Breed Utilization and Production Efficiency

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Introduction

Maximizing production efficiency, or perhaps more specifically economic efficiency, is a goal of any beef enterprise. Maximizing production/economic efficiency, with minimal effect on natural resources, also addresses an even larger goal of sustainability. Although individual owners would and should be focused on their own enterprise and its efficiency, total industry efficiency and sustainability become the global goal for the beef industry. Thus utilization of breed resources is of interest as we address the various segments of the beef industry ranging from seed stock production to providing products for consumers of beef.

In this paper and presentation, production efficiency and its significant components will be addressed first. Then the decision processes and opportunities for utilization of our various breed and population resources, as they contribute positively to production efficiency, will be discussed. Descriptions and discussion will not be in full depth nor full completeness that might be possible, but generalities will emerge.

Production Efficiency

Production/economic efficiency can be expressed as output:input ratio or as the value of output relative to, or divided by, the costs of production. Value of output is the sum of the "amount x value" of the various outputs on a ranch or feedlot or processing plant, etc. Costs of production are those realized by the ranch, feedlot, processing plant, etc. The greater the ratio, the greater the efficiency of the enterprise, or if measured as final output of beef products to total costs, the greater the efficiency of the beef industry. As cycles in supply and demand of cattle and beef, and in production costs occur, efficiency of the enterprise can vary across industry segments, but these are temporal. In the long term, all segments of the industry, will need to have an economic efficiency ratio greater than one to be sustainable.

Biological characteristics of cattle that express variation and have an impact on production efficiency should receive our focus, whether we are evaluating breed variation for making choices in breed utilization and possible crossing systems, or we are developing breeding objectives for selection within populations. The latter would vary depending on intended use of the population (or breed group) in commercial beef production, either as a sire breed or dam breed or both. These characteristics may have variation arising from 1) direct breed differences (due to the genetic makeup of the animal measured), 2) maternal breed differences (due to the genetic makeup of the dam), 3) direct (arising from the genotype of the calf) heterosis, 4) maternal (arising from the genotype of the cow) heterosis, or 5) various combinations of these.

Let's look at a limited number of studies aimed at identification of biological characteristics influencing efficiency of production of calves through slaughter. MacNeil et al. (1994) developed relative economic values for sire and dam lines fitting the Canadian beef industry, and thus very similar to the U.S. industry. Variation in feedlot gain had important economic value in both sire and dam lines as did calf survival; variation in female fertility was important for dam lines and male fertility for sire lines. MacNeil (2005) presented a further look at terminal sires and variation in economic value of characteristics. He demonstrated the importance of increasing calf survival, weight gain, dressing percentage and marbling score while decreasing feed intake and fatness (yield grade).

Barron Lopez (2013) recently examined relative economic values of component characteristics contributing to a breeding objective for a totally integrated system. His results point to the importance of increasing marbling score, muscle, and post-weaning daily gain while decreasing feed intake (through indicator traits – decreasing milk production and cow mature size) and carcass fat. Feed requirement to meet maintenance is positively related to level of milk production potential in both cows and calves (Montano-Bermudez et al., 1990) and probably to locomotor activity level, as has been shown for mice (Sojka et al., 2013).

Being able to utilize breed differences, as they contribute to a system, is warranted for growth rate, marbling and carcass fatness, fertility and calf survival, and feed intake, especially for maintenance. For systems where a breed or composite is used both as a sire and a dam, then all these characteristics are important in making choices between breeds to use. In systems where a breed is used as a terminal sire, then calf survival, growth rate, carcass marbling and fatness, and feed intake are important to consider. For systems where a breed contributes as a dam, then add in female fertility and increase the emphasis on reducing feed intake for maintenance because annual cow costs are large in the system. Montano-Bermudez and Nielsen (1990) and van Oijen et al. (1993) demonstrated that lower milk level, and its accompanying lower feed energy requirement for maintenance throughout the life cycle, enhanced economic efficiency. In addition, being able to capitalize on heterosis for dam, and perhaps sire, fertility, calf survival, and growth rate (MacNeil et al., 1994) will also contribute to increased production efficiency.

Need for Multiple Breeds

Breeds and variation between breeds open up possibilities for innovative genetic applications. Breeds differ because frequencies of alleles for many genes differ between the breeds. These differences in frequencies of alleles are the result of different selection histories, both artificial as well as natural selection, and different mutation histories that have occurred in reproductively isolated populations. Because breeds differ in allelic frequencies for many genes, we create more heterozygosity in crossbred individuals than in the average of the parental breed populations. The greater the difference in frequency of alleles for a gene, the greater the increase in heterozygosity when we cross breeds. Increased heterozygosity, along with some degree of desirable dominance, is a cause of heterosis. And magnitude of heterosis effect is defined based on the difference between a first cross and the average of the contributing pure breeds, whether in a calf or a cow or a bull.

Breeds, as noted above, will differ in at least some characteristics for direct (g^d) and/or maternal (g^m) genetic effects. In evaluating a breed for use as a dam role in commercial production, we would wish to know how the breed ranks among those available for both g^d and g^m effects. In fact, in the manner that a potential dam breed would contribute to commercial production, it is ½ $g^d + g^m$ that becomes the critical knowledge. For a breed with possible use as only a sire role in commercial production, then we would only need to evaluate the breed's strengths and weaknesses for g^d, or ½ g^d as it contributes to the system. And, if we wish to choose among breeds which will contribute both from a sire and a dam role, across generations, then the important knowledge is $g^d + g^m$ for critical characteristics contributing to production efficiency.

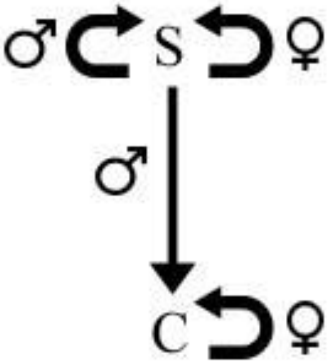
Complimentarity, or combining breeds of differing strengths, is realized in different ways with different combinations or utilization of breeds. For rotational crossing systems, because each breed will, in time, contribute equally to the other breeds as both a sire and a dam, then $g^d + g^m$ is the knowledge we need for making selections of breeds to include. Likewise, if we wish to create a new composite breed or wish to utilize an "open composite" with varying infusions of existing breeds over generations, then again, because contributions are equal in both sire and dam roles, $g^d + g^m$ is again the important knowledge to gather and evaluate for potential breeds to include in the composite. In these situations, where a breed contributes equally as both a sire and a dam, our goal is to combine breeds with varying strengths where each breed complements the other by bringing some strength to form the whole.

In the case of terminal crossing where some breed(s) fill the role of the sire breed and other breed(s) fill the role of the dam in the final, desired cross, then complimentarity has an even greater role to contribute positive attributes to the cross. Crossing smaller, lower feed intake dam breeds or crossbred dams to larger, greater growth and less waste-fat sire breeds demonstrates complimentarity at its greatest impact on production efficiency. Making use of breeds that can differ greatly in many characteristics can capitalize on significant complimentarity through "sire breed vs dam breed" strengths; we might also call this sire breed x dam breed complimentarity. Cundiff et al. (1986) presented an early comprehensive comparison of breeds for beef production based on the Germ Plasm Evaluation (GPE) project at US MARC. More recently, Cycle VII of the GPE evaluated the seven breeds with the greatest registration numbers. Wheeler et al. (2005) and Cushman et al. (2007) provided several breed comparisons from Cycle VII. Weaber (2010b) discussed many concepts on breed strengths and heterosis in detail.

For breeds being considered for use as a dam breed, fitting the breed to the environment (temperature, feedstuffs, parasite challenges, etc.) adds a further challenge. *Bos Taurus* breeds are better adapted for temperate zones, whereas inclusion of *Bos indicus* breeds in crossing or in composite breeds has value in the hot and humid portions of the US. Weaber (2010b) provides elaboration on matching breed characteristics to varying production environments.

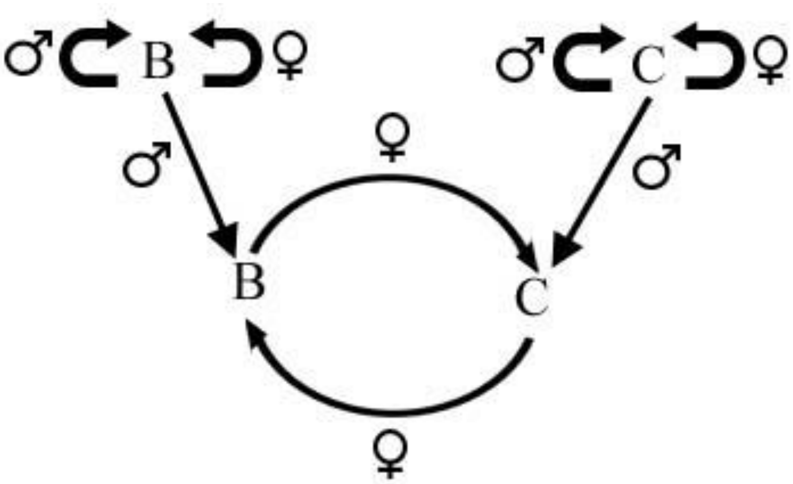
Breed Utilization

For a totally sustaining system of producing calves, multiple breeding groups are the norm. Even in the case of producing a pure breed or line of cattle, or a pure "composite" that has a defined composition of contributing breeds (e.g., ½ each of 2 breeds or ¼ each of 4 breeds), the system of breeding would have both seed stock, or bull source, and commercial sectors. We can minimize costs involved in practicing selection for the system by concentrating selection efforts in the seed stock group. Selection response in the seed stock (seed stock population shown below as “S”) portion of the system are fully realized, at the same rate in the long run, in the commercial portion (shown below as “C”) of the system. Arrows in the diagram below depict flow of breeding males and females from their source of production to their use in reproduction. For example, group S produces sons that become replacement bulls in both group S and group C. For cattle and their low female reproductive rate, commercial replacement females are born in the commercial portion. As noted above, in this type of system, a breed or composite would be chosen based on $g^d + g^m$ for the combination of important characteristics affecting production efficiency.



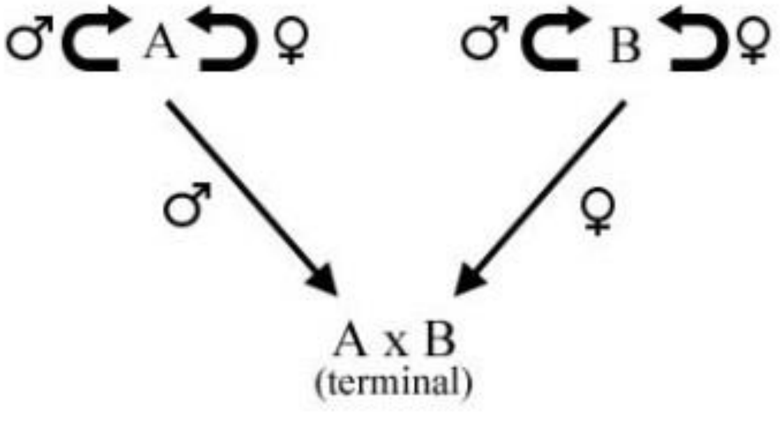
There is a large number of cattle breeds available for US producers to sample. Realistically, there are a limited number though that might play a major role in contributing to crossing systems. For ease here, let’s assume we wish to make choices among 10 breeds for use in building new composites. For composites developed from two breeds, there are 45 different combinations, and these composites would capitalize on ½ the possible calf, dam and sire heterosis. For those using four breeds, there are 210 different combinations, and based on ¼ contribution of each breed, these composites would express ¾ of the possible calf, dam and sire heterosis.

An alternative to a composite that would also capitalize on heterosis is a rotational cross. The simplest form is a two-breed rotation, and the total system for sustaining this system is depicted in the diagram below. Breeds B and C are used as purebred sires in the commercial portion of the system, given in the bottom half of the diagram. Daughters of B sires are mated to C sires throughout their life, and daughters of C sires are mated to B sires. Purebred seed stock groups are shown at the top of the diagram. Like the composite and the pure breed examples above, the two breeds are again chosen based on $g^d + g^m$ for characteristics affecting production efficiency. We would choose breeds to be compatible in birth weight to minimize dystocia in first-calf dams. Weaber (2010a) describes rotational as well as other crossing programs for beef production.



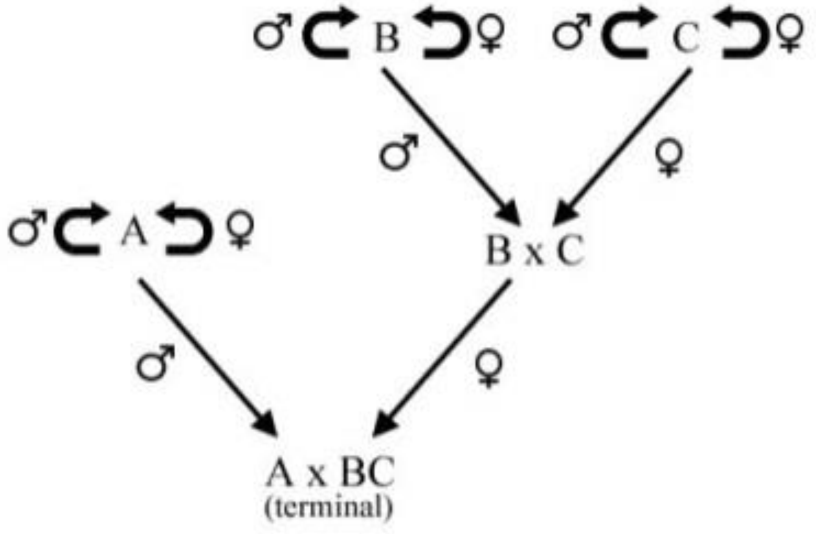
Again, imagining 10 different breeds to select from, there are 45 unique two-breed rotations, and these capitalize on ⅔ of the possible calf and dam heterosis. With three-breed rotations, there would be 120 unique rotational systems, making use of $^6/_7$ of the possible calf and dam heterosis.

The easiest crossing system to design that makes use of sire breed x dam breed complimentarity is a two-breed cross. One simply crosses the best sire breed by the best dam breed. All progeny are intended for slaughter, hence a terminal cross. Full call heterosis is realized. In the diagram below, "A" is the sire breed and "B" is the dam breed, each breed chosen for their strengths in their unique roles. Under a fully sustainable system, we would need the two purebred groups (A and B) to generate replacement breeding stock for the commercial, terminal cross as well as replacing breeding stock in the purebred populations. And, B females would probably not be mated to A sires for their first calves, if A is a greater birth weight, high growth breed. Given the low female reproductive rate in cattle, it would be difficult to realize 50% of the total system in the terminal cross, thus giving up production efficiency, including the lack of capitalizing on dam heterosis.

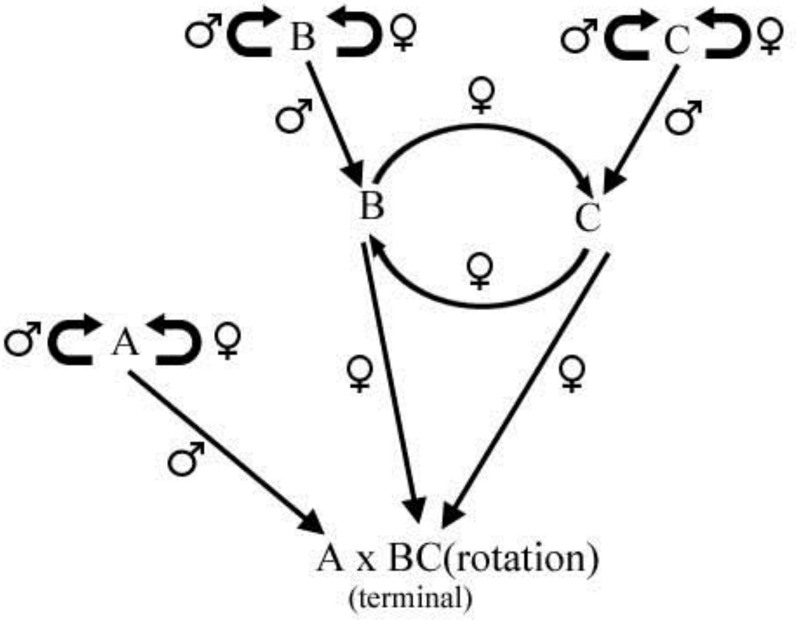


But, what if breed “B” in the diagram above were a maternal composite of two (or four or ?) breeds that had been identified with strengths in female fertility, smaller cow size and lower feed intake, etc.? Then, 50% (for a maternal composite of equal parts of two breeds, or 75% if a maternal composite of equal parts of four breeds) of the dam heterosis would be realized in a large (93+%) portion of the total system, thus enhancing production efficiency.

Most commercial swine production capitalizes on full dam heterosis as well as full offspring heterosis. Relatively high female reproductive rate in swine opens the door for realizing a high (~90%) of the system production in the commercial, terminal cross. This is depicted in the diagram below for a totally sustaining system with supporting purebred and first-cross female production (B x C). Full dam heterosis is used because the females are first crosses of lines that excel as females. When natural service was the norm, first-cross boars of two terminal sire lines were used in the terminal cross. But, as artificial insemination has become the least costly method for breeding sows, and as single, best-sire lines have been identified, the terminal three-breed cross (A x BC) now dominates the swine industry. So, why not use the same system in cattle if we can identify two dam breeds and a terminal sire breed, and thus capitalize on full dam heterosis in addition to full calf heterosis? Unfortunately, on a totally sustaining industry basis, we still have a very large portion of the system as purebred dams in the purebred C and the B x C groups as dictated by the low reproductive rate of females. And, we would probably need to avoid breeding BC crossbred heifers to A sires for their first calf.



The alternative to the three-breed cross, shown above that is working well in swine production, is the rota-terminal cross for cattle. With rotational crossing to generate replacement females, the large overhead of purebred females required in a three-breed cross is avoided. Shown in the diagram below is a two-breed rotation that generates replacement females for the rotation (breeds B and C) as well as replacement females for terminal crossing (these would be older cows, not heifers for first breeding, again to avoid calving difficulty) to sire breed A, capitalizing on sire breed x dam breed complimentarity. Here the dam breeds are represented in the rotational crosses of two dam breeds. Given the low reproductive rate of cows that can not be overcome, we still achieve much less than half the total system in the terminal cross, but all commercial cows are now two-breed rotation and contributing $^2/_3$ dam heterosis, and the terminal cross has full calf heterosis. Reflecting back to our selection from 10 different breeds to develop such a system, there are 360 unique combinations!



Simulation research by Tomsen et al. (2001) compared total-system (all purebred plus crossing groups) profitability (income – expenses) for beef production using literature data on 14 breeds of cattle. All systems were simulated for a fixed amount of grazing resource and with slaughter of young animals at a constant level of fat (0.3 inch over the rib). Because there were many crossing systems with 14 breeds, the 10 best for various crossing systems were averaged and compared to the average of the best 3 pure breeds. The average of the best 10 two-breed rotation systems was 32% greater in profitability than the average of the best 3 purebred systems. The 10 best rota-terminals (two-breed rotation dams) averaged 55% better and the 10 best composites, all composed of four breeds, averaged 51% better for profitability than the average of the best 3 purebred systems. Being able to capitalize on calf and cow heterosis plus utilize breed strengths through complimentarity explains these results.

Due to differing strengths of breeds and desirable effects of heterosis, planned crossing systems can utilize breed resources to improve production/economic efficiency of beef production. Wisely engineered crossing systems will have greater production efficiency than purebreeding for commercial beef production.

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