Inbreeding in the Elsenburg Dormer sheep stud

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Data of the Elsenburg Dormer sheep stud which was kept closed since its inception, were collected over a period of 50 years (1941—1990). These data were analysed to monitor the increase in actual level of inbreeding and to investigate the effect of inbreeding on some early growth and reproduction traits. In total, 9 551 pedigree, 8 963 birth weight and 7 782 weaning weight records were available. The average level of inbreeding of all animals over all years was 15%. At the end of the study the average inbreeding coefficient in the population was 20.5% with a minimum of 18.2% and maximum of 26.3%. The regression coefficients of lamb inbreeding on birth weight (BW), weaning weight (WW), average daily gain (ADG) and Kleiber ratio ($ADG/WW^{0.75}$) were –0.008, –0.099, –0.0009 and –0.021, respectively. All these coefficients differed significantly ($P < 0.01$) from zero. Inbreeding of the dam had no significant effect on these traits. No significant effect of lamb or dam inbreeding on average litter size (lambs born/ ewe lambing), survival rate (lambs weaned/lambs born) and stillbirths was observed.

Data van die Elsenburgse Dormerskaapstoet wat geslote was vanaf oorsprong, is oor 'n periode van 50 jaar (1941—1990) ingesamel. Hierdie data is ontleed om die toename in die werklike vlak van inteling te monitor en die effek van inteling op sekere vroeë groei- en reproduksie-eienskappe te ondersoek. In totaal was 9 551 stamboom-, 8 963 geboortegewig- en 7 782 speengewigrekords beskikbaar. Die gemiddelde vlak van inteling van alle diere oor alle jare was 15%. Aan die einde van die studie was die gemiddelde inteeltkoëffisiënt in die populasie 20.5% met 'n minimum van 18.2% en maksimum van 26.3%. Die regressiekoëffisiënt van inteling van die lam op geboortegewig (GW), speengewig (SW), gemiddelde daaglikse toename (GDT) en Kleiberverhouding ($GDT/SW^{0.75}$) was –0.008, –0.099, –0.0009 en –0.021, onderskeidelik. Al hierdie koëffisiënte het betekenisvol ($P < 0.01$) van nul afgewyk. Inteling van die ooi het geen betekenisvolle effek op hierdie eienskappe gehad nie. Geen betekenisvolle effek van lam- of ooi-inteling op fekunditeit (lammers gebore/ooie gelam), oorlewingsvermoë (lammers gespeen/lammers gebore) en peri-natale mortaliteit (doodgeboorte) is gevind nie.

Keywords: Dormer sheep, early growth traits, inbreeding depression, reproduction traits.

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Introduction

Inbreeding is important in breed improvement through selection since selection and inbreeding affect each other. Selection increases inbreeding while an increase in inbreeding results in a decrease in additive genetic variance available for selection. The more reliable the selection of superior genotypes becomes, the higher the probability that the genotypes will be related and increase the level of inbreeding. Recent advances in increasing the accuracy of breeding value prediction, as well as in accelerated breeding techniques, which could considerably increase the number of progeny from superior genotypes, have increased the interest in inbreeding as a potential future problem.

The effect of inbreeding has in the past been largely ignored in animal evaluation, mainly as a result of computational difficulties. Efficient algorithms, such as the one described by Quaas (1976), have, however, made the calculation of individual inbreeding coefficients feasible in large populations so that the effect of inbreeding can be accounted for in several ways. Many of the more traditional methods of genetic parameter estimation ignore the effect of inbreeding and assume that animals (sires) are unrelated. The average level of inbreeding in a population will give an indication of the realism with which this assumption can be made.

The level of inbreeding is an important genetic property of any population and needs to be known since it can have a marked influence on decision making and conclusions. The effect of level of inbreeding on production and reproduction traits in sheep has been the subject of many studies and the results have been well documented. In general, a decrease in the phenotypic mean with increased inbreeding is reported, but the results reported thus far are by no means conclusive.

An increase in the level of inbreeding is inevitable in any closed population of finite size. The purpose of this study was to monitor the actual level of inbreeding in a commercial sheep stud in which selection is practised and which has been kept closed since its inception in 1941, and to determine the effect of level of inbreeding on some early growth and reproduction traits.

Material and Methods

Data

Records of 9 551 lambs, the progeny of 231 sires of the registered Elsenburg Dormer sheep stud, collected from 1941 to 1990, were available for this study. The stud originated in 1941 and since then all replacements were selected from within. Seven ram families were established in 1975 and separately identified throughout the course of the project. Individual mating was practised with 25 to 30 ewes allocated to each ram during a spring breeding season (6 weeks) and care was taken to avoid close inbreeding. When individual inbreeding coefficients is calculated, it is normally assumed that the base population is non-inbred. In this study this assumption is known to be true since the base population consisted of a cross between two completely unrelated breeds, viz. the Dorset Horn and German Mutton Merino. Details of the genetic base (history), selection criteria and management of the stud are described by Van Wyk *et al.* (1993).

The entire data set (9 551) was utilized for calculation of individual inbreeding coefficients. To investigate the effect of inbreeding on growth traits, 8 963 birth weight and 7 782 weaning weight records were available after editing. For this analysis, records of stillborn lambs and of years 1941 and 1942 were excluded. For analysis of reproduction traits, records of stillborn lambs were included.

Statistical procedures

Inbreeding coefficients

All known relationships among all animals were used to compute inbreeding coefficients. The inbreeding coefficient for each animal was estimated using the algorithm of Quaas (1976). The inbreeding coefficient of the i^{th} animal was calculated as $F_i = d_{ii} - 1$, where F_i is the inbreeding coefficient and d_{ii} is the diagonal element of the i^{th} animal in Wright's numerator relationship matrix.

Inbreeding depression

The following linear model was fitted to the data:

$$Y_{ijklm} = \mu + r_i + h_j + a_k + s_l + p_m + b_1L + b_2L^2 + b_1D + b_2D^2 + e_{ijklm}$$

where Y_{ijklm} = an observation of a trait on the i^{th} animal* of the m^{th} birth status of the l^{th} sex of the k^{th} dam age group born in the j^{th} year-season,

μ = overall mean,

r_i = random effect of the i^{th} animal with zero mean and variance $I\sigma^2_r$,

h_j = fixed effect of the j^{th} year-season,

a_k = fixed effect of the k^{th} age of dam (k = 2, ..., 9 and older),

s_l = fixed effect of the l^{th} sex (l = 1, 2),

p_m = fixed effect of the m^{th} birth status (m = 1, 2, 3),

b_1L and b_2L^2 = linear and quadratic regression of the appropriate deviation from the mean on individual inbreeding,

b_1D and b_2D^2 = linear and quadratic regression of the appropriate deviation from the mean on dam inbreeding, and

e_{ijklm} = random error with zero mean and variance $I\sigma^2_e$.

(* Animals were absorbed into the other effects as described by Harvey (1988), but instead of repeatibility, heritability – estimated as σ^2_a / σ^2_p – was used. The model used may be described as an 'animal' model not utilizing the relationship matrix.)

Lambs were assigned a value of 1 if they were born dead and 0 if born alive. The corresponding values for survival rate were 1 if the animal was alive at weaning and 0 if dead at weaning.

Results and Discussion

Numbers of animals and average inbreeding coefficients from 1941 to 1990 are presented in Table 1. More than 93% of the total number of animals born during this period were inbred to some extent and the majority of these inbred animals (95.8%) had inbreeding coefficients higher than 10%. When all animals were considered, the average level of inbreeding was 15.00% compared to the 15.96% of the inbred animals. The small difference was due to the small proportion (6.1%) of non-inbred animals in the population. The maximum individual inbreeding coefficient was 49.06% (Table 1).

Table 1 Characteristics of the population

	n	%
Total no. of animals	9 551	100
Non-inbred	579	6.06
Inbred	8 972	93.94
Average F of:		
all animals		15.00
inbred animals		15.96
Maximum F		49.06

The annual mean, maximum and minimum level of inbreeding is illustrated in Figure 1. Accumulated inbreeding in the stud after 50 years averaged 20.5% with a minimum of 18.2% and a maximum of 26.3%. Figure 1 denotes a sharp increase in the annual maximum level of inbreeding to a peak in 1964 whereafter a decrease was observed. This can be attributed to increased efforts to avoid the mating of closely related animals. Although the increase in average inbreeding was not noticeably retarded, it did lead to less variation in individual inbreeding coefficients. The maximum difference in inbreeding between animals is presently less than 10%. A fairly rapid increase in the annual minimum inbreeding was observed after 1958, which indicates that all animals in the stud are now inbred.

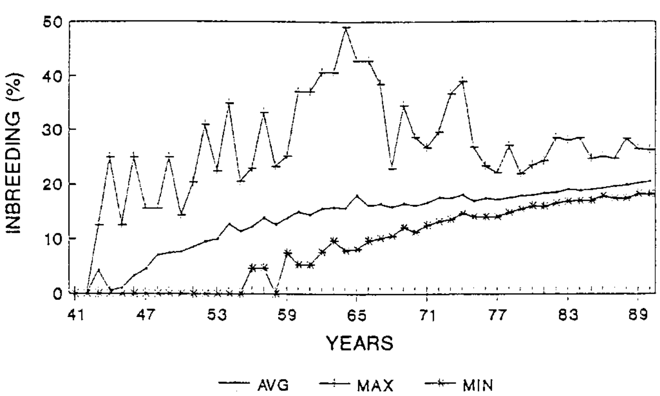

Figure 1 Annual mean, maximum individual and minimum individual levels of inbreeding (%).

Regression coefficients on lamb and dam inbreeding for some early growth and reproduction traits are presented in Table 2. These results indicate a marked adverse effect of inbreeding on most of the traits studied. The regression coefficient of birth weight on lamb inbreeding was estimated to be –0.008, i.e. a 1% increase in inbreeding coefficient should reduce birth weight by 0.008 kg. Corresponding figures for weaning weight, ADG and Kleiber ratio ($ADG/WW^{0.75}$) were –0.099, –0.0009 and –0.021, respectively. All these estimates differed significantly ($P < 0.01$) from zero. Several researchers have examined the effect of inbreeding on early growth traits in sheep (see Lamberson & Thomas, 1984 for review). The estimate for birth weight (–0.008) is generally comparable to reported estimates (Ragab & Asker, 1954; Lax & Brown, 1968; Ercanbrack & Knight, 1991).

Reported estimates of the effects of lamb inbreeding on weaning weight ranged from +0.036 to –0.177. The average regression coefficient (–0.111) from several studies (Lamberson & Thomas, 1984) for weaning weight is in general agreement with the estimate found in this study (–0.099). However, Van der Merwe (1976) reported lower regression coefficients of inbreeding on weaning weight and ADG in the same stud. This discrepancy may be due to the different approach used in this study in the calculation of regression coefficients. As mentioned previously, an animal model, where the relationship matrix is not utilized, was fitted to calculate these estimates. Hence, the effect of the animal itself was also taken into account. However, Van der Merwe (1976) used a smaller data set covering a period of only 21 years (1944— 1965). Inbreeding of the dam had a negative effect on all growth traits studied but only birth weight (quadratic), weaning weight and ADG (linear) were found to be significant (Table 2).

Lamb and dam inbreeding did not influence average litter size (lambs born/ewe lambing) significantly. This supports the findings of Lax & Brown (1968) in Merino, Lamberson *et al.* (1982) in Hampshire and Charon *et al.* (1990) in Polish Lowland sheep.

The effect of inbreeding on lamb survival has been the subject of several reports and reviews (Wiener *et al.*, 1983; Afifi *et al.*, 1984; Lamberson & Thomas, 1984), and regression coefficients varied considerably from –0.007 to –0.072. This negative effect of lamb inbreeding on survival is not supported by results from this study. The non-significant estimates in this study support the findings of Ghoneim & McCarty (1970) and Afifi *et al.* (1984) in studies on No-tail, Rahmani and Barki sheep with average levels of inbreeding of 18.5%, 14% and 11%, respectively. This result, however, is unexpected and warrants in-depth research. The first step would obviously be the application of theoretically more satisfactory (Gianola, 1982; Gianola & Foulley, 1983), but computationally far more laborious estimation procedures. The quadratic regression of inbreeding of the dam on survival was found to be highly significant ($P < 0.01$).

In agreement with the findings of Charon *et al.* (1990), inbreeding had no significant effect on the stillbirths in this population.

Table 2 Least-squares mean (LS), regression coefficients and standard errors (*SE*) for birth weight (BW), weaning weight (WW), average daily gain (ADG), Kleiber ratio (KL) and reproduction traits

			Regression coefficients (*SE*)			
			Lamb[a]		Dam[a]	
Trait	No. of observations	LS (*SE*)	Linear	Quadratic	Linear	Quadratic
Growth						
BW (kg)	8 963	3.75	–0.008**	0.018	–0.004	0.047**
		(0.02)	(0.002)	(0.015)	(0.002)	(0.017)
WW (kg)	7 782	28.70	–0.099**	0.155	–0.038*	0.126
		(0.16)	(0.017)	(0.122)	(0.017)	(0.122)
ADG (kg/d)	7 782	0.249	–0.0009**	0.0013	–0.0003*	0.0010
		(0.002)	(0.0002)	(0.001)	(0.0002)	(0.001)
KL	7 782	19.91	–0.0002**	0.0003	–0.0001	0.0001
		(0.038)	(0.0001)	(0.0003)	(0.0001)	(0.0003)
Reproduction						
Stillbirths	9 371	0.067	0.00001	–0.0018	–0.0001	0.0012
		(0.005)	(0.001)	(0.004)	(0.001)	(0.005)
Average litter size[b]	9 371	1.68	–0.001	0.012	0.001	0.014
		(0.013)	(0.002)	(0.012)	(0.002)	(0.013)
Survival[c]	9 371	0.767	0.001	–0.013	–0.002	0.023**
		(0.011)	(0.001)	(0.008)	(0.001)	(0.009)

* $P < 0.05$; ** $P < 0.01$.

[a] Change in trait/1% increase in inbreeding.

[b] Lambs born/ewe lambing.

[c] Lambs weaned/lambs born.

Conclusions

Inbreeding has accumulated to such an extent in the Elsenbrug Dormer flock over the past 50 years, that it cannot be ignored in future genetic evaluation programmes. In spite of the high level of inbreeding in this flock, production and reproduction levels were not seriously affected. This stud, maintained in its present form, could supply valuable material for future research on the subject of inbreeding.

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