficient cows. Impact of selecting for efficiency has always been important but now more than ever.

Residual Feed Intake

Phenotypic selection for efficiency in beef cattle has been almost nonexistent in the US. Consequently, this phenotype is randomly dispersed in the beef population. Limiting phenotypic selection for efficiency was inability to measure individual feed intake. With development of equipment capable of measuring individual intakes of pen-fed cattle, limitation for phenotypic selection has been removed. Historic efficiency measurement was FCR. This measurement does result in greater output per unit of input, but does so primarily by selection for increased frame size. When FCR is used as selection criteria, frame size will increase because large framed steers will have lower FCR than small framed steers at similar body weight (Thonney et al., 1981). Koch et al (1963) proposed an alternative measure for efficiency, RFI. RFI is calculated as the residual between intake and predicted intake. Predicted intake is calculated as intake required for gain and metabolic body size within a test or contemporary group. RFI is moderately heritable (Arthur et al, 1997) and phenotypically correlated with intake but not gain (Arthur et al, 2001). Lack of correlation with gain makes RFI superior to FCR as a measure of efficiency. RFI is believed to provide a measure of metabolic efficiency by the animal. Richardson and Herd (2004) estimated that over two-thirds of variation in RFI measurement was contributed by metabolic processes. If metabolic processes are reflected in maintenance and growth functions, then correlation of intake on metabolic body weight and gain should be so reflected. This is the case, with correlations of intake regressed on body weight and gain of 0.6 or greater. This is important because it provides credibility to using RFI as a selection tool for identifying animals with superior metabolic efficiency.

Intake by beef cattle will range +/- 20% from predicted intake. This 40% range in intake describes maximum and minimum efficiencies in the population. Attention has been focused on mitochondrial differences among animals as an explanation for the range in measured efficiencies that exist. Mitochondrial differences have been measured that relate to phenotypic measures of efficiency. Greatest agreement has been between oxygen uptake and RFI status, with efficient animals having more rapid oxygen uptake. Our research found no polymorphism differences in mitochondrial DNA or uncoupling protein mass or activity between efficient and inefficient animals (Kolath et al, 2006). Polar to work in poultry we found no difference in electron leak between efficiency genotypes. We did measure similar differences in magnitude of ATP production during stage III respiration between RFI phenotypes as was measured in FCR between RFI phenotypes. This led to the finding that differences in electron transport chain complex I to complex III protein ratios were similar in magnitude to FCR differences among RFI phenotypes. Our present hypothesis is that efficient animals possess a capability to establish phosphorylation homeostasis more rapidly than inefficient animals, thus reaching satiety quicker and cessation of intake sooner. We believe this explains reduced intake, tendency for less body fat, and reduced blood glucose and insulin concentrations that have been measured in efficient or negative RFI cattle. Biological differences in mitochondrial respiration should be manifested in one of two ways: (1) when dietary energy density does not limit growth potential, intake should be reduced and (2) when energy density does limit growth potential, performance should be increased.

Impact of RFI Selection on Animal Performance (Cow Herd)

Selection for efficiency is of interest due to potential feed savings by the cowherd and reduced feed costs by feedlot cattle. If RFI selection is based upon factors influencing metabolic efficiency, then it stands to reason that benefits should occur for both dam and calf, or more appropriately, maintenance and growth functions. We have conducted two experiments to determine effect of heifer RFI phenotype on forage intake as cows. In the first experiment a group of Hereford heifers fed a hay diet were RFI-tested. Prior to second parity, they were divided into the one-third most efficient (-RFI) and one-third least efficient (+RFI). Categories were determined by ranking cows one standard deviation from the mean RFI value of zero. Our goal was to contrast the most efficient against the least efficient, similar to selection that could be done in a production scenario. Cows were bred to calve during fall and intake measurements were made while grazing pasture prior to calving (late May to early August) and while lactating (late February to late April). Intake between groups was estimated by measuring forage mass in grazed areas relative to forage mass in exclosure areas. Fencing was maintained to keep forage on offer similar between efficiency groups and sufficient not to limit intake.

Average residual feed intake average for efficient cows were -4.37 and for inefficient cows 5.04 (Table 1). Initial BCS (body condition score) was not different between efficiency groups for the three-month summer grazing period. Body weight loss was similar between efficiency groups and averaged 46 lbs, consequently BCS change was also similar between efficiency groups (0.1 BCS lower). Intake by efficient cows was 27 lbs per day and by inefficient cows was 34 lbs per day. Intake by efficient cows was 21% lower than by inefficient cows. These data agreed with other research that reported a reduced forage intake by negative RFI cows (Arthur et al, 1999; Herd et al, 1998). Forage intake while lactating was expressed as dry matter intake per grazing pair. Both efficiency groups used approximately 75% of forage available to them in pastures, with intake of efficient cows being 28 lbs per day and intake of inefficient cows being 31 lbs per day. Lactating efficient cows consumed 10% less forage than inefficient cows.

Difference in intake between negative and positive RFI cows was greater during the nonlactating compared to the lactating period. This has been measured previously. A suggested reason is that extra energy consumed by inefficient animals could be captured in milk production whereas efficient animals have to consume additional feed to meet increased energy demand for milk production. Thus, there is reason to expect that intake by efficient and inefficient cows will narrow during lactation. Regardless of lactation stage, selection for efficient cows reduced forage need by the herd, with intake by efficient cows being 10 to 20% less through the year than inefficient cows without any differences in weight change or body condition score during the year (Meyer et al, 2008).

Discussion has occurred regarding RFI phenotype being diet specific. We phenotyped a group of Simmental-Angus heifers for RFI on a corn-based diet and then compared the one-third most and least efficient for forage intake in a fall/winter grazing system (Table 2). Procedures were similar to research discussed above. Forage intake by efficient cows was reduced 19% compared to inefficient cows, with intake measured while cows were nursing calves. No difference occurred in calf weaning weight or cow body weight change during the course of the experiment. We concluded that phenotyping females fed a grain-based diet will identify cows with reduced feed and forage requirements. Likewise female progeny produced from efficient sires would be expected to result in cows with reduced feed intake need.

Impact of Using RFI Phenotyped Dams and Sires on Progeny Performance (Feedlot)

Phenotypic selection for RFI in cows or sires is primarily academic if progeny don’t respond to selection pressure. Practical importance is benefit transferred to progeny. We have viewed this in two ways, one is effect of phenotyping heifers and two is effect of phenotyping bulls. Simmental-Angus heifers were RFI phenotyped after weaning and then bred to bulls of known RFI. Progeny were followed through the feedlot to determine effect of dam and sire selection for RFI on progeny performance. To date we have only analyzed data from heifer progeny. Progeny results are presented in Tables 3 and 4. Dams were divided into three groups, efficient (one standard deviation negative from the RFI mean of 0), average, and inefficient (one standard deviation positive from the RFI mean of 0). Calves were weaned and placed on corn-based diets. No differences occurred in average daily gain among progeny groups, with groups averaging 3.8 lbs per daily gain. Progeny from efficient cows consumed 92.6% and progeny from average cows consumed 97% as much feed as progeny from inefficient cows. When FCR was contrasted among efficiency groups, progeny from efficient and average cows had 12% and 8% improved feed efficiencies, respectively, compared to progeny from inefficient cows. The RFI values for progeny from efficient, average and inefficient cows were -0.41, 0.07, and 0.29, respectively. Estimating feed price at $160 per ton and feedlot gain of 650 lbs, selecting efficient dams in this research would have resulted in progeny with a reduced feed cost of $34 per head.

Similar results occurred when sire RFI phenotypes were compared. Two sires are contrasted in Table 4. Sire A had a 1.06 RFI value and sire B had a -0.99 RFI value. As expected no difference occurred in average daily gain between sire groups but heifers from the efficient sire (-0.99 RFI) consumed 89% as much feed and improved feed to gain 16% compared to heifers from the inefficient sire (1.06 RFI). Estimating feed price at $160 per ton and feedlot gain of 650 lbs, selecting the efficient sire would have reduced feed costs an average of $45 per calf the sire produced. If the bull inseminated 35 cows, the efficient bull would have had $1,575 more value in one year than the inefficient bull.

Putting RFI into Practice

I was once told that breeding a really fast mare to a really fast stallion might result in a really fast colt. This statement was made to me by a seedstock breeder regarding growth traits in cattle, but could be applied to RFI selection as well. Progeny resulting from breeding efficient cows to efficient sires will express a range of RFI phenotypes. Research conducted in our lab has typically measured a RFI range approximating 13 lbs (– 6.5 to + 6.5). We interpret these numbers as the most efficient calf consumed 6.5 lbs less feed than the average calf and the most inefficient calf consumed 6.5 lbs more feed than the average calf. When progeny of efficient matings are contrasted against progeny of inefficient matings, the range in RFI values for both groups can be 6 to 8 lbs, but mean RFI value of progeny from efficient matings will be skewed toward a negative RFI and vice versa for progeny from inefficient matings. Data of progeny in Tables 3 and 4 are examples of such. Use of a calving ease or high yearling weight sire does not mean you won't need to pull a calf or that all calves will be growth superstars, but calving ease and growth performance will be skewed in your favor. Similar results for RFI selection should be expected. From a practical standpoint the greatest benefit, in my opinion, occurs from selecting against the one-third most inefficient females and selecting for top tier efficiency in bulls. And, similar to reproduction and growth traits, progeny evaluation are stronger indicators of sire genetic value than an individual test. This is not stating that an RFI test on the individual bull is not valuable, it is very valuable. We have had bulls testing with a positive RFI (inefficient) but producing calves that trended to be as efficient as calves from negative RFI bulls.

We have interpreted our research to date that diet does not affect RFI status of cattle. Heifers testing as negative RFI when fed concentrate diets maintained efficiency advantage when fed forage-based diets. Altering protein level and post-ruminal supply of amino acids of concentrate diets did not influence RFI value of steers even though FCR was influenced. This is not the same as concluding that animals will perform the same on forage and concentrate diets. Performance on contrasting diets can be influenced by ruminal kinetics, digestive capacity, acid tolerance, etc. that provide advantage to an animal for a particular diet type, but these factors are not tied to efficiency. In the research we have done to date we have not measured a diet specific response influencing RFI phenotype. What we have measured is reranking of animals when their RFI value is compared across two tests conducted at separate times. There is a strong correlation between RFI rank of an individual animal across tests conducted at different times, but we have seen 30% or more of calves in the test change RFI rank. A majority of these calves appear to have a lower RFI value as body weight increases. We presume this response is due to composition of growth changing from lean to lipid, and is supported by backfat accounting for 5 to 8% of the variation in RFI measurement. Nonetheless measurement of RFI probably has the greatest value when taken on cattle during growth and development.

To date selection for RFI has not been associated with any other phenotypic traits to my knowledge. This is inconvenient in that it makes it relatively impossible to identify efficient animals without RFI testing. It is fortunate that RFI selection is not associated with negative effects on reproduction or growth. A significant body of research has measured greater carcass fat content of + RFI (inefficient) calves compared to – RFI calves. Cows with – RFI were reported to have greater body weight and longer post-partum interval than + RFI cows, but estimates were less than 20 lbs greater body weight and approximately 3 days longer interval. Whether these associations remain will be determined as more data is analyzed. There is agreement that single trait selection for RFI would be a mistake. We have used calves in research that ranked in the top 10% for efficiency and bottom 10% for growth. The benefit of selecting these genetics for efficiency would not outweigh loss in growth potential that would occur. More importantly, it is possible to identify animals with superior efficiency and growth traits.

Conclusion

Few management techniques can be offered to beef producers that yield a 10 to 15% improvement in production efficiency. By stacking generations selected for RFI improvement greater than 20% improvement in production efficiency can be achieved. Selection for RFI does not appear to influence other economically important traits. A growing body of research is identifying cellular energy metabolism as a primary reason for efficiency advantage. While this gives benefit to calves in the feedlot, substantial benefit also occurs for the cow herd. When forage quantity is abundant efficient cows will require less forage, and carrying capacity by the pasture will be increased. When forage quantity becomes limiting, efficient cows will outperform inefficient cows due to their reduced demand for maintenance energy. The RFI selection can significantly impact efficiency of the cow herd and progeny feedlot performance.

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Table 1. Forage intake by efficient (-RFI) and inefficient (+RFI) cows during gestation and while lactating.

Average RFI value	-4.37	5.04
Gestation, summer grazing period		
Initial body weight, lbs	1,300	1,243
Initial body condition score	5.26	5.26
Body weight change, lbs	42.9	48.6
Body condition score change	0.11	0.10
Forage DM on offer, lbs/acre	4,215	4,376
Forage DM intake, lbs	27.3[b]	34.3[a]
Lactation, winter grazing period		
Initial body weight, lbs	1,252	1,225
Initial body condition score	4.85	4.98
Body weight change, lbs	40.5	58.5
Body condition score change	-0.04	0.15
Forage utilization, %	75.5	76.3
Forage DM intake, lbs	27.5[b]	31.0[a]
Calf performance		
Age, days	144	143
Weight at end of test, lbs	310	290
Average daily gain, lbs	1.87	2.09

Table 2. Forage intake, average cow body weight and calf weaning weight of inefficient (+ RFI) and efficient (- RFI) cows.

	Treatment	
	+ RFI	- RFI
Forage intake, lbs/d	35.6[a]	31.0[b]
Calf weaning weight, lbs	601	572
Cow body weight, lbs	1,364	1,355

Table 3. Effect of dam phenotypic selection for RFI on progeny performance.

RFI group[1]	DAM RFI	Calf ADG	Calf Intake	Calf FCR[2]	Calf RFI
		lbs/d	lbs/d		
1 - RFI	-1.73	3.85	21.0[b]	5.46[b]	-0.41[c]
μ RFI	0.14	3.87	22.0[a]	5.69[b]	0.07[b]
1 + RFI	1.77	3.70	22.7[a]	6.13[a]	0.29[a]
% change		+ 4.2	-7.4	-10.9	

[1] Dams were grouped based on RFI phenotype (one standard deviation above mean RFI {1 – RFI], less than one standard deviation from mean RFI [μ RFI], or one standard deviation below mean RFI [1 + RFI].
[2] Feed conversion ratio.

Table 4. Effect of sire phenotype selection for RFI on progeny performance.

	Calf ADG lbs/day	Calf Intake lbs/day	Calf FCR	Calf RFI
Sire A	3.78	23.7[a]	6.28[a]	0.73[a]
Sire B	4.14	21.0[b]	5.06[b]	-0.60[b]
% change	+ 9.3	-11.7	-19.4	

SESSION NOTES