

Pedigree analyses of the Southern African Holstein

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The Holstein is the world's largest breed with nearly 30 million cows recorded in over thirty countries. The advantage for the South African dairy producer is that the very best animals can be sourced from a very large population and large genetic gains can be realised over reasonably short periods of time. The average Holstein cow has an increased milk production of more than 12000 kg compared to only 50 years ago. This in turn realises greater economic efficiencies, as less cows are needed to be managed for the same level of output.

Because the selection of superior animals focuses on only the very best families, some level of inbreeding in a selection program is to be expected. The Holstein was also an early adopter of BLUP technology and one of the consequences of using BLUP is that superior bull families are easily identified in a population and can thus be widely used. Inbreeding can however be minimised if a reasonable level of diversity within a breed is maintained.

This study considered numerous measures of genetic diversity and the results were then used to compare the SA Holstein to other breeds where a similar type of analysis has been conducted.

Results and discussion

Table 1 gives a summary of the numbers of animals, sires and dams used in the analyses. Of the original pedigree file of 1 million animals, only animals and known ancestors that contributed directly to the analysis were used. This left a total of 844106 animals. The numbers of founders is a measure of the number of base animals and is defined as those animals with no sire or dam recorded. In a similar study as that done for the SA Holstein, the Australian Angus had 760 000 animals and 16 500 founders. The larger the number of founders the greater the genetic diversity that one would expect among these founders.

Table 1. Summary of the SA Holstein pedigree file.

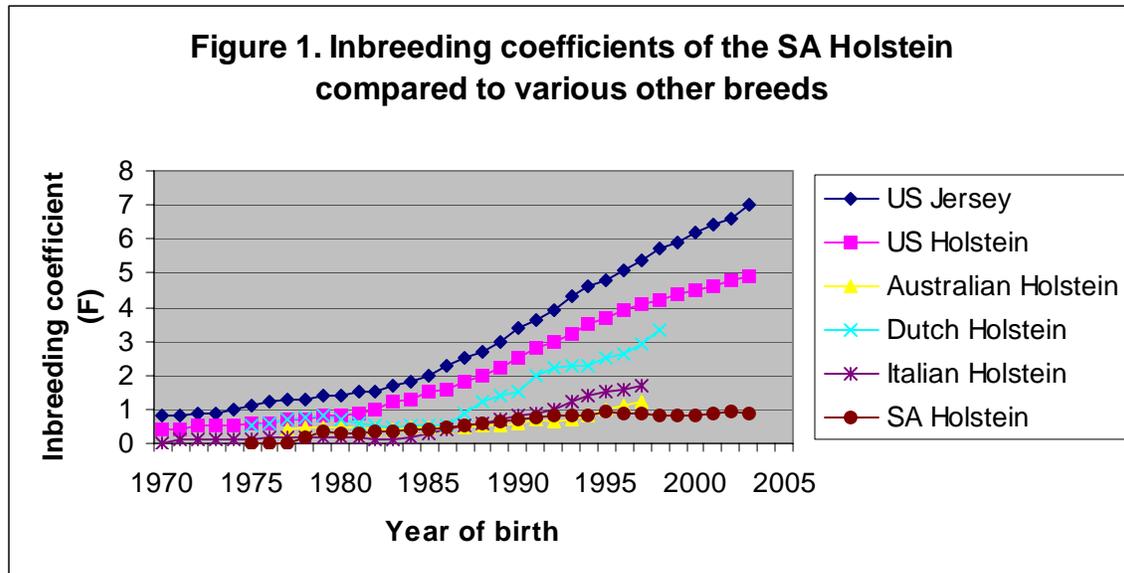
Numbers of animals	844106
Number of sires	13001
Number of dams	362735
Average number of progeny per sire	64.9
Number of founders	11664

Table 2 is a genetic diversity “scorecard” for the 2003 born calves. The 2003 born calves can be traced back 17 generations. The “average” number of generations is 4.22, this being the sum of all generations of the proportion of known ancestors at each generation. The average number of ancestors for the 2003 born calves is 123. This is less than the 738 ancestors for the Australian Angus but is similar to the Limousine and Normande breeds in France where 182 and 160 ancestors were calculated (Boichard 1997). The percentage of known ancestors after generation four has declined markedly because, as is often the norm with many breed societies, the SA Holstein traces all known ancestors back to four generations. Nearly 10% of the ancestry is still recorded at generation eight and these results are similar as the 11 % for breeds such as the Australian Angus. This breed also relies heavily on imported bulls.

Table 2. Genetic diversity “scorecard” for 2003 born calves.

Number of 2003 born calves in the study	17646
Average number of ancestors (for the 2003 born calves)	123
Maximum number of generations traced	17
Number of equivalent complete generations	4.22
Percentage of known ancestors at generation 2	99%
Percentage of known ancestors at generation 4	55%
Percentage of known ancestors at generation 8	9%
Average inbreeding coefficient	0.58%
Average inbreeding coefficient for 2003 born calves	0.89%
Percentage of calves with an inbreeding coefficient of less than 5%	31 %
Percentage of calves with an inbreeding coefficient of between 5 - 10%	2 %
Percentage of calves with an inbreeding coefficient of more than 10%	0.8 %
Effective population size	-
Effective number of founders	118
Effective number of ancestors	70
Effective number of remaining founder genomes	46

Figure 1 tabulates the average inbreeding coefficient for the SA Holstein over the last 33 years. The mean inbreeding coefficient is 0.58% and for the 2003 born calves it is 0.89%. This result is low but is only slightly less than other Holstein breeds such as the Australian and Italian Holstein (1.4 and 1,6 for the 1999 calves respectively). These two countries also import their bulls from various different sources. Missing pedigree information could have an influence on the accuracy with which the inbreeding was calculated. Although the level of inbreeding for the USA Jersey and Holstein is considered to be high (Figure 1), countries that import semen from various different sources are able to increase the diversity in the breed and hence reduce the level of inbreeding to acceptable levels.



The level of diversity can be shown in the effective population size, effective number of founders, ancestors and remaining founder genomes. *The effective population size* is the average number of individuals that actually contribute genes to the next generation. It is calculated using the relative increase in inbreeding from one generation to the other. For the 2003 SA Holstein calves, the level of inbreeding had in fact **decreased** compared to the previous generation. This means that more animals are contributing to the next generation than was the case for the previous generation. This result is not unique and a similar result was found for the French Limousine breed for example where a similar study was done.

A founder is defined as an ancestor with unknown parents. The *effective number of founders* is a theoretical number defined as the number of equally contributing founders that would be expected, given the level of genetic diversity that exists in the reference population, in the present 2003 calf crop. The effective number of founders was 118 animals. This compared to 132 for the French Normande dairy breed, 353 for Australian Angus and 790 for the French Limousine. The French Normande had more than 2 Million animals analysed, whilst the Limousine had 919 000 animals in the analysis.

The *effective numbers of ancestors* is a number that supplies us with the minimum numbers of ancestors needed to explain the complete genetic diversity in the population. Unlike the effective number of founders, the effective number of ancestors accounts for bottlenecks in the pedigree (i.e. periods or generations where the numbers of bulls used are drastically reduced). If the effective number of ancestors is reasonably close to the effective number of founders, it means that the impact of bottlenecks in the history of the breed diversity was small. The effective number of ancestors was 70. The difference was a lot less than that calculated for the Australian Angus (353 vs 61) or Normande (132 vs. 40). This means that the probability that the SA Holstein was influenced by genetic bottlenecks is very small.

The *effective number of remaining founder genomes* is the probability that a given gene (i.e. a founder gene) is still present in the population under study. It accounts for all causes of gene loss in the population over time. It thus provides a smaller number than either the effective number of founders or ancestors. The effective number of remaining founder genomes of 46 is more than the 35 recorded for the Australian Angus or French Normande (22), but less than the 206 recorded for the French Limousine.

Table 3 lists the eight sires that have contributed most to the genetic diversity of the current SA Holstein population. These 8 bulls have contributed almost 30% to the genetic diversity of the breed with sire To-Mar Blackstar having the largest contribution (8.21%). Although these sires may not necessarily have the most progeny, they have had a large influence on the diversity of the breed because it is their progeny that are widely used in later generations. Table 4 lists the top 10 bulls according to number of progeny. Sire Cymbidium Arlinda Chief is the most intensely used sire in the SA Holstein and has almost double the number of progeny compared to Keymer Appolo Rocket for example.

Table 3. Sires contributing most to the genetic diversity of the 2003 calves.

Name of Sire	Year of birth	Marginal Contribution	Cumulated Contribution
To-Mar Blackstar	1983	8.21%	8.21%
Round Oak Rag Apple Elevation	1965	3.96%	12.17%
Pawnee Farm Arlinda Chief	1962	3.71%	15.89%
Stouder Morty	1997	3.62%	19.51%
Madawaska Aerostar	1985	2.9%	22.41%
Singing brok NB Mascot	1986	2.72%	25.13%
Carlin-M Ivanhoe Bell	1974	2.53%	27.66%
Etazon Celsuis	1989	1.78%	29.43%

Table 4. The top ten most intensively used SA Holstein bulls according to numbers of progeny.

Name of Sire	Year of birth	Number of progeny
Cymbidium Arlinda Chief	1980	20439
Keymer Appolo Rocket	1976	11714
Kinglea Elevation Index	1975	11219
Masdel SWD Ivanhoe 5	1982	9943
International Bootmaker	1977	9562
Exwell Symbol	1975	7669
Meltonleigh Rosan 37 Garthmyl	1978	7112
Noord Driekuul Sandy Elevation	1975	6723
International Glen 1	1981	6634
Blauw Geertje jet-Stream 1	1981	6603

Conclusions

The SA Holstein is able to source the very best genetics from a very large international database. This has resulted in an increased production per cow and greater economic efficiencies for the breed in general. However, selection for specific families can often narrow the genetic base and narrow the genetic diversity of the breed. This can also lead to an increase in inbreeding.

This study has shown a very modest increase in the level of inbreeding for the SA Holstein over the last 30 years. Although the result is surprisingly low, it is only slightly lower than other international Holstein breeds that also import bulls from various different countries. An analysis of the pedigree file, using various different parameters, shows a reasonable level of genetic diversity within the breed. The SA Holstein should however continue to monitor the use of prominent sires and mating strategies so that the level of inbreeding is not increased in the near future.