NET FEED EFFICIENCY: POSSIBILITIES FOR THE FUTURE

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Improving feed efficiency is an important strategy in reducing feed cost and improving profitability for beef production systems. Although it may also be important to optimize the cost structure in dairy production systems, less attention has been directed to efficiency, the focus being more on maximizing productivity. Net Feed Efficiency (NFE) also known as Residual feed intake (RFI), represents the difference between actual and predicted feed intake required for the observed rate of body weight (BW) gain in beef animals, and is a measure of feed efficiency that is moderately heritable and genetically independent of growth rate and BW in growing cattle (Herd and Bishop, 2000; Arthur et al., 2001).

Current beef genetic selection programs are focused primarily on growth and carcass traits, which are easily and inexpensively measured. However, it is important that any process of selection for efficiency does not adversely impact improvements made in end-product quality (Archer et al., 1999). Nevertheless, genetic correlations between RFI and carcass traits in U.S. cattle have not been reported. Therefore, determining the relationships between RFI and meat quality and palatability prior to genetic selection for improved RFI is an important component of the development of this tool for use by industry.

Definition of Net Feed Efficiency (Residual Feed Intake)

Cost of production is the largest cost variable in the 'profitability equation' over which a producer has control. Only by reducing cost of production (via reduced feed intake, for instance), will U.S. beef producers be able to remain competitive and sustainable in a global marketplace. To reduce feed cost, Residual Feed Intake (RFI) is being utilized as a measure of efficiency in beef cattle production in Australia and is under implementation in Canada. An RFI value is the difference between actual and predicted feed intake (where predicted feed intake is based on BW and gain) during a standard 70-day post-weaning test period. To calculate RFI, data must be collected for individual animal feed intake and weight gain. Australian researchers have shown that RFI is independent of many other production parameters. As a result, it is now being used in a selection index to simultaneously target efficiency and other parameters such as performance and product quality (Arthur et al., 2004).

RFI data from the Northwest

A considerable amount of animal-to-animal variation exists for RFI in beef cattle (Herd et al., 2003). This was recently demonstrated in the U.S. when University of Idaho researchers evaluated RFI using 54 Angus steers (a contemporary group) during a 70-day post-weaning period (Szasz et al., 2004; Baker et al., 2005; Figure 1). In Figure 1, the two, circled data points represent two steers that gained approximately 1.45 kg/day (3.2 lbs/day). The lower circled data point denotes a steer that consumed approximately 18.5 kg/day (40.7 lbs/day as fed), while the top circle indicates a steer that consumed approximately 25.5 kg/day (56.1 lbs/day as fed). This 7.0-kg/day (15.4 lbs/day) difference in feed intake represents a variation of approximately 35%, and appears to be present in typical beef cattle populations. For reference, each steer's RFI value in Figure 1 is the difference between the regression line and that steer's data point.

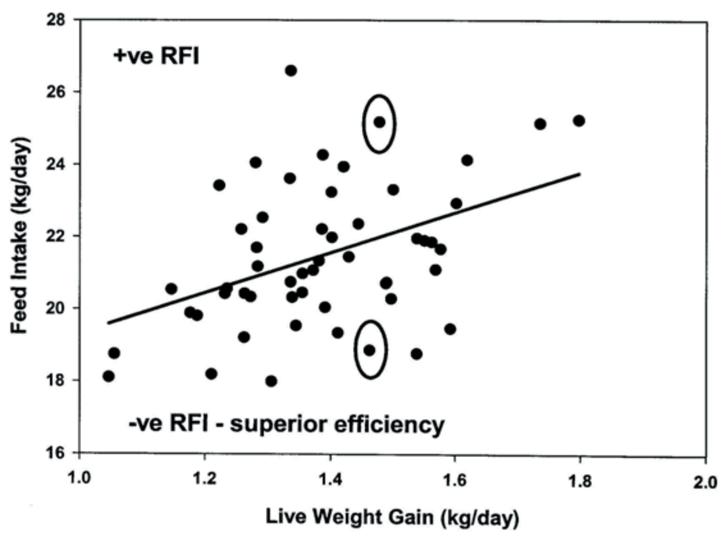

Figure 1. Relationship between feed intake and live weight gain in Angus steers (Baker et al., 2005). Of the two individual steer data points identified within circles, both gained 1.45 kg/day; however, feed consumption was 18.5 kg/day and 25.5 kg/day. This difference of over 35% represents the normal variation within any population.

Therefore, all points above the regression line have a positive RFI (less efficient), and those below the line have a negative RFI (more efficient).

These cattle were a typical cohort of purebred Angus steers that exhibited a normal range of performance characteristics. Table 1 shows these animals categorized into three groups: either inefficient (LOW, RFI values > 0.5 SD above the group mean), intermediate (MID, RFI values, mean ± 0.5 SD) or efficient (HIGH, RFI values > 0.5 SD below the mean). Note that the mean RFI value within a population, by definition will be (close to) zero. The groups differed in dry matter intake (DMI), RFI, and feed conversion ratio (FCR), but for all other growth and carcass characteristics, there were no differences.

Table 1. Performance traits of HIGH (inefficient), MID, and LOW (efficient) residual feed intake (RFI) purebred Angus steers categorized into high (> 0.5 SD above mean, HIGH), medium (+/- 0.5 SD from mean, MID), and low (> 0.5 SD below mean, LOW) RFI groups (n = 54), during a 70 day performance test (Baker et al., 2005)

	RFI Group				
Trait	HIGH	MID	LOW	SEM	*P*-value
n	16	21	17	-	-
ADG, kg	1.4	1.4	1.4	0.04	0.879
DMI, kg/d	10.3^{b}	9.9^{bc}	9.3^{c}	0.21	0.004
RFI, kg/d	0.60^{b}	-0.007^{c}	-0.53^{d}	0.06	0.001
FCR[a],	7.7^{b}	7.1^{bc}	6.7^{c}	0.19	0.002
Initial BW, kg	341.3	340.9	341.3	9.6	0.999
Day 71 BW, kg	436.8	438.3	439.1	10.7	0.988
Initial UBF[e], cm	0.33	0.30	0.34	0.02	0.310
Day 71 UBF, cm	0.66	0.69	0.65	0.03	0.691
Initial ULDA[f], cm^2	41.9	40.1	40.5	1.5	0.659
Day 71 ULDA, cm^2	54.8	58.7	57.3	1.5	0.149

[a]FCR = feed conversion ratio = DMI:ADG.
[b,c,d] Means within a row lacking a common superscript letter differ ($P < 0.05$).
[e]UBF = ultrasound Backfat.
[f]ULDA = ultrasound *longissimus dorsi* muscle area.

RFI Relationship to Other Performance Traits and Carcass Characteristics

The data shown above suggest that there appears to be no relationship between RFI and growth or partitioning of growth between fat and lean deposition, and is in agreement with previous reports (Archer et al., 1997; Arthur et al., 1997, 2001; Basarab et al., 2003; Crews et al., 2003; Nkrumah et al., 2004).

Herd and Bishop (2000) and Arthur et al. (2001) reported moderately positive phenotypic correlations between RFI and DMI of Hereford, Angus, and Charolais cattle. In agreement, Basarab et al. (2003) reported a similar positive correlation (r = 0.42) for steers from five genetic backgrounds. Our study in Angus steers also found a positive correlation (r = 0.59) between RFI and DMI.

Others (Herd and Bishop, 2000; Arthur et al., 2001; and Basarab et al., 2003) have also reported positive correlations between FCR and RFI (r = 0.53, 0.70, and 0.44, respectively). Our data were consistent with these, as a small, positive correlation (r = 0.37) between FCR and RFI was observed. Feed intake and FCR were both greater (less efficient) in HIGH steers than in LOW steers.

The importance of determining whether there may be any detrimental effects on performance traits or carcass characteristics associated with RFI needs careful consideration. Some studies have shown that there may be a tendency for more efficient animals to be leaner. If this is so, the effects of selection for RFI on product quality need to be studied. Herd and Bishop (2000) reported negative phenotypic (r = -0.22) and genetic (r = -0.43) correlations between RFI and estimated lean content in Hereford cattle. Reports on the relationship between RFI and intramuscular fat are not conclusive. Robinson et al. (1999) reported a small, positive genetic correlation (r = 0.17) between RFI and IMF. McDonagh et al. (2001) found no differences in visual marbling scores or objectively measured IMF for carcasses of a group of Angus, Angus × Hereford, Angus × Polled Hereford and Angus × Shorthorn steers which were the progeny of high or low RFI selection lines. However, Richardson et al. (2001) reported progeny from Angus cattle selected for low RFI had 13.2% less subcutaneous and intramuscular fat than progeny from those selected for high RFI. The difference between these studies may be due to differences in age and maturity of animals when traits were measured or may suggest that other unidentified variables may be influencing composition in these populations.

Literature reports of correlations between RFI and ultrasound measurements of subcutaneous fat, IMF, rump fat, and carcass fat measurements are also inconclusive. Arthur et al. (2001) reported low phenotypic (r = 0.14) and genotypic (r = 0.17) correlations between RFI and ultrasound rib fat thickness (FT) and LDA. Basarab et al. (2003) reported no relationships between RFI and ultrasound FT and marbling score. In a preliminary study, Crews et al. (2003) reported negative correlations between RFI and ultrasound FT and marbling scores. Carstens et al. (2002) found that high RFI cattle had greater rump fat thickness, but similar FT and IMF compared to low RFI steers. It may be that less efficient steers (high RFI) have a greater propensity to deposit fat than protein. Studies that have reported decreased subcutaneous fat thickness in low (more efficient) RFI steers, also report that this is not accompanied by a reduction in HCW or LDA. This suggests that yield grades are not compromised and low RFI steers may actually have increased retail meat yield. However, other authors suggest ongoing selection for low RFI may decrease subcutaneous fat levels, possibly leading to animals that fail to meet minimum market specifications for fatness (McDonagh et al., 2001). Our data in Angus steers do not support this notion as carcasses from all groups had acceptable quality and yield grades.

The problem of a possible antagonistic association between fat thickness, marbling and RFI is one which will continue to require attention. This is unlikely to become a problem in production systems, because producers are acutely aware of the benefits of selection for marbling. A recent investigation considered this issue and identified the traits of Angus sires, which had been widely used in Australia. As shown in Figures 2 and 3, Exton et al (2004) were able to identify individual bulls, which had combined traits of desirable FT, IMF and RFI being those in the upper left quadrant of each graph.

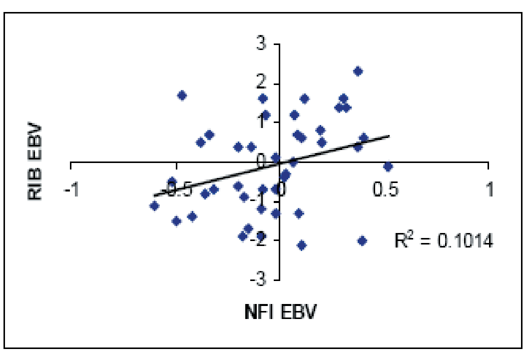

Figure 2. Rib fat estimated breeding value (EBV) *vs*. RFI (NFE) EBV of Australian Angus bulls (from Exton et al., 2004).

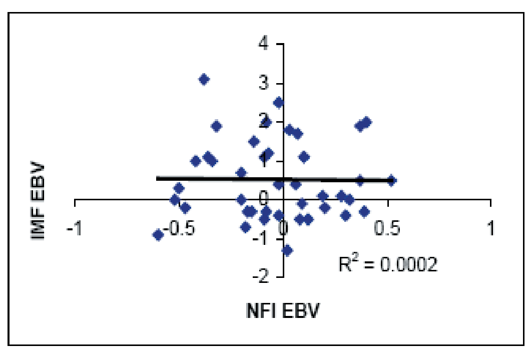

Figure 3. Intramuscular fat (IMF) EBV *vs*. RFI (NFE) EBV of Australian Angus bulls (from Exton et al., 2004).

Factors which Determine RFI

Performance traits and their correlations with RFI and FCR are well documented in the literature; however, the biological drivers of variation in RFI are largely unknown. Richardson and Herd (2004) suggested that variation in at least seven major biological processes contribute to variation in RFI (Figure 4): Protein turnover, tissue metabolism and stress, Heat increment of fermentation, ability to digest feed, activity, body composition, feeding patterns and other unknown contributors. Furthermore, modulation of energy use via physiological processes appears to have the potential to account for a substantial proportion of individual variation in efficiency (Hill and Herd, 2001). Given the present lack of understanding of the biological basis of RFI and its effect on various traits, any selection for RFI in beef cattle systems, should be accompanied by monitoring for correlated responses and clearly, more research is needed to fully understand the possible effects of RFI on end-product quality.

RFI as a Genetic Selection Tool

Since RFI is moderately heritable (h^2 = 0.16 to 0.43; Herd et al., 2003), it offers a genetic selection method to improve beef cattle efficiency without also increasing growth rate and mature size (Johnson et al., 2002). Selection for efficiency using the RFI trait could potentially improve feed efficiency in cattle through reduced feed intake (Herd et al., 2003). Selection of parents with low RFI (considered efficient) resulted in progeny that consumed less feed as yearlings but weighed the same at harvest as offspring from high RFI parents (Richardson et al., 2001). In addition, preliminary evidence suggests that selection for RFI probably does not negatively affect mature cow weight or carcass quality of progeny, but can offer an advantage in selection for reduced cow maintenance requirements (Johnson et al., 2002).

Since feed cost comprises the largest cost on most beef cow/calf and feedyard operations, efforts to reduce feed costs without negatively affecting growth, reproduction, performance, or meat quality would be extremely beneficial to the industry. However, cost-effective methods of characterizing large numbers of cattle for RFI (in order to allow genetic selection for RFI) are not yet widespread. Based on the substantial amount of variation present in RFI within a population, it is likely that commercial cow/calf producers will demand an Expected Progeny Difference (EPD) for efficiency from their seedstock suppliers. As a result, future cattle selection will probably include the conventional growth and carcass traits, newly-expanding reproduction traits, and efficiency traits such as RFI.

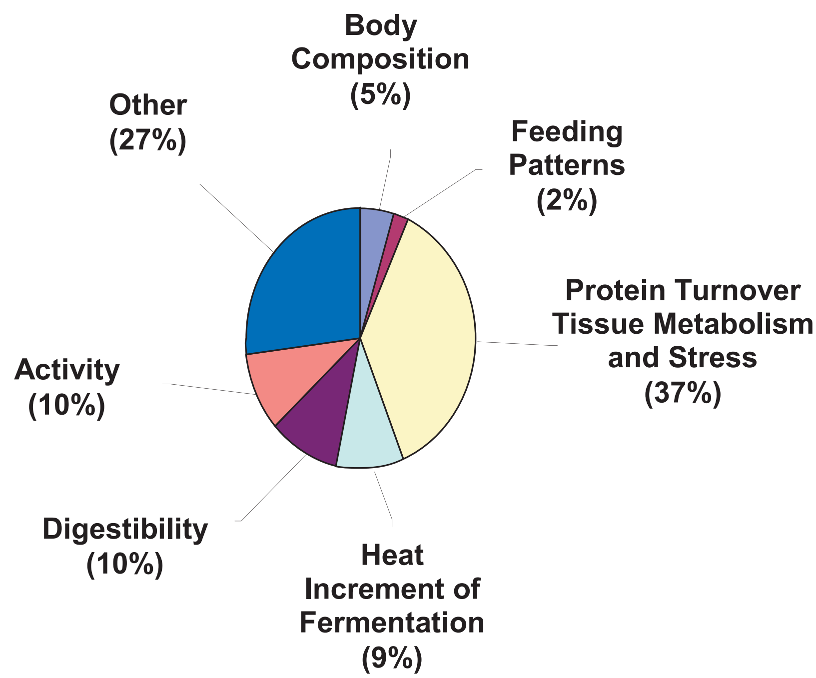

Figure 4. Contributions of biological mechanisms to variation in residual feed intake as determined from experiments on divergently selected cattle (from Richardson and Herd, 2004).

Indicator Traits for RFI

One of the greatest impediments to implementing RFI is the cost of identifying sires with superior RFI. The most reliable data are provided by measuring RFI in multiple progeny in a standard 70-day post-weaning test. Measurements of at least 15 progeny per sire are a minimum requirement, and increasing the number of progeny evaluated improves the accuracy of the trait estimate. Thus, there is a high cost associated with collecting these data. Researchers have recently begun to search for useful indicator traits for RFI.

Easily measured plasma hormones have been suggested as possible candidates. One of these insulin-like growth factor-1 (IGF-1) appears to be useful in this regard (Johnston et al., 2002, Moore et al., 2003). Thus, it is likely that in the future the cost of evaluating RFI will be reduced. However, data from indicator traits like plasma IGF-1 will still need to be validated and referenced to absolute measures of RFI. Thus, it is likely that research facilities or perhaps bull testing stations will be required to continue to evaluate a proportion of animals using a standardized animal testing protocol.

Novel Applications of RFI

Recently, we have considered whether the RFI beef model might have an equivalent in dairy production. Because RFI for beef production is independent of many other production traits and provides a moderately heritable trait useful as a selection tool, we considered devising an equivalent measure of individual variation in efficiency for dairy production. An RFI value for beef production is the difference between actual and predicted feed intake (where predicted feed intake is based on BW and gain) during a standard 70-day post-weaning test period. We have begun to investigate a model in which we have defined RFI_D (RFI for milk production) as the difference between actual and predicted feed intake (where predicted feed intake is based upon that expected for milk production over a 60 day period around the lactation peak). We have estimated RFI_D on a small number of cows (n = 25) over peak milk production. Preliminary data suggest that the variation in RFI_D is not as great as for RFI, (approximately 12% versus 35%). Thus, there appears to be an equivalent relationship for dairy animals between feed consumed and productivity, albeit over a smaller range (Figure 5).

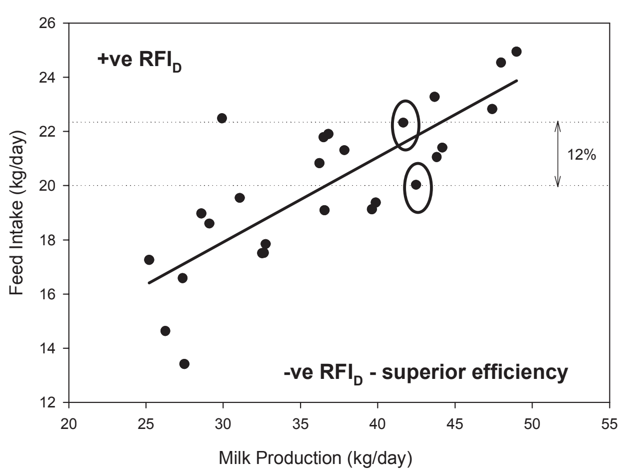

Figure 5. Relationship between feed intake and milk production in Finnish Ayrshire cows (data provided by MTT Agrifood Research, Finland). Of the two individual cow data points identified within circles, both produced 42 kg milk/day; however, feed consumption was 20 kg/day and 22.4 kg/day. This is a difference of 12%.

Data collection in the dairy context is somewhat less challenging than beef animals. Repeated measurements of feed intake and milk production of individual animals over each lactation would be possible providing an estimate of repeatability for each individual. Substantial additional data collection and careful analysis will be required before recommendations to industry can be contemplated.

Potential Impacts

Since RFI is independent of other known performance traits, a savings in feed and energy costs used to produce feed (including fossil fuel savings) can be expected. Published data (Archer et al., 2004) using two different models estimates that long-term improvement in profitability may be between 9 and 33%. Using a conservative figure of 7% cost saving and modeling this saving under typical Idaho conditions, RFI implementation could improve both resource use and economic viability of cattle operations (e.g. $217 feed cost/cow/yr × 0.07 = $15.19/cow/yr). Furthermore, long-term selection for efficiency should enable increased stocking rates for grazing cattle, increased production of beef (in weaning weight and harvest weight) using the same available resources, and reduced fecal (and nitrogen) excretion per animal. Additionally, long-term selection for efficiency should enable more effective, efficient, and sustainable use of western rangelands. These improvements in resource and rangeland use require the identification and genetic selection of animals (especially sires) with inherent superiority in feed efficiency.

The issue of the possible use of the concept of RFI in the dairy context is highly speculative at this time. We have presented a measure of efficiency of milk production and termed it RFI_D. It is not known whether RFI_D has potential as a measure of milk production efficiency, which may be useful to industry. If, like RFI, RFI_D is revealed as a heritable trait, which is independent of other production traits, such as fertility, RFI_D may provide a useful tool for selection in multi-trait genetic selection programs.

Implications

It appears that RFI has the potential to be included in genetic selection programs in the United States providing several benefits including reduced feed costs, without compromising carcass quality or meat palatability. Presently there is a lack of understanding of the biological basis to variation in RFI and of its genetic association with meat quality traits. Thus, selection for RFI should be accompanied by monitoring for any correlated response in meat quality and palatability.

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