INBREEDING vs Line-breeding

Dr Bobbie van der Westhuizen
South African Studbook and Animal Improvement Association

The level of influence of any one of the grandparents is only 50% on the individual resultant calf. But then again, breeding a full brother with his sister, is inbreeding. This is just to illustrate that line-breeding is inbreeding.

In genetic terminology and generally accepted in the literature inbreeding is defined as the breeding of two animals who are related to each other, by descent. Since most pure bred animals could be traced back to only a few, limited number, of foundation animals, all of these animals could be defined as inbred animals. The term inbreeding is, however, not generally used to refer to matings where a common ancestor does not occur within five generations from the sire or dam in the pedigree.

So what is all the fuss about inbreeding?

In terms of breeding, any animal will receive half of its genetic make-up from each of its parents, who in turn receives half of their genetic make-up from each of their parents. Therefore, any given animal receives a quarter of its genetic make-up from each of its grand-parents.

Genes are a series of unique loci (locations on chromosomes). Each locus consists of two alleles, one that originates from the sire and one from the dam. To simplify this more, let's assume that any given allele (form of the gene) could only be coded as an A or a B. Therefore, an animal could inherit, on any given locus, only an AA, AB or BB from its parents. If the animal inherits an AA or a BB from its parents on a specific locus, it is 'homozygous' for that locus, or otherwise described, for that specific gene. If it inherits an AB, the animal inherits two different copies of that specific allele and it is then generally referred to as 'heterozygous' for that locus or later on then a gene.

Inbreeding basically increases the probability that the two same copies of any given gene will occur. Therefore these alleles (or form of the gene) will be identical and derived from the same ancestor.

The closer ancestors are related to each other, the more likely it is that more genes will become 'homozygous'. For example, if the bull and cow are related, there is a big chance that the two copies of genes in their offspring will be identical copies.

In the 1920s, Sewell Wright developed what is generally called an 'inbreeding coefficient'. This coefficient describes the probability that both copies of any given gene are derived from the same ancestor. In the case where two totally unrelated animals are bred, the inbreeding coefficient of the offspring will be 0. It should be remembered, however, that all pure bred animals can be traced back to a limited number of founder individuals. As they will therefore still have common ancestors many generation back, animals in any breed will have some homozygous genes. Therefore, even if two apparent unrelated individuals are mated to each other and the calculated inbreeding coefficient of any of the offspring is zero, there is always a possibility that some undesirable genes could be homozygous and resulting in deleterious conditions.

An inbreeding coefficient of 100% is theoretically impossible in cattle and would only be possible if matings between full sisters and brothers is practiced over many generations. A single mating between a brother and sister (full sibs) from unrelated parents, will result in an inbreeding coefficient of 25% in the offspring. Assuming that there are no other related matings in the preceding generations, a mother on son or father on daughter mating will also result in an inbreeding coefficient of 25% in the progeny. A cousin on cousin mating results in a relatively lower inbreeding coefficient of 6.25% in the progeny.

Although inbreeding could be a good thing in some cases, it usually results in negative effects. For instance, the gene for Progressive Retinal Atrophy (PRA) in dogs, causes progressive blindness. Carriers of one copy of this gene, have normal vision but if one carrier is mated with another carrier, it is likely that one in every four puppies will go blind.

Inbreeding will increase both the number of affected dogs as well as the number of genetically normal dogs. Therefore, inbreeding can bring undesirable recessive genes to the surface. All affected and carrier animals must be removed from the breeding pool. This is the most effective way to remove undesirable recessive genes from the population, in the absence of a genetic test for the specific condition.

Selection is, however much more complicated as one cannot breed animals based on a single gene inheritance. Genes are inherited only in two packages: one from the sperm and one from the egg. It may be possible to eliminate one undesirable pair of genes, but the reality is that animals will become increasingly more homozygous for other genes. Inbreeding practices therefore, may improve some desirable characteristics but at the same time it is more likely to bring out undesirable combinations of genes to the surface.

It is well documented in the literature that, on average, inbreeding results in an increase in the prevalence of inherited disorders, a decrease in viability, a decrease in reproductive ability and the loss of genetic diversity.

Inbreeding can also result in developmental disruption, higher infant mortality, a shorter life span and reduction of immune system function. The immune system is closely linked to the removal of cancer cells from a healthy body, so reduction of immune system function increases the risk of tumour development.

Collectively, these effects of inbreeding are called inbreeding depression. Importantly, inbreeding depression increases as the extent of inbreeding increases.

The opposite of inbreeding is outcrossing. Outcrossing is where two totally unrelated animals in a breed are mated to each other. In the case where a highly inbred bull (with a high inbreeding coefficient) is mated to a completely unrelated cow, who on her turn is also highly inbred, the inbreeding coefficient of the animal born from this mating will be zero.

The difference between inbreeding and line-breeding.

The first question is what is line-breeding? Breeders of purebred livestock have introduced the term 'line breeding' into animal breeding in order to describe a milder form of inbreeding. Therefore, line-breeding is just a form of inbreeding, but at a slower rate. Exactly what the difference is between line breeding and inbreeding is a matter of opinion. The definition of the term tends to be different for different species.

Inbreeding, at its closest applies to what would be considered incest in human beings as parent to offspring or a mating between full brothers and sisters. However, matings between uncle and niece, aunt and nephew, half-brother and -sister, and first cousins are called inbreeding by some people and line breeding by others.

According to Morgan Hartman, the idea of line-breeding is to always keep the contribution that any one animal adds to the DNA of any calf at or below 50%. With inbreeding you regularly will find a higher degree of influence. For instance, a sire on daughter mating will result in offspring which carries 75% of its DNA from the sire and only 25% from the maternal dam. Interestingly, before the advent of genetic testing for recessive traits, the only way to ensure genetic purity of a bull, was to breed the bull to a number of his own daughters concurrently. If no genetic defects showed up in any of the offspring, the bull is likely to be genetic defect free.

According to this definition; mating two full brothers and sister will qualify as line-breeding, because the level of influence of any one of the grandparents is only 50% on the individual resultant calf. But then again, breeding a full brother with his sister, is inbreeding. This is just to illustrate that line-breeding is inbreeding.

The success and sustainability of any line-breeding strategy is to keep the inbreeding coefficients of all offspring as low as possible within family lines.

The Wye Angus herd for example is owned and operated by the University of Maryland Foundation. The herd has had no new introductions of outside genetics since 1957. Many of the cattle in the herd will have individuals occurring hundreds of times in a given pedigree, yet will only have an inbreeding coefficient of between six to seven percent. This could only been achieved, through proper pedigree and performance recording as well as the strict culling policy against any undesirable genes.

In a well-managed line-breeding programme, the level of relationship across a given herd of animals is around 12.5%. The 12.5% relationship ensures consistency of type and kind, uniformity of animals, while also allowing for enough diversity to avoid inbreeding depression across the herd.

Both inbreeding and line-breeding therefore involve the mating of animals within the same family. Breeding relatives is used to cement traits, the goal being to make the offspring homozygous (pure) for desirable characteristics. It is postulated that homozygous breeding animals tend to be prepotent and produce offspring that look like the parent stock with the risk of expression of undesirable recessive genes.

For example, how do you breed a bull with long horns?

Let's say you want to breed a bull with really long horns, and you don't care what the bull looks like apart from its colossal horns. You then go and take a tour through the whole country and select the bull with the longest horns, whose sire also had long horns. After sourcing the bull, you might look for a cow, preferably out of the same pedigree lines as the bull, or also from a pedigree where long horns are present.

The offspring of these two would be line-bred to that ancestor whom you believe to be the prime source of humongous horns.

How frequently horns of monumental proportions would turn up among offspring would depend on the strains of descent of that common ancestor to which you are line-breeding with. Suppose, for example, that among the four strains of descents, there was one that passed on superior intelligence, but hopelessly ordinary horns. This particular strain would lower the frequency of occurrence of expansive horns in the offspring. Line-breeding works best when the trait you are selecting for is consistently expressed through all strains of descent of the ancestor to which you are line-breeding. Obviously, if none of the strains of descent of that ancestor expressed his or her mammoth horns, then line-breeding to that ancestor through those strains would be utterly useless.

Line-breeding forms, to some extent, a cornerstone of any selective breeding. Selective breeding has given us cows that give the maximum amount of milk, sheep that give the maximum amount of wool, chickens that lay eggs almost every day and the most beautiful dogs in the world.

But, line-breeding is like using a satellite navigation device; if it is not used intelligently and correct, you could land up in Pretoria when you intended to go to Cape Town.

If you are to use line-breeding intelligently you have to know the basics and stick to it. If line-breeding is not conducted correctly and the average inbreeding coefficients in the herd is not kept below 6.25%, then there is no difference between a line-breed or inbreed herd. With high inbreeding coefficients, the herd is exposed to the possibility of inbreeding depression.

In selective breeding there are basically two kinds of breeding strategies. One is a very low form of line-breeding and the other one is outcrossing.

Each of these breeding strategies has its advantages and disadvantages. With line-breeding you can produce more consistent and uniform calves, you can identify breeding populations that have no genetic flaws, or identify existing flaws so they can be eliminated, you can accentuate and sustain more consistent excellence and you can develop line-bred progeny that will provide a genetic kick or hybrid vigour when they are outcrossed with non-relatives (non related lines). The danger of line-breeding when the rate of inbreeding is too high is the risk of inbreeding depression.

The advantage of outcrossing is basically what people call hybrid vigour (especially when crossing animals from different breeds).

This gives a genetic kick to offspring that are from parents that are as genetically distant from each other as possible within a given species. This is essentially the advantage derived from cross breeding, but that advantage declines in each successive generation.

To conclude:

Basically all farming animals as we know them today were, and still are, selected for different characteristics through selective breeding strategies. The most common selective breeding strategy was and still is a very mild form of line-breeding. Line-breeding could be effective, but then you must know the basic rules and breed strict to that. There is no real differences in the strict definition between line-breeding and inbreeding, it is only the rate of inbreeding that differs between these two terminologies. Therefore, if line-breeding is not conducted 100% correctly, you will eventually run into exactly the same negative effects as caused by inbreeding.

Intentional inbreeding as well as line-breeding, must be avoided as much as possible. But when a breeder decide, for whatever reason, to line-breed, the first and most important aspect is record keeping. Line-breeding cannot be conducted without proper animal recording. Record keeping must assist in early identification of any undesirable traits that may surface. Animals showing any undesirable trait must be culled immediately, as well as all carriers of such a defect or condition. Extra emphasis must be placed on reproduction and health traits and the breeder must, at all times, keep the inbreeding coefficients as low as possible (preferable below 6.25%) and ensure that the contribution of any animals' genes to offspring is kept below 50%.

"**Therefore,**
LINE-BREEDING IS JUST
A FORM OF INBREEDING,
BUT AT A SLOWER RATE."

Dr Bobbie van der Westhuizen