Beef Cattle Breeding Selection for Improved Feed Efficiency

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WHY IS FEED EFFICIENCY IMPORTANT?

Feed cost is a critical factor in raising beef cattle, accounting for 50 to 70% of the total expenses incurred in maintaining the cow herd, backgrounding calves, or finishing cattle for harvest. Therefore, even subtle reductions in the efficiency of feed use may substantially improve profit margins. Optimizing feed utilization helps producers remain cost competitive, reduces their environmental footprint by minimizing feed needs, and enhances their economic resilience when unpredictable events, such as drought, cause feed prices to spike.

Even though differences among individual cattle in energy utilization has long been recognized[1], maintenance requirements have largely remained unchanged during the last 100 years of intensive beef production. [2] Though challenging to measure, efficiency of feed use varies among animals and can be improved by selecting those animals that are most feed efficient.

WHAT FEED EFFICIENCY MEASURE SHOULD BE USED?

Efficiency is often simply defined as input/output. [3] There are different approaches used to calculate beef cattle feed efficiency, with the most common described below.

Feed conversion ratio (FCR, F/G, or F:G)

Feed conversion ratio, often called ‘feed-to-gain’, is the ratio of feed dry matter intake (**DMI**) to animal body weight gain. [4] Typically, FCR ranges from 8:1 to 4:1 in cattle, with a lower ratio being more desirable. The inverse of FCR is gain-to-feed ratio (**G/F**) which is often reported in scientific literature as average daily gain (**ADG**) divided by daily DMI. [1] While FCR is good for describing a pen of cattle’s feedlot performance, the ratio is inadequate for selection of breeding animal(s) because it directly correlates with growth, failing to account for maintenance requirements. This means that while fast gaining cattle may have a relatively low FCR, they may also have a large mature size. Large mature size results in greater maintenance energy requirements. Because mature size is moderately heritable (~0.35), the progeny of large cattle are also likely to be large with high energy requirements. Another issue with relying on FCR is that differences between animals are independent of performance. In other words, the FCR of a low gaining animal with low feed intake may be the same as that of a high gaining animal with high feed intake, and neither may be genetically desirable breeding animals.

Residual average daily gain (RADG)

Residual average daily gain (or simply residual gain; RG) is the difference between actual and predicted average daily gain based on an animal's body weight, feed DMI and body composition. A positive value is more desirable and indicates that an animal gained more rapidly than was predicted for its weight, feed DMI, and body composition. The calculation of RADG emphasizes differences in growth rate rather than differences in feed intake. As a result, selection for RADG is expected to result in improved growth performance with little impact on feed intake. Like FCR, RADG may be better suited for identifying superior feedlot cattle than for selecting breeding bulls or replacement females.

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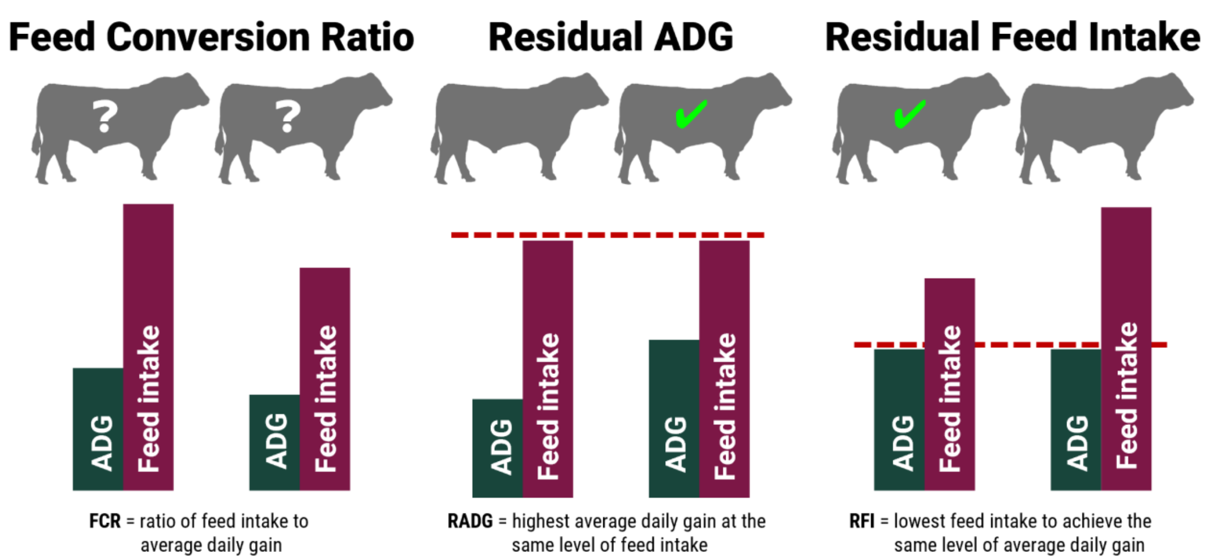
Residual feed intake (RFI)

Residual feed intake is an alternative measure of feed efficiency in growing beef cattle that is appropriate for use in genetic selection. [1; 5] Residual feed intake is the difference between the actual and predicted feed DMI based on an animal's body weight and gain. Some research has found that inclusion of a body composition estimate (fat) improves the variation accounted for by the RFI equation. A negative RFI value is more desirable and indicates that an animal consumed less feed than predicted. The advantage of using RFI is that it allows identification and genetic selection of animals that consume less feed, independent of their weight or growth performance.

> Residual feed intake is calculated from a regression as the difference between observed and expected feed DMI for an animal's metabolic body weight (BW) and ADG. [1]
>
> $$\text{Feed DMI} = \beta_0 + \beta_1(BW^{0.75}) + \beta_2(ADG) + RFI$$

Figure 1 illustrates the use of feed efficiency measures described above to make selection decisions. In the feed conversion ratio panel, the bulls have a similar FCR, even though one bull has both a lower ADG and feed intake. In this instance, using FCR would not allow for a clear selection decision. In the residual ADG panel, the bull on the right is more desireable as it has greater ADG, given the same amount of feed consumed. In the residual feed intake panel, the bull on the left has lower feed intake, given the same level of ADG. Residual feed intake also has the benefit of having a greater heritibility and being independent of animal body weight.



Trait heritability[6]	0.23	0.28	0.33
Trait genetic correlation with body weight[6]	-0.03	+0.07	-0.01

Figure 1. Feed efficiency measures in beef cattle (Adapted[6; 7]).

WHAT CAUSES FEED EFFICIENCY DIFFERENCES AMONG BEEF CATTLE?

The underlying mechanisms resulting in different feed efficiency estimates among animals are related to numerous genetic and environmental factors which are not yet fully understood. However, when comparing high RFI (less feed efficient) to low RFI (more feed efficient) cattle, the following appear to contribute to greater feed efficiency in low RFI cattle. [8-11]

- Altered feeding behavior with less time eating and slower eating rate
- Greater nutrient digestibility, likely because of lower feed DMI
- Less rumen microbial diversity
- More efficient whole body energy metabolism through reduced maintenance energy requirement and(or) increased energy efficiency
- More efficient cellular energy metabolism from enhanced electron transport chain coupling
- Reduced protein turnover with greater protein synthesis to degradation ratio
- Leaner body composition

IS FEED EFFICIENCY RANKING THE SAME FOR CATTLE RECEIVING HIGH GRAIN OR HIGH FORAGE DIETS?

Because feed reflects the largest cost in beef production regardless of the industry segment, cow-calf, stocker, grass-fed, and feedlot operators are all interested in improving feed efficiency. Ideally, selection for improved feed efficiency would work the same regardless of diet type, but reality may not be this simple. For example, feedlot cattle typically consume high-energy, grain-based diets, and the cow herd consumes moderate- to low-energy, forage-based diets. Regulation of ad libitum (full fed) feed intake may be different for these extremes in diet types. Our current understanding, which is the foundation for the publication Nutrient Requirements of Beef Cattle, is grounded in the concept that consumption of more digestible, high-energy (often high-concentrate, low-fiber) diets are controlled by animal energy demands and metabolic factors, whereas consumption of less digestible, low-energy (often high-forage, high-fiber) diets are controlled by physical factors, such as ruminal fill and digesta passage rate. [12] One may expect that feed efficiency at these two dietary extremes are potentially different traits. It is possible, therefore, that ranking of individuals for RFI could differ depending on the dietary energy concentration or forage level. That said, because there are components of animal maintenance energy requirements that are similar in both grain-fed and forage-fed cattle, there appears to be reasonable agreement in individual animal rankings of RFI (and feed DMI) among feed types. For example, feed DMI of a forage-based diet and a grain-based diet have been shown to be moderately correlated (r = 0.32 to 0.47) in Angus[13] and Charolais[14] beef cows, even though weight gain while consuming the two different diet types had no or low correlation (0.10). Likewise, feed efficiency studies using growing animals fed a high forage growing diet followed by a high grain finishing diet have reported that feed intake during the growing (high forage) and finishing (high grain) phases were highly positively correlated (r = 0.41 to 0.58). [15-17]

DOES GROWING HEIFER FEED EFFICIENCY TRANSLATE INTO MATURE COW FEED EFFICIENCY?

Sixty to 70% of overall feed energy costs for beef production is required by the cow. Of that amount, approximately 70% is needed for maintenance energy. [18] Therefore, roughly 40 to 50% of all energy required in beef production systems to produce a pound of beef is used to maintain the cow herd. Evidence from a Midwest study of integrated resource management records indicated that feed cost alone accounted for over 50% of the variation in profitability among beef cow-calf operations. [19]

One of the most comprehensive studies examining feed efficiency data of heifers and later as cows was completed at the U.S. Meat Animal Research Center (USMARC), using crossbred F_2 females containing Angus, Red Angus, Hereford, Red Poll, Simmental, Limousin, Charolais, Gelbvieh, and Pinzgauer breeds. Individual feed intake and body weight gain were measured on 687 heifers and then 622 of them as 5-yr-old cows. The heritabilities and genetic correlations are shown in Table 1. The authors concluded that feed intake and ADG are heritable and genetically correlated between heifers and cows, and that selection for decreased feed intake and ADG in growing animals should have the same directional effects on mature cows. [20]

Table 1. Heritability (diagonal) and genetic correlations (above diagonal) of average daily feed dry matter intake (DMI), average daily gain (ADG), and residual feed intake (RFI) as heifers and 5-yr-old cows[20]

	Heifer feed DMI	Heifer ADG	Heifer RFI	Cow feed DMI	Cow ADG	Cow RFI
Heifer feed DMI	**0.84**	0.86	0.52	0.84	0.83	0.25
Heifer ADG		**0.53**	0	0.66	0.73	0.04
Heifer RFI			**0.25**	0.54	0.39	0.41
Cow feed DMI				**0.53**	0.86	0.50
Cow ADG					**0.34**	0
Cow RFI						**0.16**

In an Australian study, low-RFI (more efficient) beef heifers, were found to be 7% heavier during their first lactation, but had similar fat thickness and calf weights compared with those identified as high-RFI (less efficient). However, low-RFI cows had a 15% advantage in efficiency expressed as the ratio of calf weight to cow feed intake. [21] Fortunately, many studies have not been able to detect unfavorable relationships between postweaning heifer RFI and temperament or fertility traits such as age at puberty, first-service conception rate, pregnancy rate, age at calving, calving rate, calving date, calf birth weight, or milk production. [22-25]

HOW SHOULD EFFICIENCY MEASURES BE USED IN SELECTION?

Astute cattle breeders know that single trait selection, even for feed efficiency, is not recommended. Multiple traits must be considered in successful selection strategies to maximize herd profitability. To this end, breed associations have encouraged commercial breeders to pay particular attention to economic indexes.

Sire and replacement heifer selection should focus on traits that directly impact profitability of the beef cattle enterprise. A trait that directly affects profitability is called an Economically Relevant Trait (**ERT**). An ERT must directly influence cost or revenue. Traits that do not directly influence profitability, but are genetically correlated to an ERT, are called indicator traits. Including indicator traits in selection decisions may slow genetic progress when the ERT is available. [26] When it comes to feed efficiency, feed DMI is an ERT and traits like FCR and RFI are considered indicator traits. [27] Therefore, the fastest genetic gain in herd profitability can be achieved by selecting breeding stock based on an economic index that includes ERT, such as market weight and feed DMI. [28; 21; 6] However, phenotypic feed DMI data are not yet broadly measured, collected, and included in EPD calculations by breed associations. Therefore, placing some selection pressure on feed DMI as an ERT or RFI as an indicator trait is preferred when a comprehensive index is not available.

Sire selection represents the greatest opportunity for genetic improvement in beef production systems. While genetic progress can occur through sire or replacement heifer selection, most beef producers raise their own replacement heifers, but purchase bulls outside the herd. New sire genetics then represent approximately 50% of the genetics in each successive calf crop. Assuming a sire is used for four years, and his daughters are retained, his impact will easily extend into the next decade, and granddaughters and great-granddaughters may remain in the herd for a quarter century after he last sires calves. [29] Consequently, because feed efficiency is moderately heritable, purchasing sires selected for superior feed efficiency is a powerful method for increasing overall herd feed efficiency.

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