

Short communication

Analysis of inbreeding of the South African Dairy Swiss breed

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Abstract

In South Africa, the Dairy Swiss breed, which originated in Switzerland, consists of 27 breeders and 1135 breeding cows. Pedigree information on the breed was analysed to determine its effective population size (N_e) and rate of inbreeding. The rate of inbreeding was 0.08% per year and 0.38% per generation. It was estimated that in 2008, over 90% of the animals were inbred. This is within the acceptable recommendation for an effective population size of 50 - 100, with an N_e value of 89. However, the high percentage of inbred animals may start to have a detrimental impact on the effective population size and breeders need to exercise caution in their breeding decisions.

Keywords: Effective population size, genetic diversity, inbreeding coefficient

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Brown Swiss was developed in north-eastern Switzerland, and is probably the oldest of all dairy breeds (<http://www.studbook.co.za/Society/swiss/history.php>). The first Brown Swiss bull was imported into South Africa from the USA in 1907, and was closely followed by another bull and five heifers from Switzerland. These imports laid the foundation for the first Brown Swiss herd in South Africa (Smit, 2008). The Brown Swiss Cattle Breeders' Society of South Africa was founded in 1925.

Brown Swiss originated as a dual-purpose breed. However, in most parts of the world two breeds have developed from the original. In 1974, it was decided to create separate South African herd books for the dairy (South African Dairy Swiss) and beef (Braunvieh South Africa) breeds. The South African Dairy Swiss (SA Dairy Swiss) was recognised as a separate breed by the Livestock Improvement Act of the National Department of Agriculture in 1995 (Smit, 2008). The SA Dairy Swiss is a small breed with only 27 active breeders in South Africa. The active national herd in 2009 consisted of 127 fully registered bulls, and 1 135 cows of which 755 were fully registered (2009, C. Hunlun, pers. comm., charl@studbook.co.za).

Technologies for assisted reproduction have been applied in dairy breeding, and have been effective in generating genetic gain (Sorensen *et al.*, 2005). However, these reproductive technologies and the accompanying greater selection intensity have increased inbreeding (Weigel, 2001; Kearney *et al.*, 2004; Ponzoni *et al.*, 2010). A consequence of inbreeding is a reduction of genetic variability within the population and reduced performance of animals, mainly in traits associated with fitness (Wall *et al.*, 2005), and also adversely affecting production traits (Koenig & Simianer, 2006; Maiwashe *et al.*, 2008). This leads to reduced profitability (Weigel & Lin, 2002) and unsustainable genetic improvement in the long term (Sorensen *et al.*, 2005, Maiwashe *et al.*, 2006; Ponzoni *et al.*, 2010). While the impact of inbreeding in populations of large sizes may be negligible, its effect in typical livestock populations in which selective breeding is practised can be more severe.

Effective population size (N_e) is a measure of the genetic diversity within a population (Wright, 1931) and can be calculated from the number of parents or the rate of inbreeding (Falconer & Mackay, 1996).

According to Boichard *et al.* (1997), N_e is a powerful tool for predicting the change in genetic variability over a long period, when the inbreeding increase fully reflects the number and choice of breeding animals in the previous generations. In animal breeding, the recommendation is to maintain an N_e of at least 50 to 100 (Meuwissen, 1999; Sorensen *et al.*, 2005). Therefore, monitoring effective population size (N_e) and possible control of resultant inbreeding may be crucial to implementing genetic improvement programmes (Ponzoni *et al.*, 2010). The SA Dairy Swiss had not been analysed in the past for its effective population size or its inbreeding status. The aim of this study is therefore to give an overview of its effective population size and inbreeding status.

Pedigree data were downloaded from the INTERGIS (Integrated Registration and Genetic Information System of South Africa) for the SA Dairy Swiss breed. Over the eighty-one years from 1928 to 2009 the SA Dairy Swiss pedigree database comprised 38 024 animals: 26 731 cows and 11 293 bulls. As pedigree information of foreign animals is rather incomplete on the INTERGIS, the INTERBULL database as well as the Canadian Dairy Network (www.cdn.ca) was used to retrieve and validate pedigree information of imported animals. All pedigree information was included in the analysis. However, since the SA Dairy Swiss received its own herd book in 1974, only the results from 1974 to 2008 are presented. The base population, which is defined as all animals with unknown parents, consisted of 7 622 animals.

Editing the data included checking the integrity of the pedigree for completeness and accuracy. Duplicated records of foreign animals were eliminated, and unknown parents of foreign animals in the pedigree database were added. Because the pedigree information of the imported animals was incomplete, tracing them back resulted in more records in the final dataset than the SA Dairy Swiss pedigree database. Thus, a total of 40 141 records were available for analyses. Inbreeding coefficients for all animals of the population were calculated with Poprep (www.popreport.tzv.fal.de) (Groeneveld *et al.*, 2009). An inbred animal was defined as any animal with an inbreeding coefficient greater than zero. The level of inbreeding of the population per year was calculated by averaging inbreeding coefficients by year of birth.

The rate of inbreeding per generation (ΔF) was calculated as follows (Falconer & Mackay, 1996):

$$\Delta F = (F_t - F_{t-1}) / (1 - F_{t-1}) \quad [1]$$

where F_t and F_{t-1} are the average inbreeding of offspring and their parents, respectively.

The effective population size (N_e) was calculated according to Falconer & Mackay (1996):

$$N_e = 1 / 2\Delta F \quad [2]$$

An estimate of an individual's inbreeding coefficient depends on the extent to which its ancestry is known. The more complete the knowledge of an individual's ancestry is, the more reliable its estimate of the inbreeding coefficient relative to the defined base population (Boichard *et al.*, 1997; VanRaden, 2005; Groeneveld *et al.*, 2009, Van der Westhuizen, 2009). The number of animals with unknown parents per year (thus base animals), is depicted in Figure 1.

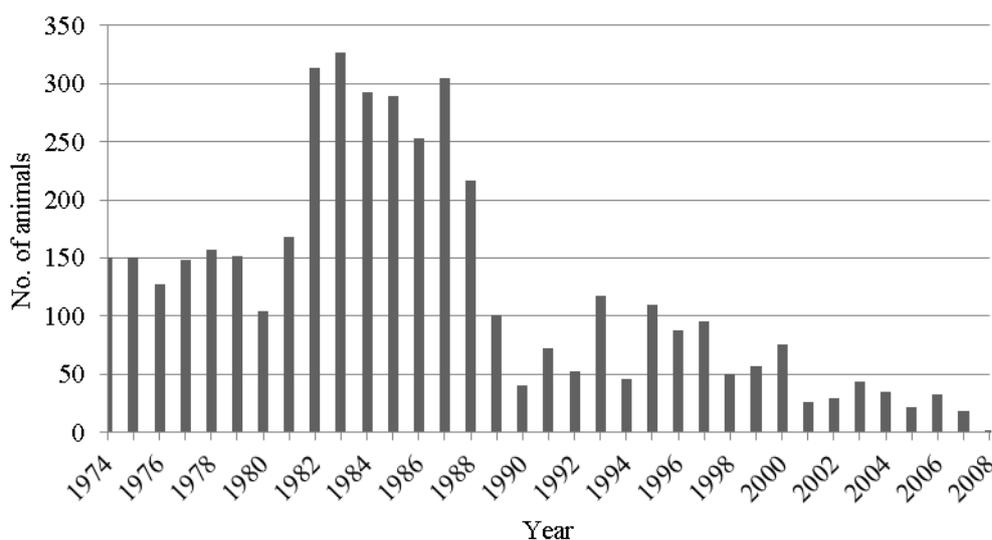


Figure 1 Number of animals with unknown parents per year.

In terms of animals born since 1974, the number of generations of complete pedigree information for the SA Dairy Swiss breed, ranged from one to six. This compares favourably with the study by Weigel (2001), in which a depth of six generations of pedigree completeness was reported. Since the number of animals was increasing, the expansion in pedigree completeness up to 1994 was a good indication of breeder participation and competent record keeping.

In 1994 the pedigree for generation 1 was 94.1% complete, while that of generation 3 was 85.3% complete, and generation 6 was 63.6% complete (Figure 2) (a generation interval equals five years). The greater percentage of pedigree completeness for generation 1 is as expected, since it is easier to trace the pedigree information back to one, two and sometimes even three generations. However, tracing a pedigree for more generations is harder, as information may have been misplaced or not recorded.

The reduced percentage of pedigree completeness from 1994 to 2004 could be the result of administrative obligations and costs associated with recording pedigrees and performance testing, because milk recording was no longer fully subsidized by the government (Liebenberg, 2010).

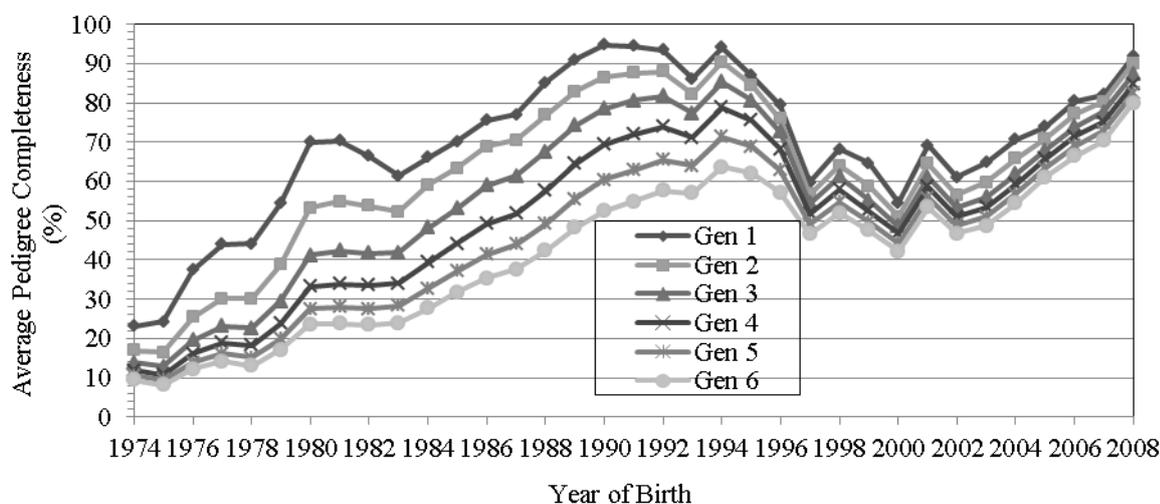


Figure 2 The average percentage of pedigree completeness for a pedigree depth of 1 to 6 generations by year of birth, between 1974 and 2008 for the SA Dairy Swiss Breed.

The rate of inbreeding of 0.08% per year (Figure 3) and 0.38% per generation for the SA Dairy Swiss Breed is well within the limits of acceptability of up to 0.5% per year and between 1% and 1.5% per generation (Van der Westhuizen & Mostert, 1998; Weigel, 2001). As reported by Nicholas (1989), rates of inbreeding of this magnitude would lead to a coefficient of variation of selection response of less than 10% over a 10-year period. However, when compared with previously published results of other South African breeds, the rate of inbreeding per year in the SA Dairy Swiss breed is greatest, followed by Jerseys (0.07%), Holsteins (0.06%), Ayrshires and Guernseys (0.05%) (Maiwashe *et al.*, 2006). These estimates, however, may not be directly comparable with the current results, as different depths of pedigree and pedigree completeness levels might influence results.

In Figure 4, the total number of animals in the SA Dairy Swiss population is indicated, as well as the total number and percentage of inbred animals since 1975. Since 1975, 33.8% of animals born in South Africa have been inbred. As the total number of animals increased, so did the number of inbred animals. After 1994, the total number of animals and the number of inbred animals decreased, while the percentage of inbred animals in the population increased. The lowest percentage of inbred animals was 5.2% in 1975. The percentage of inbred animals increased steadily until 2001 - 2002. In 2002, 51.4% of SA Dairy Swiss was inbred compared with 66% inbred animals in the Ayrshire breed (Mostert, 2003) and 63% in the Jersey breed (Mostert, 2011). After 2002, the percentage of inbred SA Dairy Swiss animals increased sharply in 2005 to 67.3% and then reached 90.2% in 2008 (with no animals having an inbreeding coefficient >6.25%). This is much greater than the 71% of inbred animals born in the Jersey population in 2009. This indicates that since the SA Dairy Swiss breed is small, breeders have a limited selection of animals to mate, compared with the

other dairy breeds. Breeders are probably mating related animals with no knowledge of the consequences or structured plan to restrict the rate of inbreeding.

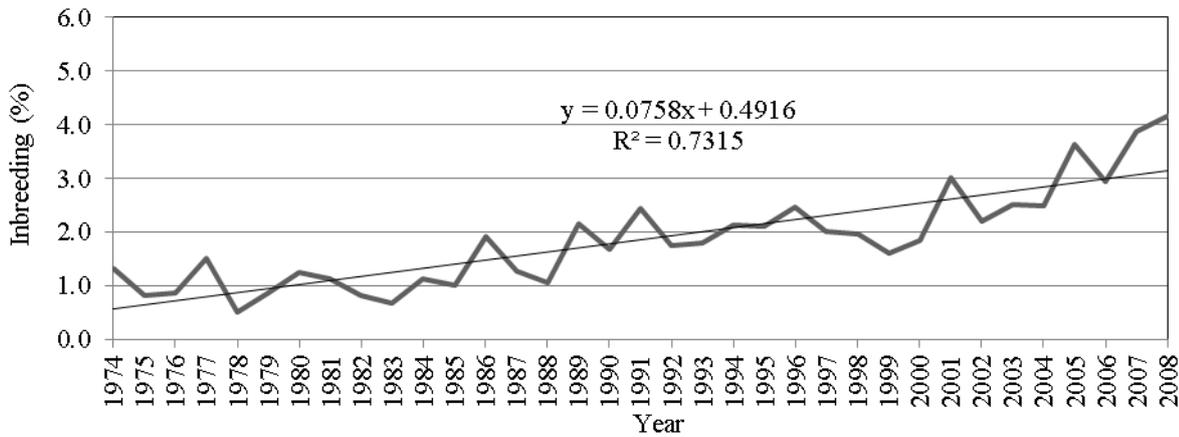


Figure 3 Rate of inbreeding of the SA Dairy Swiss breed.

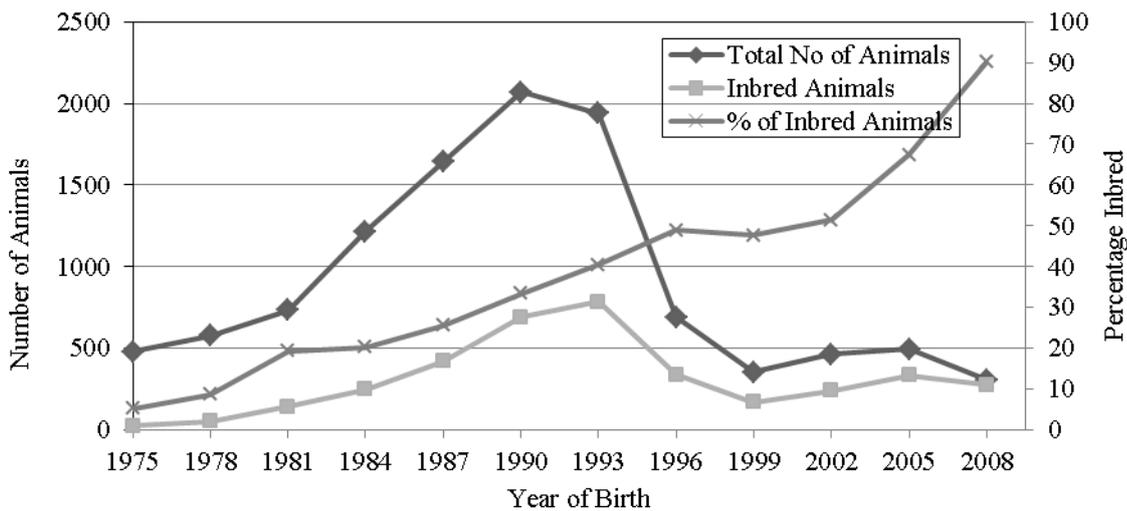


Figure 4 Total number of animals, as well as the total number of inbred and percentage of inbred animals of the SA Dairy Swiss breed since 1975.

The distribution of inbreeding coefficients and the number of animals that fall into each category of inbreeding coefficients in the SA Dairy Swiss population are summarised in Figure 5. The distribution ranged between 22.4% of the population for $0 < F < 5\%$ to 0.17% for $F > 30\%$, with 66.3% of the population having inbreeding coefficients of 0. The animals that have not been inbred include those with unknown parents, as it is assumed that unknown parents are unrelated. As a rule of thumb, breeders are advised to avoid matings that result in inbreeding coefficients of offspring greater than 6.25% (Van der Westhuizen & Mostert, 1998). The highest inbreeding coefficient for an AI bull used in South Africa in the Brown Swiss breed is Avon View Ideal from the USA, with $F = 25\%$. The highest inbreeding coefficient for an individual animal in the SA Dairy Swiss breed is a cow with an inbreeding coefficient of 39.2%, born in 2007.

When N_e is calculated, using the difference between the average inbreeding of offspring born per year and the average inbreeding of their parents (Falconer & Mackay, 1996), the SA Dairy Swiss breed had an N_e

= 56 in 2001 in comparison with the estimates of N_e found by Weigel (2001) of 61 for the Brown Swiss and 161, 65, 39 and 30 for the Ayrshire, Guernsey, Holstein and Jersey breeds, respectively. The estimates of effective population sizes reported by Maiwashe *et al.* (2006) were 148, 165, 137, and 108 for the SA Ayrshire, Guernsey, Holstein and Jersey breeds, respectively.

The SA Dairy Swiss breed had a low effective population size of 46 and 45, based on offspring born in 2006 and 2007, respectively. However, the breed's N_e improved for offspring born in 2008, increasing up to 89. If N_e is based on the change of inbreeding per generation since 1974 ($\Delta F = 0.38\%$) (Figure 3), $N_e = 132$, which is comparable with the N_e of other dairy populations reported by Maiwashe *et al.* (2006).

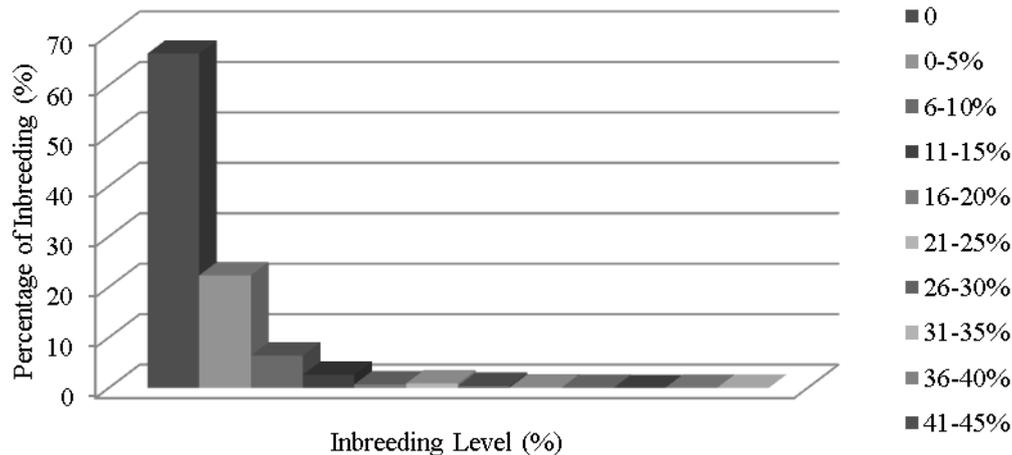


Figure 5 The distribution of inbreeding by level for individuals born from 1974 to 2008.

The larger dairy breeds (Holstein and Jersey) have lower effective population sizes in comparison with the smaller breeds (Ayrshire and Guernsey) (Maiwashe *et al.*, 2006). According to Weigel (2001) and Cleveland *et al.* (2005), the lower N_e of major dairy breeds is the result of elite sires being used extensively across countries through artificial insemination (AI). An N_e of fewer than 100 animals indicates a potential limitation in genetic diversity. This, together with the fact that the total population and herd size of the SA Dairy Swiss breed are small, implies that within-breed genetic diversity could be adversely affected and random gene frequency changes that are cumulative over generations should be expected (Maiwashe & Blackburn, 2004).

Mating decisions will play an important short-term role in curbing the levels of inbreeding in the SA Dairy Swiss population. Breeders should note the importance of decreasing rates of co-ancestry, possibly by limiting the use of popular sires, as has been done in the Canadian Holstein population (Stachowicz *et al.*, 2011). A minimum co-ancestry mating system, combined with the avoidance of sib-matings, should result in acceptable levels of inbreeding. Koenig & Simianer (2006) proposed that a combination of the optimum genetic contribution theory and specific mating plans is a viable option to control relationships and inbreeding. Furthermore, it is the responsibility of all breeders to participate in pedigree recording in order to limit the levels of inbreeding and ensure that a sustainable amount of genetic variability remains in the population. To preserve the genetic composition of dairy cattle for the future, a reserve of cryopreserved germplasm could be developed that could be used to regenerate the breed, should the need arise. Molecular genetic tools could also be used to assess genetic diversity from time to time (Maiwashe & Blackburn, 2004).

Although the rate of inbreeding in the SA Dairy Swiss population is acceptable, the percentage of animals being inbred is a major cause for concern, with 90% of the animals born in 2008 being inbred. One way to manage inbreeding will be through using mate-allocation programmes that constrain the level of inbreeding of future progeny. Estimates of effective population sizes indicate that genetic variability in South African dairy breeds is still greater than that of their counterparts in the US. While the rate of inbreeding and effective population sizes have not reached critical levels, the existence of highly inbred individuals in this

population necessitates further study to quantify the phenotypic effect of inbreeding on traits of economic importance in this population.

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