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Population structure and inbreeding effects on body weight traits of Guilan sheep in Iran

Bahareh Eteqadi, Navid Ghavi Hossein-Zadeh*, Abdol Ahad Shadparvar

Department of Animal Science, Faculty of Agricultural Sciences, University of Guilan, Rasht, Iran

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ABSTRACT

The objective of the present study was to describe the population structure and inbreeding to quantify their effects on body weights at different ages in Guilan sheep. The analysis was based on the pedigree information of 28,944 animals. Traits included were birth weight (BW, n = 14,549), 3-month weight (3MW, n = 13,109) and 6-month weight (6MW, n = 10,141). Data and pedigree information used in this study were collected during 1994–2011 by the Agriculture Organization of Guilan Province in Iran. All the animals were grouped into three classes according to the inbreeding coefficients obtained by their pedigree: the first class included non-inbred animals (F = 0%); and the second and third classes included inbred animals ($0 < F \leq 5\%$ and $F > 5\%$, respectively). The inbreeding depression was expressed as a partial linear regression coefficient estimated via a single trait animal model including fixed and random effects. The results of this study showed that the inbreeding coefficient of this population was very low (0.15%). The average relatedness was 0.000144572 and the generation interval was 2.385 years. The regression coefficients of BW, 3MW and 6MW on lamb inbreeding for a change of 1% in inbreeding were estimated to be -5.499 ± 0.66 ($P < 0.0001$), -28.406 ± 4.831 ($P < 0.0001$) and 20.078 ± 5.968 ($P < 0.01$), respectively. The utilization of a program for designed mating system, in the present flock, could be a suitable approach to keep the level of inbreeding under control.

1. Introduction

The Guilan sheep is a fat-tailed breed of domestic sheep in Iran, numbering some 400,000 animals in the north of the country, and distributed in the northern and western parts of Guilan Province in the mountains between Assalem, Khalkhal, Oshkourat, and Deilaman. This breed can also be found in some areas of Guilan-Zanjan border. Mean adult live weight in this breed is 35 kg (77 lbs) for rams and 31 kg (67 lbs) for ewes. The coat color for this breed is yellowish-white to pure white, but brown patches are found on the head, face and at the bottom of the legs. This breed is valued mainly due to its ability to live in mountainous areas with rain-fed foothills and foothill steppes with 1300 mm (51 in.) annual rainfall. Young ewes were randomly exposed to the rams for the first time at approximately 1.5 years of age. Ewes were kept in the flock up to 7 years of age. Ewes are supplemented, depending upon the ewes' requirements, for a few days after lambing. Rams were kept until a male offspring was available for replacement. During the breeding season, single-sire pens were used allocating 20–25 ewes per ram. Lambs remained with their dam until weaning. Lambs were ear-tagged and weighed immediately after lambing. During the suckling period, lambs suckled their mothers while being allowed

* Corresponding author at: Department of Animal Science, Faculty of Agricultural Sciences, University of Guilan, P.O. Box: 41635-1314, Rasht, Iran. Tel.: +98 131 6690274; fax: +98 131 6690281.
E-mail addresses: nhosseinzadeh@guilan.ac.ir, navid.hosseinzadeh@gmail.com (N. Ghavi Hossein-Zadeh).

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dry alfalfa after 3 weeks of age. Lambs are weaned at approximately 90 days of age. Animals are kept on natural pasture during spring, summer and autumn seasons. Since environmental conditions are adverse during the winter, the animals are therefore kept indoors during the winter months. The flock was mainly kept on range and fed cereal pasture, but supplemental feed, including alfalfa and wheat straw, are provided especially around mating season.

One definition for inbreeding is given by the mating of individuals whose relatedness is greater than the average degree of relationship existing in the population (Lush, 1945), and capable of changing the genotypic frequencies of a population without modifying the gene frequencies. Intensive use of a few breeding animals, where the selection intensity is high, could result in greater rates of inbreeding in the population. Measurement of the effect of inbreeding on economic traits is important in order to estimate the magnitude of change associated with increases in inbreeding. The inbreeding depression has been well documented in many populations for a variety of traits (Lamberson and Thomas, 1984; Ercanbrack and Knight, 1991; Analla et al., 1998; Dario and Bufano, 2003; Khan et al., 2007; Van Wyk et al., 2009). Some populations may show a very pronounced effect of increased inbreeding for a trait, whereas others may not demonstrate much of an effect (Negussie et al., 2002; Barczak et al., 2009). Population size and ratio of males to females are important factors that have an effect on the magnitude of inbreeding. In addition, the practices that make breeding programs effective in generating genetic gain also contribute to an increase in inbreeding (Norberg and Sorenson, 2007). The objective of this study was to describe the population structure and inbreeding, and to quantify their effects on weights at different ages of Guilan sheep in Iran from 1994 to 2011.

2. Materials and methods

Data and pedigree information were obtained from the Agriculture Organization of Guilan province (Rasht, Iran) from 1994 to 2011. The traits included were: Birth weight (BW), 3-month weight (3MW) and 6-month weight (6MW). Data included 14,549 lamb records born from 389 sires and 4708 dams for BW, 13,109 lamb records born from 365 sires and 4428 dams for 3MW and 10,141 lamb records born from 319 sires and 3395 dams for 6MW, as presented in Table 1.

The CFC program (Sargolzaei et al., 2006) was used to calculate pedigree statistics and genetic structure analysis of the population. CFC is a software package for pedigree analysis and monitoring genetic diversity and is memory-efficient and fast and applicable to very large pedigrees due to use of an indirect method, which considers the inverse of the numerator relationship matrix. The INBUPGF90 program (Aguilar and Misztal, 2012) was used for calculating regular inbreeding coefficients for individuals in the pedigree. This program calculates inbreeding coefficients using a recursive algorithm assuming non-zero inbreeding for unknown parents. The number of animals (in total), sires and dams in the pedigree were 28,944, 453 and 9967, respectively. Also, there were totally 253 full-sib groups with average family size of 2.05 in the pedigree. On the basis of individual inbreeding coefficient, all the animals were grouped into three classes: first class including non-inbred animals ($F=0$); second and third classes including inbred animals ($0<F\leq 5\%$ and $F>5\%$, respectively).

The GLM procedure of SAS 9.0 program (SAS Institute, 2003) was used for determining the fixed factors which had significant effect on the traits investigated. After data verification, defective and doubtful records were deleted (e.g., lambs without weight records or with incomplete records of parentage or with registration numbers lower than the numbers of their parents were left out). The least-squares means were estimated for each trait using the Average Information Restricted Maximum Likelihood (AIREML) algorithm of the Wombat program (Meyer, 2006) by fitting six single trait animal models which ignore or include additive direct and maternal genetic and permanent environmental effects. The models included the fixed class effects of herd-year-season of lambing, Lamb's sex (in 2 classes: male and female), type of birth (in 3 classes: single, twin and triplet), parity (in 3 classes: 1 through 3), dam's age at lambing (in 6 classes: from 2 through 7 years old), inbreeding class and random effect of animal. All the interactions were included in the models. Lamb's sex, type of birth, dam's age at lambing, herd-year-season of lambing and inbreeding class were fixed effects which significantly affected on the traits investigated. Interactions between the lamb's sex and inbreeding class were fixed effects which significantly affected on 3MW and 6MW. Interactions between the lamb's sex and type of birth, type of birth and dam's age at lambing were fixed effects which significantly affected on BW. Parity and interactions between type of birth and inbreeding class were fixed effects which significantly affected on 3MW. Also, age of animal at weighing was covariate effect which significantly affected on 3MW and 6MW.

The effective number of founders (f_e) is defined as the number of equally contributing founders that would be expected to produce the same genetic diversity as in the population under study. Even in the presence of selection, f_e will approach a constant value as long as new founders are not added to the population (MacKinnon, 2003). To account for unequal founder representation, Lacy (1989) estimated the founder equivalent (f_e) as:

$$f_e = \left[\sum_{i=1}^{n} p_i^2\right]^{-1}$$

where p_i is the expected proportional genetic contribution of founder i, calculated by the average relationship of the founder to each animal in the current population, and n is the total number of founders.

Bottlenecks, unequal founder contributions, and genetic drift, which have a greater impact in small populations, can be quantified using the founder genome equivalent (f_g):

$$f_g = \sum_{i=1}^{c}\left(\frac{p_i^2}{r_i}\right)$$

where r_i is the expected proportion of founder i's alleles that remain in the current population and can take on a value of 0.5 if one allele is present or 1.0 if two alleles are present, and c is the number of contributing founders (Lacy, 1989).

Caballero and Toro (2000) showed the interrelations among f_e and f_g parameters and proposed a new parameter, the effective number of non-founders (N_{enf}), which explains the amount of genetic diversity reduced by random genetic drift accumulated in non-founders' generations. The effective number of non-founders is obtained as:

$$N_{enf} = \left[\frac{1}{f_g} - \frac{1}{f_e}\right]^{-1}$$

Falconer and Mackay (1996) established that the average inbreeding coefficient at a given generation t could be estimated using the following equation:

$$F_t = 1 - (1 - \Delta F)^t$$

where ΔF is the change in inbreeding from one generation to the next one or new inbreeding. González-Recio et al. (2007) proposed to operate

Table 1
Characteristics of data set for Guilan sheep.

Trait	No. of records	No. of sires	No. of dams	Mean (kg)	SD (kg)	CV (%)
BW	14,549	389	4708	3.12	0.61	19.55
3MW	13,109	365	4428	15.39	3.85	25.02
6MW	10,141	319	3395	20.69	4.53	21.89

BW, birth weight; 3MW, 3-month weight; 6MW, 6-month weight; SD, standard deviation; CV, coefficient of variation.