EFFICIENCY OF MATING GROUPS IN AN ANGORA GOAT NUCLEUS UNDER SELECTION

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INTRODUCTION

Breeding programs based on a closed selection nucleus are confronted to a rapid increase of inbreeding, with loss of fitness and genetic variability. Several authors proposed methods to reduce rates of inbreeding while keeping a high genetic gain in the long term (Caballero *et al*., 1996 ; Grundy *et al*., 2000 ; Meuwissen and Sonesson, 1998 ; Nomura, 1999 ; Sonesson *et al*., 2000 ; Toro and Perez-Enciso, 1990 ; Villanueva *et al*., 1994). Among different mating strategies, circular mating groups have proven their efficiency to avoid inbreeding in conservation programs (Nomura and Yonezawa, 1996 ; Rochambeau and Chevalet, 1985 ; Wang, 1997). In this mating strategy, a population is subdivided into several groups and males are transferred between neighboring groups in a circular way. The effects of circular mating groups on inbreeding and genetic gain were investigated here, using stochastic simulation.

METHODS

A closed selection nucleus of 300 Angora goats with overlapping generations was simulated over a period of 20 years. Breeding goals of the nucleus were to increase greasy fleece weight (GFW, main trait) and to reduce the proportion of medulated fibers (MF, a secondary trait), while average fiber diameter (AFD) was maintained constant. Genetic and phenotypic parameters were previously estimated using data from a selection nucleus of Angora goats in Argentina (Taddeo *et al*., 1998). The simulation was based on a polygenic multi-trait model (Bulmer, 1980). In each reproductive cycle, 200 kids were available for selection, and 64 females and a variable number of males were selected each year for replacement. Females were maintained in the nucleus during 5 reproduction cycles (until the age of 6 years). Each scheme was run with 30 replicates.

Selection was performed by truncation on a multiple trait index with restrictions by using best linear unbiased prediction on a multiple trait animal model according to the methodology proposed by Lin (1990). The restriction was a null genetic progress on AFD.

The nucleus had one, three or six mating groups of 300, 100 and 50 females each, respectively. Males were transferred between neighboring groups in a circular way. Two policies for male replacement were analyzed: 50% of males replaced each year (except for males older than 6 years which were all culled) and 100% of males replaced each year. Three different proportions of selected males were studied: 2, 4 or 6%. Two mating systems were compared: random and positive assortative, the latest performed on predicted multi-trait index values. The variables studied were the genetic gain expressed in units of phenotypic standard deviation of the base population and the inbreeding coefficient calculated as the mean of all inbreeding coefficients of individuals born at the t^{th} year.

RESULTS AND DISCUSSION

The average of inbreeding coefficient $F^{[20]}$ and the cumulated genetics gains for GFW ($\Delta G_{GFW}^{[20]}$), AFD ($\Delta G_{AFD}^{[20]}$) and MF($\Delta G_{MF}^{[20]}$) are shown in Table 1.

Mating Groups. With 50% of male replacement and random mating, the number of mating groups had no effect on the inbreeding coefficient. On the other hand, under assortative mating, increasing the number of groups reduced the inbreeding coefficient by 20%. With 100% of male replacement, the effect of mating groups on $F^{[20]}$ was important for both mating systems, with an inbreeding decrease of 50% and 68% for random and positive assortative mating, respectively, when the nucleus was divided into 6 groups. The reductions were 25% and 39% when the nucleus was divided in 3 groups (Table 1).

Impact of mating groups on genetic gains was subjected to important interactions. With 50% of males replaced annually, the genetic gain for GFW showed an increase of 10% to 15% when the nucleus was divided, regardless of the mating system. Smaller effects of grouped matings on genetic gain for MF were observed. On the other hand, genetic gain for the restricted trait (AFD) increased when the nucleus was divided in 3 or 6 mating groups, in both mating systems. When 100% of males were replaced, the trend observed for the genetic gain of AFD was similar to the 50% situation. Dividing the nucleus into 3 groups did not change genetic gains for GFW and MF. However, with 6 groups, reductions of 20% and 35% on GFW and 26 and 41% on MF were observed with random and positive assortative mating systems, respectively.

The effects of mating groups were more important under positive assortative mating and when males remained in the nucleus for only one reproductive cycle. The division of the nucleus in three mating groups had an important effect on the coefficient of inbreeding, while genetic gains were slightly modified. Occasionally, we observed a greater genetic progress with 3 or 6 mating groups than with one mating group.

Proportion of selected males and male replacement rates. The proportion of selected males had a significant effect on inbreeding depending on the mating system. An increase in the proportion of selected males to 4% or 6% produced a reduction of the inbreeding coefficient (35% and 55% for random mating, and 20% and 35% for positive assortative mating, whatever the male replacement rate).

With 50% of male replacement and random mating, genetic gains for GFW and MF were not affected when the proportion of selected males increased from 2 to 4%. However, genetic gains decreased significantly when 6% of males were selected. In an undivided nucleus under random mating, genetic gain tended to decrease when the proportion of selected males increased. This reduction was not observed when the nucleus was divided. Similar results were observed under positive assortative mating, *i.e.* no differences in genetic progress for the three traits were observed when proportions of selected males changed from 2 to 6%. Same trends were observed in the situations involving 100% of replacement rate.

Table 1. Average of inbreeding coefficient ($F^{[20]}$) and genetic progress for greasy fleece weight ($\Delta G_{GFW}^{[20]}$), average fibre diameter ($\Delta G_{ADF}^{[20]}$) and medulated fibre ($\Delta G_{MF}^{[20]}$) (expressed in units of phenotypic standard deviation)

		50% of male replacements per year								100% of male replacements per year							
		Random Mating				Positive assortative mating				Random Mating				Positive assortative mating			
		$F^{[20]}$	$\Delta G_{GFW}^{[20]}$	$\Delta G_{ADF}^{[20]}$	$\Delta G_{MF}^{[20]}$	$F^{[20]}$	$\Delta G_{GFW}^{[20]}$	$\Delta G_{ADF}^{[20]}$	$\Delta G_{MF}^{[20]}$	$F^{[20]}$	$\Delta G_{GFW}^{[20]}$	$\Delta G_{ADF}^{[20]}$	$\Delta G_{MF}^{[20]}$	$F^{[20]}$	$\Delta G_{GFW}^{[20]}$	$\Delta G_{ADF}^{[20]}$	$\Delta G_{MF}^{[20]}$
N° of groups	**1**	0.243	1.79	0.20	-1.12	0.320	1.93	0.26	-1.22	0.193	1.66	0.18	-1.05	0.302	1.88	0.23	-1.17
	3	0.240	2.05	0.65	-1.22	0.268	2.13	0.68	-1.27	0.144	1.69	0.43	-1.02	0.183	1.89	0.55	-1.14
	6	0.243	2.02	0.61	-1.23	0.260	2.11	0.67	-1.27	0.098	1.32	0.34	-0.77	0.096	1.19	0.39	-0.69
% of males	**2**	0.343	2.03	0.50	-1.21	0.348	2.02	0.52	-1.21	0.208	1.57	0.36	-0.94	0.237	1.65	0.42	-0.97
	4	0.222	2.00	0.50	-1.22	0.272	2.06	0.50	-1.26	0.134	1.61	0.33	-0.97	0.194	1.68	0.38	-1.01
	6	0.161	1.84	0.46	-1.13	0.229	2.09	0.59	-1.28	0.092	1.49	0.27	-0.93	0.149	1.63	0.38	-1.01

Mating Systems. The effect of positive assortative mating on inbreeding changed according to the number of mating groups. When the nucleus was not divided, positive assortative mating provoked an increase of the inbreeding coefficient of 31% and 56%, for both replacement rates, while, with six groups, the difference between mating systems was almost null, whatever the male replacement strategy. A similar result was observed when analyzing the effect of mating system in relation to the proportion of selected males. With 6% of males, the positive assortative mating produced an increase of inbreeding of 40% and 60% compared to random mating for both male replacement strategies. With 2% of males, random and positive assortative mating resulted in a smaller increase of inbreeding coefficient only when 100% of males were replaced every year. There was no effect of mating systems on genetic progress with the smallest proportion of selected males (2%). However, with 6% of males, an increase in genetic progress of GFW and AFD (13% and 9% for 50 and 100% of male replacement respectively) was observed for positive assortative mating.
The differences between mating systems increased when the intensity of selection decreased and they were larger when males were replaced more rapidly. The division of the nucleus limited markedly the increase of inbreeding caused by positive assortative mating, while the loss in genetic gains oscillated around 10%.

CONCLUSION

These results illustrate the advantages of mating groups with circular male rotation in breeding programs in order to reduce the increase of inbreeding. However, the efficiency of this strategy to warrant genetic gain depends on other breeding choices, especially the mating system and the male replacement policy. Advantages of the nucleus division are more important when positive assortative mating is used and when males remain in the nucleus for only one reproductive cycle. The division of the population into groups with male circular rotation can be a practical solution for breeding programs with overlapping generations.

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