MULTI-TRAIT PREDICTION OF FEED CONVERSION IN FEEDLOT CATTLE[1]

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Introduction

Compared to growth and more recently, carcass traits, the underlying genetic variation that controls feed and forage utilization has remained unexploited in beef cattle selection programs. This is quite surprising since feed costs for a feedlot steer can easily approach $200. The opportunity to reduce costs through genetic means seems to be present since the scientific literature indicates that feed intake and efficiency traits are heritable. However to date, no Expected Progeny Differences for efficiency traits have been published by North American breed societies due to the expense associated with collection of individual feed intake records, which are needed to maximize selection response. The purpose of this paper is to provide an overview of efficiency traits and their interrelationships with other economically important traits and to offer an example of how feed efficiency has been incorporated into a multi-trait selection program in the United States.

Efficiency Traits

Efficiency in feedlot cattle is often described as *feed conversion* (or its inverse *feed efficiency)*, the units of feed consumed divided by the units of animal gain over a specific time period. For feedlot cattle, this would be the pounds of feed consumed from feedlot entry through harvest divided by the pounds of gain. Factors influencing efficiency include age, diet, temperature, breed, growth promoting implants, ionophores and many other management and environmental variables. The NRC (2000) suggests that calf-feds are probably more efficient than yearlings when placed on feed and, in general, younger animals consume less feed per unit of body weight than older ones. All of these factors are important to consider when comparing *feed efficiency* or *feed conversion* among groups of cattle from various production systems.

While *feed conversion* is useful for evaluating phenotypic performance of feedlot cattle, it is a problematic variable for genetic improvement due to the component traits being expressed at different rates and/or possible nonlinearity of the component traits. Further, selection on the ratio could lead to undesirable changes in the component traits. Table 1 illustrates fictitious groups of cattle, all with a feed conversion of 5.5. However, each has differing growth and intake rates. While the ‘low growth’ cattle converted equally to the ‘high growth’ cattle, the lower growth group would not be acceptable if the production objective was to maximize profit. In Angus Sire Alliance steer data (described later), it has been

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[1] Thanks are expressed to Circle A Angus Ranch, Iberia, MO for providing growth, feed intake and carcass data from their progeny testing program and to Ignacy Misztal of the University of Georgia for providing software (http://nce.ads.uga.edu/~ignacy/).

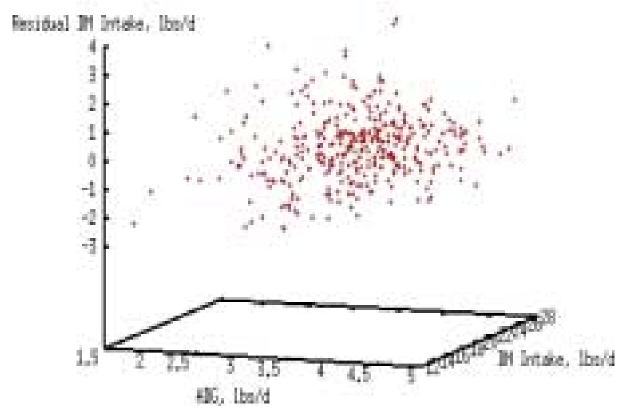
observed that there are sire groups with identical feed conversion rates, and yet, they differ for average daily gain. Therefore, breeders should be cautious on selecting for feed conversion alone.

Table 1. Example of cattle with feed conversion of 5.5 lb dry matter intake per lb gain but with differing growth and intake rates

Growth rate	ADG, lbs·d^{-1}	Daily DM Intake, lbs·d^{-1}
High	4.0	22.0
Medium	3.0	16.5
Low	2.0	11.0

To escape some of the problems of dealing with ratios, Koch et al. (1963) suggested using *residual feed intake* as a measure of efficiency. Those researchers suggested that intake could be adjusted for the level of production by regressing intake on growth rate and average body weight. The residuals or *residual feed intake* (observed values – predicted values) should then reflect efficiency of feed use. Animals with more negative values should be more efficient, since they are consuming less than the regression predicts they should. *Residual feed intake* should also be phenotypically independent of growth and weight traits used in the regression procedure since variation from those traits has been removed. This is important to note in selection programs, since efficient animals may not have acceptable levels of growth. As shown in figure 1, there is not a phenotypic relationship between residual dry matter intake and average daily gain in our Angus steer data. By definition, *residual feed intake* is phenotypically independent of those traits for which it has been adjusted.

Figure 1. Residual dry matter intake plotted with average daily gain and dry matter intake in finished Angus steers (n=353).



Genetic Parameters

Numerous reports in the literature illustrate there is underlying genetic variation for efficiency traits and genetic covariation of those same traits with other economically important traits. Koots et al. (1994a and 1994b) compiled heritability and genetic correlation estimates of numerous beef production traits. Table 2 provides those heritabilities for feed conversion, efficiency and intake, demonstrating that each is moderately heritable and would respond to selection. In fact, the reported heritability for feed conversion of .36 is 33% larger than that reported for weaning weight direct (h^2=.27).

Table 2. Heritabilities for efficiency traits of beef cattle from various literature estimates[1]

Trait	Heritability
Feed conversion (f/g)	.36
Feed efficiency (g/f)	.42
Feed intake	.41

[1]Koots et al. (1994a)

Koots et al. (1994b) also summarized the reported genetic relationships of those same efficiency traits with numerous other economically important traits. Table 3 highlights a few selected genetic correlations. Feed conversion was reported to be moderately and favorably related to post-weaning gain and feed intake, indicating that single trait selection for lower feed conversion would result in higher degrees of growth with less feed intake. Conversely, those researchers summarized that feed conversion was unfavorably, but not as strongly related with weaning weight direct and external fat thickness.

Table 3. Genetic correlations of beef cattle efficiency traits with growth and carcass traits from various literature estimates[1]

Trait	Feed conversion (f/g)	Feed intake
Weaning weight direct	.16	.67
Post-weaning gain	-.53	.53
Fat thickness	-.24	.14
Marbling score		.09
Feed intake	.38	-

[1]Koots et al. (1994b)

As described earlier, residual feed intake has gained interest from researchers as a trait that may describe animal efficiency without the problems associated with ratios. Again, residual feed intake is the deviation between the observed and predicted values where intake is regressed on production traits, usually average daily gain and metabolic body weight (mid-test weight$^{.75}$). Several recent studies have estimated heritabilities for residual intake along with genetic relationships with other production and carcass traits. Table 4 provides heritabilities reported from recent studies for residual intake along with average daily gain, feed intake and feed conversion in Angus bulls and heifers, Charolais bulls and Hereford bulls. With the exception of the estimate for feed conversion reported by Herd and Bishop (2000), heritabilities for feed intake and conversion are moderate and similar to those reported by Koots et al. (1994a). In the studies reported by Arthur et al. (2001a and 2001b), heritability for residual feed intake was .39 for both Angus bulls and heifers and Charolais bulls. Herd and Bishop (2000) reported a lower heritability of .16 for residual intake in Hereford bulls, similar to that of feed conversion reported in the same study. Nonetheless, there appears to be sufficient genetic variation to make selection progress for residual intake.

Table 4. Heritabilities from recent studies for growth and efficiency traits in three beef breeds

Trait	Angus bulls and heifers[1]	Charolais bulls[2]	Hereford bulls[3]
Average daily gain	.28	.34	.38
Feed intake	.39	.48	.31
Feed conversion	.29	.46	.17
Residual intake	.39	.39	.16

[1]Arthur et al. (2001a)
[2]Arthur et al. (2001b)
[3]Herd and Bishop (2000)

Similar to Koots et al. (1994b), more recent studies continue to confirm strong genetic relationships for feed intake and feed conversion with average daily gain, with feed conversion and average daily gain being related in a favorable direction. There appears to be no genetic relationship with residual intake and average daily gain for the three breed-sex class combinations reported. Since residual feed intake was created by regressing intake on average daily gain and weight, there should be no phenotypic relationship present; however, Kennedy et al. (1993) points out that the phenotypic adjustment does not guarantee that residual intake will be genetically unrelated to production, but in these studies it does appear to be unrelated.

Table 5. Recent reports of genetic correlations among efficiency traits

	Feed intake		Feed conversion		Residual feed intake		
	Angus[1]	Charolais[2]	Angus[1]	Charolais[2]	Angus[1]	Charolais[2]	Hereford[3]
Average daily gain	.54	.39	-.62	-.46	-.04	-.10	.09
Feed intake			.31	.64	.69	.79	.64
Feed conversion					.66	.85	.70

[1]Arthur et al. (2001a)
[2]Arthur et al. (2001b)
[3]Herd and Bishop (2000)

Residual intake is highly genetically correlated in favorable directions with feed intake and feed conversion. These studies in Angus, Charolais and Hereford cattle indicate that if selection against residual intake (for lower, or more efficient cattle) was practiced, correlated responses in lower intake and better feed conversion would result.

Less information is available on the genetic relationships that exist for residual intake with meat quality and composition traits, particularly in steers. However, Arthur et al. (2001a) reported a genetic correlation of .17 between residual intake and ultrasound rib fat in Angus bulls and heifers, indicating that a small but favorable relationship with leanness (for terminal breeding programs) may exist. That report is further substantiated by the genetic correlation of -.43 between carcass lean content and residual intake in Hereford bulls reported by Herd and Bishop (2000).

The Angus Sire Alliance

The Angus Sire Alliance was initiated in 1996 by Circle A Angus Ranch, Iberia, MO, as a program that combines marketing and technology efforts to test and identify the most profitable terminal Angus genetics. The technical aspects of the program have been described at earlier BIF meetings (Herring and MacNeil, 2001).

Production and Carcass Data: Angus seedstock producers nominate a young sire to be tested in the program by providing semen and the sire for breeding use in Circle A Angus Ranch commercial operations. Sires are bred artificially to commercial Angus females at all three of their commercial cow-calf ranches in Iberia, Huntsville and Stockton, MO. Cows, at random, are also allocated to each sire for natural service use at one of the ranches. Other Angus sires developed from Circle A purebred operations are tested through the program. Traits measured on steer offspring include calving ease, birth weight, weaning weight, backgrounding starting and ending weight, feedyard starting and ending weights, yearling weight, yearling ultrasound %IMF, yearling ultrasound ribeye area, yearling ultrasound fat thickness, carcass weight, carcass marbling score, carcass %KPH, carcass ribeye area and carcass 12-13th rib fat thickness. Data collected on heifers include calving ease, birth weight, weaning weight and yearling weight. Steer contemporary groups are established at birth and defined by birth pasture. These contemporary groups remain together and are not sorted from that point forward through harvest. At weaning, steers are backgrounded at the ranches for approximately 120 days. They are then shipped to a cooperating feedyard until harvest.

Figure 2. Calan Broadbent Feeding Gates used for measuring intake at Angus Sire Alliance Research Center

Feed efficiency: After the backgrounding period, some of the steer contemporary groups are placed in the Angus Sire Alliance Research Center at Huntsville, MO, to be evaluated for individual daily dry matter intake (figure 2). The research barn houses 96 Calan Broadbent Feeding Gates. Initial weights are taken at the beginning of the test and daily feed intake is recorded from this day to the end of the feeding period. A stepwise series of five finishing rations that are identical to the series of rations fed to the remaining test cattle at the commercial feedyard are used throughout the finishing period. Steers are weighed and ultrasonically scanned midway through the test. The afternoon prior to harvest, steers are weighed and then transported overnight to a commercial facility for slaughter and carcass data collection.

These data have made it possible to provide some preliminary estimates of genetic parameters for feed efficiency traits in Angus steers. Table 6 provides a description of the steers, both with and without intake records, used in this analysis. The deviation of weaning weight from carcass weight (adjusted to a final live weight using an assumed 62% dress) was used to compute average daily gain. Test average daily gain was computed using actual starting and final weight for those steers with intake records. Metabolic mid-weight for steers with intake records was computed using the actual weight collected midway through the feeding trial. Residual intake was computed as the deviation of the observed from predicted values by regressing average daily intake on test average daily gain and metabolic mid-weight.

Table 6. Descriptive statistics for Angus Sire Alliance steers

Trait	N	Mean	Std. Dev.	Min	Max
Slaughter age, d	3960	445	21	364	503
Average daily gain[a], $lbs \cdot d^{-1}$	3937	2.9	.43	1.1	4.5
Test average daily gain[b], $lbs \cdot d^{-1}$	353	3.6	.5	1.8	5.0
Intake, $lbs \cdot d^{-1}$	353	20.3	2.2	12.2	26.2
Mid-weight, $lbs^{.75}$	353	190	16	151	234
Feed conversion	353	5.7	.7	3.9	9.0
Residual intake, $lbs \cdot d^{-1}$	353	0.0	1.1	-2.5	4.0
Carcass weight, lbs	3960	751	73	476	993
Fat thickness, in	3932	.56	.18	.10	1.4
Ribeye area, in^2	3927	11.8	1.4	6.2	8.2
USDA yield grade	3912	3.4	.7	.5	6.4
Marbling score[c]	3941	5.8	1.0	2.1	10.8

[a]Calculated using weaning weight and estimated live slaughter weight (estimated from carcass weight using a 62% dressed weight)
[b]Calculated using initial and final live weights from steers with intake records
[c]4.0=Slight^{00}; 5.0= Small^{00}; etc.

Genetic and environmental (co)variances were estimated with a 6-trait animal model for post-weaning gain, daily dry-matter intake, feed conversion, residual daily intake, fat thickness and marbling score. For steers without intake records, their average daily gain, fat thickness and marbling records were included in the analysis. A fixed effect of contemporary group and a random direct genetic effect were fit for all traits. An additional covariate for slaughter age was included for marbling score and fat thickness. An average information REML algorithm was used to estimate genetic and environmental (co)variances among all traits. Heritabilities and genetic correlations are provided in table 7.

Table 7. Heritability (diagonal) and genetic correlations for feed efficiency and carcass traits in Angus steers

	ADG	Intake	FC	RI	FAT	MAR
Average daily gain (ADG)	.28	.56	.01	.23	.04	-.04
Intake		.44	.55	.92	.46	.20
Feed conversion (FC)			.15	.65	-.09	.14
Residual intake (RI)				.50	.46	.10
Fat thickness (FAT)					.40	.23
Marbling score (MAR)						.45

We emphasize that these results are preliminary (n=353 animals with intake records) and may change as more data become available. Heritabilities for average daily gain, intake and feed conversion are similar to those reported by studies in table 4. However, the heritability for residual intake in the present study of .50 is higher than those reported by Arthur et al. (2001a and 2001b) and Herd and Bishop (2000).

Genetic correlations for average daily gain:intake, feed conversion:intake and residual intake:feed conversion were all moderate and similar to those reported in the earlier referenced studies. While Arthur et al. (2001a and 2001b) and Herd and Bishop (2000) reported large genetic correlations between residual intake and intake, our estimated relationship was even larger (r_g=.92), with all reports indicating that selection for lower residual intake (more efficient cattle) would decrease overall feed consumption.

Different from the same reports is our estimate of no relationship between feed conversion and average daily gain. Because of the strong genetic correlation we report between residual intake and intake, this lack of relationship could be due to intake driving feed conversion rather than gain. We also estimated a small genetic relationship between residual intake and average daily gain. While residual intake is phenotypically independent of average daily gain (r_p=.0), it may need to be estimated using genetic rather than phenotypic regression (Kennedy et al., 1993) as more data become available.

We were also able to estimate genetic relationships with carcass marbling and fat thickness. Of interest was the genetic correlation of .46 between residual intake and fat thickness, indicating that selection for lower residual intake would result in compositionally leaner cattle at harvest. This is a stronger relationship than that reported by Arthur et al. (2001a) and Herd and Bishop (2000).

<u>Multi-trait selection:</u> While feed consumption accounts for a major portion of costs associated with terminal feedlot animals, growth and carcass traits contribute additionally to net return. Maximizing profit for terminal production systems may not necessarily mean using the most biologically efficient genetics for feed

consumption. Profit should be maximized, however, if each of the traits that contribute to profit is appropriately weighted by its relative economic value and subsequently used in an economic selection index to rank sires for profit. Herring and Macneil (2001), from these same data, computed Expected progeny Differences (EPD) for birth weight, weaning weight direct, post-weaning gain, intake, marbling score and yield grade. Relative economic weights were then computed from a bio-economic simulation for each of the traits for a terminal Angus production system. The EPD and relative economic values were then combined to rank sires for net return per progeny for the terminal system, resulting in a range of $42 per calf among the sires.

Archer et al. (1999) suggested that while it may be more appropriate to use intake and gain EPD with economic selection index, producers are more acclimated to using individual EPD rather than selection index. Therefore, they suggest that genetic values for residual intake rather than intake or feed conversion are a better alternative. However, we suggest that rather than spend educational efforts on a new trait, those efforts would perhaps be better spent assisting cattlemen with understanding and implementing economic selection indexes that include component traits of feed efficiency.

Efficiency – Future Efforts
Even though the improvement of feed and forage utilization could significantly improve profitability of U.S beef operations, there are no genetic predictions available for improvement of efficiency in growing or adult animals. Inadequacies in current knowledge include a lack of understanding of genetic relationships of efficiency with other economically important traits both within and across growing and adult cattle. Further, very little is understood about the underlying physiological mechanisms that control the utilization of feed and forage.

The most obvious obstacles to providing broadscale genetic predictions for efficiency are the expense of gathering individual feed intake records and the identification of which animals should be the focus of intake collection efforts. Genetic predictions could be generated without intake records based only on relationships with other traits such as growth and fat. However, Expected Progeny Differences computed without intake records and based only on relationships with other traits would not identify animals that defy the norm.

So, what possible solutions exist for genetically improving feed efficiency in feedlot cattle for terminal production systems? Ideally, records would be generated from steer progeny in a feedlot setting and would originate from a structure similar to that used for designed progeny testing for carcass traits. Several breed associations already have ongoing progeny testing programs for carcass traits, and these programs could be expanded to collect individual intake data. This approach would require existing commercial feedyards to install individual intake measuring equipment and designate personnel for day-to-day oversight.

Secondly, there are approximately 58 central bull test stations in the United States that are operated by land grant university extension programs. Historically, these stations were used as genetic testing platforms for growth traits in purebred bulls. Some of these stations already have individual feed intake equipment. If funding were available, other central test stations could be retrofitted with intake measuring equipment. Working with beef cattle breed associations, contemporary groups of bulls that most appropriately represent sires used on a broad scale could be targeted for testing.

Of course, both of these approaches would require significant levels of funding and expertise to implement and maintain. Recent advances in intake measuring equipment are notable, and uses of these technologies for collection of field data may be approaching reasonable costs. Depending on test length, initial equipment costs and depreciable equipment life, test costs over and above normal animal production costs may now be as little as $50 per animal (Alison Sunstrum, Growsafe Systems Ltd., *personal communication*).

It has been demonstrated that feed efficiency in feedlot cattle is moderately heritable, and thus should respond to selection if Expected Progeny Differences were available. There were 28.5 million steers and heifers harvested from U.S. feedlots in 2001. Assuming averages for dry-matter conversion of 6.5, $120/Ton feed costs, and 500 lbs of feedlot gain, a 2% reduction in feed consumption holding all other traits constant would provide an $111 million improvement in net return to U.S. beef producers. To achieve this end, cattlemen will have to assist through direct support or lobbying of federal funding for facilities and operating capital to support research and development of programs to improve feed and forage efficiencies. Feed and forage efficiency improvement will increase ranch profit through reduced input costs and reduce potential environment disruption through reduced animal waste production.

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