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Research Paper

Genetic and phenotypic aspects of growth rate and efficiency-related traits in sheep

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ABSTRACT

A large set of Baluchi sheep growth data collected at Abbasabad Sheep Breeding Station, Mashhad, Khorasan Razavi, Iran, was used to estimate phenotypic and genetic parameters for growth rate from birth to weaning (GRa), weaning to six months of age (GRb), and weaning to 12 months of age (GRc) and corresponding Kleiber ratios (KRa, KRb, KRc), efficiency of growth (EFa, EFb, EFc) and relative growth rate (RGRa, RGRb, RGRc). Genetic parameters were estimated by REML procedure fitting a series of six univariate animal models including various combinations of maternal effects. The most appropriate model for each trait was determined by the Akaike Information Criterion (AIC). In addition, a multi-variate analysis was done to estimate (co)variance components between traits. Estimates of direct heritabilities (h^2) were, respectively, 0.06, 0.03 and 0.10 for GRa, GRb, and GRc; 0.06, 0.06, and 0.05 for EFa, EFb and EFc; 0.07, 0.04 and 0.06 for KRa, KRb and KRc; and 0.07, 0.05 and 0.05 for RGRa, RGRb and RGRc. For traits measured in the pre-weaning growth phase, maternal genetic effect was significant. The estimates of maternal heritability (m^2) for GRa, KRa, EFa and RGRa were 0.11, 0.11, 0.04 and 0.04, respectively. Estimates of the additive genetic coefficients of variation (CV_A) were used as a measure of genetic variability and ranged between 1.68% (RGRa) and 14.67% (EFb). Genetic correlations between traits ranged from −0.81 (EFa-KRc) to 0.94 (ADGa-KRa) and phenotypic correlations ranged from −0.72 (KRa-EFc) to 0.99 (GRb-RGRb). Overall, results showed little additive genetic variation in growth rate or efficiency-related traits of Baluchi sheep, indicating little opportunity for genetic improvement of these traits in this breed through selection. In addition, significant maternal effects on traits related to pre-weaning growth indicated the importance of including maternal effects in genetic evaluation of traits measured early in life.

1. Introduction

The most recent statistics indicate that the sheep population of Iran is about 25 million head, comprising 25 breeds which account for roughly half of the livestock production of Iran (Sefidbakht, 2011). The Baluchi is a domesticated breed of sheep that originated in southwestern Pakistan, eastern Iran and southern Afghanistan. This breed comprises 12% of the total sheep population in Iran and, because of its large population, makes a significant contribution to the total meat and mutton production. The animals of this breed are small, with fat tails, carpet wool and white colour. They are good foragers and adapted to a wide range of harsh environmental conditions in the north-eastern parts of Iran, including the North-Khorasan, Razavi-Khorasan and South-Khorasan provinces (Bahreini-Behzadi et al., 2014).

The first priority of sheep production in Iran is meat production which is mainly because of nutritional habits and religious reasons. Milk and wool are not as important as meat and make only a small contribution to the incomes of rural families. To date, sheep production in Iran has relied mainly on natural pastures. In the recent years, the pasture area has decreased at an alarming rate due to destruction by human activities as well as significant decreases in annual precipitation and the occurrence of long periods of drought (Sefidbakht, 2011). As a result, the sheep population in Iran has decreased over the past 4 decades from almost 35 million head to 25 million head (Sefidbakht, 2011). During the same period, the population of Iran has doubled from 35 million to 75 million. Thus there has been a 28% decrease in the sheep population, but a doubling of the human population that has to be fed. On the other hand, owing to governmental forces aimed at decreasing the rate of pas-

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ture destruction, sheep production is shifting from migratory and semi-intensive systems to intensive systems in which feed intake comprises most of the production costs. Therefore, there will be two challenges against sheep production in Iran: first, increase in mutton production in spite of decrease in the sheep population and, second increase in efficiency of meat production, i.e., reducing the cost of mutton production. To achieve these goals, genetic variation regarding both the growth rate and efficiency of feed utilization among animals should be exploited by breeders to improve these characters.

The extent to which a trait can improve depends on the amount of additive genetic variance in the population. The additive variance is often measured as heritability (h^2), the fraction of the total phenotypic variance that is additive (Falconer and Mackay, 1996) in which it derives its relevance from the breeder's equation, $R = h^2S$, where R is selection response and S is the selection differential. For growth rate, which determines the amount of weight gain that can be achieved in a given time period, estimates of heritability ranged from 0.03 to 0.78 (Gizaw and Joshi, 2004; Savar-Sofla et al., 2011). These values indicate good scope for improvement through selection. Traits related to efficiency of growth, such as the Kleiber ratio (Kleiber, 1947), relative growth rate (Fitzhugh and Taylor, 1971) and efficiency of growth (Dass et al., 2004) also show great phenotypic variation among animals, and this phenotypic variation has, to some extent, a genetic origin and is therefore heritable. However, the magnitude of heritability partly depends on the relative contribution of non-genetic factors to the total variation, so traits that are influenced heavily by environmental factors will, by definition, have low heritabilities in spite of high additive genetic variability. An alternative is to measure the potential response as the expected proportional change associated with a unit of selection using the additive coefficient of variation (CV_A). The CV_A scales the component of additive genetic variance by the trait mean instead of by the total variance and so is not confounded by the magnitude of other variance components. The CV_A can be high in traits with low heritabilities if there is a high variance of residual error in trait development, as is expected for most fitness-related traits such as fertility and longevity (Houle, 1992). Under directional selection, levels of CV_A can be related directly to the response to selection (Kruuk et al., 2000). Estimates of CV_A allow us to have an insight in to the genetic variability of traits as well as to compare precisely traits measured at different times or in different populations.

In mammalian species, maternal effects contribute complexity to phenotypic measurements for many traits, and especially those measured early in life (Wolf et al., 1998). Maternal effects are unrelated to the offspring's own genotypes and have their own genetic and environment origins. For example, in mammals, lactation has a critical effect on offspring growth rate and performance, and may be determined by both the mother's genotype and her environment. To obtain accurate estimates of heritabilities, the contribution of maternal effects to phenotypic variation of interested traits should be quantified. Otherwise, the heritability is often overestimated (Ghafouri-Kesbi et al., 2011).

Many authors including Eskandarinasab et al. (2010), Ghafouri-Kesbi et al. (2011) and Ghafouri-Kesbi and Rafiei-Tari (2015) demonstrated that efficiency-related traits have positive genetic correlation with growth-related traits. Therefore, selection for growth rate is expected to increase both the growth performance and the efficiency of feed utilization. While genetic information for growth-related traits is available for Baluchi sheep (Safaei et al., 2010; Jafargholi et al., 2011; Jalil-Sarghale et al., 2014), there is no previous information regarding genetic parameters for Kleiber ratio, efficiency of growth and relative growth rate in Baluchi sheep. Therefore, this study was conducted to make a comprehensive survey on growth rate and efficiency-related trait of Baluchi sheep. Results can be used by breeders of Baluchi sheep to plan suitable breeding programs for this breed.

2. Material and methods

2.1. Data and management

The data used in the present study were obtained from the Abbasabad Sheep Breeding Station (flock 1), Mashhad, Khorasan Razavi, Iran. This experimental population of Baluchi sheep was founded in the early 1960s. In general, the flock was maintained using conventional commercial procedures. The mating period began in late August or early September and lasted for 51 days. Lambing took place from the beginning of February to the end of March. At birth, the relevant information about the newborn lambs such as sex, birth type, birth date, birth weight, and sire and dam ID were recorded. In addition, body weights were recorded at monthly intervals from birth until 4 months of age. Body weights for 6, 9 and 12 months of age were also recorded. Lambs were weaned at an average age of approximately 90 days. They were then raised separately from older animals until one year of age. During this period, they were not subjected to any form of culling unless they were physically unsound. Animals were kept indoors during winter and received a ration consisted of wheat and barley straw, alfalfa hay, sugar beet pulp and concentrate. According to the requirement, the food of the ewes was supplemented with concentrates during pregnancy and the nursing period. To protect animals from various diseases, vaccinations were performed twice a year. The sheep were dewormed with anthelmintic drugs and dipped in an anti-parasite bath twice a year.

2.2. Evaluated traits

Data used in the current study included birth weights (BW) and body weights at weaning (WW), 6 months (W6), and yearling age (YW). In order to account for the differences among animals in age at measurement, weaning, 6-month and yearling weights were adjusted to 90, 180 and 365 days of age, respectively. The increases in weight for the different growth phases, (i.e., birth to weaning, weaning to 6-months, and weaning to yearling age) were used to calculate growth rates (GRa, GRb, GRc) as the total gain divided by the number of days in the period. Estimates of GRa, GRb and GRc were then used to calculate corresponding Kleiber ratios as $KRa = GRa/WW^{0.75}$, $KRb = GRb/W6^{0.75}$ and $KRc = GRc/W12^{0.75}$ and efficiencies of growth as $EFa = (WW\text{-}BW/BW) \times 100$, $EFb = (W6\text{-}WW/WW) \times 100$ and $EFc = (YW\text{-}WW/WW) \times 100$. Body weights were also used to calculate relative growth rate from birth to weaning (RGRa), weaning to 6 months (RGRb) and weaning to yearling age (RGRc) as: $RGRa = Log_e(WW) - Log_e(BW)/90$, $RGRb = Log_e(W6) - Log_e(WW)/90$, $RGRc = Log_e(YW) - Log_e(WW)/275$.

Accordingly, 4 traits (response variables) including growth rate, Kleiber ratio, efficiency of growth and relative growth rate, each measured in 3 growth phases, were considered for further analyses.

2.3. Statistical analysis

To obtain accurate estimates of genetic parameters, non-genetic factors which influence the phenotypic expression of different genotypes should be either controlled experimentally or accounted for statistically. In the framework of the animal model, non-genetic factors, referred to as fixed effects, can be included such that an individual's phenotype is 'corrected' for known sources of variation, such as sex, birth type, etc. For animal breeding applications, the inclusion of fixed effects is used to protect against downward bias in heritability estimates. To identify fixed effects, least square analyses were conducted using the GLM procedure (SAS, 2004) with a