Breed and Composite Selection

Robert L. (Bob) Weaber, Eastern Kansas Research and Extension Centers, Kansas State University

With more than sixty breeds of beef cattle present in the United States, the question of "Which breed should I choose?" is difficult to answer. The top ten breeds in fiscal year 2017 reported registrations accounting for more than 90% of the pedigreed beef cattle in the U.S. These top ten breeds and their crosses represent most of the genetics utilized in commercial beef production, providing a hint at the breeds that possess the most valuable combinations of traits as recognized by beef producers. The breed, composite, or combination of breeds employed in a breeding program can have a large impact on the profitability of a commercial beef operation and the value of animals it produces as they move through the beef complex. The breed or biological type of an animal influences economically important production traits including growth rate, feed intake, reproductive efficiency, and carcass merit.

Large differences exist today in the relative performance of various breeds for most economically important traits. These breed differences represent a valuable genetic resource for commercial producers to use in structured crossbreeding systems to achieve an optimal combination of traits matching the cowherd to their production environment and to use sire selection to produce market-targeted progeny. As such, the selection of the "right" breed(s) to use in a breeding program is an important decision for commercial beef producers. The determination of the "right" breed(s) to use is highly dependent on a number of characteristics of a farm or ranch; not every operation should use the same breed or combination of breeds.

Breed and Composite Defined

A common definition of a breed is a genetic strain or type of domestic livestock that has consistent and inherited characteristics such as coat color or pattern, presence or absence of horns, or other qualitative criteria. However, one can also consider performance traits as common characteristics shared by individuals of a breed. In simple terms, these common characteristics are the performance traits that are often associated with a breed as its reputation has grown over time and represent the core traits for which a breed of livestock has been selected for over time. Breeds differ in the level of performance for various traits as a result of different selection goals of their breeders.

A composite is something that is made up of distinct components. In reference to beef cattle, the term composite generally means that the animal is composed of two or more breeds. A composite breed then is a group of animals of similar breed composition. Composites can be thought of as new breeds and managed as such. The American breeds including Beefmaster, Brangus, Brahman, and Braford are examples of new breeds formed as composites. More recent developments include Continental by British breed crosses such as SimAngus, Balancer, and LimFlex.

Beef Breed and Composite Characterization

A great deal of research has been conducted over the last 40 years at various federal and state experiment stations to characterize beef breeds in the U.S. These studies have been undertaken to examine the genetic merits of various breeds in a wide range of production environments and management systems. During this time, researchers at the U.S. Meat Animal Research Center (MARC) have conducted the most comprehensive studies of sire breed genetic merit via their long-term Germplasm Evaluation (GPE) project. This project evaluated over 30 sire breeds in a common environment and management system. The data summarized by the MARC scientists consisted of records on more than 20,000 animals born between 1978 and 1991, with a re-sampling of the most popular sire breeds in 1999-2000. The various sire breeds evaluated were mated to Angus, Hereford, and crossbred cows. Thus, the data reported were for crossbred progeny. During the study, Angus-Hereford crossbred calves were produced in the study as a control for each cycle of the GPE project. More recently, a new sampling system was implemented at US-MARC to continuously resample the largest breeds every two years.

A popular output from the GPE program are the across-breed EPD adjustment factors that enable comparing selection candidates from different breed sources. The estimates are updated and released early in the year to provide the timeliest results in advance of the spring bull buying season. Table 1 lists the 2021 across-breed adjustment factors that are added to the EPD of an animal of a specified breed to put that animal's EPD on an Angus base (Kuehn and Thallman, 2021). See www.beefimprovment.org for the most current adjustment factors. However, to gain a sense for average breed differences at a phenotypic level and to inform breed choice, producers should focus on breed of sire differences also reported from GPE data. The GPE data enables producers to compare relative breed performance in a common environment. Table 2 presents the sire breed means for 2019 born animals under production conditions similar to US-MARC (located in south-central Nebraska). The means in this table, also updated annually, represent the average phenotypes for various traits of calves produced by bulls from each breed with their respective breed average EPD. Differences in trait means in Table 2 represent genetic differences for each trait when sires are used in a common environment and mated to cows of similar genetic merit. Heterotic effects are not included here. Table 2 provides a more contemporary look at the differences in breed genetic potential for various traits and accounting for genetic trends occurring in each breed due to selection. Due to selection pressure placed on growth and maternal traits over time, many breeds have made considerable gains in those traits. In some cases, the large gains in performance have resulted in changes in the overall biological type of a breed.

Use of Breeds and Composites for Genetic Improvement

Inclusion or exclusion of germplasm from a breed (or composite) is a valuable selection tool for making rapid directional changes in genetic merit for a wide range of traits. Changes in progeny phenotype that occur when breeds are substituted in a breeding program come from two genetic sources.

The first source of genetic impact from a substitution of a breed comes through changes in the *additive genetic effects* or breeding values that subsequent progeny inherit from their sire and dam. Additive genetic merit is the portion of total genetic merit that is transmissible from parent to offspring and on which traditional selection decisions are made. In other words, additive genetic effects are heritable. EPD are estimates of one-half of the additive genetic merit. The difference in average performance for a trait observed between two breeds is due primarily to differences in additive genetic merit.

The second source of genetic change is due to non-additive genetic effects. Non-additive effects include both dominance and epistatic effects. Dominance effects arise from the interactions of paired alleles at each locus. Epistatic effects are the interaction of genes across loci. The sum of these two interactions result in heterosis observed in crossbred animals. Since each parent only contributes one allele to an offspring and dominance effects depend on the interaction of a pair of alleles, a parent cannot transmit dominance effects to its progeny within a breed. However, the selection of which breeds and how much of each breed to incorporate into progeny has a large impact on dominance (or heterosis) effects which affect phenotype. Because epistatic effects arise from the interaction of genes at different loci, independent segregation of chromosomes in the formation of gametes causes pairings of genes not to always stay together from one generation to the next. Like dominance effects, epistatic effects are not impacted by mate selection but by the frequency of different alleles and their dominance effects across breeds.

Table 1. January 2021 adjustment factors to add to EPDs of eighteen different breeds to estimate across-breed EPDs.

Breed	Birth Wt. (lb)	Weaning Wt. (lb)	Yearling Wt. (lb)	Maternal Milk (lb)	Marbling Score[a]	Ribeye Area (in^2)	Fat (in)	Carcass Wt. (lb)
Angus	0.0	0.0	0.0	0.0	0.00	0.00	0.000	0.0
Hereford	0.9	-16.6	-41.3	-11.1	-0.35	0.06	-0.076	-69.7
Red Angus	2.3	-21.3	-28.9	1.6	-0.11	0.29	-0.035	-7.2
Shorthorn	3.5	-23.1	-37.6	-4.9	-0.15	0.32	-0.039	-3.0
South Devon	3.1	-30.9	-57.9	2.6	-0.37	0.39	-0.042	2.2
Beefmaster	3.8	24.1	2.5	4.2				
Brahman	9.4	55.8	19.9	13.6	-0.69	0.11	-0.154	-33.9
Brangus	2.8	16.5	10.2	14.1				
Santa Gertrudis	4.9	39.7	35.1	17.5	-0.47	0.21	-0.074	-2.1
Braunvieh	2.1	-14.2	-40.6	-1.2	-0.63	1.17	-0.117	-38.9
Charolais	6.0	28.5	20.3	8.4	-0.33	0.80	-0.198	6.6
Chiangus	2.4	-23.6	-42.9	4.3	-0.40	0.53	-0.122	-26.1
Gelbvieh	3.2	-9.7	-17.2	7.1	-0.56	0.77	-0.112	-12.3
Limousin	1.7	-10.9	-35.4	-4.8	-0.39	0.61	-0.082	-4.5
Maine-Anjou	1.8	-28.5	-57.9	-7.6	-0.53	1.06	-0.169	-26.5
Salers	2.1	-17.7	-31.5	8.3	-0.78	0.53	-0.063	0.5
Simmental	1.7	-16.2	-25.5	-2.8	-0.19	0.50	-0.066	-4.5
Tarentaise	2.2	26.9	-8.1	11.1				

[a] Marbling score units: 4.00 = Sl^{00}; 5.00 = Sm^{00}. Note that Brahman EPDs for marbling are reported on a scale where 400 = Sl^{00} and 500 = Sm^{00}. When converting sires from other breeds to a Brahman basis, the adjusted EPD should be multiplied by 100. Likewise, when Brahman EPDs are adjusted to other breeds, the EPD should be divided by 100 before adding the adjustment factor.

Table 2. Breed of sire means for 2019 born animals under conditions similar to USMARC.

Breed	Birth Wt. (lb)	Weaning Wt. (lb)	Yearling Wt. (lb)	Maternal Milk (lb)	Marbling Score[a]	Ribeye Area (in^2)	Fat (in)	Carcass Wt. (lb)
Angus	84.5	525.0	1050.8	506.9	5.99	13.81	0.697	935.6
Hereford	87.0	502.7	989.7	494.1	5.13	13.62	0.623	891.4
Red Angus	83.8	504.5	1012.1	509.1	5.68	13.59	0.667	908.7
Shorthorn	88.7	487.9	978.2	500.6	5.24	13.86	0.568	894.6
South Devon	87.4	495.1	974.9	502.1	5.11	13.92	0.546	879.2
Beefmaster	87.3	516.7	993.8	495.7				
Brahman	94.4	540.5	996.2	502.8	4.70	13.60	0.542	882.3
Brangus	87.0	508.1	1002.7	505.5				
Santa Gertrudis	88.4	513.6	991.9	500.6	4.93	13.45	0.615	897.9
Braunvieh	88.1	497.0	974.0	514.0	5.31	14.76	0.485	881.2
Charolais	89.6	526.8	1025.1	501.0	5.16	14.70	0.498	922.5
Chiangus	87.5	492.2	979.1	500.9	5.27	14.11	0.548	894.5
Gelbvieh	86.3	524.6	1030.4	509.2	5.11	14.55	0.559	915.8
Limousin	86.0	522.4	1011.1	498.9	5.07	14.75	0.552	917.4
Maine-Anjou	86.0	483.3	948.9	492.9	4.98	14.54	0.491	882.3
Salers	85.4	506.3	996.3	506.8	5.00	14.42	0.544	897.9
Simmental	86.8	527.0	1034.5	503.2	5.30	14.56	0.531	919.9
Tarentaise	86.0	509.5	966.7	494.3				

[a] Marbling score units: 4.00 = Sl^{00}; 5.00 = Sm^{00}

Both additive and non-additive genetic effects can have a significant impact on a particular phenotype; therefore, it is important that both are considered during breed selection. Due to their different modes of inheritance, different tactics must be employed to capture the benefits of each.

Additive genetic merit may be selected for in two distinct ways. First, by the selection of individuals *within* a breed that have superior genetic merit for the trait under selection. Typically this is achieved through the use of EPD to identify selection candidates. The rate of improvement in phenotypes due to selection within breed is limited by the heritability of the trait. Heritability describes the proportion of phenotypic variation that is controlled by additive genetic variation. So, for traits with moderate to high heritability, considerable progress in progeny phenotype may be achieved through selection of superior animals within the breed as parent stock. The second approach to change additive genetic merit is through the selection of animals from a different breed(s) that excels in the trait under selection. *Across* breed selection can provide rapid change in progeny phenotype given that large differences exist between breeds in a number of economically relevant traits. Selection of superior parent stock from a different breed that excels in a trait is often more effective than selection within a breed (Gregory et al., 1999) as the breed differences have a heritability of nearly 100%.

The use of breed differences to achieve the best overall results across multiple traits *may be* achieved through the implementation of the concept of breed complementarity. Breeds are complementary to each other when they excel in different traits and their crossbred progeny have desirable levels of performance in a larger number of traits than either of the parent breeds alone. Making breed and mating selections that utilize breed complementarity provide an effective way to aggregate the core competencies of two or more breeds in the progeny. Moreover, use of breed complementarity can be a powerful strategy to genetically match cows to their production environment and progeny to the marketplace. For example, a crossbreeding system that mates Charolais bulls to Hereford-Angus crossbreed cows utilizes breed complementarity. The Charolais bull contributes growth and carcass yield to progeny genetics while the Hereford-Angus crossbred cows have many desirable maternal attributes and contribute genetics for carcass quality. When considering crossbreeding from the standpoint of producing replacement females, one could select breeds that have complementary maternal traits such that females are most ideally matched to their production environment. Matings to produce calves for market should focus on complementing traits of the cows and fine-tuning calf performance (growth and carcass traits) to the marketplace.

There is an abundance of research that describes the core competencies (biological type) of many of today's commonly used beef breeds as described earlier (i.e., Table 2). Traits are typically combined into groupings such as maternal/reproduction, growth, and carcass. When selecting animals for a crossbreeding system, breed should be the primary consideration. Breeds selected for inclusion in a mating program will be dependent on a number of factors including current cow herd breed composition, forage and production environment, replacement female development system, and calf marketing endpoint. All of these factors help determine the relative importance of traits for each production phase.

Table 3. Matching genetic potential for different traits to production environments[1].

Production Environment		Traits					
Feed Availability	Stress[2]	Milk Production	Mature Size	Ability to Store Energy[3]	Resistance to Stress[4]	Calving Ease	Lean Yield
High	Low	M to H	M to H	L to M	M	M to H	H
	High	M	L to H	L to H	H	H	M to H
Medium	Low	M to H	M	M to H	M	M to H	M to H
	High	L to M	M	M to H	H	H	H
Low	Low	L to M	L to M	H	M	M to H	M
	High	L to M	L to M	H	H	H	L to M
Breed role in terminal crossbreeding systems							
Maternal		M to H	L to H	M to H	M to H	H	L to M
Paternal		L to M	H	L	M to H	M	H

L = Low; M = Medium; H = High.
1 Adapted from Bullock et al., 2002.
2 Heat, cold, parasites, disease, mud, altitude, etc.
3 Ability to store fat and regulate energy requirements with changing (seasonal) availability of feed.
4 Physiological tolerance to heat, cold, internal and external parasites, disease, mud, and other factors.

One of the challenges of breed selection is the interaction of the animal's genotype with its production environment. Table 3 describes common production environments by level of feed availability and environmental stress and lists optimal levels of a variety of performance traits (Bullock et al., 2002). Here, feed availability refers to the regular availability of grazed or harvested forage and its quantity and quality. Environmental stress includes parasites, disease, heat, and humidity. Ranges for mature cow size are low (800 to 1,000 lb), medium (1000 to 1,200 lb), and high (1,200 to 1,400 lb). Clearly, breed choices should be influenced by the production environment in which they are expected to perform.

Crossing of breeds or lines is the primary method to exploit beneficial non-additive effects called heterosis. Heterosis refers to the superiority of the crossbred animal relative to the average of its straightbred parents and heterosis results from an increase in heterozygosity of a crossbred animal's genetic makeup. Heterozygosity refers to a state where an animal has two different forms of a gene. It is believed that heterosis is primarily the result of gene dominance and the recovery from accumulated inbreeding depression of pure breeds. Heterosis is, therefore, dependent on crossbred animals having a greater percentage of heterozygous animals than is present in straightbred animals. The level of heterozygosity an animal has depends on the random inheritance of copies of genes from its parents. In general, animals that are crosses of unrelated breeds, such as Angus and Brahman, exhibit higher levels of heterosis due to more heterozygosity, than do crosses of more genetically similar breeds such as a cross of Angus and Hereford.

Generally, heterosis generates the largest improvement in lowly heritable traits. Moderate improvements due to heterosis are seen in moderately heritable traits. Little or no heterosis is observed in highly heritable traits. Traits such as reproduction and longevity have low heritability. These traits respond very slowly to selection since a large portion of the variation observed in them is due to environmental effects and non-additive genetic effects, and a small percentage is due to additive genetic differences. But, heterosis generated through crossbreeding can significantly improve an animal's performance for lowly heritable traits, thus the importance of considering both additive and non-additive genetics when designing mating programs. Crossbreeding has been shown to be an efficient method to improve reproductive efficiency and pre-weaning productivity in beef cattle.

Improvements in cow-calf production due to heterosis are attributable to having both a crossbred cow (called maternal or

Table 4. Units and percentage of heterosis by trait for *Bos taurus* crossbred calves.

Trait	Heterosis Units	Heterosis Percentage (%)
Calving Rate, %	3.2	4.4
Survival to Weaning, %	1.4	1.9
Birth Weight, lb.	1.7	2.4
Weaning Weight, lb.	16.3	3.9
Yearling Weight, lb.	29.1	3.8
Average Daily Gain, lb./d	0.08	2.6

Table 5. Units and percentage of heterosis by trait for *Bos taurus* crossbred dams.

Trait	Heterosis Units	Heterosis Percentage (%)
Calving Rate, %	3.5	3.7
Survival to Weaning, %	0.8	1.5
Birth Weight, lb.	1.6	1.8
Weaning Weight, lb.	18.0	3.9
Longevity, years	1.36	16.2
Lifetime Productivity		
Number of Calves	.97	17.0
Cumulative Weaning Wt., lb.	600	25.3

Table 6. Units and percentage of heterosis by trait for *Bos Taurus* by *Bos indicus* crossbred calves.[1]

Trait	Heterosis Units
Calving Rate, %[1]	4.3
Calving Assistance, %[1]	4.9
Calf Survival, %[1]	-1.4
Weaning Rate, %[1]	1.8
Birth Weight, lb.[1]	11.4
Weaning Weight, lb.[1]	78.5

1 Adapted from Franke et al. 2005; numeric average of Angus-Brahman, Brahman-Charolais, and Brahman-Hereford heterosis estimates.

dam heterosis) and a crossbred calf (called individual or calf heterosis). Differing levels of heterosis are generated when various breeds are crossed. Similar levels of heterosis are observed when members of the *Bos taurus* species, including the British (e.g. Angus, Hereford, Shorthorn) and Continental European breeds (e.g. Charolais, Gelbvieh, Limousin, Maine-Anjou, Simmental), are crossed. Much more heterosis is observed when *Bos indicus*, or Zebu, breeds like Brahman, Nelore and Gir, are crossed with *Bos taurus* breeds. The increase in heterosis observed in British by *Bos indicus* crosses for a trait is usually two to three times as large as the heterosis for the same trait observed in *Bos taurus* crossbreds (Koger, 1980). The large increase is especially true with heterosis observed in the crossbred cow. The increase in heterosis is sensible as there are more genetic differences between species than within a species. Heterosis effects reported in Tables 4 through 7 will be divided and noted into those observed in *Bos taurus* crosses or *Bos taurus* by *Bos indicus* crosses. Table 4 details the individual (crossbred calf) heterosis and Table 5 describes the maternal (crossbred cow) heterosis observed for various important production traits in *Bos taurus* crossbreds. These heterosis estimates are adapted from a report by Cundiff and Gregory, 1999, and summarize crossbreeding experiments conducted in the Southeastern and Midwest areas of the U.S. Table 6 describes the expected individual heterosis of *Bos taurus* by *Bos indicus* crossbred calves, and Table 7 details the estimated maternal (dam) heterotic effects observed in *Bos taurus* by *Bos indicus* crossbred cows. *Bos taurus* by *Bos indicus* heterosis estimates were derived from breeding experiments conducted in the southern U.S.

The heterosis adjustments utilized by multi-breed genetic evaluation systems are another example of estimates for individual (due to a calf) and maternal (due to a crossbred dam) heterosis. These heterosis adjustments are presented in Table 8 and illustrate the differences in expected heterosis for various breed-group crosses. In general the Zebu (*Bos indicus*) crosses have higher levels of heterosis than the British-British, British-Continental, or Continental-Continental crosses.

The production of crossbred calves yields advantages in both heterosis and the blending of desirable traits from two or more breeds. However, the largest economic benefit of crossbreeding to commercial producers comes from the crossbred cow. Dam heterosis improves both the environment a cow provides for her calf as well as her longevity and durability. The improvement of the maternal environment a cow provides for her calf is manifested in improvements in calf survivability to weaning and increased weaning weight. Crossbred cows exhibit improvements in calving rate of nearly 4% and an increase in longevity of more than one year due to heterotic effects. Heterosis results in increases in lifetime productivity of approximately one calf and 600 pounds of calf weaning weight over the lifetime of the cow. Crossbreeding can have positive effects on a ranch's bottom line by not only increasing the quality and gross pay weight of calves produced but also by

Table 7. Units and percentage of heterosis by trait for *Bos Taurus* by *Bos indicus* crossbred dams.[1,2]

Trait	Heterosis Units	Heterosis Percentage (%)
Calving Rate, %[1]	15.4	--
Calving Assistance Rate, %[1]	-6.6	--
Calf Survival, %[1]	8.2	--
Weaning Rate, %[1]	20.8	--
Birth Weight, lb.[1]	-2.4	--
Weaning Weight, lb.[1]	3.2	--
Weaning Wt. per Cow Exposed, lb.[2]	91.7	31.6

1 Adapted from Franke et al. 2005; numeric average of Angus-Brahman, Brahman-Charolais, and Brahman-Hereford heterosis estimates.

2 Adapted from Franke et al. 2001.

Table 8. Individual (calf) and maternal (dam) heterosis adjustments for British, Continental European, and Zebu breed groups for birth weight, weaning weight, and post weaning gain.

Breed Combinations	Birth Weight (lb) Calf Heterosis	Birth Weight (lb) Dam Heterosis	Weaning Weight (lb) Calf Heterosis	Weaning Weight (lb) Dam Heterosis	Postweaning Gain (lb) Calf Heterosis
British x British	1.9	1.0	21.3	18.8	9.4
British x Continental	1.9	1.0	21.3	18.8	9.4
British x Zebu	7.5	2.1	48.0	53.2	28.2
Continental x Continental	1.9	1.0	21.3	18.8	9.4
Continental x Zebu	7.5	2.1	48.0	53.2	28.2

(Wade Shafer, Am. Simmental Association, personal communication; adapted from Williams et al., 2013) increasing the durability and productivity of the cow factory.

The effects of dam heterosis on the economic measures of cow-calf production have been shown to be very positive. The added value of maternal heterosis ranges from approximately $50/cow/year to nearly $100/cow/year depending on the amount of maternal heterosis retained in the cowherd (Ritchie, 1998) Heterosis expressed by dams accounted for an increase in net profit per cow of nearly $75/cow/year (Davis et al., 1994) Their results suggested that the benefits of dam heterosis on profit were primarily the reduced cost per cow exposed. Crossbred cows had higher reproductive rates, longer productive lives, and required fewer replacements than straightbred cows in their study. All of these factors contribute to reduced cost per cow exposed. Further, they found increased outputs, including growth and milk yield, were offset by increased costs.

When it comes to crossing breeds with the goal of producing high levels of maternal or individual heterosis, not all breeds are equal. Heterosis depends on an animal having two different alleles or alternate forms of a gene at a locus. The likelihood of having different copies of genes at a locus is greater in breeds that are less related than when the breeds crossed are closely related. For instance, Angus and Hereford, both British breeds, are more similar than Angus and Simmental (a Continental European breed) which are more similar than Angus (a *Bos taurus* breed) and Brahman (a *Bos indicus* breed). Since heterosis offers considerable advantages to commercial producers in terms of reproductive efficiency, productivity, and economic returns, care should be given when selecting breeds for inclusion in a crossbreeding system. Just as breeds differ in the amount of heterosis generated when crossed, crossbreeding systems achieve differing levels of heterosis depending on the number of breeds and their fractions represented in each animal. A more complete discussion on crossbreeding and crossbreeding systems appears in a separate chapter in this manual.

Summary

Selection of appropriate breeds for a particular production system can be a challenging task. Consideration during the selection process should be given to a number of criteria (Greiner, 2002) including:

- Climate (frost-free days, growing season, precipitation)
- Quantity, quality, and cost of feedstuffs available
- Production system (availability of labor and equipment)
- Market end points and demands
- Breed complementarity
- Cost and availability of seedstock

The selection of breeds and the genetics they contribute to the cowherd can have a large impact on profitability through the aggregate effects on each of the above criteria. Clearly, breeds need to be selected to fit a specific production system, whether that is selling replacement females, weaned feeder calves, or carcass components. For most producers, that production system should employ a structured crossbreeding system that utilizes two or more breeds. The breeds (and/or composites) chosen should produce calves that are appropriate for the market targeted. Moreover, the system and breeds included should provide a mechanism for the use of crossbred cows that are matched to the production environment in terms of mature size and lactation potential so as to capture the benefits of maternal heterosis. Selection of breeds that are too large and/or produce too much milk for the forage environment in which they are expected to produce may result in lower reproductive efficiency and increased supplemental feed costs. Selection of breeds provides an opportunity for the beef producer to impact both additive and non-additive genetics of the cowherd. Optimization of these two genetic components requires a disciplined approach to breed selection.

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