Perspectives on Cow Efficiency from USMARC Research

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Introduction

Cow efficiency has rightfully been promoted as the optimal goal in genetic improvement programs for commercial cow/calf production. Unfortunately, definitions of cow efficiency are often lacking and tend to focus on population measures such as weight weaned per cow exposed or per unit of land area. These measures are very useful to measure operation progress over time but do little to sort individual animal attributes that contribute to efficiency.

Instead, from a genetic evaluation perspective, we need to focus on relevant individual animal traits that contribute to progress in cow efficiency. A short list, that likely does not include all possible traits, could include measures of female fertility, cow energy requirements (maintenance, growth, and lactation), cow and calf survival including disease resistance, calf growth potential, cow and calf intake, and cow longevity. Some of these traits overlap in their definition; for instance, cow energy requirements and cow intake both target the feed cost complex. While one could argue that intake is the economically relevant trait, variation in energy requirements could modify intake for periods where energy is not measured or when different draws on energy occur (e.g, lactation, pregnancy, growth). Use of any of these traits in selection programs would depend on deriving decision support tools such as indices to utilize the measures.

Some key challenges of these traits are that many are difficult to measure and that they often have low estimates of heritability. Calf growth is an exception that is obviously a long-standing component of current genetic evaluation systems; unfortunately, non-genetic effects of the dam and genetic effects of the sire can mask the genetic effects of the cow. However, individual measures of intake can be very expensive to obtain and measured of fertility and especially longevity can dramatically increase generation intervals or decrease prediction accuracy because of the time required to obtain these traits. Thus, any outside information to help inform producer decisions regarding these trait complexes can be very helpful. The USDA, ARS, U.S. Meat Animal Research Center (USMARC) has a long history of providing useful genetic results to the beef cattle industry that can help with these decisions. Many of these results have been in the form of breed differences; these can elucidate which breeds may be useful to add to increase efficiency in commercial cow herds. The purpose of this paper is to summarize history and current results from the USMARC germplasm evaluation (GPE) program and other genetic resource populations relative to beef cow efficiency.

Components of efficiency from historic USMARC research studies

Historical studies at USMARC helped to establish components of energy utilization for different stages of production in different breeds. In many of these studies breeds with high or low genetic potential for growth and/or lactation were compared such that some breeds showed high potential for low growth, low lactation; high growth, low lactation; low growth, high lactation; or high growth, high lactation. By examining energetic requirements for these production characteristics in representative breed groups, Ferrell and Jenkins (1985) established that animals with a high capacity for milk production or growth also had higher maintenance requirements, even during mature (low growth) non-lactating life stages.

An additional study by these same authors (Jenkins and Ferrell, 1994) examined the effect of different diet regimes on cow biological efficiency for 9 different cow breeds. Regimes were 58, 76, 93, or 111 g/wt$^{.75}$ of dry matter, corresponding to low vs. high levels of intake for maintenance (where the first levels were insufficient for maintenance). Intake allowance increased during lactation at a constant rate for each regime (18g/ wt$^{.75}$). Response variables measured were birth and weaning weight of calves from the cows, calving rate, cow weight and cow condition score. Cows were recorded up to 5 yr. Cow body composition was strongly affected by dry matter regime as intended. Breed differences were observed for overall efficiency based on predicted functions of calves weaned per cow over the five years; in general, lower frame/growth breed types generally exhibited higher efficiency at lower intake levels than larger breeds with higher growth potential. The main driver of efficiency was the number of calves born and raised per cow, and breeds that were able to raise a calf to weaning in most of the 5 years were the most efficient regardless of calf weight weaning. Some of the low frame/growth breeds excelled at producing a calf each year, even under the lowest intake regime. Fertility continues to be the main driver of cow efficiency and is likely even more important in environments where cows are challenged with reduced intake.

Given the importance of fertility, any strategy that can increase cow fertility should be considered. Crossbreeding provides a valuable tool to address fertility, especially since genetic selection for fertility can be slow given a low estimated heritability and low realized accuracy due to it being measured on adult cows. Nunez-Dominguez et al. (1992) and Cundiff et al. (1992) examined crosses of Hereford, Angus, and Shorthorns relative to purebreds of the same three breeds. Crossbred cows produced an average of 0.97 calves over a 12-yr span (with culling open cows) than purebreds. Additionally, cumulative calf weaning weight was 30% higher from crossbred cows mostly due to higher numbers of calves weaned. These studies established that heterosis from crossbred cows can lead to real gains in biological and economic cow efficiency. These advantages are often overlooked in production systems today. Income from crossbred vs. purebred cows was over 22% higher – a number that could easily lead to a net loss or gain in commercial operations.

These classical studies established fertility and lifetime productivity as primary drivers of cow efficiency. Still there is room for improvements in efficiency through decreased feed costs as long as cows continue to produce calves. One primary driver of these feed costs is cow size and variation in maintenance energy requirements after size is accounted for. Recent studies at USMARC have focused on variation in cow weight and intake requirements.

Current breed differences and genetic variation in cow intake

The current USMARC continuous GPE program evaluates 18 different cattle breeds that represent over 99% of the registered cattle in the US. This study annually produces an array of crossbred and purebred (> 7/8 of one breed) calves. The majority of heifers from this program are retained to evaluate maternal traits, thus leading to tools that could impact mating decisions for cow efficiency. While not all the traits mentioned above related to cow efficiency have been evaluated, there have been considerable efforts related to cow intake costs; specifically, mature cow weight as an indicator of feed costs, direct cow intake, and maintenance energy as a new indicator of cow costs.

Mature weight has been increasing dramatically in US beef cattle herds in the era of genetic evaluation. Ribeiro et al. (2022) analyzed mature weights from the GPE population using data from parity 1 through 8; weights were recorded 3 times per year for each cow. Models fitted were either multivariate (each parity separately) or repeatability models with fixed effects of birth year x season (contemporary group) and fixed covariates for heterosis, age in days, and breed percentage; a fixed parity was also fitted in the repeatability model. A subjective body condition score (1-9 scale) was collected with each weight and was analyzed using the same models. Breed effects for mature weight, body condition score, and mature weight adjusted for body condition (using genetic regression) are shown in table 1. From these values, British breeds were generally as large or larger than continental breeds for mature weight. Most breeds differences for mature weight were within standard error with the exceptions of Beefmaster, Braunvieh, Gelbvieh, and Maine Anjou, all of which were significantly smaller with Braunvieh being the smallest by far. When adjusted for condition score, in general the breed means converged implying that some larger mature weight breeds were larger due to condition score. However, if these values are used to make breeding decisions, it is likely better to examine effects of unadjusted mature weight and condition score separately for their impact on cost in the breeding objective. Based on these results, if mature weight is a primary driver of feed cost, no breed will eat significantly less feed in the cow herd as even the lower weight of Braunvieh is likely partially offset by increased energy required for lactation. These results demonstrate the need to increase granularity in variation in mature weight within breeds and, eventually, actual feed intake measurement of mature cows for true feed costs.

Breed	**Mature Weight (lb)**	**Adj Mature Weight (lb)**	**Condition Score**
Angus	0	0	0
Red Angus	-47.8 (20.5)	-53.8 (18.1)	0.04 (0.08)
Beefmaster	-76.1 (25.8)	-56.9 (22.7)	-0.13 (0.10)
Brahman	20.9 (30.0)	9.3 (26.5)	0.08 (0.12)
Brangus	-45.0 (24.7)	-27.3 (21.8)	-0.12 (0.10)
Braunvieh	-194.7 (29.3)	-113.5 (26.0)	-0.55 (0.11)
Charolais	14.3 (20.3)	14.3 (17.9)	0.004 (0.08)
Chiangus	-33.1 (26.5)	-7.9 (23.4)	-0.17 (0.10)
Gelbvieh	-71.2 (20.5)	7.1 (18.1)	-0.53 (0.08)
Hereford	-30.4 (19.2)	-14.3 (16.8)	-0.11 (0.07)
Limousin	-76.3 (20.3)	-17.4 (17.9)	-0.40 (0.07)
Maine-Anjou	-62.6 (26.0)	-19.8 (22.9)	-0.29 (0.10)
Salers	-20.1 (28.0)	9.5 (24.7)	-0.20 (0.10)
Santa Gertrudis	-33.1 (27.6)	27.3 (24.5)	-0.41 (0.10)
Shorthorn	-49.8 (24.7)	24.0 (21.8)	-0.50 (0.09)
Simmental	-17.0 (19.6)	15.4 (17.2)	-0.22 (0.07)

Table 1. Breed differences (SE) from repeatability models for mature weight, mature weight adjusted for body condition score, and condition score.

Measuring feed intake as the true economically important trait in relation to cost of production is more desirable than a proxy through cow weight. However, measurement of individual feed intake is costly and rarely performed on mature animals. Phenotypes on growing steers and heifers may still be useful if they are correlated to mature cow intake. The USMARC has reported intake and gain for heifers on a pre-breeding roughage ration and steers on a concentrate ration. These values were last summarized in Retallick at al. (2017). Breed differences from these analyses are reported in Table 2:

Breed	**Steer ADFI (lb)**	**Steer ADG (lb)**	**Heifer ADFI (lb)**	**Heifer ADG (lb)**
Angus	0	0	0	0
Hereford	-1.74 (0.63)	-0.08 (0.12)	-2.12 (0.59)	-0.05 (0.10)
Red Angus	-0.68 (0.61)	-0.15 (0.11)	-1.51 (0.56)	-0.19 (0.09)
Shorthorn	-2.20 (0.71)	-0.22 (0.13)	-2.25 (0.66)	-0.22 (0.11)
South Devon	-4.09 (1.47)	-0.60 (0.39)	-3.47 (1.41)	0.03 (0.24)
Beefmaster	-1.70 (0.76)	0.16 (0.15)	-3.43 (0.74)	-0.20 (0.12)
Brahman	-2.91 (0.77)	-0.27 (0.15)	-2.98 (0.70)	-0.41 (0.12)
Brangus	-0.38 (0.74)	-0.07 (0.14)	-1.29 (0.70)	-0.26 (0.12)
Santa Gertrudis	-1.25 (0.74)	0.05 (0.14)	-2.29 (0.67)	-0.25 (0.11)
Braunvieh	-3.28 (0.77)	-0.40 (0.15)	-4.06 (0.67)	-0.66 (0.11)
Charolais	-1.15 (0,64)	-0.04 (0.12)	-1.93 (0.60)	-0.17 (0.10)
Chiangus	-2.74 (0.74)	-0.18 (0.14)	-2.31 (0.65)	-0.26 (0.11)
Gelbvieh	-2.32 (0.61)	-0.16 (0.12)	-1.59 (0.56)	-0.25 (0.09)
Limousin	-2.73 (0.62)	-0.01 (0.12)	-3.24 (0.56)	-0.35 (0.09)
Maine Anjou	-3.63 (0.74)	-0.33 (0.14)	-2.43 (0.67)	-0.22 (0.11)
Salers	-2.67 (0.73)	-0.30 (0.14)	-2.59 (0.67)	-0.31 (0.11)
Simmental	-0.09 (0.63)	-0.04 (.12)	-1.17 (0.61)	-0.15 (0.10)
Tarentaise	-2.60 (1.49)	-0.33 (0.30)	-4.25 (1.25)	-0.69 (0.21)

Table 2: breed differences for average daily gain (ADG) and average daily feed intake (ADFI, dry-matter basis) of steers and heifers where steers were fed a concentrate (finishing) ration and heifers were fed a growing (roughage) ration for heifer development.

From this study, breeds vary greatly in their use of feed and resulting growth. While Angus animals generally showed the largest growth potential, they also generally had the highest feed intake. Several breeds (e.g., Limousin) ate much less without a large sacrifice in gain. Likely, these differences, at least in finishing steers, were due to differences in composition of gain. Lean growth takes much less energy than growth due to fat because of the higher energy density of fat. In general, heifers on growing rations demonstrated similar trends. Some breeds looked particularly efficient when growing on a roughage ration. South Devon, American composites, Braunvieh, Limousin and Tarentaise all had significantly lower intakes during the trails with some only having only marginally lower gain. While these results are useful for growing and finishing animals, a main question that remained was whether the resulting feed efficiency measures would translate to mature cows.

To answer this question, Freetly et al. (2020) examined genetic correlations between heifer intake and growth and the same measures in mature cows from Cycle VII of the GPE program. Breeds were Angus, Hereford, Red Angus, Charolais, Gelbvieh, Limousin, and Simental and cows were 4-way crosses of these seven breeds. This study utilized dry cows that had been measured for feed intake and gain as yearlings and then were kept dry and unbred at age 5. The cows were fed a restricted ration for 112d (120 kcal ME/kg $BW^{.75}$) and then allowed to eat the ration ad libitum for 84 d following. Because of the restriction, cow weight gain increased with ad libitum feed intake during the 84 d. Resulting cow intake and gain was analyzed in multi-trait models with yearling heifer intake and gain. Breed differences for cow intake were not statistically significant though effects were large in magnitude; the cows for this study were all crossbred with approximately ¼ influence of 4 different breeds, thus standard errors were high for specific breed effects. Genetic correlations between heifer and cow intake and gain were high and significant. The genetic correlation between heifer intake and cow intake was 0.84 ± 0.14, and the genetic correlation between heifer gain and cow gain was 0.73 ± 0.19. Based on these correlations, selection for decreased feed intake and increased gain in heifers would result in corresponding changes in cow intake and gain. Thus, cow input costs could be alleviated through selection on heifers without direct measurement of cow intakes. As a caveat, selection for increased growth in steer progeny would still have the potential to decrease efficiency in cows and heifers. Use of complimentary terminal breeds could alleviate this antagonism. Commercial cow producers should consider selection for maternal cow efficiency traits in their cow herd and use terminal crossing to address calf marketability.

As a further proxy for cow feed requirements, cows from the continuous GPE program were evaluated for variation in metabolizable energy required for maintenance (Freetly et al., 2023). To obtain metabolizable energy for maintenance (MEm), 5-year-old cows were fed during their first and second trimester of pregnancy in Calan Gates to measure dry matter intake. The intake period was 84d with weights taken every 3 weeks. The MEm was derived as:

$$MEm = MEi - MEpreg - MEg$$

where MEi was the metabolizable energy predicted from the intake recorded in the Calan Gates, MEpreg was the predicted metabolizable energy required for pregnancy based on fetal age and resulting calf birth weight, and MEg was the predicted metabolizable energy as a function of the cow metabolic body size and the weight gain while intake was recorded. Resulting MEm was moderately heritable at 0.31 ± 0.107. Thus, MEm predicted from cow intake trials could be used as a proxy for cow intake requirements to recover further energy requirements after accounting for metabolic body weight. If cow intake can be facilitated in seedstock populations, this approach can provide good inputs for genetic evaluation without cows needing to gain weight like growing animals on intake trails.

Future steps in cow efficiency

As stated earlier, fertility and longevity are the key pieces missing from recent continuous GPE sampling. Snelling et al. (20xx) did prototype a longevity measure of sustained cow fertility that predicted number of calves weaned and cumulative weaning weight over a cow's lifetime using random regression modeling. Further work on genetic parameters and breed differences for heifer and lifetime fertility is planned.

All the studies on intake referenced rely on feeding yearlings or cows in a drylot setting. However, measuring intake in pasture foraging situations remains a real need as drylot rations are mixed and exclude diet/grass selection and other sources of variation within grazing ecosystems (less overfilling, more energy and protein variation, variation in forage density). As of now, we are only assuming that fed rations reflect cow intake on pastures.

Another consideration is variability in feed resources in different locations of the United States and whether some cows are more efficiency in warmer or dryer environments. Currently, USMARC is joining with partner institutions in Texas (Texas Agrilife Research Station, Beeville, TX) and Oklahoma (USDA, ARS, Oklahoma and Central Plains Agricultural Research Center, El Reno Oklahoma) to evaluate cows from the GPE program in different environments and management settings. Right now, each alternate location has received and calved breeding females from the USMARC GPE herd. In the future, we plan to continue to share semen and bulls across each location to maintain genetic ties. We fully expect to produce breed differences, genetic interactions, and multi-location genetic and genomic parameters from these collaborations. Each of these results will further contribute to our understanding of cow efficiency under different environmental conditions.

Further selection for any of these traits will require measurement in adult females (sometimes after many parities for traits such as longevity). Traditionally, genetic predictions could only be obtained accurately through daughter records, which is detrimental to genetic change due to a higher generation interval and/or decreased prediction accuracy. Genomically enhanced EPD predictions can improve accuracy considerably and make these traits much more accuracy with records from other relatives. However, large amounts of data, preferably from commercial sources, are still required to benefit from genomic enhancement. Continued development of ways to accurately record the traits mentioned, especially in commercial production settings, has the potential to dramatically improve cow efficiency.

Conclusion

Cow herd efficiency remains one of the most important keys to profitability in commercial cattle production. Thus, measures of cow efficiency will remain an important component of the genetic and nutritional research programs at USMARC and in the GPE program. Research and commercial producers must continue to focus on the cost of cow herd inputs and maintenance while providing and increasing opportunities for cows to produce a calf each year. Continued ideas of traits to measure and systems to utilize maternal breeding objectives in conjunction with terminal crossing will remain keys to long-term profitability in commercial cattle production.

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