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Estimation of genetic and phenotypic parameters for daily milk yield of Black Bengal does

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Abstract: The objective of this study was to evaluate the genetic and phenotypic parameters for daily milk yield (DMY) in Black Bengal does. Genetic parameters were estimated using a residual maximum likelihood procedure, fitting an animal model while ignoring maternal genetic or permanent environmental effects. The least squares mean for DMY was 354.76 g. DMY was significantly ($P < 0.01$) affected by parity, litter size, and season of kidding. The heritability of DMY was low (0.15) and the fact that the trait can only be measured in females suggests that progeny testing may be the best sire selection method for this trait.

Key words: Black Bengal does, daily milk yield, heritability, genetic parameters, fixed factors

1. Introduction

Goat milk has been recommended as a substitute for those who suffer from allergies to cow milk or other food sources. Between 40% and 100% of patients allergic to cow milk tolerate goat milk. Therefore, there is a growing awareness of the importance of goats as a source of milk. Worldwide, more people drink goat milk than milk from any other species. The potential for the increased use of goats as animals for milk production in many developing countries is quite high.

The genetics of milk production in goats seem to be similar to that in cattle and sheep. However, in terms of live weight, the goat is believed to be more efficient in milk production than the other 2 species. Haas and Horst (1) indicated that in spite of a higher relative metabolism in goats, the expenditure of nutrients for the production of milk was less in goats than in cattle or buffalo as a result of the goat's lower maintenance requirements; this could be of great nutritional and economic importance. The milk yield of goat is significantly affected by various factors such as breed, age of the goat at kidding, season of kidding, and parity of the dam (2). Several factors have also been reported to influence the efficiency of milk production and lactation length (3). The magnitude of each factor on milk yield differs among different husbandry and management practices. The study of such factors will help the goat breeder to be more competent in minimizing the losses. A very important economic criterion for the productive adaptability of goat is their milk production potential.

Genetic parameters for milk performance traits in dairy goats have been estimated mainly on the basis of a lactation yield model. Test day (TD) models, if properly applied, can be more efficient than lactation yield models. Using a TD model, TD records can be directly included in genetic evaluations and environmental effects can be better accounted for. TD models offer the possibility of simplifying the recording scheme. Numerous studies in dairy cattle (4) and fewer in goats (5) and sheep (6) have dealt with the use of TD records as an alternative to standardized lactation yields. Use of TDs has the advantage of directly considering records at their origin. Under TD models, records on the sample day are considered directly in analysis and no assumption about the length of lactation has to be made.

In Bangladesh, no estimates of genetic and environmental parameters for milk production in goats are available. This study was therefore designed to estimate the genetic and environmental parameters of daily milk yield (DMY) in Black Bengal goats using an animal model.

2. Materials and methods

2.1. Location

The study was conducted from April 2007 to June 2010 in the Nucleus Breeding Flock at the Artificial Insemination

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2.2. Animals and management

A total of 41 Black Bengal does were used in this study. The animals were reared semiintensively. The does were stall-fed twice daily on a diet consisting of Napier, German, and/or maize fodder ad libitum. The feed was supplemented with commercial concentrate (Surma Feed, BRAC Feed Mill, Sreepur and Gazipur, Bangladesh) in pellet form in the morning and again in the afternoon at the rate of 250 g/doe daily. Grazing was also allowed for animals 4 h in the morning throughout the year except during inclement weather. Does were kept in kidding pens under close observation and proper care for 3 to 4 days before the expected date of parturition. Clean and safe water was made available at all times. Throughout this study the nutrition of animals remained uniform. All the females were inseminated routinely with frozen semen of the Black Bengal bucks. Inbreeding was avoided in the flock.

All the breeding animals and progeny were identified with a neckband tag in order to maintain their individual identity and pedigree. The identities of newborns and their parents, date of kidding, sex of kid, litter size, and parity of does were recorded. Record sheets were maintained for each individual under study, with full details of each parameter along with pedigree information. Newborn kids were allowed to suckle their does and were left with them from 0600 to 1800 hours daily until 3 months of age. Milk recording began on postpartum day 15. Milk production records were calculated from individual TDs made at fortnightly intervals. Kids were weaned at 3 months of age. Kids were kept separated from their dams overnight (12 h) preceding the day of milk recording only. The milk consumption by a kid was estimated as the difference between the body weight before and after suckling. The total amount of milk consumed by the kid was taken as the morning milk yield of the doe. The DMY was then estimated for each doe, multiplying morning milk yield by 2. Incomplete records and records from abnormal lactations were removed before analysis.

2.3. Statistical analyses

The significance of fixed effects (nongenetic factors) was tested by least squares analyses of variance using the general linear model procedure of the Statistical Analysis System (7) according to the following linear model:

$$Y_{ijkl} = \mu + S_i + M_j + R_k + E_{ijkl},$$

where Y_{ijkl} is the dependent variable of daily milk yield, μ is the overall mean, S_i is the fixed effect of the *i*th parity, M_j is the fixed effect of the *j*th litter size, R_k is the fixed effect of the *k*th season of kidding, and E_{ijkl} is the residual error. The year was divided into 3 seasons: winter (from November to February), summer (from March to June), and rainy (from July to October). The significant means were separated using Duncan's multiple range test.

Genetic parameters were estimated with the residual maximum likelihood (REML) procedure fitting an animal model using VCE 4.2.5 software (8). The models used to estimate genetic parameters included random effects and all the fixed effects that were found significant in least squares analysis. The model that fitted was as follows:

$$y = Xb + Za + e,$$

where y = vector of observations, b = vector of fixed effects, a = vector of random animal effects (direct genetic), X = incidence matrix for fixed effects, Z = incidence matrix for random effects, and e = vector of random residual effects. It was assumed that all effects in the models were independent and normally distributed.

3. Results

Basic statistics for daily milk production of Black Bengal goats are given in Table 1.

3.1. Fixed effects

Least squares means and standard errors for DMY of does are shown in Table 2. DMY was significantly ($P < 0.01$) influenced by the factors included in the model.

3.2. Phenotypic and genetic parameters

The estimated additive genetic and error variances as well as heritability are presented in Table 3.

4. Discussion

The milk yield of Black Bengal goats in the present study was higher than that reported by Husain (9) for rural scavenging conditions of 121 mL/day for the same breed, but comparable with the results of Hossain et al. (10). The variation may be due to feeding and management system. Agrawal and Bhattacharyya (11) reported the average DMY of Black Bengal goat to be 340 g, which is close to our study's results.

4.1. Fixed effects

Milk yield increased gradually with the progress of parity (lactation number) in the present study. Milk yields were

Table 1. Basic statistics for daily milk yield (g) of Black Bengal does.

No. of observations	Minimum	Maximum	Least squares means	Standard deviation	CV (%)
62	100.00	880.00	354.76	158.57	34.67

Table 2. Least squares means with standard errors for daily milk yield of Black Bengal does as affected by various factors.

Factors	Daily milk yield (g)
Parity	
First	$305.2^{c} \pm 30.91$
Second	$395.9^{b} \pm 38.52$
Third	$480.0^{a} \pm 52.02$
Litter size	
Single	$303.4^{b} \pm 34.70$
Twin	$457.4^{a} \pm 38.41$
Season of kidding	
Winter	$406.6^{b} \pm 32.29$
Summer	$326.6^{c} \pm 26.86$
Rainy	$430.0^{a} \pm 69.33$

Means with different superscripts within each column differ significantly (P < 0.01).

Table 3. Estimates of additive genetic variance (σ^2a), residual variance (σ^2e), phenotypic variance (σ^2p), and heritability (h^2) for daily milk yield of Black Bengal does.

Trait	σ^2a	σ^2e	σ^2p	h^2
Daily milk yield	1660.787	9712.894	11,373.681	0.15 ± 0.04

305.2 ± 30.91, 395.9 ± 38.52, and 480.0 ± 52.02 g for the first, second, and third lactations, respectively. The highest milk yield was obtained in the third lactation, whereas the lowest occurred in the first lactation. The results of this study were in accordance with the findings of other studies made in the tropics (10,12). This study also agrees with the results of Zaraibi goats in Egypt (13), of Verata goats in Spain (14) and other Spanish breeds (15), and of Alpine and Saanen breeds in France (16). Peak milk yield was attained during the third parity, probably due to the increased animal size (greater digestive capacity) and udder combined with advancing age, which led to the development of the mammary glands (an increase in the number of alveoli and muscle fibers in a limb). Mourad (17) observed that milk yield of does increased gradually with age. Mavrogenis et al. (18) found that the age of the goat had a significant effect on milk yield of Damascus goats in Cyprus. Boichard et al. (19) reported that age at kidding significantly affected the milk yield of Alpine and Saanen goats. Gall (16) reported that body weight was the main source of variation in milk yield if age was held constant; the regression coefficient of milk yield on body weight was 4.76 units.

Litter size significantly affected (P < 0.01) milk yield of does. This result is in agreement with the findings of Valencia et al. (20). Single-kidded dams were inferior in milk yield compared to multiple-kidded dams. Mourad (17) observed that litter size affected milk yield of goats until weaning. Goats with twins produced more milk than goats with singles. Similar results were found in Zaraibi goats in Egypt (13) and in Verata goats of Spain and other Spanish breeds (21). This also agrees with the findings of Gonzalo et al. (21), who reported that multiple births in Churra ewes resulted in higher milk yields than single births.

DMY was significantly (P < 0.01) affected by season of kidding. Goats that kidded in the rainy season were the highest yielders (430.0 ± 69.33 g), followed by goats that kidded in winter (406.6 ± 32.29 g), while the lowest yield (326.6 ± 26.86 g) was recorded by goats that kidded in summer. The present result is in agreement with the findings of Mourad (17), Valencia et al. (20), and Caricella et al. (3). Kala and Prakash (22) found that season of kidding accounted for variations in milk yield in 2 Indian goat breeds. The present result does not agree with the findings of El-Abid and Nikhaila (23) in different tropical and temperate breeds. The difference in DMY between different seasons of the year reported in this study might be attributed to climatological conditions of different seasons and availability of nutritious fodder and biomass in the farm and grazing fields.

4.2. Phenotypic and genetic parameters

The heritability estimate for DMY in the present study was 0.15. There are no literature references regarding heritability estimates for DMY in Black Bengal goats. However, the estimated heritability for DMY in Black Bengal goat was comparable with the heritability reported by Delgado et al. (24) for Murciano-Granadina goats in the highlands of Spain and Weppert and Hayes (25) for Alpine, Saanen, Toggenburg, and Nubian goats in Canada.

The low heritability estimate reported in this study reflects the low additive genetic variance compared to the large phenotypic variance. The heritability estimate in the present study is lower than that of Kala and Prakash (0.36) (22) for Jamunapari and Barbari goats in India, Schaeffer and Sullivan (0.29) (5) for purebred dairy goats in Canada, Morris et al. (0.34) (26) for Saanen goat in New Zealand, and Hamed et al. (13) (0.26) for the Zaraibi goats in Egypt. However, the present estimate is higher than those reported by Abdel-Raheem (27) for Zaraibi goats in Egypt (0.10) for total milk yield. According to Pollot and Gootwine (28), a low level of additive genetic variance is not due to any factor associated with the data set; rather, it is a real genetic effect in the population. This result emphasizes that the environmental conditions in this farm were very important for Black Bengal goats.

The heritability estimate for DMY obtained in this study was lower than those reported in the literature. Early literature reviews of heritabilities of milk yield in dairy goats (29) reported estimates ranging from 0.16 to 0.60 with an unweighted mean value of 0.32. Later references reported heritabilities of milk yield in the range of 0.18–0.32 (14,18,22,30). Estimates by the REML method ranged from 0.29 to 0.31 (19). Literature estimates for 90-day milk yield were in the range of 0.29–0.52 (18).

Estimates of heritability of a trait can vary considerably from study to study, depending upon breed, population sampled, environmental and management conditions, and errors, both random and systematic, in the estimation procedures (30). Many authors working on various breeds of goat have reported a variety of estimates, such as 0.17, 0.18, 0.20, 0.22, 0.24, 0.30, 0.34, and 0.35 as reported by Weppert and Hayes (25) for Alpine, Toggenburg, Saanen, and Nubian goats in Canada; Rabasco et al. (14) for the Verata goat; Kennedy et al. (30) for the Nubian goat in California; Morris et al. (26) for the Saanen goat in New Zealand; and Boichard et al. (19) for Alpine and Saanen goats in France, respectively. The majority of these estimates were larger than those obtained in this study. The Black Bengal goat probably showed less genetic variability than other breeds. The small heritability obtained suggests that regardless of genetic evaluations and selection methods used, the genetic gain would be relatively small.

This study has shown the importance of some nongenetic factors (parity, litter size, and season of kidding) on DMY; they could also account for genetic evaluations. The nongenetic effects were very important to the milk yield and need to be controlled or adjusted when comparing animals' individual productivity. The heritability estimate obtained from DMY was low, indicating that selection for DMY will take a long time. The low heritability estimate and the fact that the trait can only be measured in females suggest that progeny testing is the best sire selection method for this particular trait. The low heritability estimate of DMY may indicate that higher DMY could be better achieved through a better control of the environmental factors associated with this trait.

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