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Inbreeding and its effects on fleece traits of Inner Mongolia cashmere goats

Shengchao Dai[a,1], Caixia Wang[a,1], Zhiying Wang[a], Zhixin Wang[a], Yanjun Zhang[a], Qing Na[a], Jinquan Li[b], Ruijun Wang[a,*]

[a] College of Animal Science, Inner Mongolia Agricultural University, Hohhot, Inner Mongolia 010018, China
[b] Key Laboratory of Animal Genetics Breeding and Reproduction, Hohhot, Inner Mongolia 010018, China

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ABSTRACT

The objective of the present study was to evaluate the level of inbreeding and its effects on fleece traits in Inner Mongolia cashmere goats. Data of 36,901 records for 23 year (1990–2012), collected from the breeding flock of Inner Mongolia cashmere goats maintained at the Arbas stock farm, were used in the analyses. The traits studied were cashmere weight (CW), fiber length (FL), and fiber diameter (FD). The average inbreeding coefficient for the whole population was 4.01%, ranging from 0 to 35.94%. The mean rate of inbreeding was 0.32% per year for all animals. To investigate the effect of inbreeding on phenotypic values, genetic parameters and estimated breeding values, two different models including no measure of inbreeding and individual inbreeding coefficients Fi (linear and quadratic) were take into account. The results suggest that both cashmere weight and fiber length increased at low levels of inbreeding, but decreased when levels of inbreeding were higher than 12.5% and 4.4%, respectively, while FD became thinner with any increase of Fi. Moreover, the estimation of genetic parameters and breeding values for the studied characteristics was essentially unaffected by inclusion of Fi in the model.

1. Introduction

Inbreeding, or mating among relatives, can be an important tool to improve the quality of the flock, as it can increase the ratio of homozygotes, uncover and eliminate recessive genetic defects, and help with consolidating desired characters (Gipson, 2002). Inbreeding is also used to establish inbred line. However, the increased homozygosity, associated with inbreeding, can also lead to a decline in performance, fertility, survival and vigor (Muasya et al., 2006; Khan et al., 2007; Marete et al., 2011; Malhado et al., 2013) by increasing homozygosity for deleterious recessive alleles, decreasing heterozygosity for alleles at loci with heterozygote advantage, or decreasing genotypic diversity among animals (Garg, 2004). Reductions caused by mating between related individuals are called inbreeding depression.

Negative effects of inbreeding, not only in domesticated animals but also in wild animals, have been reported by numerous studies (Hudson and Van Vleck, 1984; Keller and Waller, 2002; Selvaggi et al., 2010; Mattey et al., 2013). The Inner Mongolia cashmere goat is one of the most important breeds of cashmere goat, well known for the fine quality of its cashmere. In recent years, selection of superior animals using animal model best linear unbiased predictors (BLUP) of breeding value has been implemented. The use of these breeding values alone may lead to an increase of

* Corresponding author. Tel.: +86 471 4309178; fax: +86 471 4309178.
E-mail address: nmgwrj@126.com (R. Wang).

[1] These authors contributed equally to this work.

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Table 1
Detailed description of inbreeding and studied traits.

	Fi (%)	CW (g)	FL (cm)	FD (μm)
No. records	36,901	27,307	9461	8529
Mean	4.01	740.04	10.38	14.34
SD	4.61	204.88	1.74	1.02
CV (%)	114.95	27.68	16.75	7.14
Min	0.00	304.00	4.03	10.84
Max	35.94	1870.00	18.43	18.77

mating among closely related individuals. Thus, the aim of this study was to estimate the level of inbreeding and to assess the effects of inbreeding on fleece traits in Inner Mongolia cashmere goats.

2. Material and methods

2.1. Goat population

The goat under observation were bred on the Arbas stock farm (latitude 39°06′ N and longitude 107°59′ E) located in Inner Mongolia Autonomous Region (IMAR) in China. The flock was founded in 1984 and is the main breeding base for the Inner Mongolian cashmere goat in Inner Mongolia. The animals, in the light of age and sex, were managed in 12 different herds (1 constituting adult bucks, 6 constituting adult does, 2 constituting yearling bucks and 3 constituting yearling does). The average herd size was approximately 200 except the adult bucks herd, which had an average herd size of about 100.

This flock was managed for mating at the beginning of October, and the mating period lasted almost 50 days. All operations were achieved through artificial insemination, and the ratio of bucks to does was about 1:200–300. Kidding occurred from March to May. Kids were weaned at 4 months of age. All animals were identified with identification number, date of birth, birth statue, sex and birth weight, and consequently full pedigree information was comprehensively and clearly recorded. Conventionally, the flock was reared in a desert pasture throughout the year in spite of the hot and dry summer, cold and windy winter, and spring. It was grazed on *Caragana stenophylla* Pojark, *Caragana korshinskii* Kom, *Agropyron cristatum* Gaerth, *Agropyron cristatum* Schut, *Allium polyrhizum* Turcz, *Artemisia frigida* Willd, *Artemisia ordosica* Kraschen, *Stipa breviflora* Griseb, *Haloxylon ammodendron* Bunge, some of which are grazed only by goats.

2.2. Data

Pedigree of 36,901 animals born between 1990 and 2012 on the Arbas stock farm, located in southwestern IMAR in China, were used to compute inbreeding coefficients. Although the flock was started from 1984, the members were mainly and frequently introduced from outside during the establishment stage (1984–1990). Therefore, all animals born before 1990 were assumed to be unrelated with zero inbreeding coefficients. The flock had been in existence for 23 years and had been closed to outside breeding for the past 23 years. In addition, 2008–2012 production data were used to study the effect of inbreeding on fleece traits.

The kid traits considered in present study were cashmere weight (CW), fiber length (FL) and fiber diameter (FD). Zhou et al. (2003) and Wang et al. (2013) described the measurement of the traits and the collection of the data in detail. Detailed description of inbreeding and studied traits are shown in Table 1.

2.3. Statistical analysis

The inbreeding coefficient for each animal (Fi) was calculated with software WOMBAT (Meyer, 2006) using an average information (AI) algorithm.

The significance of fixed effects was verified using the GLM procedure of the SAS program (SAS Institute, Inc., Cary, NC, 2003), as well as statistical analysis to determine the significance of inbreeding (Fi). Influencing factors containing year of production (five levels), herd (twelve herds), dam ages (2–7 years), birth type (single or twins) and sex (female or male) were considered. Fixed effects of year, herd, dam age and sex were found significant for CW ($P < 0.05$). For FL and FD only year, herd and dam age were included ($P < 0.05$).

Based on previous study (Dai et al., 2012; Wang et al., 2013), neither maternal genetic effects nor maternal permanent environment effects had a significant influence on the traits examined in this study. Thus, the phenotype of offspring was only affected by individuals' genotype and environment for the studied characteristics. Therefore, the effect of inbreeding on each fleece traits was estimated using a univariate animal model described by Allain and Roguet (2003). The linear form of the mixed model was fitted as follows:

$$y_i = X_i b_i + Z_i a_i + W_i p_i + e_i \quad (1)$$

where y_i is the vector of animal records for the ith trait; b_i is the vector of fixed effects for the ith trait; a_i is the random vector of direct additive genetic effects of animals for the ith trait; p_i is the random vector of permanent environmental effects of animals for the ith trait; e_i is the random vector of residuals for the ith trait. X_i, Z_i, and W_i are incidence design matrices relation records of the ith trait to fixed effects, direct additive genetic effects and permanent environmental effects of animals, respectively.

The single-trait models were then fitted excluding (Model 1) and then including (Model 2) individual inbreeding coefficients (linear and quadratic) as covariates to determine the effect of inbreeding on the traits, additive variance and ranking of individuals.

Estimates of inbreeding depression, genetic parameters and breeding values were obtained using the restricted maximum likelihood (REML) method implemented with software WOMBAT (Meyer, 2007).

3. Results and discussion

The average value of Fi for all animals was 4.01%, ranging from 0 to 35.94% (Table 1). Fig. 1 shows the evolution of the mean value of Fi by year of birth of individuals from 1990 to 2012. A trend of more or less linear increase was observed in the mean Fi, which ranged from zero to about 7% during the 23 years.

Nevertheless, average inbreeding in 2002 and 2010 shows varying degrees of decline. That is because breeders chose matings with the intention to avoid inbreeding depression. According to Fig. 1, animals born during the period of 1990–1992 were assumed to have no inbreeding. That is, inbreeding and relationships among animals in the flock before 1990 were ignored. In other words, measured inbreeding occurs since 1993 is rising as the population gradually becomes more related over time. The mean rate of inbreeding for all animals was 0.32% per year.

Presented in Table 2 are linear and quadratic regression coefficients of individual inbreeding coefficients on the different traits and the maximum level of inbreeding that could be absorbed by population before beginning to negatively influence its performance. The regression coefficients were significant for all fleece traits ($P < 0.01$), except for the quadratic term of Fi on fiber diameter.

The estimated linear and quadratic regression coefficients of individual inbreeding for CW were 4.574 and −0.183, respectively. This finding demonstrates that inbreeding at a low level may be resulted in a favorable effect on cashmere production. However, the value of Fmax, based on the quadratic effect, indicates a decline in the weight of cashmere for inbreeding levels higher than 12.5% (Table 2). Significant ($P < 0.001$) quadratic regression coefficient of Fi suggested that a non-linear negative effect was noted to decrease cashmere weight by a high range values of individual inbreeding in this study. Analogous to present study, a significantly non-linear effect of inbreeding on fleece weight had been observed by Ercanbrack and