Livestock Science 161 (2014) 1–5

Contents lists available at ScienceDirect

Livestock Science

journal homepage: www.elsevier.com/locate/livsci

Modeling genetic covariance structure across ages of fleece traits in an Inner Mongolia cashmere goat population using repeatability and multivariate analysis

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ARTICLE INFO

Article history:
Received 3 July 2013
Received in revised form
26 November 2013
Accepted 26 November 2013

Keywords:
Parameter estimates
Genetic expression
Covariance structure
Fleece traits

ABSTRACT

The objective of this study was to estimate the parameters necessary to determine whether the genetic expression of fleece traits in Inner Mongolia Arbas cashmere goats was unified at different ages. Fleece traits, including fiber diameter (FD) and fiber length (FL), were measured between 2008 and 2012, as goats aged from 1 to 5 years old, and were modeled using repeatability and several multivariate models that varied in covariance structure. Bayesian information criteria were used to choose the most ideal model. In the preferred model, FD could be partitioned into yearlings and older goats, while FL could be partitioned into yearlings, 2 year olds, and older goats. The heritabilities of FD in yearlings and older goats were 0.35 and 0.27, respectively, and the genetic correlation between yearlings and older goats was 0.93. For FL, the estimates of heritability were 0.18, 0.38, and 0.29 within the 3 age groups. The genetic correlations were 0.94 for yearlings with 2 year olds and older goats and close to 1.00 for 2 year olds with older goats. These findings provide useful information for designing more ideal and effective breeding programs to improve fiber quality.

1. Introduction

Cashmere is regarded as one of the most coveted natural products; its softness provides comfort, while its soft texture gives the garment elegance and distinction (McGregor and Postle, 2006). Watkins and Buxton (1992) explained that the greatest appeal of cashmere is its extreme softness. Inner Mongolia Arbas cashmere goats (IMCGs) are well known for the brightness, elasticity, and softness of their cashmere fibers. Fiber diameter (FD) is the most important factor in assessment of the softness of cashmere. In China, the price of raw cashmere fluctuates with fleece grade. Fiber length (FL) should reach a certain value to facilitate the processing of cashmere. Therefore, the next breeding goals of Inner Mongolia cashmere goats are to select for individuals that will ensure FDs of less than 13 μm and FLs of more than 9.6 cm.

Many studies have estimated the genetic parameters of fleece traits in cashmere goats (Bigham et al., 1993; McGregor and Butler, 2009; Wang et al., 2012; Visser et al., 2009; Zhou et al., 2002). Most of these studies have been performed with the assumption that measurements of fleece traits at different ages are consistent and represent the same trait; however, few studies have analyzed

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http://dx.doi.org/10.1016/j.livsci.2013.11.028

the genetic diversity of the same fleece trait at different ages in cashmere goats. Fozi et al. (2012) explained that some production traits are expressed on multiple occasions in an animal's lifetime. In some cases, they occur as repeated records of the same trait; thus, selection for lifetime performance of FD and FL could be accurately based on only one shearing. However, more often, measurements at different ages represent different traits, and therefore, an appropriate covariance structure should be modeled to enable correct interpretation of data and to help design reasonable selection strategies that balance the additional expenditure of fleece trait measurements, with the benefits of increased selection accuracy. Studies by Brash et al. (1997), Coelli et al. (1998), Okut et al. (1999), Huisman and Brown (2009), and Fozi et al. (2012) revealed that covariance structures of FD and FL during a sheep's lifetime were not uniform. However, no reports have demonstrated differences in the covariance structure for fleece traits in goats.

The objective of this study was to compare various covariance structures of FD and FL in IMCGs at different ages using repeatability and several multivariate models and then to find the most appropriate model to determine whether FD and FL in IMCGs at different ages should be considered as repeated measurements of a single trait or as different traits. Thus, we sought to develop an intelligent measurement program based on the results obtained in this study, which could reduce the labor and expenditures associated with the measurement process. This is the first study to examine the differential genetic expression for fleece traits across goats' lifetimes by comparing 5 models with various covariance structures, and the results of this study will facilitate the improvement of breeding quality.

2. Materials and methods

2.1. Feeding and management

Data analyzed in this study were collected during 2008–2012 from a cashmere goat flock in Inner Mongolia located at the Arbas stock farm (latitude 39°06′ N and longitude 107°59′ E) in southwestern Inner Mongolia in China. Twelve herds (3 comprising yearling ewes, 2 comprising yearling rams, 6 comprising adult ewes, and 1 comprising adult rams) were reared by different herdsmen. Apart from the adult rams herd, the other herds had an average herd size of about 200 goats. Traditionally, goats were raised in a desert pasture the entire year, with a hot and dry summer, cold and windy winter, and spring season. The composition of primary vegetation in the area included *Caragana stenophylla* polark, *C. Caragana rorsninskii* kom, *Agriopyron cristutum* gaertn, *A. cristutum* schut, *Alium polyrhizum* turcz, *Artemisia frigida* willd, *Artemisia ordosica* praschen, *Stipa breviflora* griseb, and *Haloxylon ammodenron* bunge, some of which are grazed only by goats. Mating occurred at the beginning of October, and the mating period lasted nearly 50 days. Artificial insemination was used in the flock. The ratio of ewes to rams was about 1:200–300. Lambs were born during the months of March–May, and all lambs were recorded by identification number, date of birth, birth statue, sex, and birth weight. Pedigree information was comprehensive and clearly organized to show kids, sires, and dams. Kids were weaned at 4 months of age; the average weaning weight was 20.0 kg.

2.2. Cashmere measurement

To acquire accurate information on the fleece traits of IMCGs, every individual was measured from 1 year old (yearling), until they were eliminated from the flock or until death. Molted cashmere was harvested once a year by combing in May and weighed using an electronic scale following harvest. The combing date, cashmere weight, and body weight at the harvest of molted cashmere were recorded. Patch samples of 10 cm^2 from the side of the shoulder were obtained by shaving the area at the beginning of combing. The samples were first washed with petroleum ether to remove contaminants, such as soil and grease. Then, laboratory assistants carefully separated the staples from the samples. Using standard PM procedures, observations of FD and FL were repeated 160 and 50 times, respectively. Both traits were measured to the nearest 0.5 μm and 1 mm, respectively. Data were extracted from 95% confidence intervals (mean $\pm$ 1.96σ) to apply to the analysis.

2.3. Data and traits

The traits analyzed in this study were FD and FL in IMCGs at 1–5 years of age. Outliers were excluded from analysis, and individuals without duplicate records were discarded. A total of 4635 FD (n=927) and 5025 FL (n=1005) records were analyzed in this study. The basic statistics of these data are shown in Table 1. FD increased with age, while FL reached a maximum at 2 years of age and declined thereafter.

2.4. Statistic analysis

The fixed effects of fleece traits have been analyzed by Zhou et al. (2003) and Wang et al. (2012) with a general linear model (GLM) procedure using SAS (8.0) software (SAS Institute, 1999). Therefore, referring to their results, the influencing factors, including year of production (2008–2012), herd (12 herds), birth status (simple or

Table 1
Statistical analysis and data structure for Mean body weight(MBW), mean fiber diameter (MFD) and fiber length (FL) measured at the first, second, third, fourth, and fifth shearings of Inner Mongolia Arbas cashmere goats.

Statistic	Ages				
	1	2	3	4	5
MFD (μm)	13.76	14.48	14.62	14.68	14.77
s.d.	0.92	0.9	0.95	0.92	0.95
FL (cm)	10.69	10.87	10.22	10.08	9.86
s.d.	1.77	1.69	1.74	1.57	1.59
MBW (kg)	33.66	40.51	44.12	45.91	46.39

Notes: MBW: mean body weight; MFD: mean fiber diameter; FL: fiber length.