UNDERSTANDING COW SIZE AND EFFICIENCY

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Introduction

Cattlemen have debated cow size and efficiency since the early days of the business. While efficient cattle production has been researched for over a century, it remains remarkably misunderstood. This misunderstanding can be costly for the industry as well as individual cattle operations because important and expensive management decisions are erroneously made based on misinformation or lack of understanding. However, a more productive way to frame the efficiency question is “which cattle are most efficient in a specific environment and production system?” In nature, different breeds of the same species can appear markedly different because they have adapted differently to best fit their specific environment. Similarly, different cattle are efficient in different environments and production systems. Gaining a better understanding of the interrelated components of efficiency is critical for cattlemen seeking to maximize profit in their specific operations.

The Interrelated Components

Defining Efficiency. Achieving optimal efficiency is an important goal in all businesses. In a food animal production system, overall efficiency is best measured by the ratio of total costs to total animal product from females and their progeny over a given period of time (Dickerson, 1970). It is important to note that this ratio is the inverse of the output/input ratio most commonly used in business. Despite this concise definition, defining optimum efficiency in the cattle business is complicated. Overall efficiency of a cattle production system is a combination of biological efficiency, or feed consumed to beef produced, and economic efficiency, or dollars spent to dollars returned. Though related, biological and economic efficiency may not be identical. Optimizing the relationship between them is a complicated process, and doing so requires understanding and managing the genetic potential of cattle, the environment in which cattle are asked to perform, and decisions about when and what product a producer is marketing.

The Efficiency Conundrum. Dickerson (1970) noted that on the ranch, an efficient cowherd exhibits early sexual maturity, a high rate of reproduction, low rates of distochia, longevity, minimum maintenance requirements, and the ability to convert available energy (native or nonnative forage) into the greatest possible pounds of weaned calves. He stated that to maximize efficiency in the cow calf context, the objective is lean growth and earlier sexual maturity with minimum increase in mature weight. For a cow on a ranch, the ability to reproduce is by far the most important contributor towards efficiency, and the ability to reproduce in a given feed environment is related to its mature size.

Cundiff (1986) reported that in comparison to cattle in a ranch environment, cattle that excel in the production of retail product typically produce heavier birth weights, reach puberty at older ages, have lower propensities to marble, and have higher maintenance requirements due to heavier mature weights and greater visceral mass. Continental breeds of cattle with these characteristics were introduced in the United States beginning in the 1970's. Their importation was a reaction to both the "green revolution" of the 1960's, which reduced the cost per unit feed in the feedlot industry, and to new industry-changing technologies which favored heavier slaughter weights for packers (Ferrell and Jenkins, 2006). Essentially, a market was developed to reward cattle with the genetic potential to take full advantage of low cost feed. Furthermore, the packing industry continues to reward large framed cattle. Hanging the greatest pounds of carcass, which yield the largest amount of meat possible in the assembly line, is what is most efficient for that segment of the industry. It is relatively easy to recognize that efficiency in the feedlot and packing plants is the driving force behind the market signals incentivizing cattlemen to select for increased growth traits and carcass weight. Selecting for increased weaning weight leads to an increase in mature cow size, which, depending on feed availability, may or may not be efficient in a grass environment (Kelley, 2002). However, in the last several decades, ranchers have successfully mitigated the increased cost of larger cows with low cost supplemental feed. Doing so is a rational response to market signals, as long as supplemental feed remains inexpensive and readily available.

Making the efficiency conundrum even more complicated are the differences that also exist in how economic efficiency is achieved. On a ranch, the goal is to have the highest percentage of calf crop at the heaviest weight without causing dystocia, and therefore maximum total pounds of calves, with the minimum amount of investment and costs. In a feedlot, the goal is simply to produce the most pounds of beef possible in order to profit at a margin above feed costs. Because the drivers behind the cost structures are different, the solution to the puzzle, an efficient animal, may also be different.

It is evident then that biological and economic efficiency for cattle production are not always positively correlated due to the segmentation of the beef cattle industry, which has logically, and economically, separated itself into three highly competitive segments. The first is the ranch, where cattle must be efficient in what is often a limited energy, forage-based, high investment per unit business. The second segment is the feedlot, where cattle must be efficient in a high energy, grain-based, low investment per unit, margin based business. The third is the packing segment, which has the lowest investment per unit and is also a margin based business. The reality is that biological traits supporting efficient use of grazed forages in the first segment of the industry are markedly different from biological traits supporting efficient use of harvested concentrates in the second (Notter, 2002). Nationwide, only a small number of cow-calf producers maintain ownership of their cattle through the backgrounding, yearling, or feeding segments (Melton, 1995). The price received for weaned calves follows prevailing market prices and is adjusted for a number of factors including weight, lot size, uniformity, health, horns, condition, fill, breed, muscling, and frame size. Feeder cattle buyers prefer larger framed, heavier muscled cattle (Schroeder et al., 1998). A cow-calf producer that selects solely for smaller framed cattle based on the assumption that they are more biologically efficient may find their cattle heavily discounted in the market place, which, by definition, would decrease the economic efficiency of the operation.

The Interplay between Genetic Potential and the Environment. Biological efficiency depends upon the interaction between genetic potential and the environment; specifically the availability and variability of feed resources. Cattle partition food energy in the following order: maintenance, growth, lactation, and reproduction. Essentially, a cow takes care of herself, then the calf on the ground, then the calf to come. Energy required for maintenance varies. Ritchie (2001) described high maintenance cows as those that tend to have high milk production, high visceral organ weight, high body lean mass, low body fat mass, high output, and high input. High maintenance cattle also tend to reach puberty at a later age, unless they have been selected for milk production (Arango, 2002). Low maintenance cows tend to be low in milk production, low in visceral organ weight, low in body lean mass, high in body fat mass, low output and low input (Ritchie, 2001). However, it is very important not to confuse maintenance requirements with efficiency. Efficiency is a ratio of input to output, and maintenance energy is an input, but not an indication of output.

In one of the most comprehensive experiments conducted on cow efficiency, researchers at the USDA Meat Animal Research Center (MARC) studied the biological efficiency of nine different breeds of cattle over a range of feed energy intakes (Jenkins and Ferrell, 1994). Ranking for efficiency among the breeds, three British and six Continental, depended on feed intake. At lower feed energy intake, the MARC researchers found that breeds that were more moderate in genetic potential for growth and milk production (Angus, Red Poll, and Pinzgauer) were more efficient because of higher conception rates. This clearly underscores the overriding importance of reproduction in a discussion about efficiency. At lower energy intakes, and because of their greater maintenance requirements, the breeds with greater growth and milk potentials had less energy to commit to reproduction. However, at high energy intakes, the Continental breeds with greater genetic potential for milk production and growth were more efficient than the British breeds because they were able to reproduce and the extra available energy was converted into milk, resulting in heavier calves. At high energy intakes those breeds with lower genetic potential for growth and milk production could not convert the additional energy into milk and therefore the cows themselves, rather than their calves, got fatter, essentially an unproductive use of energy.

In another study, efficiency was investigated in three calvings of small, medium, and large Brahman cattle. The small and medium framed cattle were more efficient for the first two calvings, but by the third, when the large framed cattle had reached their full growth potential, the large cattle were more biologically efficient (Vargas, 1999). These results reiterate that, both between and within breeds, maximum efficiency occurs at a level of feed intake that does not limit reproduction and also provides sufficient energy for milk production to meet the growth potential of the breed as expressed in the calf (Jenkins and Ferrell, 2002). Alternatively, if nutritional input exceeds genetic potential for either reproduction or production, efficiency declines (Jenkins and Ferrell, 1994).

Matching growth and milk production to the feed resources available is key to creating efficient cows (Greiner, 2009). The natural availability of feed resources varies greatly across the United States; Iowa and Georgia are vastly different environments than the arid Great Plains and the high deserts of Nevada. Utilizing cattle with different genetic potentials for production is a logical response to environmental variation.

In a analysis of a 165,000 cow database, the authors of this paper found a statistical relationship between cow maintenance energy EPDs and calf weaning weights. As maintenance energy EPDs increase, so does cow weight; bigger cows generally have higher maintenance energy requirements. Furthermore, as cow maintenance energy EPDs increase, and, so does calf weaning weight; bigger cows generally have bigger calves. The important application of these relationships is in the calculation of how much additional maintenance energy requirements cost relative to how much additional profit is realized through additional weaning weight. An increase in 12 additional required Megacalories per year for cow maintenance, which is roughly two pounds of corn, equates to an additional three pounds of weaning weight. When corn and calf prices are adjusted for inflation, the additional profit from the extra pounds has exceeded the additional cost of corn every year since 1975 by at least $2.50. The practical implications of these findings are that the increase in the nation's average cow size is a rational response to inexpensive feed, and, if a cow will get bred in her environment, the additional maintenance energy requirements of a larger cow is more than paid for by the additional weight of her calf.

Metabolic Weight versus Live Weight. The average elephant weights 220,000 times as much as the average mouse, but requires only about 10,000 times as much energy in the form of food calories to sustain itself. This is because of the mathematical and geometric relationship between body surface area and volume, which in biology is articulated by Kleiber's Theory. It states that metabolic weight = live weight$^{\wedge .75}$ (Kleiber, 1932). Essentially, the bigger the animal, the more efficiently it uses energy. For instance, eighty seven 1200 lb cows require the same amount of food energy for maintenance as one hundred 1000 lb cows (Table 1).

Live Weight	Metabolic Weight	Animal Unit Equivalent (% of 1000 lbs)	Equivalent Herd Size (Baseline: one hundred 1000 lb cows)
800	150	85%	118
850	157	89%	113
900	164	92%	108
950	171	96%	104
1000	178	100%	100
1050	184	104%	96
1100	191	107%	93
1150	197	111%	90
1200	204	115%	87
1250	210	118%	85
1300	216	122%	82
1350	223	125%	80
1400	229	129%	78
1450	235	132%	76
1500	241	136%	74
1550	247	139%	72
1600	253	142%	70

Table 1: Metabolic weight, animal unit equivalent, and equivalent herd size for each fifty pound live weight class interval in beef cattle.

An understanding of Klieber's Theory is of practical importance when calculating equivalent herd sizes (Table 1). The biology of maintenance energy requirements dictates that while a larger cow will consume more food than a smaller cow, its additional feed requirements, as a percentage, are less than its additional weight, as a percentage. For example, though a 1200 pound cow weighs 20% more than a 1000 pound cow, the 1200 pound cow's feed requirements are only 13% more. Knowing equivalent herd sizes based on Kleiber's Theory is the only way to accurately compare the efficiency of different sizes of cattle. However, a biological understanding of how maintenance energy varies with size is not useful unless paired with an economic understanding of how herd size impacts profitability.

If herd size is adjusted correctly, switching from a larger to smaller cattle will not increase total fixed costs or feed costs, but will increase variable costs, depreciation costs, and investment costs in terms of cattle inventory. Therefore, the gross income generated by selling a greater number of lighter calves must outweigh these additional variable, depreciation, and investment costs in order to justify the decrease in cow size. Alternatively, switching from smaller to larger cattle will decrease variable, depreciation, and investment costs, with no change to fixed costs or feed costs. However, producers in highly variable feed environments may benefit from a greater number of smaller cattle because of the economic risk associated with low reproduction rates of larger cows if supplemental feed is unavailable or expensive.

Tools for Approaching Cow Efficiency

If a producer has decided that the current size of their cows is not right for their production system, the following discussion of both ineffective and effective tools to increase efficiency provides valuable insight for making a profitable adjustment.

The Problem with Calf Weight/Cow Weight as a Measure of Efficiency. The ratio most commonly used to quantify efficiency is fundamentally flawed in several respects. Weaning weight divided by cow weight results in a ratio in which the numerator indicates output and the denominator assumes a level of input through a commonly accepted association of cow weight and feed requirements. Several studies have found that this ratio is inferior to weaning weight as an estimation of efficiency (Dinkel and Brown, 1978, Cartwright, 1979). This is because using the ratio as a selection measure results in selecting based on two phenotypes of different individuals and the consequent confounding of direct and maternal genetic effect on these phenotypes (MacNeil, 2005). For instance, milk production potential, though unaccounted for directly in the ratio, has a great impact on both the numerator and the denominator.

Using weaning weight divided by cow weight to differentiate between two cows on a ranch as a measure of efficiency is tenuous at best, for several important reasons. First of all, blanket estimates and assumptions of feed intake may not be accurate. Feed intake depends on body condition score, sex, stage of production, age, quality of forage, and environmental stress (Cartwright, 1979). What makes Jenkins and Ferrell's (1994) nine breed study of efficiency so meaningful is that efficiency was not based on assumed or estimated feed intake, but on actual energy intake, which was measured at every feeding. Secondly, the calf weight/cow weight ratio dilutes the impact of the most important component, which is reproduction. Both cows are much more efficient than their open counterparts. A fifty pound difference in weaning weight is minimal compared to a four hundred pound calf versus no calf. Thirdly, the cow with the heavier calf (assumed heavier milk production) will have greater visceral mass and therefore greater intake even when dry. Fourthly, the cow with greater milk production may be at greater risk for not re-breeding because of the order in which feed energy is partitioned. Finally, pasture observations of calf weight as a percentage of cow weight can be misleading because of differences in calf age, sex, and other variables.

Though it does not reflect individual cow efficiency, the ratio of total pounds weaned divided by number of cows exposed is the best measure of efficiency for the entire herd. This ratio recognizes the most important maternal trait of efficiency, reproduction, without confounding variables. Increasing this ratio without increasing input costs will result in increased net profit.

The Problem with Culling for Efficiency. Selecting for genetic change in a cow herd through female culling is not an effective method for changing the overall efficiency of a commercial cowherd for several reasons. First, cattle in commercial herds have long generation intervals, which makes progress in genetic change extremely slow. Secondly, the selection differential for efficiency within the same herd is probably smaller than is commonly held and, as has been previously discussed, cannot be effectively and reliably measured. Third, culling based on traits with low heritability is ineffective. Finally, since an individual cow contributes little to the overall genetic makeup of a calf crop, it is much more effective to select for efficiency through bulls.

Optimizing a Breeding System. For a profit-driven producer, no matter the environment and market end point, the goal is to produce as much product as possible through a cow herd. Setting up a breeding system to capture genetic potential in a given environment and given market will optimize efficiency. Cross breeding programs take advantage of breed complementarity and breed differences, making them an ideal way to positively and relatively quickly produce genetic change for efficiency. For example, a terminal sire bred to a cross bred female will wean approximately 28% more pounds of beef per exposed female than a single breed (Field and Taylor, 2003).

Optimizing a Production System. Indigenous feed resources vary dramatically by geographic location. The natural variation of animals of the same species around the world speaks to the fact that nature defines the "right" genetics for efficiency differently in different environments. Jenkins and Ferrell's (1994) study concurs with this natural phenomenon. Forage production west of the 100th meridian is vastly different than ranching in areas with high annual precipitation, not only in amount but also in frequency and reliability. Availability of low cost feed also varies by region and even by ranch within a region, and should impact decisions about efficiency. Price and availability of feed may be a good indicator of whether or not a ranch is in a high feed environment or not. Furthermore, environments can be categorized not only by level of feed availability, but also by levels of stress, which include cold, heat, parasites, disease, mud, and altitude (Bourdon, 1988). For instance, the efficiency of *Bos indicus* cattle in tropical and sub-tropical environments is due to their heat tolerance, an advantage the British breeds do not have (Field and Taylor, 2003).

Besides environment, market end point is the other paramount factor impacting the efficiency of a beef cow-calf production system. Increased milk potential is most beneficial when calves are sold at weaning and maximum pre-weaning growth is rewarded in the marketplace. In a retained ownership scenario, calf growth due to maternal milk production is less critical because the calf's own growth potential has a longer period of time to capture profit for the rancher. Furthermore, when selling cattle by the head, as is the case with seed stock or replacement heifer operations, number of head, not pounds, is the key metric.

In a traditional production system where a rancher sells calves at weaning, the most efficient cow is the one with the highest milk potential that can, without reducing the percentage of calves successfully weaned, repeatedly produce a calf by bulls with the growth and carcass characteristics valued most in the marketplace. Such a cowherd fits with their environment, native forage, while producing calves best suited for their eventual environment, unlimited grain. This is why crossbreeding systems that exploit heterosis and complementarity and match genetic potential with market targets, feed resources and climates provide the most effective means of breeding for production efficiency (Cundiff, 1993).

Optimizing Herd Size. The optimal herd size for any ranch varies greatly depending upon its rainfall, infrastructure, investment, and manpower. An efficient cow herd is one that nets the most profit by keeping marginal revenue above marginal cost. Because of Kleiber's Law, cow size, in relation to available feed resources, determines herd size. A rancher can increase herd size by reducing cow size up to a certain point without increasing feed and fixed costs, but doing so does increase investment and variable costs. The cost structure of each ranch is unique and can vary over time, as will profit margins. Each producer must evaluate their unique system and determine, based upon biological and economic determinants of herd size, what is most profitable for them.

Conclusion

Efficiency in animal production is a measure of input costs to total animal product. Determining the right size of cow for any specific production system necessitates understanding how beef industry segmentation affects the interaction of biological and economic efficiency. Antagonisms exist between ideal genetic traits at different stages in the chain of cattle production, and in different environments. Maintenance energy should not be confused with efficiency and must be calculated and discussed in terms of the animal's metabolic weight.

Improving efficiency requires measurement, and though popular, literature does not support calf weight/cow weight as a better measurement of efficiency than weaning weight. Improving efficiency of a cowherd through culling is ineffective compared to prudent bull selection. Market end points have a profound impact on efficiency. For the majority of cow calf producers in the nation, the most efficient cow is the one with the highest milk potential that can, without reducing the percentage of calves successfully weaned, repeatedly produce a calf by bulls with the growth and carcass characteristics valued most in the marketplace. Size, of cow, through the biology of metabolic weight, should dictate herd size, and optimal herd size varies with the cost structure of a specific production system.

No one breed or size category of cattle excels in all traits or is most efficient in all environments. Any “one size fits all” approach will result in un-captured profit, and therefore suboptimal efficiency. The question of efficiency needs to be discussed in the context of a specific system, which requires careful analysis of the environment, market, and goals of that system.

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