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Feed efficiency - how should it be used for the cow herd?

Andrew Roberts, Rick Funston[*], Travis Mulliniks, Mark Petersen, and Mike MacNeil.
USDA-ARS, Fort Keogh Livestock and Range Research Laboratory, Miles City, MT
[*]University of Nebraska West Central Research and Extension Center, North Platte

Introduction

Improving cow herd efficiency is critical because approximately 70% of the feed inputs required to produce a slaughter animal are used for maintenance, the majority of which is utilized by the dam (Williams and Jenkins, 2006). To date, much of the efforts to improve efficiency in cattle have focused on different measures of feed efficiency (variations in amount of feed consumed and rate of weight gain) determined during the growing phase. While this approach provides pertinent information concerning efficiency during the growing phase, the relationship to cow efficiency remains to be determined. When considering the usefulness of feed efficiency as an indicator of cow efficiency, it is important to assess the specific approach used to determine feed efficiency and compare the input and outputs that contribute to efficiency during the different phases of production. In cows, the most critical factor influencing output component of efficiency is lifetime reproductive rate, not weight gain. Lifetime reproductive rate is a cumulative process and may require years to establish which has limited efforts to identify processes contributing to variation in output among individual animals. Furthermore, nutrition and management components of cow-calf production in range environments are more complex and subject to greater seasonal and annual variation than in confined settings where harvested feeds of relatively homogeneous quality are typical of the feedlot phase of production, and while technology exists to measure feed intake of individual animals in a feedlot setting, methods are not available for quantifying feed intake under grazing conditions.

The wide variations in environmental and management conditions existing in cow-calf production contribute to the challenge of establishing genetic components of efficiency universal for all cows and likely impart the need to match different genetic types to different production environments. Matching cow type to production environment is becoming increasingly more important due to rising costs of providing supplement feed when production potential exceeds nutrient availability. Increasing cost associated with providing supplemental feed to the cow herd may lead to greater distinctions between biological and economic efficiency in the cow-calf phase compared to other segments. For example, cows that consume more calories during the vegetation growing season and gain sufficient weight to exist on less harvested feed inputs during winter may require less total economic input than cows with greater potential for feed conversion that consume less during the growing season, but require more calories from harvested feed later. Efficiency of beef cattle production requires a balance between amount and cost of nutritional inputs with prolonged optimal output. A provocative question to consider is whether traditional approaches of providing sufficient feed to a herd of cows to achieve a relatively high rate of reproduction results in improved efficiency or not? Is this analogous to selecting a type of cattle and managing the environment to sustain the type?

Feed Efficiency

A review of characteristics and limitations of different measures of feed efficiency is important when considering what potential impact each might have on cow efficiency. Some common approaches used to express feed efficiency include: 1) feed conversion ratio (ratio of feed eaten to weight gain; **F:G**), 2) ratio of weight gain to feed intake (**G:F**), 3) residual feed intake (**RFI**) and 4) residual growth (**RG**). Residual feed intake is the difference above or below the average feed intake for a given size and growth rate; animals with negative RFI values are considered to be more efficient (consume less than average to achieve their rate of gain) than animals with positive RFI values (consume more than average to achieve their rate of gain. Residual gain is the difference in the rate of gain for a given amount of feed consumed; animals with positive RG are considered more efficient (gained above average for their level of feed intake) than animals with negative RG.

A major limitation to these and other methods of expressing feed efficiency is they result in a single value to describe differences in both feed intake and growth rate. Within each approach, it is possible to have animals with the same efficiency value that are vastly different. For example, an 8:1 feed conversion ratio describes an animal that consumed 8 lb of feed and gained 1 lb per day. This is also the ratio for an animal that consumed 24 lb of feed and gained 3 lb per day. Thus, while these two animals are equally effective at converting feed to body weight, one does it much faster than the other. Total time required to achieve a final weight can have a large impact on overall efficiency of animals in the feedlot, and needs to be considered. This same criticism exists for other methods of expressing feed efficiency. Another limitation is the different methods of expressing feed efficiency may not correspond to similar results. Data shown in Figure 1 illustrate RFI and RG values on a set of animals do not result in similar ranking. Some animals with negative RFI values (considered efficient) are negative for RG (indicates inefficient). Likewise, some animals with positive RFI values are positive for RG, which corresponds to inefficient and efficient ranking by the two approaches, respectively. Furthermore, interactions of genotype and environment may influence measures or RFI (Durunna et al., 2011). This indicates ranking of animals may change depending on diet (or other conditions) used to establish RFI. Diet change can also result in large differences in F:G or G:F values, limiting comparisons across studies. These limitations indicate the need to re-evaluate how these measures should be used to improve efficiency in growing animals, let alone what impact they may have on efficiency in the cow herd.

Information concerning associations of feed efficiency measures in growing animals and traits important to the cow-calf segment of beef production is scarce. A recent report indicates an absence of correlations among F:G, RG or RFI with cow fertility, calving difficulty or perinatal mortality (Crowley et al., 2011). However, these researchers did observe correlations indicating efforts to improve these measures of feed efficiency could be associated with older age at first calving. The lack of correlation with other traits could be interpreted as being positive (i.e., selection wouldn’t be detrimental). Alternatively, another interpretation might be the outcome is influenced by the limitations discussed above; animals with similar values for a feed efficiency measurement may be very heterogeneous thereby precluding the detection of a correlation.

Constraints for feed efficiency described above can be resolved by using alternative approaches. Because feed intake and growth rate are two separate traits, it is appropriate to use both measures in a selection index. An example of this approach is provide by MacNeil and Herring (2005), who derived a selection index with relative economic values of -22 for dry matter intake (DMI) and 104 for postweaning gain, providing an indication of the relative weighting factors for these two traits. Likewise, Rolfe and coworkers (2011) recently reported selection indexes including both RFI and weight gain produced better genetic progress for positive economic outcomes than selection for G:F or RFI alone.

Cow Efficiency

Although current emphasis is being placed on feed efficiency of animals in the growing and finishing phase, there is more potential to alter overall efficiency of production if focus is placed on the cow herd. Consider the differences between feed conversion in a growing animal (several pounds of feed required to produce a pound of gain) and the tons of feed a cow will consume to produce a calf. The relative lack of vertical integration in cattle production also extends the need for trying to improve efficiency in the cow herd, as this extends improvement in efficiency to this portion of the production cycle.

Like feed efficiency in growing animals, approaches for establishing differences in cow efficiency should adequately account for variation in both the input and output traits. However, methods to measure feed consumption by individual animals under range conditions are lacking at this time. Thus, information concerning the magnitude of differences in feed intake that exists among animals in grazing environments is scarce. Measures of DMI during confined feeding of heifers (Herd et al., 2003) and young cows (McDonald et al., 2010) appear to be predictive of level of feed consumption later in life. However, there is evidence re-ranking of animals by DMI can occur depending on age and diet (Durunna et al., 2011). This indicates predicting differences in feed intake of cows under grazing conditions later in life from measures earlier in life may be more accurate if forage type diets are used for the testing.

Although the lack of methodology to easily measure feed intake under range conditions limits the ability to establish differences in feed consumption, opportunities exist to improve economic efficiency of production by focusing on differences in output within a given nutritional environment. This can be viewed as an approach to match genotype (or biological type) to environment. The first and most important output to consider is reproductive success; cows must produce a calf. Weight of calf produced can be considered as a secondary output. The nutritional environment is influenced by yearly and seasonal variations in plant growth and amount harvested (grazing intensity). The traditional approach to deal with seasonal and annual variations in forage resources is to provide supplemental feed. Type and amount of harvested feed required is a function of the difference between nutrition required and nutrition available. Nutrition required is dependent on stage and level of production. Stage of production (i.e., calving season) can be altered to provide the best match of nutrient requirements with nutrient availability throughout the growing season. Level of production is a result of genetic selection. If genetic potential for production markedly exceeds the nutrient resources available, reproductive failure will occur in the absence of substantial supplemental feeding. A question producers need to ask is whether the genetic selection imposed over time has influenced quantity of supplemental feed required? Management practices that minimize costs associated with feed inputs, including altering type and amount of harvested feeds required throughout a production cycle will impose selection for economic efficiency.

Current approach to assess balance between nutrient requirement and availability is to use body condition score (**BCS**). The commonly accepted recommendation is that cows be managed (fed) to achieve a BCS of 5 to 5.5 at initiation of breeding. This recommendation is based on research that indicated lower BCS was associated with more cows that failed to conceive. However, the response is not absolute; some cows are capable of rebreeding at BCS less than 5. Furthermore, the normal variation among animals in a herd will result in some cows being below and some above the average BCS of the herd at any given time. This variation may reflect differences in stage and level of production (especially milk), cow size (maintenance energy requirements) and fleshing ability. Some of this variation reflects differences in how cows prioritize the partitioning of nutrient intake towards the different biological processes (self preservation/body reserve, milk and reproduction).

Research at New Mexico State University provides evidence not all animals need to be fed to a BCS of 5 (Mullinks et al., 2011). Grouping animals by BCS at parturition (BCS 4, 5, or 6) did not have an influence on pregnancy rates or calving interval in young cows grazing native range with minimal feed inputs ($35-50/hd/yr) when evaluated over a 6 yr period (Table 1). These results may be partially explained by the management of the cows used in this study. First, the cows used in this study were offspring of cows that have been managed in a low input production system for multiple generations. In addition, variation of BCS

Table 1. Effects of calving BCS on reproduction, cow weight and weight change, serum metabolites, and calf weight in young cows grazing native range.

	Calving BCS[1]				
Measurement	4	5	6	SEM	*P*-value
Cows, No.	186	108	57		
Body Condition Score					
Calving	4.3	5.0	5.8	0.1	< 0.01
Branding	3.9	4.3	4.8	0.2	0.05
Weaning	4.6	4.8	5.3	0.1	0.01
Calving date[2], Julian d	61	61	67	5	0.28
Days to resumption of estrus	84	82	80	9	0.93
Pregnancy, %	92	91	90	--	0.68
Calving interval, d	371	375	371	8	0.85

[1]Calving BCS of 4 (mean BCS = 4.3 ± 0.02; range 3.5 - 4.5), 5 (mean BCS = 5.0 ± 0.03; range 5.0 - 5.25), or 6 (mean BCS = 5.8 ± 0.06; range 5.5 - 7.0).
[2]Calving date of the study year.

among cows in the present study was a response to the collective effects of management, genetics and environment and not due to nutritional manipulation to achieve certain calving BCS. The approach of experimentally decreasing nutrient intake and causing cows to lose BW prior to calving to achieve a certain body condition may have unaccounted-for negative effects on reproductive efficiency that were not apparent in non-manipulated cows who would be normally thinner. Overall, extensive and strategic range cow herd management implemented over multiple generations may create lower BCS thresholds for reproductive success while decreasing production/feed costs.

Management Strategies for Cow Efficiency

A question to consider is whether traditional approaches of providing sufficient feed to a herd of cows to achieve BCS that will relate to comparatively high rate of reproduction results in improved efficiency or not? Numerous research studies have shown this approach is advantageous when evaluated over a year of production. However, the long term impacts of "feeding to breed" have not been evaluated. If some proportion of the cows in a herd could reproduce with less supplemental feed, and additional feed is only needed to ensure the less efficient cows remain productive, then current guidelines may actually be sustaining less efficient cows in the herd and thus be counterproductive toward improving lifetime productivity. Providing supplemental feed to maintain cows in production may be analogous to selecting a type of cattle and managing the environment to sustain the type.

In the fall of 2001, researchers at Ft. Keogh initiated a long-term study to address the question of what happens when cattle are managed corresponding to restriction imposed by a limited environment and provided relatively minimal inputs rather than fed for a desired level of production? Cattle used in this research were from the **CGC** composite herd developed at Ft. Keogh (50% Red Angus, 25% Charolais and 25% Tarentaise). In 2001, the CGC herd was divided into two groups for lifetime treatments. During December to March of each year, cows were fed what was expected to be **adequate** levels of winter supplemental feed (~ 4 lb alfalfa hay per cow/day) and the other group was fed **marginal** levels of feed (~ 2.4 lb alfalfa hay per cow/day), based on average quality and availability of winter forage (Roberts et al., 2009a). All cows were managed as one herd throughout the rest of the year until the following winter when they were again separated into their respective winter feeding treatment groups. Each year at weaning, heifer calves from these cows were randomly assigned to be developed for 140 days on either all they could eat (**Control**) or restricted (**Restricted; 80% of Control**) levels of harvested feed. Each subsequent winter, Control heifers were fed with the Adequate cow herd and Restricted heifers were fed with the Marginal herd. As would be expected, growth of heifers during the postweaning development period was reduced by the restriction treatment (1.14 vs. 1.5 lb/d for Restricted vs. Control; Figure 2). Because heifers in the restricted group grew at a slower rate, the overall difference in amount of feed provided to the restricted animals was 27% less than the control. Restricted heifers had greater G:F during the 140 day restriction and greater ADG when grazing on pasture after restriction; both indicators of improved efficiency (Roberts et al., 2009a). Average pregnancy rates were for the two treatment groups over the last 8 years are 89.1 and 91.9 % for restricted and control groups, respectively. An economic evaluation of cost to achieve equal number of pregnant heifers indicated a $21 savings in feed cost/pregnant heifer for the restricted fed group over the control (Roberts et al., 2009b). Several studies in Nebraska (Funston et al., 2011a) have demonstrated similar decreases in development costs and subsequent target weights at breeding without impacting pregnancy rates. Methods used for restricting development rate differed between Nebraska (i.e., lower quality diet) and Fort Keogh (i.e., lower quantity fed), however, with similar results. These studies indicate an opportunity to improve efficiency and decrease production costs by decreasing amount and (or) quality of harvested feeds used for heifer development.

Top panel of Figure 3 depicts pre-breeding weights of the Ft Keogh CGC cows at 2 to 5 years of age, after heifer development using the two nutritional schemes. For these data, animals are grouped by their postweaning development treatment and by pre-partum winter feeding treatment their dam was assigned to. Heifers restricted during the postweaning period and subsequently fed less during each winter remained lighter than their contemporary controls. Because these animals are lighter, it is expected they might also have reduced maintenance requirements. An interesting result from this study is the level of supplemental feed provided during gestation influenced weight of their daughters later in life. Cows out of dams provided marginal levels of supplemental feed during the winter were heavier than cows out of dams provided adequate winter supplemental feed. These results appear to be due, in part, to differences in BCS at time of weighing. The finding that level of winter supplementation influences subsequent generation provide an example of what scientist are referring to as uterine or fetal programming. Maternal nutrition during gestation has been reported to influence fetal organ development, muscle development, and postnatal calf performance including carcass characteristics and reproduction (Funston et al., 2011b).

Bottom panel of Figure 3 depicts retention of cows on the Ft Keogh study. The main criteria for retention were production and weaning of a calf, with a few animals being culled for structural problems or disposition. As with body weight data described above, retention data shown in Figure 2 are grouped by individual and dam treatments. Retention at 2nd, 3rd, and 4th breeding was greater for control cows than restricted cows (black line vs. grey lines in Figure 3). At present, neither dam nor individual animal treatment effects are evident on retention to 5 and older (total retention of 228 out of 505 possible at 5th breeding). Greater losses at the younger ages (2-4) are consistent with these age groups having greater nutritional requirements associated with continued growth. The results are also consistent with what would be expected based on previous studies that observed positive associations with level of supplement and reproductive performance. If current results do not change over time allowing more cows opportunity to reach the older age groups, the absence of differences at older ages may be indicative of relatively stable populations evolving under each management protocol. It will be of interest to determine if offspring from these populations differ with respect to capacity to function under reduced feed inputs.

Biological Type and Efficiency

The management strategies for efficiency discussed above revolve around the idea that efficiency within a given production environment will vary due to biological type. In general, production potential (growth and/or milk) is positively associated with maintenance requirements, and as such, animals with greater production potential will likely require greater feed inputs (Ferrell and Jenkins, 1985). It is well documented that decreased energy availability can result in increased postpartum interval and or failure to resume cycling in sufficient time to allow rebreeding. The negative effects of energy limitation on postpartum interval have been shown to be more adverse in breeds with high growth potential than breeds with moderate growth potential (Nugent et al., 1993). Interestingly, negative effects of energy restriction on postpartum interval were more severe in high growth breeds with moderate genetic potential for milk than high growth breeds with high milk potential. Effects of energy restriction on postpartum interval were not different between moderate growth breeds classified as either moderate or high potential for milk. However, when reproduction and calf output were evaluated, breed crosses with low potential for milk production were determined to be more biologically efficient than breed crosses with medium or high potential for milk (Montano-Bermudes and Nielson 1990). These and other studies provide compelling evidence that efficiency of production can be improved by matching genetic potential for growth and milk with the production environment.

Currently some breed associations publish maintenance energy EPD that provides indication of differences in cow maintenance based on average requirements for a given mature size (adjusted to a common BCS) and level of milk production. These EPD can be used when working within a breed to help match genetic potential for production to production environment. At present, these EPD do not account for animals above or below average for a given mature weight and level of milk production. This deficiency will likely be overcome as more information on variation in individual animal feed intake is acquired.

Summary

In cows, the most critical factor influencing the output component of efficiency is reproductive rate, and not necessarily weight gain. Thus benefits of selecting animals with desirable measures of feed efficiency on cow efficiency remain to be determined. The feed input component of cow efficiency in range settings is more complex and subject to greater seasonal and annual variation than in confined settings relying solely on relatively homogeneous harvested feed typical of the grower/finishing phase. Methods to measure feed intake while grazing under range conditions are lacking. Seasonal and annual variations in quantity and quality of forage can result in greater distinctions between biological and economic efficiency in the cow-calf phase compared to other segments. For example, cows that consume more calories during the growing season and gain sufficient weight to exist on less harvested feed inputs during winter may require less total economic input than cows with greater biological efficiency that consume less during the growing season, but require more calories from harvested feed later. While supplemental feed has been relatively inexpensive over the last several decades, changes in demand for feed resources due to increased utilization for bio fuels has resulted in large increases in feed prices. More now than ever, efficiency of beef cattle production will require a balance between economic aspects of nutritional inputs and prolonged optimal output.

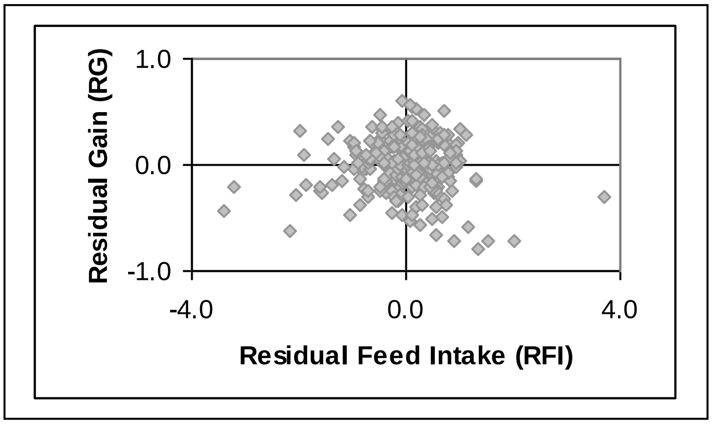

Figure 1 Relationship between Residual Feed Intake (RFI) and Residual Gain (RG). Animal which ate less food than the average for a given weight and rate of gain have negative RFI, and are thought tobe more efficient than average). Animal which gained more weight than the average of animals at similar weight and level of feed intake have positive RG values and are considered more efficient than average. Animals in the upper left quadrant (n=61) are classified as efficient by both approaches. Animals in lower right quadrant (n=68) are classified as inefficient by both approaches. Classification of efficiency for animals in the lower left (n=51) and the upper right (n=80) are opposite by the two approaches.

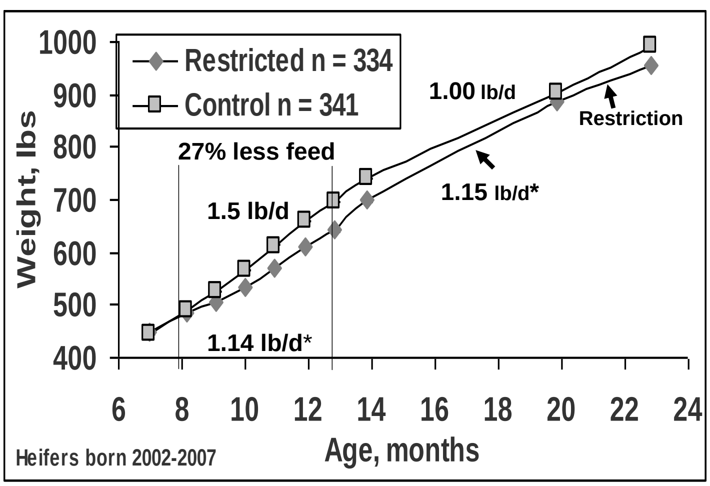

Figure 2. Growth of heifers developed for 140 days during the post weaning period (time period bracketed by vertical lines) when fed either all they could eat (Control) or restricted to 80% of Control intake at common body weight (Restricted). Diet was 64% Corn silage, 23% alfalfa, and 13% supplement). Restricted Heifer development improved efficiency, as indicated by greater gain:feed during the 140 restriction and greater ADG, and lighter weight after restriction, when grazing on summer pasture.

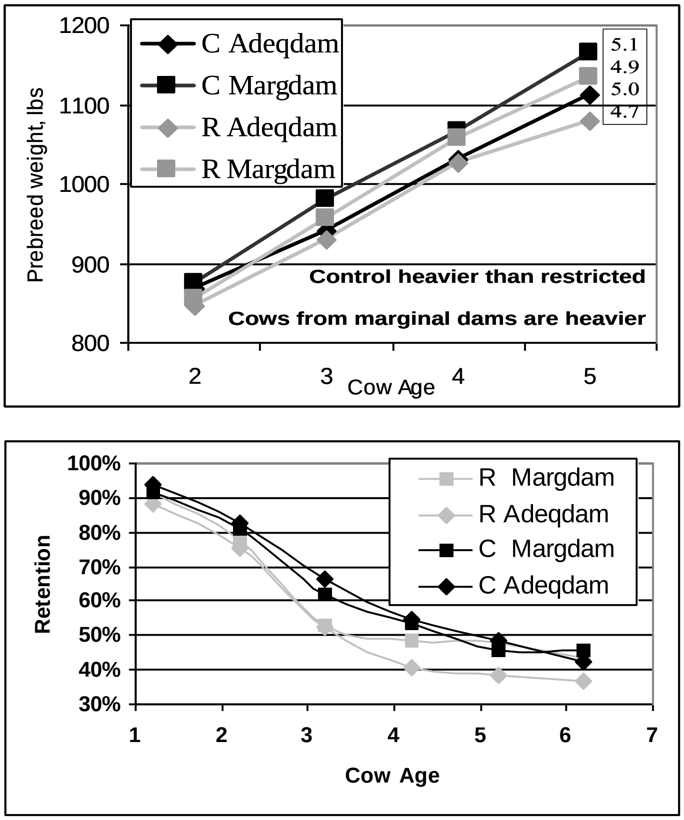

Figure 3. Prebreeding weight (top panel) and retention (bottom panel) of cows at different years of age. Cows were born from dams which were provided either adequate (Adeqdam) or marginal (Margdam) levels of supplemental winter feed prepartum. Cows were developed on control (C) or restricted (R) levels of feed during the postweaning period (see Figure 2) and then fed either marginal or adequate levels of supplemental feed each winter. Restricted cows remained lighter than Controls (grey vs. black lines). Cows out of marginally supplemented dams (square symbols) were heavier than cows from adequately supplemented dams (diamond symbols) due, in part, to differences in body condition (numbers shown in upper right corner of top panel). During first 3 years of production, retention was greater for control cows than restricted cows (black line vs. grey lines). Evidence to date (study not yet over), indicate dam treatment may influence differences in retention of Restricted cows later in life.

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