Net feed intake: Potential selection tool to improve feed efficiency in beef cattle

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Introduction: Recent economic analysis of standardized performance assessment (**SPA**) data from Texas, New Mexico and Oklahoma cow-calf operations (McGrann, 2002) revealed that grazing and feed costs per cow had a greater impact on determining net income per cow than weaning rates, calf weaning weights or pounds of calf weaned per cow exposed. Likewise, analysis of Iowa and Illinois SPA data found that total feed costs accounted for over 50% of the herd-to-herd variation in net income per cow. Results from these SPA databases illustrate that improvements in feed efficiency would significantly impact unit costs of production and improve profitability of cow-calf enterprises, thereby improving the competitiveness and long-term sustainability of the beef industry.

A recent analysis conducted by Danny Fox at Cornell University demonstrated that a 10% improvement in feed efficiency has a much greater impact on feedlot profitability than a similar 10% improvement in average daily gain (Fox et al., 2001). Results from this analysis showed that a 10% improvement in rate of gain alone as a result of a 7% increase in appetite improved profits 18%, primarily as the results of fewer days on feed and a reduction in non-feed costs. However, a 10% improvement in feed efficiency resulted in a 43% increase in profits. An additional impact of an improvement in feed efficiency with no concurrent reduction in feedlot performance is that the amount of manure produced would be significantly reduced. Thus, our ability to identify cattle that are superior for feed efficiency would greatly facilitate our ability to produce beef from available feed resources in an environmentally sustainable manner. The objective of this paper is to discuss the challenges to measuring efficiency of feed utilization in cattle and to address the merits of using a relatively new trait, net feed intake, to identify more efficient cattle.

Maintenance Energy Costs: The biological efficiency of converting feed energy to meat protein is much lower in beef production systems (5%) compared to pork (14%) and broiler chicken (21%) production systems, due in part to a much lower reproductive rate in cattle that greatly increases the "overhead" costs associated with maintaining the breeding herd. In producing beef, approximately 70% of total feed energy is used by the cow herd, and of feed energy used by the cow herd, more than 70% is needed to support maintenance energy requirements of cows (Ferrell and Jenkins, 1984). Consequently, more than half (70% x 70% ≈ 50%) of the total feed energy needed to produce beef is associated with the energetic costs of supporting maintenance requirements of cows.

Numerous studies have found that significant breed differences exist in cow maintenance energy requirements (Ferrell and Jenkins, 1984). In addition, there is some evidence to demonstrate that genetic variation in maintenance energy requirement exists within breeds (Carstens et al., 1989; DiCostanzo et al., 1990). These studies suggest that there may be opportunities to select more efficient cows if we could measure cow maintenance energy costs. The dilemma we face, however, is that measuring maintenance energy requirements using indirect calorimetry is an expensive and time consuming process, such that it is impractical to consider measuring this trait in individual cattle for selection purposes. In addition, numerous breed comparison studies have shown that positive genetic relationships exist between cow maintenance efficiency and the genetic merit for productive traits like milk production and growth. Consequently, as selection pressure has been applied to increase growth and maternal milk traits to improve production efficiency, overhead costs associated with cow maintenance have likely increased as well. In the future, the genetic antagonisms between cow maintenance requirements and productive traits will need to be considered in our attempts to identify more biologically efficient cows.

Recent research conducted at Colorado State University has lead to the development of an expected progeny difference (**EPD**) for cow maintenance energy requirements (Evans et al., 2002). The equation used to predict the EPD for cow maintenance energy requirements includes mature body weight and maternal milk EPDs. A prototype EPD for this trait has been completed for the Red Angus breed and the EPD is expressed in Mcal of energy per year. The ability to select cows for reduced maintenance energy requirements would impact profitability through a reduction in feed costs assuming that productive traits remain unaffected. Alternative indicator traits and more direct measures of maintenance energy requirements will need to be considered in the future to improve the accuracy and genetic prediction of this prototype EPD.

Net feed intake: Most studies that have examined genetic variation in feed efficiency have been conducted with growing cattle, with little work done on mature cattle. The most commonly used measure of feed efficiency used in these experiments is gross efficiency or its inverse, feed conversion ratio (**FCR**; feed per gain). Feed conversion ratio is a gross measure of efficiency in that it does not account for feed requirements needed for maintenance and growth. A number of studies have demonstrated that FCR is moderately heritable (Koots et al., 1994). However, because FCR is negatively related to growth (see Table 1), applying selection pressure against FCR will enhance genetic merit for growth. As such it is difficult to determine if variation in efficiency measured as FCR represents inherent differences in metabolic efficiency or differences in growth or maturity pattern. Using FCR as a trait to select for feed efficiency in growing cattle will not only result in increased growth, but also increases in cow mature body size (Herd and Bishop, 2000). Therefore, selection for FCR will likely increase feed costs of the breeding herd and not necessarily improve feed efficiency of integrated beef operations.

Table 1. Heritability estimates (**bold**) and genetic correlations (above the diagonal) for growth and efficiency traits in Angus bulls and heifers†

Trait[a]	ADG	BW	FI	FCR	NFI
ADG	**0.28**	0.53	0.54	-0.63	-0.04
BW		**0.04**	0.65	-0.01	-0.06
FI			**0.39**	0.31	0.69
FCR				**0.29**	0.66
NFI					**0.39**

†Adapted from Arthur et al. (2001a).
[a]FCR = feed conversion ratio; NFI = net feed intake.

An alternative measure of feed efficiency is net feed intake (**NFI**), which is a measure of the variation in feed intake beyond that needed to support maintenance and growth requirements (Archer et al., 1999). Net feed intake is calculated as the difference between actual feed intake and the amount of feed an animal is expected to eat based on its size and growth rate. Cattle that are larger and faster growing would be expected to consume more feed than cattle that are smaller and slower growing. Therefore, cattle that eat less than expected based on their body weight and ADG will have a negative NFI and thus have a superior net feed efficiency. Recent studies have shown that NFI is moderately heritable in cattle (Table 2) and genetically independent of growth and body weight (Table 1).

Table 2. Heritability estimates for net feed intake (**NFI**) in beef cattle.

Breed	No. of cattle	Location	NFI Heritability	Reference
British	1324	USA	.28 ± .11	Koch et al., 1963
British	1116	Australia	.46 ± .07	Archer et al., 1998
Hereford	540	England	.16 ± .08	Herd and Bishop, 2000
Charolais	1302	France	.43 ± .06	Arthur et al., 2001a
British	1180	Australia	.39 ± .04	Arthur et al., 2001b

The Australians have been conducting NFI research with beef cattle since 1993, and have recently published results from a five-year selection experiment in which low NFI (improved net feed efficiency) females were mated to low NFI bulls and high NFI females were mated to high NFI bulls (Arthur et al., 2001c). The performance of steer progeny generated after five years of selection (almost two generations) were compared. The steer progeny from the low NFI parents (improved net feed efficiency) gained the same (3.17 vs 3.08 lb/day) and weighed the same (845 vs 838 lb) as the steer progeny from the high NFI parents. However, the steers from the low NFI parents had lower NFI (-1.19 vs 1.56 lb/day), consumed less feed (20.7 vs 23.3 lb/day) and had lower FCR (6.6 vs 7.8) compared to steers from the high NFI parents.

This study revealed that NFI is a trait that will allow producers to select cattle that are more efficient without having to select cattle that have increased genetic merit for growth and thus increased mature body size. The Australian beef industry has rapidly adopted the use of this technology to select more efficient cattle and the Australian Angus Breed Association is now reporting estimated breeding values for NFI (Figure 1).

TAMU NFI study: We have recently completed a trial designed to characterize NFI in crossbred steers calves and to examine correlated responses with performance traits and ultrasonic measures of carcass composition (Carstens et al., 2002). One hundred and eighty Braunvieh-sired steers from the Spade Ranch were fed a pelleted roughage-based diet for 77 days using Calan electronic gate feeders. Dry matter intakes were strongly correlated with growth rates (r = 0.65) and final BW (r = 0.75), but were less than unity, suggesting that opportunities exist to alter the relationship between feed intake and growth traits in growing cattle. Similar to results from previous Australian studies, we found that NFI was not related to final body weight or ADG.

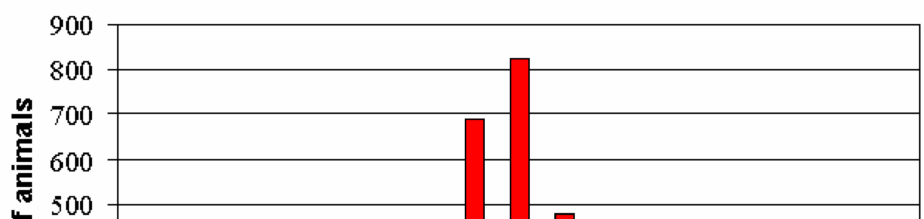

Figure 1: Frequency distribution for Angus bulls from the Australian Angus Breed Association with estimated breeding values for net feed intake (Analysis of bulls with accuracies > 19%; January, 2002)

In contrast to the lack of a correlation between NFI and growth rate, there was a large negative correlation between FCR and growth rate (r = -0.72). Bishop et al. (1991) and Arthur et al. (2001a) also found large negative correlations between FCR and growth rate (-0.54 and -0.74, respectively). In the current study, NFI was positively correlated with feed intake (r = 0.59) and FCR (r = 0.49). These correlations are similar to the phenotypic correlations reported by Herd and Bishop (2000) and Arthur et al. (2001a; 2001b), which ranged from 0.60 to 0.72 for NFI with feed intake and from 0.53 to 0.61 for NFI with FCR.

To further examine the relationships between NFI and performance traits, steers were ranked by NFI and separated into low, medium and high groups. As shown in Table 3, the high NFI steers (less efficient) weighed the same and gained the same as the low NFI steers, but the high NFI steers consumed 21% more DM feed per day and had 23% higher FCR compared to the low NFI steers.

Table 3. Characterization of performance traits in steers with low, medium and high net feed intake (**NFI**)[a]

Parameter[b]	Low NFI	Medium NFI	High NFI	SE	P-value
Number of steers	54	64	51	--	--
NFI, lb/day	-2.16	-0.11	1.94	0.13	.0001
Final BW, lb	715.0	714.1	712.1	11.9	.98
ADG, lb/day	2.24	2.29	2.24	0.07	.90
Feed intake, lb DM/day	17.49	19.29	21.10	0.13	.0001
FCR, feed DM/gain	7.91	8.66	9.71	0.25	.0001

[a]Low, medium and high NFI steers were < 0.5 SD, ± 0.5 SD, and > 0.5 SD from the mean NFI of 0.0 ± 1.6 lb/day (mean ± SD), respectively.

Likewise, in a study involving 75 steers fed a high-barley diet, Basarab et al. (2001) found that high NFI steers (> 0.5 SD above the mean) consumed 9% more feed per day and had 17%

higher FCR compared to low NFI steers (< 0.5 SD below the mean), even though growth rates and BW for the high and low NFI steers were similar. In this same study, heat production was estimated using slaughter balance techniques. They found that the low NFI steers (more efficient) produced 17% less heat than steers with high NFI. These results would suggest that NFI may be a trait that reflects genetic differences in metabolic processes that impact key components of efficiency such as maintenance energy requirements.

Ultrasound measures of 12th rib and rump fat thicknesses obtained at the end of study were negatively related with NFI (r = 0.22 and 0.18), but ultrasound measures of ribeye area and intramuscular fat percentage were not correlated with NFI. High NFI steers had greater rump fat thickness than low NFI steers (Table 4). These results are similar to recent studies reported by Arthur et al. (2001a) and Herd and Bishop (2000), and suggest that cattle with low NFI may be slightly leaner than cattle with high NFI. In contrast to these studies, Basarab et al. (2001) found that empty body composition at slaughter was not correlated with NFI in growing steers. Richardson et al. (2001) found that steer progeny from low NFI parents gained more empty body protein during the study than steer progeny from high RFI parents, however, they concluded that less than 5% of the variation in sire NFI was explained by the variation found in the empty body composition of their steer progeny. Increased leanness may have contributed to the improved feed efficiency of steers with low NFI, but the magnitude of this contribution appears to be small. Given that the magnitude of this difference in composition between low and high NFI steers was minimal, it is likely that other factors such as heat increment of feeding, activity, energy requirements for maintenance and growth, or protein turnover were also involved in accounting for the observed differences in feed efficiency found in this study.

Table 4. Characterization of ultrasound measures of carcass composition in steers with low, medium and high net feed intake (**NFI**)[a]

Parameter[b]	Low NFI	Medium NFI	High NFI	SE	P-value
Number of steers	54	64	51	--	--
NFI, kg/day	-2.16	-0.11	1.94	0.13	.0001
12th rib fat, in	0.156	0.161	0.167	0.004	.13
Rump fat, in	0.153	0.161	0.167	0.005	.04
Ribeye area, in^2	8.18	8.22	8.26	0.14	.90
Intramuscular fat, %	2.84	2.83	2.89	0.08	.73

[a]Low, medium and high NFI steers were < 0.5 SD, ± 0.5 SD, and > 0.5 SD from the mean NFI of 0.0 ± 1.6 lb/day (mean ± SD), respectively.

Implications: Based on previous research from Australia and Canada and recent research findings from our laboratories, it appears that NFI is a trait that has considerable potential to allow producers to select for more efficient cattle without the concurrent increases growth and mature body size that would occur if selection pressure were applied against feed conversion rate (**FCR;** feed per gain). The ability to identify cattle that consume less feed with no reductions in performance will improve feed efficiency and profitability as well as to reduce the environmental impact of animal waste.

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