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# Effect of different sources of specific variance on the weight development and wool production of the Karnobat sheep breed

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## Abstract

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Subject of the study were 279 ewes of the Karnobat sheep breed, ownership of Institute of Agriculture – Karnobat, born in the period between 2010 and 2015. The live weight traits at weaning (100 days), at 9 months, at 1.5 years, at 2.5 years and the wool production at 1.5 years, 2.5 years and 3.5 years were studied. The information was extracted from the pedigree book of the breed for the three line groups. The data was obtained in conformity with the standard methods and guidelines in the Instruction Codex for Breeding for Preservation of the Local (Indigenous) Sheep Breeds in Bulgaria (2003). Analysis of variance per each age was conducted on the basis of multi-factor linear models (Harvey, 1990). The estimation of heritability coefficients were under Becker (1968). The differences among levels of studied factors were established on the basis of the Student's distribution (Hayter, 1984). It was established that the average live weight of the Karnobat ewes was 23.289 kg at 100 days, 32.463 kg at 9 months, 41.840 kg at 1.5 years and 43.575 kg at 2.5 years. The average wool yield per ewe was 3.923 kg from first shearing, 2.858 at 2.5 years and 2.778 at 3.5 years. Lineage did not have significant effect on the phenotypic expression of the traits live weight and wool production of the ewes from the Karnobat breed. Year of birth had reliable influence on the live weight and wool production of the ewes from the Karnobat breed at all studied ages ($P < 0.001$). The coefficients of heritability of the trait live weight are low at 100-day and 9-month age ($h^2 = 0.092$, $h^2 = 0.194$,), and moderate at 1.5 and 2.5 years ($h^2 = 0.303$, $h^2 = 0.399$). The heritability estimates of wool yield are low at all studied ages ($h^2 = 0.076$ to $h^2 = 0.141$).

*Keywords:* Karnobat sheep; breed; breeding lines; live weight; wool yield; heritability

## Introduction

The Karnobat sheep is a local autochthonous breed, bred mainly in Southeastern Bulgaria and the name derives from that area. Breeding these animals is an age-old tradition related to the lifestyle and livelihood of the people. In relation to that, the breed is of particular importance in the ecological, economic and social aspect of the development of the Southeastern region. According to the latest monitoring, the population includes 1145 sheep and 39 rams bred on 7 farms. Almost all active rams in the range are close or distant descendants of the herd of Institute of Agriculture – Karnobat. In practice, this creates prerequisites for increasing the level of homozygosity in the population endangering its stability. Regardless of the state's financial support, agro-environment payments and the new subsidy scheme for sheep under selection control, the enlargement rate is low and the risks to a population of such small size remain. The issue of preserving unique global genetic reserves is becoming more and more important in view of the growing threat of significant climate change and its consequences for the humanity. For the survival and increasing the number of local Karnobat sheep and other valuable indigenous breeds, it is necessary to develop sustainable conservation and development projects. The peculiarities, the production traits and the status of the local Karnobat sheep population have been studied by Balevska et al. (1958, 1970, 1973); Baulov et al. (1983); Boykovski et al. (2008); Dimitrov et al. (2003); Hristova (2013); Iliev (2002, 2007, 2012); Stefanova et al. (2002, 2005, 2011); Tyankov (1973). Staykova and Iliev (2017) have made a contemporary assessment of the status and perspectives of the Local Karnobat sheep breed. Staykova et al. (2017) have published data regarding the economical indicators when raising these animals. Iliev et al. (2017) have researched the fattening and slaughter qualities of Karnobat lambs, fattened to 30 kg pre-slaughter live weight. At this stage it is necessary to avoid the risk of loss of genetic variability and to start building genealogical structure of the breed, by laying out new lines, studying the productivity and the different effects on it, in the current state of the population. Scientific literature lacks analyzes of the factors affecting the productivity of the local Karnobat breed, as well as information on the heritability coefficients of the main productive traits. This motivates the current study.

The aim of this study is to establish the sources of specific variance on the live weight and wool production of the local Karnobat breed.

## Material and Methods

Subject of the study were 279 ewes of the Karnobat sheep breed, ownership of Institute of Agriculture – Karnobat, born in the period between 2010 and 2015. Live weight was studied at the following ages: weaning (100 days), 9 months, 1.5 years, 2.5 years; and wool production: 1.5 years, 2.5 years and 3.5 years. The data was obtained in conformity with the standard methods and guidelines in the Instruction Codex for Breeding for Preservation of the Local (Indigenous) Sheep Breeds in Bulgaria (2003). Live weight was recorded to the nearest 0.5 kg, taking into account the age at weaning in days, and then made equivalent to 100 days for data comparability. Wool yield is measured to the nearest 0.1 kg. Wool production recorded at 1.5 years was realized for 18-month wool growth, and at the other ages – for 12 months. An analysis of the variant, based on a multifactor linear model (Harvey, 1990), was constructed for each studied age, having the following expression:

$$Y_{ijklm} = \mu + A_{ijklmno} + B_{pqhij} + e_{ijklm},$$

where: μ is overall mean for all age groups;

$A_{ijklmno}$ – effect of breeding line (fixed) for all ages – 3 levels (lines);

$B_{pqhij}$ – effect of year of birth (fixed); 6 levels (2010 – 2015)

$e_{ijklm}$ – residual effects ≈ N (O, $\delta e^2$)

The heritability coefficients are under the method of Becker (1968). The differences among the levels of the studied factors are established on the basis of the Student's normal distribution of data (Hayter, 1984):

$$(yi - yj) / S \sqrt{( 1/ni + 1/nj)} /2,$$

where (yi – yj) is the difference between mean values of the levels of the studied factor; S – quadratic deviation; ni и nj – number of observations (individuals) for the respective levels.

## Results and Discussion

In this study no significant effect of breeding line was established on the phenotypic manifestation of the trait live weight at the studied ages (Table 1). The other source of variation, year of birth, has a significant influence on all the studied ages ($P < 0.001$), the F-values increasing with the advance in age – from F = 7.726 at 100 days to F = 85.844 at 2.5 years. The variation coefficients of the studied trait were from 4.28% at 2.5 years to 9.62% at 100-day age. The highest variability at this early age is presumably due to the maternal effect on body weight, which is eliminated in subsequent ages. Tyankov et al. (2003) and Panayotov et al. (2003) also establish a low variation of the trait, which appears to be a specific feature of the breed, compared to other local breeds (Panayotov et al., 2003). Determination coefficients increase with age from $R^2 = 0.355$ to $R^2 = 0.789$, indicating that after 9 months greater portion of the variation of the trait is explained by the included sources of variability. The same trend is observed in terms of wool production. No differences related to breeding line were observed (Table 2), but there is highly significant influence of the complex envi-

**Table 1. Analysis of variance of the trait live weight**

| Sources of variance | df | F | P | $R^2$ | CV% |
|---|---|---|---|---|---|
| 100 days | | | | | |
| Breeding line | 2 | 0.191 | n. s. | 0.355 | 9.62 |
| Year of birth | 5 | 7.726 | *** | | |
| 9 months | | | | | |
| Breeding line | 2 | 0.320 | n. s. | 0.533 | 5.90 |
| Year of birth | 5 | 21.464 | *** | | |
| 1.5 years | | | | | |
| Breeding line | 2 | 0.768 | n. s. | 0.614 | 4.94 |
| Year of birth | 5 | 32.510 | *** | | |
| 2.5 years | | | | | |
| Breeding line | 2 | 2.111 | n. s. | 0.789 | 4.28 |
| Year of birth | 5 | 85.844 | *** | | |

*** – P < 0.001; ** – P < 0.01; * – P < 0.05

**Table 2. Analysis of variance of the trait wool yield**

| Sources of variance | df | F | P | $R^2$ | CV% |
|---|---|---|---|---|---|
| 1.5 years | | | | | |
| Breeding line | 2 | 1.401 | n. s. | 0.322 | 11.92 |
| Year of birth | 5 | 5.820 | *** | | |
| 2.5 years | | | | | |
| Breeding line | 2 | 0.196 | n. s. | 0.394 | 13.31 |
| Year of birth | 5 | 9.635 | *** | | |
| 3.5 years | | | | | |
| Breeding line | 2 | 0.642 | n. s. | 0.444 | 12.23 |
| Year of birth | 4 | 12.248 | *** | | |

*** – P < 0.001; ** – P < 0.01; * – P < 0.05

ronmental factor year of birth (P < 0.001) in three consecutive record ages. The F-values increase with age and ranging from 5.820 to 12.248. The variation of this trait ranges from 11.92% to 13.31%. Panayotov et al. (2003) found a higher average variation of the fleece weight of 24.10%.

The results in Table 3 show that the weight development of the animals from line 68 is best, with positive LS estimates at all ages. At the respective ages the ewes from line 013 and line 410 showed negative deviations from the mean of the studied sample, with the exception of 9 months for the former line and 18 months for the latter. The differences were not statistically proven. The ewes born in 2010 and 2011 show superiority in the trait live weight at all ages (P < 0.05, P < 0.01, P < 0.001). The deviation for 2010 was most significant at 2.5 years (+ 3.382 kg) and for 2011 at 9 months (+ 1.993 kg). Those in 2013 were also positive, with the exception of 2.5 years (P < 0.05, P < 0.01, P < 0.001). The animals born in 2014 are characterized by negative weight developmental deviations for all ages (P < 0.05, P < 0.01, P < 0.001). They have worst performance at 2.5 years (- 2.087 kg), with highly significant differences with the other groups. In those born in 2015, the results were the same (P < 0.05, P < 0.01, P < 0.001), with the exception of 100-day weight, where the deviation is positive but negligible. The ewes born in 2012 show lowest live weight at 9 months, their weight at 100 days being by 1.545 kg lower than in the other groups. Maternal effect was then eliminated and they are presented with a positive deviation for the latest two ages (P < 0.05, P < 0.01, P < 0.001). The average live weight of the local Karnobat breed found in this study was 23.289 kg at 100 days, 32.463 kg at 9 months, 41.840 kg at 1.5 years, and 43.575 kg at 2.5 years. Nearly 90 years ago, Hlebarov (1933) claimed that the local Karnobat sheep was a small breed with an average live weight of 31.260 kg and weight at weaning of 20.170 kg. The same author (Hlebarov, 1940) found improvement of this trait over the next 7 years, with an average weight of 37.700 kg. In a contemporary research, Panayotov

**Table 3. LS-estimates (LSC) of the effect of the breeding line and the year of birth on live weight at different age**

| Age | 100 days | | | 9 months | | | 1.5 years | | | 2.5 years | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | LSC | LSM ± SE | n | LSC | LSM ± SE | n | LSC | LSM ± SE | n | LSC | LSM ± SE |
| Line | | | | | | | | | | | | |
| 013 | 97 | -0.047 | 23.242±0.192 | 97 | 0.071 | 32.534±0.165 | 97 | -0.195 | 41.645±0.178 | 95 | -0.272 | 43.303±0.163 |
| 68 | 112 | 0.116 | 23.405±0.187 | 112 | 0.075 | 32.538±0.161 | 112 | 0.165 | 42.004±0.174 | 108 | 0.277 | 43.852±0.159 |
| 410 | 70 | -0.069 | 23.220±0.212 | 70 | -0.146 | 32.317±0.235 | 70 | 0.029 | 41.869±0.197 | 68 | -0.005 | 43.570±0.180 |
| Year of birth | | | | | | | | | | | | |
| 2010 | 64 | 0.1001 | 23.388±0.271 | 64 | 0.569 abc | 33.032±0.233 | 64 | 2.142 abAB | 43.981±0.251 | 59 | 3.382 ABCD | 46.957±0.234 |
| 2011 | 57 | 1.190 Am | 24.479±0.281 | 57 | 1.993 aAlBC | 34.456±0.241 | 57 | 1.436 lCD | 43.276±0.260 | 55 | 1.899 alEFG | 45.474±0.239 |
| 2012 | 42 | -1.545 lABCD | 21.744±0.318 | 42 | -0.233 AmDE | 32.230±0.273 | 42 | 0.105 alEF | 41.945±0.295 | 42 | 0.681 AlbHI | 44.256±0.267 |
| 2013 | 40 | 0.544 B | 23.833±0.544 | 40 | 0.494 lmno | 32.957±0.276 | 40 | 0.271 bmG | 42.111±0.298 | 39 | -0.186 BEbcJ | 43.389±0.272 |
| 2014 | 39 | -0.296 mC | 22.993±0.326 | 39 | -1.394 bBDn | 31.069±0.280 | 39 | -1.404 CEm | 40.436±0.302 | 39 | -2.087CFHcm | 41.489±0.274 |
| 2015 | 37 | 0.009 D | 23.297±0.333 | 37 | -1.429 cCEo | 31.034±0.285 | 37 | -2.550BDFG | 39.290±0.308 | 37 | -3.689 DGIJm | 39.886±0.279 |
| μ | 279 | 23.289±0.140 | | 279 | 32.463±0.121 | | 279 | 41.840±0,129 | | 271 | 43.575±0.118 | |

μ –overall LS mean
Significance of differences within columns – when symbols identical: A to Z – P < 0.001; a to k – P < 0.01; l to z – P < 0.05

et al. (2003) and Iliev (2002, 2012) published lower than our values for the weaning trait and higher at 1.5 and 2.5 years. The data for the average live weight of the Karnobat ewes from our study are similar to those obtained by Tiankov et al. (2003) and Iliev (2007) at the age of 2.5 and lower at 18 months when entering the main herd. Boykovski et al. (2003) reported increase in average live weight from 35.300 to 43.000 kg for local Karnobat ewes under better management and feeding conditions over a 5-year period.

The information in Table 4 regarding wool production trait shows positive deviations from the sample average of the ewes from line 68 at all studied ages. The differences were not statistically proven except for the age of 2.5 years at P < 0.05. The animals from line 013 and line 410 exhibit negative deviations from the mean, except those from the latter line at 18 months. Those born in 2012 and 2013 had superior yield of unwashed wool for 3 subsequent measurements (P < 0.05, P < 0.01, P < 0.001). The deviation was most significant in the first 2.5 years (+ 0.141 kg). The ewes born in 2011 show a lower wool production than the average (-0.298 kg) at 18 months but compensate with positive LS-estimates for subsequent ages. Those born in 2014 and 2015 are presented with negative results except for 18 months for the first (P < 0.05, P < 0.01, P < 0.001). At 2.5 years, they gave 0.348 kg lower wool yield than the average for the studied sample. The 2010 generation showed inconsistent estimates of the different ages. The average wool yield of the local Karnobat breed found in this study was 3.923 kg from first shear, 2.858 at 2.5 years and 2.778 at 3.5 years. It is noteworthy that the performance at the first age is about 35% higher, due to the fact that the lambs are not sheared and the wool growth is up to first shearing at 18 months. Even higher average values for this age was obtained by Panayotov et al. (2003) – 4.200 kg and Tyankov et al. (2003) – 4.156 kg. Hlebarov (1933) reported the average weight of the fleece of the Karnobat sheep of 2.423 kg. Iliev M., (2002, 2007) establishes higher average values for wool production at different age (3.100 kg, 3,300 kg) compared to our results. The same author in another study (Iliev, 2012) published an average level of 2.900 kg and Tiankov et al. (2003) – of 2.5 to 3 kg, which was close to the results obtained for 2.5- and 3.5-year old ewes.

The analysis of the results for the studied traits shows a tendency for productive superiority of the ewes from line 68 compared to their age peers from the other lines. Lineage differences, however, were too small and statistically insignificant, with the exception of 2.5 years of age at P < 0.05. The ewes born in 2010 and 2011 are better in live weight, and those from 2012 and 2013 show higher wool yield. These data, along with the low F-values, indicate the lack

**Table 4. LS-estimates (LSC) of the effect of the breeding line and the year of birth on wool yield at different age**

| Age | 1.5 years | | | 2.5 years | | | 3.5 years | | |
|---|---|---|---|---|---|---|---|---|---|
| | n | LSC | LSM ± SE | n | LSC | LSM ± SE | n | LSC | LSM ± SE |
| Line | | | | | | | | | |
| 013 | 97 | -0.062 | 3.861±0.040 | 95 | -0.003 l | 2.855±0.329 | 77 | -0.029 | 2.749±0.033 |
| 68 | 112 | 0.001 | 3.924±0.039 | 109 | 0.196 lm | 2.878±0.321 | 86 | 0.032 | 2.810±0.032 |
| 410 | 70 | 0.061 | 3.984±0.044 | 69 | -0.016 m | 2.842±0.036 | 55 | -0.004 | 2.774±0.037 |
| Year of birth | | | | | | | | | |
| 2010 | 64 | 0.119 A | 4.042±0.056 | 61 | -0.144 mbc | 2.715±0.047 | 56 | 0.071 A | 2.848±0.432 |
| 2011 | 57 | -0.298 Alam | 3.625±0.582 | 55 | 0.189 mA | 3.048±0.048 | 54 | 0.150 B | 2.928±0.043 |
| 2012 | 42 | 0.046 l | 3.969±0.660 | 42 | 0.141 bdB | 2.999±0.054 | 37 | 0.076 C | 2.854±0.050 |
| 2013 | 40 | 0.077 a | 3.999±0.067 | 39 | 0.121 ce | 2.979±0.055 | 37 | 0.051 a | 2.829±0.049 |
| 2014 | 39 | 0.064 m | 3.987±0.068 | 39 | -0.046 d | 2.813±0.055 | 34 | -0.348 ABCa | 2.429±0.052 |
| 2015 | 37 | -0.079 | 3.915±0.069 | 37 | -0.261 ABe | 2.598±0.056 | | | |
| μ | 279 | 3.923±0.029 | | 273 | 2.858±0.024 | | 218 | 2.778±0.025 | |

μ –overall LS mean
Significance of differences within columns – when symbols identical: A to Z – P < 0.001; a to k – P < 0.01; l to z – P < 0.05

of lineage differentiation in live weight and wool production traits. Definitive for their phenotypic manifestation were the environmental factors and the dynamics of their effect.

The heritability estimates for the trait live weight (Table 5) established in the study were low to moderate increasing with age from $h^2 = 0.092$ to $h^2 = 0.399$. As it was mentioned above, maternal effect appears to take place at an early age, while, as heritability coefficients show, the effect of the sire is expressed at later age. For the trait unwashed wool yield the values were low, in the range from $h^2 = 0.076$ to $h^2 = 0.141$. Scientific literature rarely includes studies on the heritability coefficients of the different economic traits in indigenous breeds of sheep bred in Bulgaria. This is due to the fact that they use maintenance selection without intensive pressure to increase productivity. The heritability of the main productive traits in the local Karnobat breed has not been investigated so far. Antonova (1972) studied the heritability coefficients for the main productive traits in the F1 crossbreeds of Karnobat ewes with Caucasian rams. During the first crossbreeding stage the author (Antonova, 1972) published heritability coefficients for live weight $h^2 = 0.790$ and for wool production $h^2 = 0.600$. Baulov & Antonova (1984) found that the coefficients of heritability for live weight range from $h^2 = 0.335$ to $h^2 = 0.539$ in crossbreds from the same herd in the breeding process, and for 18 months the value was $h^2 = 0.137$. According to Tiankov et al. (2003), the heritability of live weight of combined-purpose breeds, such as the local Karnobat breed, varies widely from $h^2 = 0.060$ to $h^2 = 0.700$, depending on the factors that determine it. The range of the coefficient for unwashed wool yield was from $h^2 = 0.100$ to $h^2 = 0.600$, according to the same authors. Our study showed rather low $h^2$ values in Karnobat sheep.

The results about heritability show the additive paternal effect and usually confirm the analysis of variance. Staykova (2014) found a significant decrease in the $h^2$ values for live weight and wool yield of the Copper-Red Shumen sheep breed over a period of 10 years. In the absence of such data

**Table 5. Heritability coefficients (h²) of the productive traits in ewes at different ages**

| Traits | N | n | $h^2$ |
|---|---|---|---|
| Live weight | | | |
| 100 days/ | 26 | 279 | 0.092 |
| 9 months | 26 | 279 | 0.194 |
| 1.5 years | 26 | 279 | 0.303 |
| 2.5 years | 26 | 271 | 0.399 |
| Wool yield | | | |
| 1.5 years | 26 | 279 | 0.076 |
| 2.5 years | 26 | 271 | 0.141 |
| 3.5 years | 23 | 218 | 0.122 |

for the Karnobat sheep, we can assume that due to the close genetic link and general phylogenetic development of the two breeds the state of the gene pool is analogous. Probably in the local Karnobat breed the level of homozygosity is even higher, as the population is much smaller. Supporting selection based on purebred line breeding aims to preserve genetic variability. Despites, there is a decrease in the genetic determination of the variance of the productive traits to a certain extent, depending on the nature of the trait. The low heritability coefficients reflect a narrow genetic diversity, expressed as the additive component of the variability of the main productive traits.

The dynamics of the heritability of the productive traits, along with the analysis of variance provide information on the degree of genetic determination and homozygosity. Enriching the population's allelofund by creating new unrelated breeding lines would widen the phenotypic variation of all productive traits. The use of rams to guarantee certain genetic distances would increase the vitality of the population.

## Conclusions

Breeding line has no significant effect on the phenotypic manifestation of live weight and wool production traits in the local Karnobat breed.

Year of birth has highly reliable impact on the live weight and wool production of the local Karnobat breed of all studied ages ($P < 0.001$).

The coefficients of heritability of the trait live weight are low at 100-day and 9-month age ($h^2 = 0.092$, $h^2 = 0.194$,), and moderate at 1.5 and 2.5 years ($h^2 = 0.303$, $h^2 = 0.399$). The heritability estimates of wool yield are low at all studied ages ($h^2 = 0.076$ to $h^2 = 0.141$).

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