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Improving Feed Efficiency Through Genetics

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INTRODUCTION

Feed efficiency is not a new topic to the beef industry. Historically this topic has been revisited by the industry every 10 to 15 years with little benefit to the producer. The lack of progress in understanding the genetics of feed efficiency stems from the difficulty in trying to accurately measure individual intakes, coupled with extreme costs and a long generation interval. Feed efficiency is difficult to define and needs to be evaluated in the producing female, as well as the growing/finishing animal. Heritability of feed efficiency has been estimated to be moderate, with values ranging from .28-.44. These values indicate that variation among and within beef cattle populations do exist for feed efficiency. This means genetic selection will work as a tool to improve feed efficiency. The main benefit of understanding the genetics of feed efficiency and developing tools to improve efficiency is reduced production costs. With 70-80% of the total variable costs in beef production being feed costs, the slightest improvement in feed efficiency will have a significant impact in profitability in multiple areas of beef production. Technology has developed to a point that we can better measure, record, analyze and implement selection for energy efficiency.

MEASURES OF FEED EFFICIENCY

Selection for feed efficiency has frequently resulted in indirect selection for increased mature body weight, such that over a given weight range cattle are physiologically younger. Increases in average daily gains have resulted in beef cattle being slaughtered at a much earlier age. The problem with these selection criteria, although good in the short term, is that it results in increased female mature body size. This increase in mature cow weight results in higher production costs and less efficient use of feed resources, coupled with some other unfavorable correlated responses like increased birth weight.

The most common measure of efficiency, historically across the industry, has been the feed conversion ratio (feed intake/gain). Indirect selection for this trait has occurred through selection for growth as mentioned in the previous paragraph. Feed conversion ratio, the most extensively used measurement of efficiency, is greatly influenced by growth and composition of gain. For the reasons already mentioned, this is not a measure on which one should place a high degree of selection pressure on. Traditional measures of feed efficiency all suffer from the same limitation. The measure is related to other traits; in animal breeding terms, if selection pressure is placed heavily on reducing feed intake/gain ratio, we should expect correlated responses in increases in growth traits, such as birth weight and mature weight.

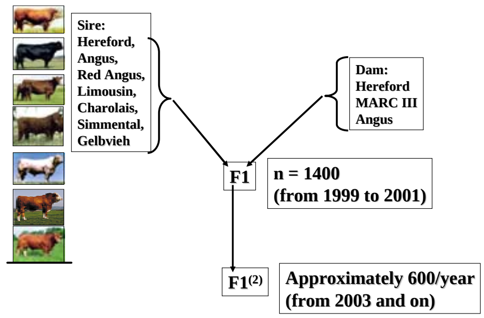
Residual feed intake (RFI) is presently the trait of choice among most researchers working in area of cattle energy utilization. The idea of RFI was first described in cattle by Koch et al. (1963). The approach uses an analysis where feed intake phenotype is forced to be independent of other traits under selection in beef cattle. This means that the measure of feed intake for an individual is not directly correlated with growth rate, fat deposition, milk production, size, etc. With this in mind, RFI allows for selection for favorable feed efficiency without being detrimental to the other important traits in beef production. The downside is that no data presently exists to analyze the long-term consequences of selection for RFI. RFI is the residual term from the regression of intake on body size and production traits (average daily gain, growth, milk, etc.). The lower the RFI value, the more efficient the animal is in terms of energy utilization. Many variations in calculations of RFI have been proposed, including the incorporation of body composition. The problem with RFI is deciding on a universal model to be used by the industry. Example RFI using a model regressing intake on weight and total gain versus a model regressing intake on weight and lean gain plus fat gain may change the rank of the animals in regards to RFI. Lessons from other species (poultry) using RFI in selection, suggest potential antagonistic effects may result for maternal traits. These correlated responses have not been well described for RFI due to lack of data available for mammals. Presently, the National Beef Cattle Evaluation Consortium (NBCEC) has put together a committee of university, industry and USDA experts to work toward a definition of RFI that will be utilized by the industry.

Currently, the data required for EPD development related to feed efficiency is limited. Mathematical models have and are being developed to predict energy intake for the finishing and maternal phases of beef production (Tedeschi et al., 2005; Williams and Jenkins, 2003). These models, as they become validated, could become useful tools in building the data needed to create EPDs for genetic selection.

USDA FEED EFFICIENCY PROGRAM

The USDA's, Meat Animal Research Center has begun implementing experiments scheduled for the next ten years to gather much needed data to help with the overall understanding of production efficiency, with an emphasis being placed in the area of feed efficiency. This project is comprised of two large experiments. The first is "Genomic basis of variation in efficiency of nutrient utilization in beef cattle (steers)," and the second is, "Genomic basis of variation in efficiency of nutrient utilization in beef female cattle." Both experiments will use animals produced from the Germplasm Evaluation (GPE) experiments, Cycle VII. Cycle VII was designed as the industry cycle. Industry bulls from seven breeds were utilized based on number of registrations. The breeds included are: Angus, Hereford, Red Angus, Charolais, Limousin, Simmental, and Gelbvieh. Angus, Hereford, and MARC III (composite- ¼ Angus, ¼ Hereford, ¼ Red Poll, ¼ Pinzgauer) females were artificially inseminated to industry bulls to produce F1 bulls and females. F1 bulls are multi-sire pasture mated to F1 females to produce a third generation $F1^2$ (Figure1).

Figure 1.
Structure of the GPE cycle VII population.

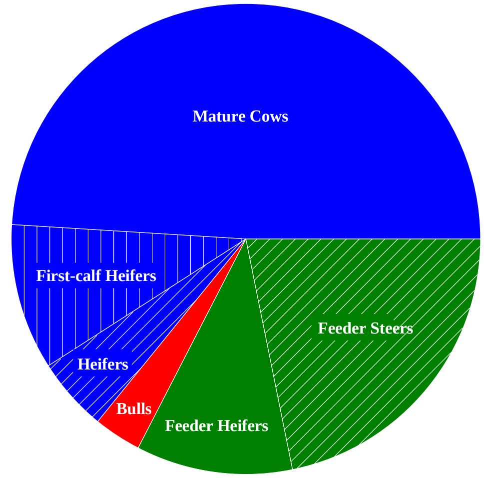


All sire progeny identification is determined using DNA paternity testing. The F1^2 generation is the set of calves being used for the energy utilization studies. This "industry" population was designed to identify quantitative trait loci (QTL) and validate marker tests in a population that is directly tied to the industry. Additionally, GPE VII data, combined with industry data, will assist in the development of multi-breed genetic evaluations.

The finishing phase of feed efficiency is measured in ~250-270 steers per year. Spring born GPE VII steers are fed a finishing ration ~140 days and serially slaughtered at 123, 137, 150 and 158 days. Animals are fed once daily with feed weighbacks recorded weekly. Body weights are recorded at the beginning and end with additional body weights recorded every 28 days. An additional phenotype collected includes flight speed (temperament), and blood sample taken every six weeks. Each steer has cooler data and rib cutout data available to estimate empty body composition, along with Warner Bratzler sheer force and taste panel to evaluate tenderness. Duration of this experiment is 2003-2012 with data collected on ~2,500-3,000 steers. In the first two years, 2003 and 2004, MARC has recorded individual intakes on 524 steers.

Feed efficiency of the growing and producing female has a large impact on beef production. With a large portion of the variable costs of production being feed for the producing female (Figure 2), research in this area is long overdue. Little data exist relating feed efficiency in the growing/producing female and the finishing animal.

Figure 2.
Proportion of the metabolizable energy used by class of cattle in beef production.



To build the data needed for the producing female, MARC has just initiated an experiment scheduled to continue through 2019. This experiment will use the females produced in the GPE VII $F1^2$ generation (sibs to the steers). Shortly after weaning, heifers will be fed a grower diet for ~170 days with feed intakes recorded similarly to steer contemporaries. Weights will be recorded every 14 days and flight speed every 6 weeks. During this time all females will be monitored for age of first estrus. All heifers will be bred to calve at approximately 24 months of age. Each female will be given the opportunity to calve seven consecutive years with twice opens being culled from the study. Milk production, udder and teat scores, feet and legs scores, flight speed and temperament will be recorded for first and seventh parturition. Females will be scored for condition, weighed, and measured for hip height three to four times a year. Calving data will include birth weight and dystocia scores. Progeny weaned from the $F1^2$ females will be weighed every 28 days after weaning. Following weaning after the seventh parturition weaning, mature females will be assessed for feed efficiency on forage diet. Phase 1 of the mature cow feed intake portion of the study will determine a fixed amount of feed over 112 days, based on each cow's maintenance requirements to maintain a body condition score of 5.5. During phase 2, cows will be fed *ad libitum* with the same forage ration for an additional 112 days. Both phase 1 and 2 cows will be weighed every 14 days.

In addition to building the data to increase the understanding of feed efficiency in the producing female, this study is assembling a large data set to assist in evaluating retention traits. The reasons a female leaves the herd are lack of production (either pounds of calf produced or failed reproduction), structure (feet and legs), udder/teat scores, dental condition and temperament. The first incisor and first molar will be measured on the females as they exit the experiment. We are presently evaluating GPE VII F1 females that are five years of age and following them out to eight to nine years of age to see if a measure at five years of age can be used successfully to predict dental condition (wear) in the aging female and does a measurement at a younger age correlate to dental measurements at an older age. The goal is to build a set of indicator traits that can be used in younger female to predict retention (longevity).

GENETIC SELECTION FOR FEED EFFICIENCY THE FUTURE

In the short term, the industry will see the development of EPDs for feed efficiency, most likely in the form of RFI, using models to predict the individual animal's RFI. The first EPD for RFI will most likely be for the finishing phase of beef production. Presently these models are being validated with actual individual feed intake data gathered in finishing animals through the NBCEC feed efficiency group. As EPDs are implemented for feed efficiency, they need to be used with care. In other words, extreme selection pressure for feed efficiency using an EPD developed for the finishing phase without knowledge of the correlated responses or long-term effects on fitness and adaptability could potentially lead to a less efficient cow herd. At the present, we do not know if the relationship for energy efficiency in the finishing animal is positively or negatively correlated with the producing female. These unknowns are a primary justification for the female production efficiency experiment. Phase 1 and 2 of the mature cow analysis will generate data that allows one to look at differences in actual individual maintenance requirements and characterize individuals that may be extremely efficient when feed resources are limited and less efficient or the same when energy is in excess. Jenkins and Ferrell (1991) previously showed differences between breeds in energy efficiency relative to energy intake levels by measuring heat production with indirect calorimetry. Hereford females were more efficient than Simmentals when fed low levels of energy, but as energy levels increased they became similar, and at the highest level, less efficient than Simmental females. Changes in the rumen environment and digestibility in response to finishing versus mature cattle diets, would also make one think that feed efficiency in the finishing animal may not be the same as the mature cow.

DEVELOPMENT OF MARKER AND MARKER ASSISTED SELECTION

One of the primary objectives of the steer and female experiments are to develop the tools needed to help create EPDs and markers to be used for marker-assisted selection. For a trait that is extremely difficult to measure in the industry setting, application of genetic markers provides opportunities to improve economics of beef production through the genetic selection for feed efficiency, without measuring feed intake directly. If differences exist between cow efficiency and finishing efficiency, markers would be an excellent way for producers to assure improvement for a desired phase of production. Identification of QTL requires large pedigreed populations with individual DNA samples and phenotypic data. The feed efficiency projects at MARC will map QTL in the producing female at two life stages (growing and mature) and during the finishing phase in steers. From these QTL, markers will be developed for industry application of marker-assisted selection to improve energy efficiency in beef cattle.

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