Genetic and environmental sources of variation of milk yield of Skopelos dairy goats

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Accepted 8 August 1999

Abstract

Lactation records of the Skopelos dairy goat population were used to assess the importance of various environmental effects and to estimate genetic parameters for 90-day milk yield (9OMY) and total milk yield (TMY) on untransformed and on log scale. Average 9OMY, TMY and days of milking were 164.7, 239.2 kg and 187 days, respectively. Herd, production year, lambing month, birth type, lactation number, the herd by year, year by month, year by lactation number interactions and days of milking were found statistically significant for TMY. Heritability estimates were 0.15 and 0.14 for 9OMY and TMY, respectively. Higher heritabilities of 0.24 and of 0.28 were estimated on the log scale for 9OMY and TMY, respectively. Genetic and phenotypic correlations between 9OMY and total milk yield were found high, of 0.95 and 0.80, respectively.

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Keywords: Goat; Milk yield; Heritability; Correlation

1. Introduction

In the group of Aegean islands called the Northern Sporades, east of the Magnisia continental region of Greece, a goat breed called the “Skopelos goat” (deriving its name from the island of Skopelos) has been known to have excellent productivity potential. According to the local authority of the agricultural development service of the island of Skopelos the breed numbers in its area of origin around 8,000–10,000 animals. The animals are small bodied (68 cm height at withers) but exceptionally heavy (56 kg for the adult females). The breed is characterized by smooth glossy hair coat with dominating red brownish coloration. Both males and females are horned (Pappas et al., 1992). The commercial average milk yield of the recorded does was 258 kg in 1991 (Pappas et al., 1992) with an average of 263 kg during years 1986–1992 (Rogdakis et al., 1996). Fat content of milk is reported exceptionally high (6.08%, Pappas et al., 1992; 5.6%, Rogdakis et al., 1996). Protein and lactose content is 4.0% and 4.6%, respectively. The prolificacy is 1.4 kids per doe and year, the average birth weight of kids is 3.3 kg, while the kids’ body
Reliable and specific population parameter estimates of heritabilities and genetic correlations of production traits are essential in predicting breeding values accurately as well as in developing efficient breeding schemes. For dairy goats, a number of genetic parameter estimates have been reported in the past for milk yield, based on paternal half-sib correlations (Bouillon and Ricordeau, 1975; Steine, 1976; Roenningen, 1980; Mavrogenis et al., 1984; Sullivan et al., 1986; Constantinou, 1989; Mavrogenis et al., 1989; Kala and Prakash, 1990) on dam-daughter regression (Constantinou et al., 1985; Rabasco et al., 1993) on the MINQUE method (Kennedy et al., 1982) or on the REML method (Boichard et al., 1989; Bishop et al., 1994; Andonov et al., 1998).

The aim of this study was to assess the importance of various environmental factors and to estimate genetic parameters for milk yield in the Skopelos breed using an animal model on untransformed and transformed data.

2. Materials and methods

2.1. Data

Lactation records ($n = 24,420$) for milk yield from 4962 does recorded during years 1988–1997 were collected from the center of livestock genetic improvement located at Karditsa in Central Greece. Initial data edits involved dam number, herd code, production year, lambing month, lactation number, birth type (single, twin), days in milk, 90-day milk yield (90MY) and total milk yield (TMY). A total of 4990 records were excluded from the initial data set according to the following criteria: milk yield less than 110 kg or higher than 730 kg; days of milking less than 110. The records retained were 19,430 lactations from 4802 does (data set 1). Five month lambing classes, January, February, October, November and December, and six lactation number classes, 1–6, were built. A smaller data set (no. 2) with pedigree information was used for estimation of genetic parameters. This data included 1251 lactation records from 1029 does. The number of sires and dams with progeny records were 56 and 130, respectively. A statistically significant linear correlation was detected between herd means and herd phenotypic standard deviations (SD) for untransformed data ($r = 0.66$, $p < 0.001$). Log transformation was employed in an attempt to adjust for heterogenous variance across herds.

2.2. Test of significance of environmental effects

The mathematical model for 90MY included: herd, year, month, birth type, lactation number and the herd by year, year by month and lactation by year interactions. Analysis of TMY included, apart from the above environmental effects, days of milking as a linear and quadratic covariate. The significance of the various environmental effects was determined by least squares analysis of variance (SAS, 1996).

2.3. Parameter estimation

Genetic parameters for 90MY and TMY were estimated by bivariate analysis applying an animal model with animals’ additive genetic effect as the only random effect. The (co)variance structure for this analysis can be described as

$$\begin{align*}
V(\mathbf{a}) &= \sum_A \otimes \mathbf{A} \\
V(\mathbf{e}) &= \sum_E \otimes \mathbf{I},
\end{align*}$$

where $\mathbf{a}$ is the vector of the animals’ direct effects, $\mathbf{e}$ the vector of residual errors, $\sum_A$ the $q \times q$ matrix of additive genetic covariances ($\sigma_{aa}$), $\sum_E$ the matrix of error covariances ($\sigma_{ee}$), $\mathbf{A}$ the numerator relationship matrix between animals, $\mathbf{I}$ the identity matrix with order of the number of records and $\otimes$ denotes the direct matrix product. All remaining covariances were assumed to be zero. The fixed effects part of the model included the effects found statistically significant for the two traits in the previous test. (Co)variance components as well as standard errors of estimates were estimated by a derivate-free algorithm using the DFREML computer program (Meyer, 1997).

3. Results

3.1. Descriptive statistics

Estimates of means and CVs for 90MY, TMY and days of milking for data set 1 and data 2 are
summarized in Table 1. 9OMY, TMY and days of milking were 164.7, 239.2 kg and 187 days for data set 1 and 155.7, 224.2 kg and 167 days for data set 2. Furthermore, log transformation of data resulted in a non-significant correlation ($r = 0.09$) between herd means and herd phenotypic SD.

### 3.2. Environmental effects

Herd, production year, lambing month, birth type, lactation number and the herd by year, year by month and year by lactation number interactions were found to be statistically significant for 9OMY and TMY in data set 1. In data set 2 all the main effects and only the herd by year interaction were significant for 9OMY and TMY. Days of milking were found statistically significant as a quadratic covariate for TMY in both data sets.

### 3.3. Genetic parameters

Table 2 presents the variance components, heritabilities, genetic and phenotypic correlations for 9OMY and TMY. To facilitate a comparison on the linear and log scales, variance component estimates of log scale are multiplied by $10^5$. The heritability estimates for untransformed data for 9OMY and TMY were 0.15 and 0.14, respectively. Log transformation of the data did not significantly change the additive genetic variances for 9OMY but reduced that of TMY. Most evident was the reduction in residual and therefore in phenotypic variances. As a result, higher heritabilities of 0.24 and of 0.28, after log transformation, were estimated for 9OMY and TMY, respectively. Genetic correlation between 9OMY and milk yield (MY) was found to be 0.95 and 0.93 for untransformed and transformed records, respectively. Phenotypic correlation was estimated of 0.80 and 0.78 on the untransformed and on the log scale, respectively.

### 4. Discussion

#### 4.1. Environmental effects

The importance of the various environmental effects on milk yield has been also examined in other studies. Mavrogenis et al. (1984) found that year of kidding, month of kidding, age of the goat and the year by month interaction had a significant effect on milk yield of Damascus goats in Cyprus. In a later study, Mavrogenis et al. (1989) noted the importance of herd, season of kidding, season by year interaction and the

<table>
<thead>
<tr>
<th>Trait</th>
<th>$\bar{x}$ (±S.E.)</th>
<th>CV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9OMY (kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set 1</td>
<td>164.7 ± 0.4</td>
<td>32.2</td>
</tr>
<tr>
<td>Set 2</td>
<td>155.7 ± 1.3</td>
<td>29.5</td>
</tr>
<tr>
<td>TMY (kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set 1</td>
<td>239.2 ± 0.7</td>
<td>38.9</td>
</tr>
<tr>
<td>Set 2</td>
<td>224.2 ± 2.4</td>
<td>38.6</td>
</tr>
<tr>
<td>Days of milking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set 1</td>
<td>187 ± 0.3</td>
<td>21.1</td>
</tr>
<tr>
<td>Set 2</td>
<td>167 ± 1.0</td>
<td>20.4</td>
</tr>
</tbody>
</table>

#### Table 2

<table>
<thead>
<tr>
<th>Trait</th>
<th>$\sigma^2_a$ (kg²)</th>
<th>$\sigma^2_e$ (kg²)</th>
<th>$\sigma^2_p$ (kg²)</th>
<th>$h^2$ (±S.E.)</th>
<th>$r_A$ (±S.E.)</th>
<th>$r_P$ (±S.E.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9OMY</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NT</td>
<td>107.12</td>
<td>597.66</td>
<td>704.78</td>
<td>0.15 ± 0.04</td>
<td>0.95 ± 0.13</td>
<td>0.80</td>
</tr>
<tr>
<td>LT</td>
<td>102</td>
<td>322</td>
<td>424</td>
<td>0.24 ± 0.04</td>
<td>0.93 ± 0.13</td>
<td>0.78</td>
</tr>
</tbody>
</table>

| TMY         |                   |                   |                   |             |              |              |
| NT          | 185.08            | 1136.64           | 1321.72           | 0.14 ± 0.04 | 0.80         |              |
| LT          | 117               | 299               | 416               | 0.28 ± 0.04 |              |              |

$^a$ NT: non-transformed data; LT: log transformed data. $\sigma^2_a$: additive genetic variance; $\sigma^2_e$: error variance; $\sigma^2_p$: phenotypic variance; $h^2$: heritability; $r_A$: genetic correlation; $r_P$: phenotypic correlation.
lactation number on milk yield of Damascus goats. Boichard et al. (1989) reported that month within year, age at kidding and birth type significantly affected milk yield of Alpine and Saanen goats. Kala and Prakash (1990) found that year and season of lambing accounted for variation of milk yield in two Indian goat breeds while Rabasco et al. (1993) found that production year, lactation number and birth type but not herd, were significant effects for milk yield in the Spanish Verata goats.

4.2. Parameter estimates

Herd means were found not to be correlated to herd phenotypic SD after log transformation. Transforming records to algorithms was thus an appropriate method to equalizing variances across herds implying that heterogeneity of variance was just a scale effect. Estimated variances on the untransformed scale, expressed as a coefficient of variation (CV), was 0.063 and 0.056 for genetic effects ($\sigma^2_A/\mu_y$) and 0.148 and 0.140 for residual effects ($\sigma^2_e/\mu_y$) for 90MY and TMY, respectively. CV on the log scale was 0.061 and 0.045 for genetic effects and 0.109 and 0.072 for residual effects of 90MY and TMY, respectively. Thus, log transformation resulted in reduction of genetic but in proportionally higher decreases in residual variances. As a result higher heritability estimates for 90MY and TMY were obtained when compared to the untransformed scale. Higher heritabilities for log yields have been also reported in dairy cattle (Hill et al., 1983; De Veer and Van Vleck, 1987). Genetic variance components are also found to be related to the mean although this relationship has not been consistent (Hill et al., 1983; Lofgren et al., 1985; Mirande and Van Vleck, 1985).

Heritability estimates for TMY obtained from untransformed records were lower but those obtained after transformation were comparable to those reported in the literature. Early literature reviews of heritabilities of milk yield in dairy goats (Iloeje and Van Vleck, 1978; Shelton, 1978) reported estimates ranging from 0.16 to 0.60 with an unweighted mean value of 0.32. Later references reportedheritabilities of milk yield in the range of 0.18–0.32 (Kennedy et al., 1982; Mavrogenis et al., 1984; Constantinou et al., 1985; Sullivan et al., 1986; Constantinou, 1989; Mavrogenis et al., 1989; Kala and Prakash, 1990; Rabasco et al., 1993). Estimates by the REML method ranged from 0.29 to 0.31 (Boichard et al., 1989; Bishop et al., 1994; Andonov et al., 1998). Literature estimates of 90MY were in the range of 0.29–0.52 (Mavrogenis et al., 1984, 1989; Constantinou et al., 1985; Constantinou, 1989). Genetic correlations between 90MY and TMY were very high. These estimates are agreement with other studies (Mavrogenis et al., 1984, 1989; Constantinou et al., 1985; Constantinou, 1989).

The present findings suggest that genetic variability in milk yield is adequate for selection provided that herd variation has been accounted for. Selecting on the basis of part lactation records is probably as efficient, in view of the very high and positive genetic correlations between 90MY and TMY. 90MY as a trait to select for, appears to be more advantageous because it is standardized for lactation length, is obtained on a much shorter time interval and can be recorded with reduced costs than total milk yield. Attention, however, should be paid when selection is practiced on milk yield because of the negative genetic correlations between milk yield and fat content and milk yield and protein content (Bouillon and Ricordeau, 1975; Boichard et al., 1989; Kala and Prakash, 1990; Andonov et al., 1998). Selection on milk yield would result in loss of protein and fat contents with a negative impact on quality of various dairy products (goat cheese and yogurt). An answer to this problem might be selecting the breeding animals for fat yield or attempting to introduce independent culling levels for milk yield and milk contents (Kominakis et al., 1998).

5. Conclusion

Employment of log transformation on milk yield records in an attempt to adjust for heterogenous herd variation resulted in higher heritability estimates for milk yield in Skopelos dairy goats. TMY and 90MY have similar heritabilities and are genetically highly correlated. Thus, the latter could be used as an alternative selection criterion.

References


