

Variability by Crossbreeding

Author: Gary W. Rogers, Global Technical Advisor, posted 12/9/2008

The variability of crossbreds has been a topic of discussion among farmers trying crossbreeding. Since crossbreeding now is gaining momentum we would like to highlight the topic of genetic variation, and Gary W. Rogers, Global Technical Adviser of Geno Global has written an article on this subject.

Many of the world's most popular dairy breeds have now been selected for increased milk production and for improvement in several other traits for many generations. This intense selection has been successful in improving milk production and for improving the other traits that have been the focus of the selection programs. However, this same intense selection has led to an increase in inbreeding in many of the populations. Inbreeding is defined as the mating of animals more closely related than the average of the population and it reflects changes in variability at the gene level. Selection and inbreeding has also led to a decline in fertility, health and survival in most of the dairy cattle populations. To help understand the increase in inbreeding that is occurring in the Holstein population, geneticists currently estimate that the effective size of the global Holstein population is between 35 and 60 animals even though there are close to 30 million Holsteins worldwide. As a consequence of the increased inbreeding and the decline in fertility and health, many commercial (not seedstock producers) dairy producers have chosen to use crossbreeding. They are utilizing several breeds including a few breeds that have been simultaneously selected for improved milk production, improved fertility and improved health. Crossbreeding is defined as the mating of sires of one breed or breed combination to cows of another breed or breed combination. Crossing NRF sires with pure Holstein cows and crossing NRF sires with $\frac{1}{2}$ Holstein and $\frac{1}{2}$ Jersey dams has become common place in the US in recent years. Resulting crossbred cows have the advantage of hybrid vigor and improved additive genetic effects (improved average fertility and health from the NRF breed due to past selection) for fertility and health from the NRF breed. Currently, most of the new heifers calving in New Zealand herds are crossbreds. However, New Zealand has primarily used Jerseys and Holsteins for crossing to date. Crossbreeding in dairy cattle has reached a level that has never been seen before because dairy producers now recognize the benefits of crossbreeding for commercial production. In addition, we now have several breeds that are economically competitive in commercial dairy herds as a result of thoughtful and prudent selection in the past.

Variability of crossbreds compared with purebreds is a common topic of discussion for dairy producers and especially those that have not chosen to utilize crossbreeding. Many dairy producers tend to favor a more uniform herd because their dairy farm housing and milking system is designed for cows that are of specific size and performance. However, many other dairy producers are happy with considerable variability because they are able to handle this variability in their system. It is important to understand that crossbreeding of widely differing breeds will result in crosses that differ more from any single parental breed but that does not mean that the variation within the crossbred cows will be greater than variability within either one of the parental breeds. A common concern among US dairy producers about using Jersey sires on Holstein dams is related to how well the $\frac{1}{2}$ Jersey and $\frac{1}{2}$ Holstein crosses will work in their housing system and milking facility because they will be considerably smaller than a pure Holstein. We also find dairy

farms that have facilities designed for smaller cows that have the opposite concern. This variability in cow size can be important from a management standpoint, but the variability in other traits like production traits and reproduction can also be important to some dairy producers as well.

To understand how crossbreeding impacts variability it is important to understand what inbreeding and crossbreeding do for important traits in dairy cattle. Inbreeding increases what geneticists call homozygosity. This means that inbreeding increases the number (and percentage) of genes where the copy of the gene on one chromosome is identical to the copy on the other chromosome of the pair (cattle have 30 pairs of chromosomes). Effectively inbreeding concentrates genes that are more alike and this concentration increases as the level of inbreeding increases. Although the formation of completely inbred lines in cattle is not possible (would take too long), scientists have bred what are essentially completely inbred lines in mice. Within an inbred line of mice, all the mice are very similar. When two mice from the same inbred line are mated, they essentially produce offspring that are genetically identical, much like identical twins. On the other hand, crossbreeding reduces homozygosity (or completely eliminates homozygosity if animals that are crossed are completely inbred and from a different line or breed). It is interesting to note that the crossbreeding of completely inbred lines or breeds does not result in more variation in the offspring compared with the parental breeds or lines. It does, however, result in completely heterozygous offspring that are all alike genetically. Although breeds of dairy cattle are not completely inbred, the first generation that results from crossing two breeds (usually called F1s) tend to be very uniform and usually are as uniform as either of their purebred parental breeds. In other words, the variability among the crossbreds from this first cross is expected to be the same as the variability that we see within each of the parental breeds. Of course these crossbred animals will not have the same performance or be the same size as their parental breeds unless the parental breeds are very similar in performance and size. For example, crossing Jersey sires on Holstein dams will not produce offspring that are the same size as either the Holstein dams or the Jersey dams but they will average somewhere in between the weights of the parental breeds. However, these first generation crosses between Jerseys and Holsteins will not be more variable than either of their parental breeds.

Keep in mind that we will always have variability in size and performance in dairy cattle because the environment plays a major role in cow size and performance. Even identical twins will be very variable because genetics only accounts for about $\frac{1}{2}$ the variation in size and even much less for other traits like milk yield. Effectively the variation due to environmental effects dwarfs the variability due to genetic effects within a breed when we look at most traits that are of interest to dairy producers. Variability in traits like fertility, disease resistance, and survival among a large group of genetically identical cows (could only make these genetically identical cows with cloning to test this) would essentially be indistinguishable from the variability of unrelated cows within a breed unless we had thousands of cows in each group for observation. Basically over 90% of the variation in these traits is due to influences of the environment. So essentially for all practical purposes, dairy producers will not be able to recognize a difference in variability within a breed compared to the variability within a first generation breed cross for most traits.

So the question then arises, "what about variability within subsequent crossbred cows after the first generation cross?" We have several options for breeding this first

generation crossbred cow. In the US many first generation crosses of Jerseys and Holsteins are being mated to NRF sires. Most geneticist would also call this resulting cow (the $\frac{1}{2}$ NRF, $\frac{1}{4}$ Jersey and $\frac{1}{4}$ Holstein cows) a first generation cross (F1) as well because the crossbred cow is essentially from breeds that are different than the NRF. Some $\frac{1}{2}$ Jersey and $\frac{1}{2}$ Holstein cows will be mated back to either a Jersey sire or a Holstein sire and we call this a backcross. In New Zealand, many of these $\frac{1}{2}$ Jersey and $\frac{1}{2}$ Holstein cows are being bred back to $\frac{1}{2}$ Jersey and $\frac{1}{2}$ Holstein crossbred bulls. Geneticists commonly call the resulting crossbred group from breeding a $\frac{1}{2}$ Jersey and $\frac{1}{2}$ Holstein cow to a $\frac{1}{2}$ Jersey and $\frac{1}{2}$ Holstein bull an F2 generation. It is different from a backcross because the sire used is not a purebred but the sire has the same breed makeup as the cow). If we breed this first generation cross (for example, a $\frac{1}{2}$ NRF and $\frac{1}{2}$ Holstein) back to one of the parental breeds (for this example breed back to Holstein sire) we get a $\frac{1}{4}$ NRF and $\frac{3}{4}$ Holstein backcross. The variability among these backcross cows will be greater than the variability of the first generation crosses ($\frac{1}{2}$ NRF and $\frac{1}{2}$ Holstein) but for most traits it will be difficult for an individual dairy producer to see this as the difference in variation will only be small. It may be easier for producers to detect more variation in traits like size and color patterns but variation within these backcrosses in fertility and health and probably in production traits will be virtually indistinguishable from variation for these traits within the parental breeds.

The variability among F1 crossbreds that result from breeding $\frac{1}{2}$ Jersey and $\frac{1}{2}$ Holstein cows to NRF bulls may result in similar variability to the backcrosses described above ($\frac{1}{4}$ NRF and $\frac{3}{4}$ Holstein). However, these resulting 3 breed crosses could be more variable for some traits like size, coat color patterns and fat content of the milk because the $\frac{1}{2}$ Jersey and $\frac{1}{2}$ Holstein dam can contribute a variable set of genes for size and many other traits to the $\frac{1}{2}$ NRF, $\frac{1}{4}$ Jersey and $\frac{1}{4}$ Holstein offspring. Variability in three breed crossbreds will have variability that is dependent on the differences among the parental breeds. It will especially depend on the differences in size and performance among the two parental breeds that were used to produce the crossbred cow used for mating to the sire from the third breed. However, for most traits (other than size and coat color patterns and fat content) it will be difficult for an individual dairy producer to see this difference in variation because it will be small compared to the influence of the variation due to the environment. Variation in traits like fertility and health and probably in milk production will be virtually indistinguishable from variation for these traits within the parental breeds.

The variability among the F2 crossbreds that, for example, results from mating $\frac{1}{2}$ Jersey and $\frac{1}{2}$ Holstein cows to $\frac{1}{2}$ Jersey and $\frac{1}{2}$ Holstein crossbred bulls will result in more variability in the offspring than we will see in a backcross (example $\frac{1}{4}$ NRF and $\frac{3}{4}$ Holstein) or a cross that results from breeding a third breed sire to a crossbred cow that is $\frac{1}{2}$ Jersey and $\frac{1}{2}$ Holstein. This type of mating where crossbred cows are mated to crossbred bulls that are from the same parental breeds will result in more variability in the offspring than most three breed crosses and certainly more than backcrosses. However, even for these F2 individuals it may be difficult for producers to see more variability in fertility and many other traits. However, producers will see considerable variability in the F2 generation for size and coat colors and patterns if the original pure breeds involved substantially differ for these traits.

Crossbreeding programs can result in more variation in the herd than we see in herds with only one pure breed included. However, the variation among the various breed combinations that result is generally more important than the variation within the various crossbred animals within a specific crossbred genotype (for example, Jersey by Holstein crosses). The possible exception to this is when crossbred cows are mated to crossbred bulls and the original crossbreds used in the program result from breeds that are very different in size, color and performance. Rotating two breeds in a crossbreeding program where purebred bulls are utilized in alternating generations or rotating three breeds in a crossbreeding program where purebred bulls are utilized in a specific sequence will result in more variation in the herd compared to a situation where only one pure breeding is used for the herd. However, generally the variation within various crosses is not nearly as important and observable as the variation among the various crossbred genotypes or the variation among the pure breeds. Rotational crossbreeding programs should result in acceptable variation in performance as long as the breeds chosen are suitable for commercial dairy production and purebred bulls are used in a systematic breeding rotation. Commercial dairy farms should choose breeds for crossbreeding that offer excellent performance for traits that are economically important and they should choose breeds that will result in cows that will work well in their housing and milking facilities.