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The Value of Heterosis in Cow Herds: Lessons From the Past That Apply to Today

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THE VALUE OF HETEROSIS IN COW HERDS: LESSONS FROM THE PAST THAT APPLY TO TODAY

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INTRODUCTION

Beef cattle producers are currently faced with a multitude of challenges. The traditional cattle cycle appears to have deviated from conventional wisdom, in part because of increasing grain prices due to a biofuels ‘industry’ that has become a competitor for grain resources that the U.S. fed cattle industry has grown dependent upon. A suite of genetic tools have been provided, or are in the works, to address issues such as feed efficiency, fertility, and longevity; along with more traditional EPDs for production and carcass/ultrasound traits. Established EPDs have proven to be very successful at allowing producers to take advantage of additive genetic differences between animals. Newer molecular technology has attempted thus far to gather more insight into secondary traits such as meat quality and feed efficiency. The fact is that producers are provided with an extensive set of tools from which to make within breed genetic gain. It is often advantageous for animals not to excel in only one trait but to be complete in their genetic profile for reproductive, growth, and end product merit. It is challenging for one breed to do all this in an efficient manner. One of the oldest and truest methods of finding that balance is through the use of crossbreeding.

Advantages of crossbreeding can be thought of as: 1) Taking advantage of breed complementarity, 2) Taking advantage of non-additive effects (dominance and epistatic) and 3) capturing heterosis (hybrid vigor).

BREED SELECTION

Correct breed selection is the critical first step to initializing a crossbreeding system. Choosing a breed(s) is dependent upon:

1. Production and marketing goals
2. Production environment
3. Available feed and labor resource

Choosing a breed that is best suited to your production environment is dependent on several factors including the availability of feed, and level of stress (temperature, amount of moisture, etc.). Table 1 outlines the biological type of cattle that are best suited for particular levels of feed resources and stress.

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

Production Environment		Traits					
Feed Availability	**Stress[2]**	**Milk**	**Mature Size**	**Ability to store energy[3]**	**Resistance to stress[4]**	**Calving ease**	**Lean yield**
High	Low	M to H[5]	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

[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.
[5] L = Low; M = Medium; H = High.

The decision of whether or not to utilize a particular strategic system of crossbreeding depends upon individual production goals. *First must come the blinding realization that no one breed excels in all areas that lead to profitability*. In order to take advantage of breed complementarity, breeds must be paired such that they excel in different areas that are critical to the overall production goal(s). Table 2 provides across breed adjustment factors for the comparison of EPDs but can easily be used to classify breeds into types based on propensity for growth and milking ability.
For instance, if the goal is to sell calves at weaning then it would make sense to use a breed, most likely Continental, which will maximize direct weaning weights. However, this purebred system will maximize outputs, but may require large inputs as well. With that in mind, perhaps it would make more sense from an economic perspective to use a British breed as the genetic base for all dams and use a continental breed for sires thus minimizing the input costs from the female side yet still capturing added growth in the calves due to the direct growth provided by the sire breed. This would be a very simple example of a crossbreeding system.

Table 2. 2006 Adjustment factors for comparison of EPDs across various breeds[1]

Breed	Birth wt.	Weaning wt.	Yearling wt.	Milk
Angus	0.0	0.0	0.0	0.0
Charolais	10.0	38.8	53.1	1.3
Gelbvieh	4.7	6.2	-22.6	4.6
Hereford	2.9	-2.5	-15.7	-18.3
Limousin	4.1	1.8	-21.5	-16.4
Red Angus	3.0	-1.6	-0.8	-8.1
Saler	4.2	29.0	42.1	11.2
Shorthorn	7.1	30.6	44.6	15.0
Simmental	5.8	22.6	20.8	11.9

[1]Adapted from Van Vleck and Cundiff, 2006.

CROSSBREEDING SYSTEMS

There are many other crossbreeding systems that vary significantly in terms of difficulty. Items that can influence the success of a crossbreeding system include:

1) Number of cows in the herd
2) Number of available breeding pastures
3) Labor and management
5) Production and marketing system
6) Availability of high-quality bulls of the various breeds

Two breed terminal

In this simple situation, cows of breed A are bred to bulls of breed B and all offspring are sold. In this system the offspring are F1s and will benefit from 100% of the possible individual heterosis.

Three breed terminal

In this situation cows that are F1 feamles comprised of ½ breed A and ½ breed B are mated to bulls of breed C for the production of terminal offspring. In this system, calves not only benefit from 100% of the possible individual heterosis, but maternal heterosis is realized as well. In general, the females should be a cross of two maternal breeds that emphasize efficiency and milking ability while the sire breed should inject growth.

Two breed rotation

A two-breed rotation is a simple crossbreeding system requiring two breeds and two breeding pastures. The two-breed rotational crossbreeding system is initiated by breeding cows of breed A to bulls of breed B. The resulting progeny (A*B) chosen as replacement females would then be mated to bulls of breed A for the duration of their lifetime. The service sire is the opposite breed of the female's own sire. These progeny are then one-quarter breed A and three-quarters breed B. Since these animals were sired by breed B bulls, they are mated to breed A bulls. Each succeeding generation of replacement females is mated to the opposite breed of their sire. Initially only one breed of sire is required. Following the second year of mating, two breeds of sire are required. After several generations, the amount of retained heterosis stabilizes at about 67% of the maximum heterosis, resulting in an expected 16% increase in the pounds of calf weaning weight per cow exposed above the average of the parent breeds (Ritchie al., 1999). In this system, a minimum of two breeding pastures and 50 cow units are required.

Three breed rotation

A three-breed rotational system achieves a higher level of retained heterosis than a two-breed rotational crossbreeding system does. After several generations, the amount of retained heterosis stabilizes at about 86% of the maximum heterosis, resulting in an expected 20% increase in the pounds of calf weaning weight per cow exposed above the average of the parent breeds (Ritchie et al., 1999). Like the two-breed system, distinct groups of cows are formed and mated to bulls of the breed that represents the smallest fraction of the cows breed makeup. A cow will only be mated to a single breed of bull for her lifetime.

A minimum of three breeding pastures is required for a three-breed rotational system. Replacement females must be identified by breed of sire to ensure proper matings. The minimum herd size is approximately 75 cows with each one-third being serviced by one bull of each breed. Scaling of herd size should be done in approximately 75 cow units to make the best use of service sires, assuming one bull per 25 cows. Replacement females are mated to herd bulls in this system, so extra caution is merited in sire selection for calving ease to minimize calving difficulty. The progeny produced from these matings that do not conform to the breed type of the herd should all be marketed. Breeds used in rotational systems should be of similar biological type to avoid large swings in progeny phenotype due to changes in breed composition. The breeds included have similar genetic potential for calving ease, mature weight and frame size, and lactation potential to prevent excessive variation in nutrient and management requirements of the herd.

When choosing a crossbreeding system it is critical to consider more than the amount of heterosis retained. After all, each system requires different levels of input (pastures, etc.) and differing levels of difficulty. Table 3 describes the advantages and requirements for the above mentioned crossbreeding systems.

Table 3. Summary of crossbreeding systems by advantage and other factors[1]

Type of system		**Advantage[2]**	**Retained heterosis[3]**	**Minimum no. of breeding pastures**	**Minimum herd size**	**No. of breeds**
2-breed rotation	A*B rotation	16	67	2	50	2
3-breed rotation	A*B*C rotation	20	86	3	75	3
Terminal cross with straightbred females[4]	T*A	8.5	0	1	Any	2
Terminal cross with purchased F1 females	T*(A*B)	24	100	1	Any	3
Rotating	A*B x A*B	12	50	1	Any	2
unrelated	A*B x A*C	16	67	1	Any	3
F1 bulls	A*B x B*C	19	83	1	Any	4

[1]Adapted from Ritchie et al., 1999.
[2]Measured in percentage increase in lb of calf weaned per cow exposed.
[3]Relative to F1 with 100% heterosis.
[4]Gregory and Cundiff, 1980.

HETEROSIS

Too often heterosis (hybrid vigor) is thought to be the exclusive goal of crossbreeding. Heterosis is nothing more than an unexpected and often beneficial deviation from the average of the two parental lines. Hybrid vigor can also be thought of as the 'anti-inbreeding'. Inbreeding increases uniformity by increasing homozygosity but also creates 'inbreeding depression' or a general decrease in survival and reproductive traits that can be caused by a decrease in heterozygosity. Percent heterosis can be calculated as:

% Heterosis = [(crossbred average – straightbred average) ÷ straightbred average] x 100

A simple example would be the percent heterosis realized in the average weaning weight from breeding a herd of Breed A cows to a group of Breed B bulls. Let 525 pounds be the average weaning weight of the F1 calves, 450 be the average weaning weight of the Breed A population, and 550 be the average weaning weight of the sire's population. The pounds of heterosis would be:

Pounds of heterosis = 525 – [(450+550)/2] = 25 pounds

and the percent of heterosis would be:

% heterosis = 25/[(450+550)/2] = .05 or 5%

The amount of heterosis that is realized for a particular trait is inversely related to the heritability of the trait. This is logical since traits that are lowly heritable have a small additive component (proportionally speaking) and crossbreeding takes advantage of dominance and epistatic effects. With that in mind, traits of low heritability (reproductive traits) generally benefit from heterosis the most (Table 4). They generally have a heritability of less than 10% and can be improved thru the adequate use of crossbreeding systems. End-product traits on the other hand that benefit from heritability in the moderate to high range benefit less from heterosis.

There are three main types of heterosis:

1. Individual
2. Maternal
3. Paternal

Table 4. Individual heterosis: Advantage of the crossbred calf[1]

Trait	Observed Improvement	% Heterosis
Calving rate	3.2	4.4
Survival to weaning	1.4	1.9
Birth weight	1.7	2.4
Weaning weight	16.3	3.9
ADG	0.08	2.6
Yearling weight	29.1	3.8

[1]Adapted from Cundiff and Gregory, 1999.

Retained Heterosis

Unfortunately there exists a popular misconception that heterosis exists only in the first generation of crossbreds (F1). Heterosis is *retained* in the breeding of crossbred animals and is related to the probability of alleles from different parental lines joining together. For instance, if two F1 animals are mated, heterosis in the corresponding offspring is called *retained heterosis* and is equal to the following:

Heterosis retained = 1- [($P_{S1}P_{D1}$) + …. + [($P_{Sn}P_{Dn}$)]

Where P_{S1} is the proportion of the sire from breed 1 and P_{D1} is the proportion of the time from breed 1 and n is equal to the total number of breed involved.

Maternal Heterosis

The offspring of a F1 female will benefit from maternal heterosis (Table 5). Most commonly thought of as realized heterosis of milk production.

Table 5. Maternal heterosis: Advantage of the crossbred cow[1]

Trait	Observed Improvement	% Heterosis
Calving rate	3.5	3.7
Survival to weaning	0.8	1.5
Birth weight	1.6	1.8
Weaning weight	18.0	3.9
Longevity	1.36	16.2
Cow Lifetime Production:		
No. Calves	0.97	17.0
Cumulative Wean. Wt., lb.	600	25.3

[1]Adapted from Cundiff and Gregory 1999.

Paternal Heterosis

Fewer examples of paternal heterosis exist and consequently crossbred sires have often been ignored. The benefit of crossbred or composite sires lies in their ability to inject heterosis and breed complementarity into a herd with greater ease than the rotational crossbreeding systems described above.

COMPOSITES

Some of the first such animals are the American Breeds, or Brahman Derivatives. Perhaps there is no greater example of breed complementarity (breeding animals to adapt to a specific environment) and consequently of heterosis.

The American Gelbvieh Association, North American Limousin Foundation, and American Simmental Association are three breed associations that have implemented new programs to introduce composites such as the Balancer, Lim-Flex, and SimAngus, respectively. There is no doubt that some of these programs have met with opposition from within the respective associations due to an ignorant stance that purebred animals are superior. I greatly admire those who have pushed, pulled, and prodded these programs thru.

Crossbred females have proven to be very profitable and well accepted from a commercial standpoint. The use of crossbred bulls has not been accepted so easily. Some common fears have been the perception of larger amounts of variation within composite populations and the lower accuracy of EPDs of composite animals. In a study of three composite lines at MARC and their parental purebreds, there were no statistical significant differences in the coefficient of variation for reproduction, production, or carcass traits measured (Table 7) (Gosey, 2005). Admittedly, EPDs of composite animals may not have the benefit of the amount of information that purebred animals do. There is no doubt that a multibreed genetic evaluation could help alleviate this problem but first we must all accept the cumbersome but much needed device called ‘whole herd reporting’.

Table 7. Coefficients of variation for purebred vs. composite steers[1]

Trait	Purebreds	Composites
Birth weight	0.12	0.13
Wean weight	0.10	0.11
Carc. weight	0.08	0.09
Retail Product %	0.04	0.06
Marbling	0.27	0.29
Shear Force	0.22	0.21

[1]Adapted from Gosey, 2005.

CONCLUSIONS

A phenomenon as old and as recognized as heterosis still seems to spark debate and unfortunately confusion. Just open up the breed association journal of your choice and odds are you will find an article discussing the value of crossbreds versus straightbreds (in a few isolated cases you may find the reverse). A quick search of the scientific literature will provide numerous studies quantifying heterosis for specific traits under specific crosses. Traditional crossbreeding systems have been shown to maximize heterosis but can be very cumbersome in practice. Although using composite seedstock may not reach the same levels of retained heterosis, they may very well prove to be the compromise between attaining acceptable levels of heterosis and ease of implementation. Care must be taken in the formation of these composites and adequate selection must take place on both sides of the pedigree (selecting both paternal and maternal lines for composite formation). Crossbreeding is yet another tool in the tool box of genetic improvement and like anything else can be very profitable if understood and used correctly.

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