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*Dairy Updates*

# Crossbreeding Dairy Cattle

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## Crossbreeding

The primary goal of dairy cattle breeding is to increase the efficiency of milk production, and some farmers have considered crossbreeding as an alternative to achieve this goal. Easy access to genetic material from almost anywhere in the world, together with standardization of sire evaluations (i.e. INTERBULL), and strong competition among several breeds (e.g., Holstein, Jersey, and Brown Swiss), are some of the factors that are making crossbreeding increasingly feasible. Certain climates can be very demanding on milking animals, especially during the summer, and the prices of the feedstuffs can vary. These factors can affect reproductive performance, health, and survival. The volume of solids (fat and protein) in milk has become increasingly important, and milk prices heavily influenced by milk composition. Crossbreeding is one alternative for improvement of milk composition, health, fertility, and survival, because differences between breeds are much greater than the differences within breed and extra benefits can be achieved from heterosis. Historically, the strength of breed associations and personal preferences of purebred breeders are factors that have limited the acceptance of crossbreeding in many dairy populations [7].

Inbreeding in most of the dairy breeds is increasing at a rate of two to three percent per decade, and this concern also makes crossbreeding increasingly attractive. Losses due to inbreeding depression can be recovered when two purebred lines are crossed. Hybrid vigor (heterosis) is the opposite phenomenon of inbreeding depression. In dairy cattle, inbreeding can impair fertility, health and maternal effects. Inbreeding depression occurs when an animal that is heterozygous at a particular locus has greater performance than expected, based on the average of animals that are homozygous (for either allele) at the same locus. This difference occurs when dominance affects a specific trait (such as fertility). For example, if genes that affect fertility are dominant, inbreeding will generate a reduction in fertility that is dependent (linearly or not) on the inbreeding coefficient 'F.' If there is an epistatic interaction between loci affecting this trait, the reduction will not be linear, but rather proportional to $F^2$. Theoretical expectations are not observed in some circumstances, such as when some highly inbred animals are not viable (and therefore don't survive long enough to be observed for traits like fertility or milk production).

The amount of heterosis is the difference between means for the crossbred line and the average of the two purebred lines. Heterosis depends on the difference in gene frequencies between the two parental populations, and heterosis will be maximized when one allele is fixed in

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one population and the alternative allele is fixed in the other population. Crosses between different pairs of populations (e.g. Jersey and Holstein or Brown Swiss and Holstein) will show different amounts of heterosis, because gene frequencies differ in each pair of populations. In the second generation (after crossbreeding of individuals in the first generation), we expect to observe half of the heterosis that occurred in the first crossbred generation. Epistasis can play an important role on the amount of heterosis. When two populations are crossed, some traits may not express full heterosis because pairs (or sets) of genes in each population have co-adapted.

Much of our experience on dairy crossbreeding comes from countries like New Zealand, where more than 20 percent of milk-recorded animals come from crosses between the Holstein and Jersey breeds. However, the specificity of environmental and management conditions in New Zealand makes extrapolation of these results to other countries difficult. In New Zealand, like in several other European countries, purebred animals and crossed animals are included in the same national evaluation, and the corresponding genetic evaluation methodology accounts for expected heterosis.

Calf survival is lower in the Jersey breed than in Holsteins, and this trait is influenced by both direct (genotype of the animal) and maternal (genotype of the mother) effects. In the case of maternal effects, the character has two components. The first generation will have full heterosis but the maternal part will come from one of the parental (inbred) lines. The second generation will have half of the heterosis of the first one (expected) on the non-maternal part, but the maternal component will come from the first generation (with full heterosis). The results shown in Table 1 suggest that breed differences and heterosis are important factors in calf survival, because purebred animals (of both breeds) had poorer performance than crossbred animals.

Calving ease is also an important problem on the Holstein breed. Previous studies have shown that approximately 23 percent of

Table 1: Calf survival scores

| Sires | Dams | Scores |
|---|---|---|
| Jersey | Jersey | 2.2 |
| Jersey | Crossbred Jersey x Holstein | 2.7 |
| Holstein | Holstein | 2.9 |
| Holstein | Crossbred Jersey x Holstein | 3.2 |
| Jersey | Holstein | 3.3 |
| Holstein | Jersey | 3.6 |

Scores scale: 1 (poor survival) to 5 (excellent survival)

Table 2: Calving ease scores

| Sires | Dams | Scores |
|---|---|---|
| Holstein | Holstein | 2.2 |
| Holstein | Crossbred dams | 2.9 |
| Holstein | Jersey | 3.6 |

Scores scale: 1 (many problems) to 5 (few problems)

Table 3: Female fertility scores

| Cow Type | Scores |
|---|---|
| Holstein purebred | 2.6 |
| Holstein Jersey crossbred | 3.2 |
| Jersey purebred | 3.6 |

Scores scale: 1 (poor fertility) to 5 (excellent fertility)
Results are from a survey of US producers [7]

Holstein heifers have calving problems and that 28 percent of these (difficult) calves die at birth. For this trait, differences among breeds are obvious. For example, Jersey animals almost never have calving problems (Table 2).

Regarding traits associated with reproductive performance—a critical concern in the dairy industry—improvement through conventional selection has been very slow within breed due to low heritability and due to the detrimental correlated responses to increased yield per cow (Table 3).

Results in Table 3 show that the fertility of crossbred animals was slightly superior to the average of parental breeds. Furthermore, the superiority in fertility among Jersey cows makes this breed more resistant to involuntary culling than Holsteins, even though they produce more energy-corrected milk per unit of live weight than Holsteins.

There is a large difference between Jerseys and Holsteins in milk composition (Figure 1), which is very important for the cheese industry and determines milk price in several markets. This makes crossbreeding more profitable in markets where a substantial premium is placed on fat and protein percent. The differences in

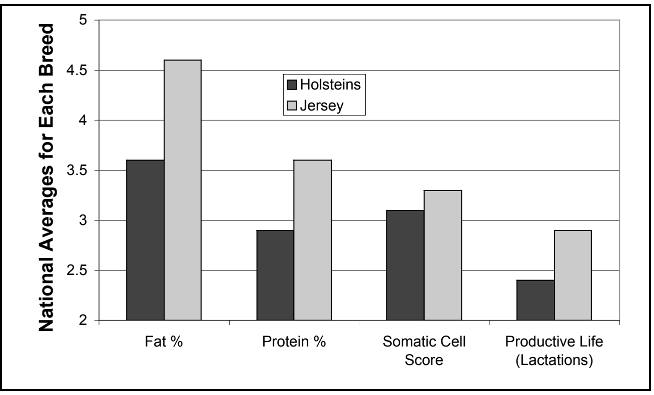


*Figure 1: Comparison between the Holstein and Jersey breeds for fat, protein, somatic cell score and productive life in the US*

somatic cell score suggest a higher susceptibility to mastitis in the Jersey breed when compared with Holsteins. Finally, Figure 1 shows that Jerseys survive, on average, one-half lactation longer than Holsteins. Studies have shown that the heterosis for longevity traits is about 15 to 20 percent in the first crossbred generation.

The size of cows produced from crossbreeding is also a concern among breeders, especially those who have recently remodeled or built new freestall facilities.

Several schemes are available for creating replacement animals via crossbreeding. The two-breed rotational cross may be the most viable option in several situations [4]. An example is the use of Jersey sires on Holstein cows, and this will generate 50% Holstein : 50% Jersey $F_1$ offspring with full heterosis. Using Holstein sires on these $F_1$ animals, will result in a 75% Holstein : 25% Jersey backcross animal in the next generation, and half of the original heterosis would be retained. Using Jersey sires in the next generation would lead to 62.5% Jersey : 37.5% Holstein offspring, and three-quarters of the original heterosis would be realized. After many generations, all animals in the herd will be 67% Holstein : 33% Jersey or 67% Jersey : 33% Holstein, depending on the generation, and two-thirds of the original (first-cross) heterosis will remain (Figure 2).

Theoretical advantages of a three-breed rotation are clear, but few studies have utilized this scheme in dairy cattle. As an example, we could use Jersey sires on Holstein cows to

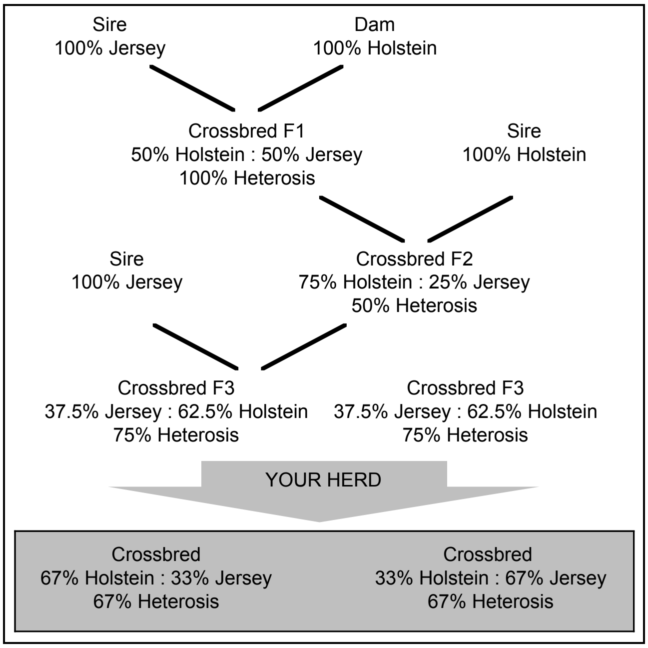


*Figure 2: Crossbreeding plans: Two-breed rotation*

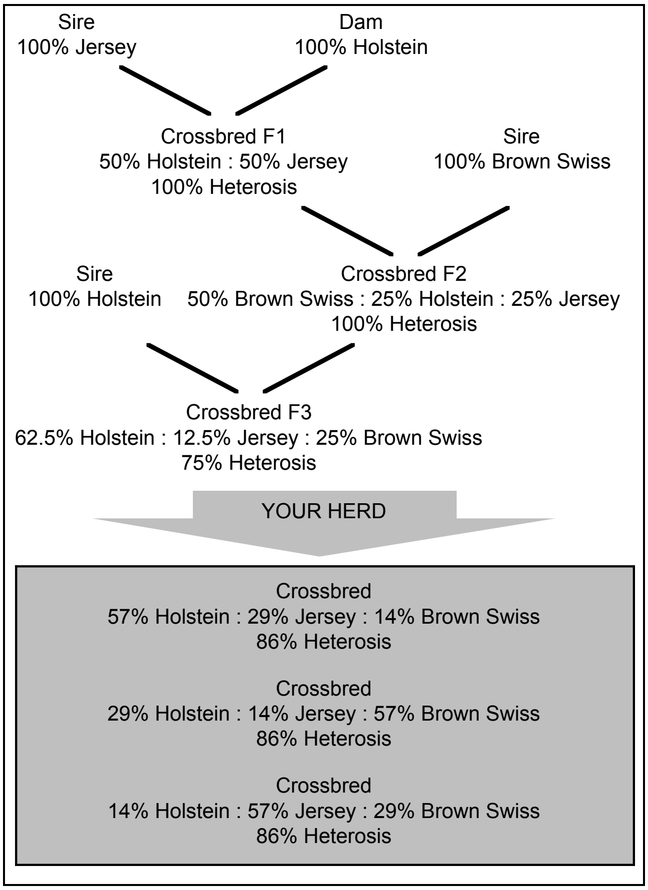


*Figure 3: Crossbreeding plans: Three-breed rotation*

generate $F_1$ animals that are 50% Holstein : 50% Jersey. Using Brown Swiss sires as mates for

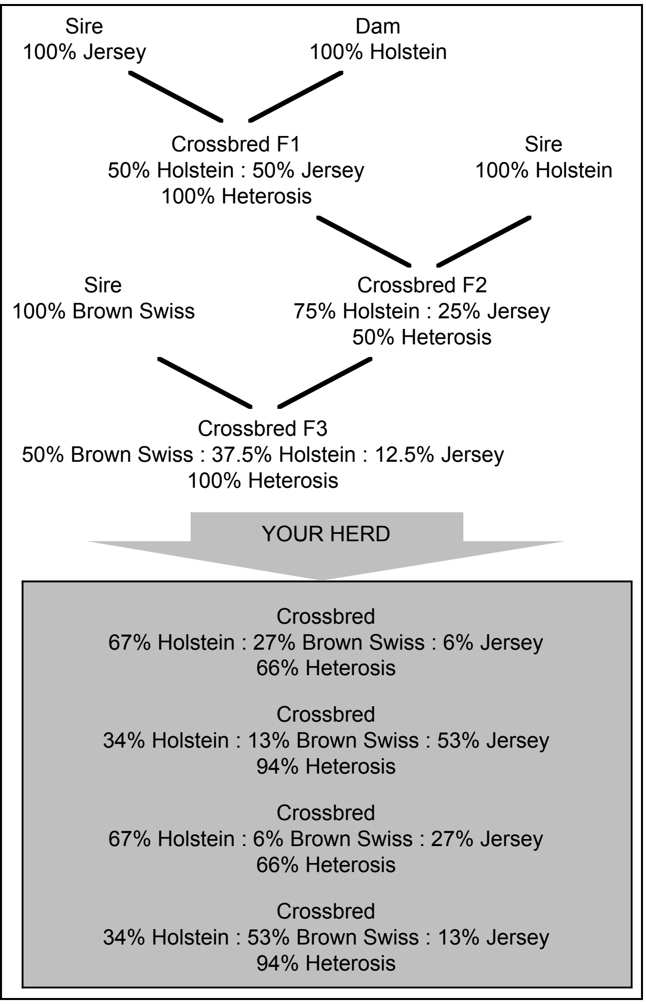


*Figure 4: Crossbreeding plans: Two-breed rotation*

the $F_1$ females would generate animals that are 50% Brown Swiss : 25% Holstein : 25% Jersey in the next generation, and full heterosis would be retained. Using Holstein sires in the next generation would generate animals that are 62.5% Holstein : 12.5% Jersey : 25% Brown Swiss, and three-quarters of the heterosis would be realized. Over time, the proportions of Holstein, Jersey, and Brown Swiss genes in a given generation will vary widely (depending on the most recent breed(s) of sire), and the percentage of Holstein genes could be quite low in some animals (Figure 3). For this reason, some scientists have suggested using Holstein sires in every other generation, even in a three-breed rotation. For example, a producer with Holstein cows today might mate his cows to Jersey sires in generation 1, Holstein sires in generation 2, Brown Swiss sires in generation 3, Holstein sires in generation 4, Jersey sires in generation 5, and so on.

Several AI companies are marketing semen from crossbred sires (typically $F_1$ Jersey sire x Holsein dam or Holstein sire x Jersey dam crosses), so it is possible to create 75% Holstein : 25% Jersey animals or 75% Jersey : 25% Holstein cows in the first generation by using this semen on Holstein or Jersey cows, respectively.

Crossbred animals may not be superior to their parental purebreds for any of the individual traits, but they may be more profitable when all the traits are considered together as lifetime profitability [1]. The ranking of genotypes depends on the environmental conditions, as well as the criteria for economic evaluation [2]. The genotype that is best under some circumstances may not necessarily be the best in others, and the ideal genotype must consider the limitations or constraints of each environment. If feed is limiting, for example, genotypes should be ranked on total profit per unit of energy, and the economic evaluation criteria should reflect costs and revenues over the entire herd life of the animal.

A study under New Zealand conditions involving Jersey x Holstein crosses found significant heterosis for milk, fat and protein yield; live weight; days to first insemination; embryonic loss; and longevity. In another study under New Zealand conditions [3] the two-breed (Holstein and Jersey) rotational cross was shown to be more profitable per hectare than a three-breed rotational cross (including Ayrshires) or a purebred selection scheme.

Under Canadian conditions [4] heterosis among Ayrshires x Holstein crosses were 16.5 percent, 20.0 percent, 17.2 percent, 16.6 percent, and 17.9 percent for milk, fat, protein, lactose and lifetime milk revenue respectively. Under US conditions, Touchberry [5] concluded that crossbred Guernsey x Holstein animals exceeded purebreds by 14.9 percent for profit per cow per lactation and 11.4 percent for profit per cow per year. Under US conditions, production data from 10,442 crossbred animals and 140,421 purebred animals, as well as longevity data from 41,131 crossbred animals and 726,344 purebred animals [6] provided heterosis estimates of 3.4 percent, 4.4 percent, 4.1 percent, and 1.2 percent for milk, fat, protein, and longevity respectively. Heterosis for somatic cell score was not significant. Values for Brown Swiss x Holstein and Jersey x Holstein crosses for Lifetime Net Merit and Lifetime Cheese Merit were US$44 and US$113 higher than for purebred Holsteins, meaning that the crossbred animals were more profitable under these payment systems. Purebred Holsteins were superior for Lifetime Fluid Merit, indicating that crossbreeding is unlikely to be profitable unless payment incentives exist for milk solids.

Finally, Weigel and Barlass [7] reported that among 50 producers that have been doing crossbreeding, 40 plan to continue crossbreeding, six plan to stop and four are undecided. Calving ease, fertility, component percentages, longevity, and calf vitality were the main advantages of crossbreeding on these farms, and the main disadvantages were marketability of slaughter animals and bull calves, lack of uniformity in the herd, difficulty in choosing mates for the next generation, and reduced milk volume.

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