Strategic Use of Heterosis

Todd Thrift, Matt Hersom and Joel Yelich

University of Florida

Traditionally, in the beef cattle industry from 1920-1960's, crossing two breeds of beef cattle was considered an undesirable mating plan. Progressive cattlemen of this era had purebred Herefords, Shorthorns, or Angus. Any commercial producer that had crossbred animals quickly "graded up' to the breed of their choice and high levels of linebreeding were common. Dr. Lush (1945) suggested that crossbreeding was very common with swine and sheep breeders, becoming common with poultry and "rarer in cattle and horses".

Early work in crossing cattle in the Gulf Coast recognized the value of combining different breeds particularly when the survival of existing purebreds was very low. Crossbreeding has been practiced with great success in the Gulf Coast for nearly 100 years. Even during times when it was considered highly undesirable by many in the cattle business.

With the coming of the Continental breeds to the United States in the 1960's a whole new era of crossbreeding occurred. Introduction of large-framed fast growing European cattle resulted in a huge shift in cattle type. New genes from Continental cattle resulted in improved performance and often much of this performance was attributed to the new, breed. In fact some of the improvement in performance was likely a result of heterosis. It was often said that "I tried some of those new Simmentals, or Charolais, or Limousins, (or any continental breed) and man they are good….calves grow like crazy." Some of this increase in performance was certainly additive gene action. Some was no doubt heterosis. After one breed was used for a few years then a switch was often made to the next "hot" breed. This resulted in a repeat of the cycle as new genes where brought in from a different breed often resulting in improved performance and as a by-product, heterosis. In the process, the beef industry learned a hard lesson in genotype by environment interactions. Large framed, high-milking cows resulted as heifers from these crosses were kept. These cattle as a whole were fertile until the feed resources became limited during times of drought. What had resulted from this random crossing of breeds was an infusion of new genetics, a general increase in cow size and milk yield, increased nutrient requirements, some level of heterosis, and a rainbow of coat color patterns.

In the 1990's it was suggested that crossbreeding might be to blame for creating the problem of too much variation in the beef cattle industry. Certainly, crossing breeds did contribute to the variation in coat color. But coat color has never been a good indicator of uniformity. The 1991 Beef Quality Audit (Lorenzen et al., 1993) showed that beef was too variable in many carcass traits. These carcass traits are mostly moderate to highly heritable. Improvement in highly heritable traits is best accomplished via selection. Several breeds have been highly successful at improving carcass traits via this method. While focused selection for carcass traits was occurring in the last 25 years some in the cattle industry rekindled the theory of cattle that are one color are less variable in composition. Great strides have been made at improving carcass

traits in the purebred cattle industry and the breeding and selection decisions of the last two decades are now being realized as improvements in beef quality. But reproductive traits have not had similar improvement. In our estimation, there may even be a general decline in reproductive performance which has been masked by the effects of environmental modification most often in the form of available feed resources. Today's cow has better nutrition, but improvements in weaning weight have been marginal and reproduction has been stagnant. Reproduction is low in heritablity but subject to high levels of heterosis when breeds are crossed. The crossbred cow has been shown to be superior in many aspects including age at puberty, reproduction, and longevity. Despite this questions are still being raised "does heterosis still exist?"

Heterosis or hybrid vigor is simply defined as the improved performance of the crossbreds as compared to the average of the two purebreds that were used to make the cross. Higher levels of heterosis are realized when there is a large difference in the gene frequency between the breeds crossed for the trait of interest. Simply put, the more diverse the two breeds are the more heterosis is realized in the cross.

Crossbreeding systems are designed to combine various breed strengths (or minimize weaknesses) and take advantage of heterosis. Much of the early crossbreeding work was conducted with English crosses in the 1960's. Suggestions have been made that heterosis was valuable only when English type cattle were small and slower growing. Today's English type cattle are larger and in fact the data would suggest as large as many Continental cattle in mature cow size evaluations. Implications have been made that heterosis is no longer needed to improve production.

Studies that were specifically designed to evaluate heterosis of crossing different breed are less common today. Current research relating to genetic evaluations is focused on genomics and the search for genes controlling phenotypes. At one time, many states had large research herds of cattle to estimate the relative effects of breeds and crosses. These studies involved large numbers of breeds across many geographic regions. Data published from these studies formed the basis for much of what is known today about animal breeding and crossbreeding. Unfortunately these experiments are long term and by the time full results are obtained the industry has already moved on to the "next great breed." The early work with crossbreeding serves as a solid foundation still today and the results are still completely applicable to modern cattle production. Crossbreeding, and the accompanying heterosis, is still a valid and highly effective means of improving pounds of calf weaned per cow exposed. Its effects are mediated predominantly through increased fertility of the crossbred cow, increased survival of the crossbred calf, and longevity of the crossbred cow. These effects are often 20-25% (35% when using *Bos indicus* x *Bos taurus*) improvement in pounds of calf weaned per cow exposed. No other technology in the beef production provides this type of return from both biological and economic perspectives.

Certainly crossbreeding is not as simple as placing two breeds together. Depending on the system utilized there are requirements for extra pastures, calving ease bulls for yearling heifers, and marketing multiple types of offspring that may be multiple colors. Many of the more complicated systems only function appropriately with 500 or more cows. Ninety percent of the

cow calf producers in the US have less than 100 cow herd size. These obstacles result in low adoption of true crossbreeding programs. Instead what often results is a corrective mating plan that results in some heterosis but rarely maximizes hybrid vigor.

The lack of adoption of crossbreeding in the beef cattle industry is a result of several factors. Many producers crossbred and receive the benefits of crossing in the form of heterosis. However, very few utilize a planned crossbreeding program. Many of these mating systems have been well established for over 75 years. A full outline of these systems is beyond the scope of this article. An overview of breeding systems has been provided by Hammack (2011). Experimental results have repeatedly shown great benefit but execution of the systems is often difficult.

Crossbreeding systems may be divided into three types: Terminal, Rotational, or Composite. There are also combinations of these systems that work to generally increase heterosis.

In general, terminal sire systems maximize heterosis but do not produce their own replacement heifers. Many terminal systems are used in theory but often fall apart when a producer decides to keep some "big, good-looking, replacement heifers" from a terminal mating. Numerous examples of this occurred in the 1980-90's.

Rotational systems provide some level of hybrid vigor and produce replacement females. Often herd size is a limiting factor and these systems work best in large herds with ability to market different types and colors of offspring.

Composite systems have the advantage of some hybrid vigor and the production of replacements with the simplicity of straightbreeding. Some have suggested that the composite program would work best for small producers (1-2 bull herds). Successful examples of these systems are in place in the United States. Many of the composites that were initially formed used the red recessive gene to set color pattern. The price discrimination of non-black cattle in the US has limited the acceptability of some of the composite populations. It should be noted that the suggestion is not for a producer to develop his or her own composite but rather utilize a composite that has been developed by a larger purebred breeder. Composite formation is complex and requires a large number of cows to avoid inbreeding depression. Utilization of an existing composite is simple and similar to straightbreeding. Many of the early composite breeds like Brangus, Beefmaster and Santa Gertrudis were formed to provide a specific mix of *Bos indicus* and *Bos taurus*. Residual heterosis that resulted was a bonus but not the initial game plan. More recent development of composites from 4 breeds (25% each breed) result in more heterosis. Most of these composites have been developed in temperate climates and very few are available in tropical or subtropical regions. One quarter to one third of cows in the United States are in the South and face the challenges of heat stress for a large percentage of the year. However, beef industry structure may not lend itself to large scale adaption of composite systems. History has shown that many producers do not stick with a breed (or system) long enough to realize the benefits. Too often the lure of some new breed or cross often diverts the attention from the original plan. A historical review of beef industry trait selection would suggest that we often blow with the wind and almost always overshoot our target.

There is a belief that the only crossbred female that is worthwhile to have is the F1. In reality she is the Cadillac of females and will express maximal heterosis. But she is expensive to create from existing populations of purebreds. However, crossbreeding systems do not have to be started with purebreds. A simple sorting based on phenotype is all that is required. A producer might sort cattle into red and black coat color. The red cattle might receive an Angus bull and the black females receive a Herford bull. They will receive these sire types the rest of their productive lives and one has effectively started a two breed rotation.

In the Gulf Coast, the sort most common would be cows with *Bos indicus* influence (more ear) and those with minimal *Bos indicus* (less ear). The appropriate breeds may be picked to produce a calf of desirable type while keeping a specific level of *Bos indicus* percentage AND get some level of heterosis. Crossbreeding systems that are simple often have greater success even though they may not maximize heterosis. It is important to remember that the haphazard crossing of breeds is not a crossbreeding system.

Another serious impediment to crossbreeding has been our failure to have frank discussions about breeds and their strengths and weaknesses. For years it was taboo to say negative things about breeds for fear of hurting feelings or reducing a breeder's ability to merchandise cattle. There is not one breed that rises above all others in terms of maternal, growth and carcass in all environments. Many breeds excel at two of those categories and some in three categories. But no one breed excels in all three categories to be a perfect fit for all environments. The value of heterosis that is often forgotten and which we have found experimentally is that the **heterosis realized is often greatest in the harshest environments**.

The strategic use of heterosis requires a long term plan. Many small producers (<100 cows) would benefit from the use of a terminal sire system. They should purchase crossbred replacement heifers that fit their environment and resources. The independence of many of our cattle producers often interferes with the application of this plan. "I can't buy as good as I can raise" is often heard as the reason why terminal systems are not more popular. The fallacy in this plan is that only about half of the cows can exist in a terminal system. The other half of the cows must be in a system that makes replacement females. Rotational systems produce replacement heifers, but to function they require larger herd sizes and more pastures during the breeding season. Composite systems offer the merit of producing replacement heifers and providing hybrid vigor at some level.

It is possible to put together strategic crossbreeding plans using the breeds that exist in large numbers in the US. These plans have been laid out for 100 years yet adoption still remains only moderate. It must be stressed to producers that these plans are a 20 year decision. Some level of crossbreeding should continue to exist as the benefits to reproduction, calf survival and cow longevity are well established.

The dairy and egg industries have had great success in straightbreeding. Both of these industries work in a controlled environment and predominantly select for one trait. The modern dairy cow is a milk machine, but it is well documented that fertility, longevity and survival have all declined resulting in higher replacement cost to the dairy industry. The beef industry must

function in multiple environments and select for multiple traits. The most important of those traits is reproduction which is highly improved by crossbreeding. Regardless of breeding plan selected, the commercial industry should adopt the use of a crossbred cow. The benefits of early puberty, increased fertility, earlier calving, greater lbs. of calf /cow exposed and improved cow longevity are too great to be overlooked. As producers look for increased production and economic efficiencies, they already have the largest tool at their disposal in the breeding system they implement.

The most practical crossbreeding programs for small producers who want to raise their own replacements heifers is a two breed rotation or composite system. Larger more complicated systems yield more heterosis but often fail due to complexity of implementation. Regardless of the system utilized, much of the benefit to be realized from crossing breeds is a result of the use of a crossbred cow. Mating systems that emphasize the crossbred cow offer much advantage.

Mention of breeds in this publication is solely for illustration purposes. No endorsement is implied.

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