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Determination of andrological and spermatological parameters in Southern Karaman breed rams under threat of extinction

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ABSTRACT

Background: Agriculture and livestock breeding are industries that contribute significantly to national economies by providing basic food resources, supplying raw materials to the industrial sector, and creating a large employment area. In sheep breeding, which has an essential role in animal husbandry, the protection, production, and widespread use of local sheep breeds are crucial. In this respect, data on the spermatological properties of rams of the Southern Karaman breed are limited.

Aim: This study aimed to determine the andrological and spermatological parameters of Southern Karaman rams.

Methods: Morphometric measurements were initially conducted on the ram testicles as part of the andrological examination. In order to determine the spermatological characteristics, the volume, motility, and concentration of semen obtained with an electro-ejaculator were determined, and the ratios of dead, live, and abnormal spermatozoa were determined. Testosterone levels were measured by the ELISA method in blood samples taken from rams.

Results: The average body weight of Southern Karaman breed rams was 63.80 ± 4.12 kg. As a result of morphometric measurements, the mean right testis length, width, and thickness were 12.27 ± 1.87, 5.47 ± 0.59, and 6.16 ± 0.68 cm, respectively, and the mean left testis length, width, and thickness were 12.37 ± 1.91, 5.45 ± 0.76, and 6.23 ± 0.84 cm, respectively. The mean scrotum thickness was 0.38 ± 0.03 cm, and the mean scrotum girth was 29.87 ± 3.22 cm. It was measured as 724.28 ± 156.18 ml mean testicular volume. The spermatological findings were evaluated; the average semen volume obtained from Southern Karaman rams was 0.64 ± 0.22 ml, the average mass activity score (1–5) was 4.28 ± 0.95, the average total motility value was 81.42% ± 12.14%, the average semen concentration was 1688.57 ± 429.24 × 10^6 sperm ml^{-1}, the average viability rate was 79.00% ± 3.26% and the average abnormal sperm rate was 3.85% ± 1.21%. The average blood serum testosterone level was 4.91 ± 0.74 ng/ml.

Conclusion: There is insufficient information about the reproductive performance of Southern Karaman rams, which is an important but endangered breed specific to Turkey, and as a result of this study, testicular characteristics, spermatological, and hormonal characteristics of Southern Karaman rams were included them in the literature.

Keywords: Andrology, Endangered breed, Semen, Southern Karaman ram, Testicles.

Introduction

In Turkey, as in many countries around the world, population growth and rapid increase in income levels have increased the need for meat and milk production, resulting in a production deficit. In order to solve this problem, livestock productivity and production processes need to be improved. Meeting the demand in meat and milk production is possible by increasing both the number of animals and yields per unit. For this reason, it is necessary to determine the reproductive characteristics of domestic sheep breeds to increase their fertility and improve their yield characteristics through both pure breeding and crossbreeding (Akçapınar, 1994).

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The process from production to mature spermatozoa, which carry the genetic makeup of rams, occurs in the testicles. Morphological or physiological reproductive disorders in the testicles can significantly affect ram productivity. Therefore, it is important to determine the testicular and spermatological characteristics of rams to be used in flocks before or during the breeding season. Testicular health and sperm quality directly impact fertility (Hafez, 1987).

Sheep, which constitute an important part of Turkey's livestock, have different breeds in different regions. One of these breeds is Southern Karaman, which is bred in the Toros Mountains. Southern Karaman is characterized as a separate breed formed as a result of the crossbreeding of Karagül rams brought by Yoruks (Turkmens) migrating from Turkistan to the Mediterranean during the Ottoman period with Akkaraman and Dağlıç sheep existing in the mountainous regions of Antalya, Mersin, and Adana. The Southern Karaman breed is frequently preferred in breeding due to its resistance to environmental conditions, especially cold weather conditions. This breed, which is raised in the high-altitude regions of the Toros Mountains (2,000–2,500 m), is very important in terms of productivity (Yalçın, 1990; Ertuğrul *et al*., 2009; Akay *et al*., 2020; Özdemir and Özüdoğru, 2020; Özüdoğru and Özdemir, 2021).

Within the scope of the "Protection of Gene Resources" project carried out by the Ministry of Agriculture and Forestry of the Republic of Turkey, the number of pure Southern Karaman breeds is insufficient. For this reason, it is necessary to find pure samples by conducting more comprehensive field surveys and to establish conservation herds consisting of a sufficient number of animals. Increasing the population of the Southern Karaman breed and improving its yield characteristics are very important in increasing the economic contribution of livestock breeding activities with this breed to the economy, especially in terms of fertility. Determination of andrological parameters and spermatological characteristics of rams plays a critical role in this process.

In this study, the andrological and spermatological characteristics of Southern Karaman breed rams shown in Figure 1 were determined, and the factors affecting these characteristics were tried to be revealed. In addition, the possible effects on fertility were examined, and how these data can be used in the genetic improvement of the breed and in supporting livestock breeding activities were examined. This study will increase the productivity level of the Southern Karaman breed and create a more sustainable livestock breeding model.

Materials and Methods

In the research, 7 Southern Karaman breed rams, which were 1.5 years old, clinically healthy, had known fertility, and no pathological findings were found because of genital organ examination, were used as animal material. Animal welfare principles for research were observed throughout the study. This research was conducted during the breeding season. The animals were housed within the premises of the Bahri Dağdaş International Agricultural Research Institute and fed with high-quality roughage and concentrate feeds. Drinking water was provided ad libitum.

Fig. 1. A view of the Southern Karaman breed rams used in the research.

Morphometric measurements

After determining the body weights, the scrotal thickness and girth, length and width of each testicle, including the epididymis over the scrotum, and the thickness of each testicle over the scrotum were measured. Morphometric measurements of the reproductive organs were recorded in "cm". To measure the volume of the testicles, a 2 l container was filled with water at 37°C, and both testicles were immersed in the water. The volume of overflowing water in this container, including both the testicles and scrotum, was determined as the testicular volume in "ml" (Aksoy *et al*., 1994; Gündoğan *et al*., 2003; Türk *et al*., 2005).

Semen collection

Since semen could not be collected from the rams by artificial vagina during the breeding season, semen was collected using an electro-ejaculator in accordance with the technique. During this process, the rams were kept in a special area and under physical restraint, and animal welfare rules were respected.

Semen analyses

Routine semen examination, volume, mass activity, motility, concentration, viability ratio, and morphologic examination were performed.

Volume

The volume of semen was recorded in "ml" by reading according to the measurement lines on the graduated semen collection goblet.

Mass activity

A small drop of fresh semen was placed on a slide on a heating table set at 37°C. The mass activity was

examined under a microscope at 10 × 10 magnification without covering the slide with a coverslip. Three different fields were examined, and a score between 0 and 5 was assigned (Hafez, 1987; Bearden *et al*., 1992).

Motility

First, a clean slide was placed on a heating plate set at 37°C and heated. Subsequently, 0.5 ml of Tris-based diluent [Tris (3.63 g), fructose (0.5 g), citric acid (1.99 g), and distilled water (100 ml)] (Gündoğan *et al*., 2010) and 3 µl of fresh semen were placed on the slide, and the coverslip was closed. Motility was determined under a microscope at 10 × 40 magnification. The evaluation was performed by averaging the motility rates in at least 3 different fields and recording a value between 0% and 100 % (Hafez, 1987; Bearden *et al*., 1992).

Concentration

Semen concentration was determined using the hemocytometric method (Bearden *et al*., 1992; Demirci, 2000).

Viability ratio

A smear slide was prepared with semen samples and stained using the Eosin-Nigrosin stain (Sönmez and Demirci, 2004). The spermatozoa with pink-stained heads were considered dead, and those without staining were considered viable, and the viability ratios were calculated. The results were recorded as "%".

Morphological examination (abnormal sperm ratio)

To determine the abnormal sperm rate in semen samples, we prepared slides using Tile ink. The proportion of abnormally shaped spermatozoa was expressed as "%" (Bearden *et al*., 1992; Demirci, 2000).

Determination of testosterone hormone levels

Testosterone levels in serum samples obtained from the animals at the end of the study were determined by the ELISA method. The blood serum samples obtained from the animals were read in a special device with the help of commercial testosterone kits (Sheep Testosterone, T ELISA Kit), and the results were recorded as "ng/ml".

Statistical analysis

A post hoc power analysis was performed using the G*Power 3.1 software. Assuming an effect size of $d = 1.0$ (large), $\alpha = 0.05$, and a sample size of $n = 7$, the statistical power ($1-\beta$) was calculated as approximately 0.77. Despite the limited sample size, this indicates a moderately high probability of detecting a true effect, which is common in studies involving endangered or rare livestock breeds. One-sample *t*-tests were conducted to compare Southern Karaman semen parameters with known means from published studies on Akkaraman and Karayaka breeds. The total motility (81.42% ± 12.14%) of Southern Karaman rams was not significantly different from that of Akkaraman rams (mean = 81.7%, $p > 0.05$), suggesting comparable fertility potential (Gündoğan *et al*., 2002). A Pearson correlation test was conducted to determine the possible relationship between morphometry and spermatological traits. Statistical analyses, including one-sample *t*-tests and Pearson correlation, were performed according to the methods described by Petrie and Watson (2013). Data were analyzed using the SPSS V.22 package program. Descriptive statistics were used to summarize the study data. In order to reveal reference values, the lowest and highest values in the 95% confidence interval were calculated. Data are presented as mean and standard deviation.

Ethical approval

The approval certificate (16.08.2024/178) was obtained from the Local Ethics Committee of the Ministry of Agriculture and Forestry, Bahri Dağdaş International Agricultural Research Institute Directorate.

Results

Morphometric results

Table 1 shows the body weights, right and left testicular length, width and thickness values, scrotal thickness and girth values, and testicular volumes of Southern Karaman breed rams.

Spermatological results

The average volume of semen collected from Southern Karaman rams was 0.64 ± 0.22 ml. The mean mass activity score of the semen was 4.28 ± 0.95, while the average total motility value was determined as 81.42% ± 12.14%. The mean sperm concentration in the semen of Southern Karaman rams was $1688.57 \pm 429.24 \times 10^6$ sperm ml^{-1}. Regarding sperm viability, the average live sperm ratio was found to be 79.00% ± 3.26%, whereas the average dead sperm ratio was 21.00% ± 3.26%. Morphological examination revealed that the average total abnormal sperm ratio was 3.85% ± 1.21%.

Testosterone hormone level

The average serum testosterone level of Southern Karaman rams was 4.91 ± 0.74 ng/ml.

Because of the research, all spermatological findings and serum testosterone levels of Southern Karaman rams are shown in Table 2.

Discussion

Body weight, morphometric measurements of reproductive organs, and spermatological characteristics are crucial in determining the reproductive characteristics of male animals and their breeding value.

In the study, it was determined that the average body weight of Southern Karaman rams was 63.80 kg as a result of weighing. İnce and Karaca (2009) found the average body weight as 66.62 kg in Karya rams and 50.40 kg in Çine Çaparı rams. Koyuncu *et al*. (2000) reported the average body weight of Karayaka rams as 41.8 kg. According to the data obtained within the scope of animal husbandry projects carried out under the Ministry of Agriculture and Forestry of the Republic of Turkey, it was determined that the average adult body weights were 62 kg in Akkaraman rams, 90–100 kg in Kangal Akkaraman rams, 50–90 kg in Morkaraman rams, 53 kg in Dağlıç rams, 74 kg in İvesi rams, 58 kg in Karagül rams, and 70 kg in Sakız rams.

Table 1. Morphometric parameters of Southern Karaman rams.

Body weight (kg)		Right testis length (cm)		Left testis length (cm)		Right testis width (cm)		Left testis width (cm)		Right testis thickness (cm)		Left testis thickness (cm)		Scrotum thickness (cm)		Scrotum girth (cm)		Testis volume (ml)	
Mean ± SD		Mean ± SD		Mean ± SD		Mean ± SD		Mean ± SD		Mean ± SD		Mean ± SD		Mean ± SD		Mean ± SD		Mean ± SD	
63.80 ± 4.12		12.27 ± 1.87		12.37 ± 1.91		5.47 ± 0.59		5.45 ± 0.76		6.16 ± 0.68		6.23 ± 0.84		0.38 ± 0.03		29.87 ± 3.22		724.28 ± 156.18	
95% CI*		95% CI*		95% CI*		95% CI*		95% CI*		95% CI*		95% CI*		95% CI*		95% CI*		95% CI*	
Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
59.98	67.61	10.54	14.01	10.60	14.13	4.91	6.02	4.74	6.16	5.52	6.80	5.45	7.01	0.35	0.42	26.89	32.85	579.83	868.73

*95% confidence interval. The upper and lower range values in the 95% confidence interval are shown.

Table 2. Spermatological parameters of the Southern Karaman rams.

Semen volume (ml)		Mass activity (Score 1–5)		Motility (%)		Concentration ($\times 10^6$ sperm ml^{-1})		Live sperm rate (%)		Dead sperm rate (%)		Abnormal sperm rate (%)		Testosterone (ng/ml)	
Mean ± SD		Mean ± SD		Mean ± SD		Mean ± SD		Mean ± SD		Mean ± SD		Mean ± SD		Mean ± SD	
0.64 ± 0.22		4.28 ± 0.95		81.42 ± 12.14		1688.57 ± 429.24		79.00 ± 3.26		21.00 ± 3.26		3.85 ± 1.21		4.91 ± 0.74	
95% CI*		95% CI*		95% CI*		95% CI*		95% CI*		95% CI*		95% CI*		95% CI*	
Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
0.43	0.84	3.40	5.16	70.19	92.66	1291.58	2085.55	75.97	82.02	17.98	24.03	2.73	4.98	4.22	5.60

*95% Confidence Interval. The upper and lower range values in the 95% confidence interval are shown.

When the average body weights were evaluated, the differences between the breeds and even between the individuals within the same breed were very high, and the rams of the Southern Karaman breed had a medium-sized body size.

In the present study, the average right testicle length was 12.27 ± 1.87 cm, and the average left testicle length was 12.37 ± 1.91 cm in rams of the Southern Karaman breed. These values were determined as 10.8 ± 0.06 and 10.8 ± 0.06 in Akkaraman rams, 10.07 ± 0.08 and 10.08 ± 0.10 in İvesi rams, 10.5 ± 0.12 and 10.5 ± 0.16 in Dağlıç rams, and 9.7 ± 0.06 and 9.7 ± 0.03 in Sakız rams, respectively (Gündoğan *et al*., 2002). Similarly, the average testicular length of Karakoyun rams, a local breed, was measured as 12.31 ± 0.48 cm (Kulaksız *et al*., 2010). The testicle length of Kangal Akkaraman rams, a variety of the Akkaraman breed, was 12.21 ± 1.24 cm during the breeding season and 11.72 ± 1.30 cm outside the breeding season (Koçyiğit *et al*., 2021). The average testicular length of the Karayaka rams was measured as 9.2 ± 0.11 cm by Koyuncu *et al*. (2000). The testicular length of the Southern Karaman rams was higher than that of Akkaraman, İvesi, Dağlıç, Sakız, and Karayaka rams and was close to the testicular lengths of the Karakoyun and Kangal Akkaraman rams.

In the study, the average testicular widths of the Southern Karaman rams were measured as 5.47 ± 0.59 cm and 5.45 ± 0.76 cm for the right and left testicles, respectively. In studies conducted with different breeds, these values were 7.0 ± 0.12 and 6.9 ± 0.12 cm in Akkaraman rams, 6.7 ± 0.06 cm and 7.1 ± 0.06 cm in İvesi rams, 6.7 ± 0.09 and 6.9 ± 0.10 and 7.2 ± 0.07 cm and 7.3 ± 0.06 cm in Sakız rams, 4.1 ± 0.05 and 5.90 ± 0.18 cm in Karayaka rams, 5.64 ± 0.92 cm in Karya rams, and 5.19 ± 0.90 cm in Çine Çaparı (Koyuncu *et al*., 2000; Gündoğan *et al*., 2002; İnce and Karaca, 2009; Kulaksız *et al*., 2010). When these measurement results were compared, it was determined that the testicular widths were close in the Southern Karaman, Karayaka, Karya, and Çine Çaparı rams.

In this study, the average scrotal thickness and average scrotal girth length were measured as 0.38 ± 0.03 and 29.87 ± 3.22 cm, respectively, in rams of the Southern Karaman breed. In the previous studies, scrotal thickness and scrotal girth lengths of Akkaraman, İvesi, Dağlıç, Sakız, and Karayaka rams were measured as 0.6 ± 0.03, 0.57 ± 0.01 and 34.3 ± 0.44 cm, 35.3 ± 0.56, 32.2 ± 0.17, 33.7 ± 0.88, 29.80 ± 1.08 cm, respectively (Gündoğan *et al*., 2002; Kulaksız *et al*., 2010). In Karya and Çine Çaparı rams, the scrotal girth length was measured as 33.98 ± 0.36 and 32.70 ± 0.34 cm, respectively (İnce and Karaca, 2009). In a study in which the scrotal girth length of Kangal Akkaraman rams was evaluated in and out of the breeding season, the scrotal width was determined as 33.94 ± 4.02 cm in the breeding season and 32.33 ± 4.07 cm out of the breeding season (Koçyiğit *et al*., 2021). When the values obtained from different breeds were compared, it was concluded that scrotal thickness was lower in Southern Karaman breed rams than in other breeds, and scrotal girth length was close to that of Karayaka breed rams.

In this study, the volume of testicles in Southern Karaman breed rams was determined as 724.28 ± 156.18 ml. This value was measured as 813.3 ± 11.16, 916.7 ± 2.11, 841.7 ± 11.55, 776.7 ± 11.16, and 573.70 ± 25.66 ml in Akkaraman, İvesi, Dağlıç, Sakız, and Karayaka rams, respectively (Gündoğan *et al*., 2002; Kulaksız *et al*., 2010).

In this study, spermatological parameters were also examined in Southern Karaman breed rams, and an average volume of 0.64 ± 0.22 ml of semen was obtained. This volume was measured as 1.1 ± 0.02, 1.0 ± 0.02, 0.9 ± 0.01, 1.0 ± 0.02, and 0.98 ± 0.08 ml in Akkaraman, İvesi, Dağlıç, Sakız, and Karayaka rams, respectively (Gündoğan *et al*., 2002; Kulaksız *et al*., 2010). In a study conducted by Koçyiğit *et al*. (2021) with Kangal Akkaraman rams, semen was collected both during and outside the breeding season, and the semen volume was reported as 1.26 ± 0.12 and 1.02 ± 0.21 ml, respectively. When these results were evaluated, it was observed that in one ejaculation, rams of the Southern Karaman breed gave less volume of semen compared with rams of other breeds.

Mass activity was found to be 4.28 ± 0.95 on average in rams of the Southern Karaman breed in this study. This spermatological parameter was found to be 4.77 in Karya rams and 3.58 in Çine Çaparı breed (İnce and Karaca, 2009). In Akkaraman, İvesi, Dağlıç, Sakız, Karakaş, and Norduz rams, the mass activity was determined as 4.60 ± 0.09, 4.50 ± 0.09, 4.30 ± 0.09, 4.60 ± 0.09, 3.77 ± 0.08, and 3.81 ± 0.07, respectively (Gündoğan *et al*., 2002; Karakuş and Cengiz, 2007). In Kangal Akkaraman rams, the mass activity was found to be 4.27 ± 0.46 during the breeding season and 3.55 ± 0.51 outside the breeding season (Koçyiğit *et al*., 2021). It is concluded that the mass activity in Southern Karaman rams had very close averages with Dağlıç and Kangal Akkaraman rams within the breeding season.

Total motility, which is an important parameter for evaluating fertility, was found to be 81.42% ± 12.14% in the Southern Karaman rams. Total motility values were 81.7% ± 1.08% in Akkaraman rams, 80.7% ± 0.95% in İvesi rams, 78.3% ± 1.01% in Dağlıç rams, 82.3% ± 1.04% in Sakız rams, 79.35 ± 0.88% in Karayaka rams, 87.27% ± 0.68% in Karakaş rams, and 88.62% ± 0.56% in Norduz rams (Gündoğan *et al*., 2002; Karakuş and Cengiz, 2007; Kulaksız *et al*., 2010). In a study conducted with Kangal Akkaraman rams in and out of the breeding season, total motility values were found to be 85.55% ± 4.50% and 76.94% ± 5.46%, respectively (Koçyiğit *et al*., 2021). In a study in which some spermatological parameters of four different breeds, including Akkaraman and İvesi rams, were examined, total motility values of Akkaraman, İvesi, Corriedale, and Merinos rams were found to be 65.7%, 65.5%, 68.1%, and 65.4%, respectively (Aksoy *et al*.,

1994). Similarly, in a study including Akkaraman and Corriedale rams, total motility values of Akkaraman, Corriedale, Dorsetdown, and Hampshire rams were 90% ± 0.0%, 90% ± 0.0%, 87.5% ± 2.5%, and 87.5% ± 2.5%, respectively (Gülyüz and Yıldız, 1995). As a result, when total motility values were compared, although the value of Southern Karaman rams was in parallel with the values obtained from other breeds, there are many genetic and environmental factors affecting total motility. The concentration is the number of spermatozoa in 1 ml of semen, and this value was calculated as 1688.57 ± 429.24 × 10^6 sperm ml^{-1} in Southern Karaman breed rams. Semen concentration was determined as 1890 × 10^6 sperm ml^{-1} in Karya rams and 1560 × 10^6 sperm ml^{-1} in Çine Çaparı rams (İnce and Karaca, 2009). In a study conducted with Akkaraman, İvesi, Dağlıç, Sakız, and Karayaka rams, the concentration values were 3200 ± 0.02, 3000 ± 0.02, 2800 ± 0.03, 3100 ± 0.03, and 3653.16 ± 179.16 × 10^6 sperm ml^{-1}, respectively (Gündoğan *et al*., 2002; Kulaksız *et al*., 2010). Similarly, in a study conducted with rams of different breeds, the semen concentration was found to be 3040 × 10^6 sperm ml^{-1} in Akkaraman rams, 2920 × 10^6 sperm ml^{-1} in İvesi rams, 1940 × 10^6 sperm ml^{-1} in Corriedale rams, and 2600 × 10^6 sperm ml^{-1} in Merino rams (Aksoy *et al*., 1994). In a study including Akkaraman and Corriedale rams, semen concentrations were calculated as 3300 ± 0.1 × 10^6 sperm ml^{-1}, 2900 ± 0.1 × 10^6 sperm ml^{-1}, 3050 ± 0.15 × 10^6 sperm ml^{-1}, and 3200 ± 0.1 × 10^6 sperm ml^{-1} in Akkaraman, Corriedale, Dorsetdown, and Hampshire rams, respectively (Gülyüz and Yıldız, 1995). In a study conducted with Kangal Akkaraman rams in which the effect of breeding season on spermatological parameters was examined, it was observed that semen concentration was 2950 ± 0.34 × 10^6 sperm ml^{-1} during the season and 1580 ± 0.18 × 10^6 sperm ml^{-1} out of season (Koçyiğit *et al*., 2021). In a study conducted with Karakaş and Norduz rams, these values were 1580 ± 0.05 × 10^6 sperm ml^{-1} and 1740 ± 0.04 × 10^6 sperm ml^{-1}, respectively (Karakuş and Cengiz, 2007). As a result, when the semen concentrations of different breeds were evaluated, and the semen concentration values of Southern Karaman breed rams were close to those of Karakaş, Norduz, and Çine Çaparı breed rams. The dead sperm rate was determined as 21.00% ± 3.26% on average in Southern Karaman breed rams. The average dead sperm rates were 13.35 ± 0.63, 5.03 ± 0.39, and 5.99 ± 0.33 in Karayaka, Karakaş, and Norduz rams, respectively (%) (Karakuş and Cengiz, 2007; Kulaksız *et al*., 2010). For Karya, Çine Çaparı, İvesi, Akkaraman, Corriedale, and Merino rams, it was found as (%), 11.48, 14.81, 10.76, 6.67, 9.50, and 13.00, respectively (Aksoy *et al*., 1994; İnce and Karaca, 2009). In Kangal Akkaraman rams, it was found to be 7.65% ± 1.27% during the breeding season and 10.68% ± 2.48% outside the breeding season (Koçyiğit *et al*., 2021). In the present study, the rate of dead spermatozoa was higher in Southern Karaman rams than in other breeds, and many individual and environmental factors affect this rate.

Abnormal sperm rate was determined as 3.85% ± 1.21% on average in Southern Karaman rams. İnce and Karaca (2009) found this rate to be 7.84% for Karya rams and 17.71% for Çine Çaparı rams. In different studies conducted with Akkaraman rams, the abnormal sperm rate was calculated as 3.9% ± 0.02% and 5.75% ± 0.25% (Gülyüz and Yıldız, 1995; Gündoğan *et al*., 2002). It was determined to be 3.9% ± 0.02%, 4.2% ± 0.03%, and 10.99% ± 0.58% in Sakız, Dağlıç, and Karayaka rams, respectively (Gündoğan *et al*., 2002; Kulaksız *et al*., 2010). Koçyiğit *et al*. (2021) determined this rate as 4.40% in the breeding season and 8.48% outside the breeding season in Kangal Akkaraman rams. In different studies conducted in Corriedale and İvesi rams, abnormal sperm rates were found to be 6% and 11.25% and 3.9% and 11.75%, respectively (Aksoy *et al*., 1994; Gülyüz and Yıldız, 1995; Gündoğan *et al*., 2002). This rate was found to be 9.04% in Merino rams and 5.75% and 5.6% in Dorsetdown and Hampshire rams, respectively (Aksoy *et al*., 1994; Gülyüz and Yıldız, 1995). Karakuş and Cengiz (2007) found that the abnormal sperm rates in Karakaş and Norduz rams were 7.40% ± 0.31% and 9.89% ± 0.26%. When the abnormal sperm rates were compared, the abnormal sperm rate detected in the semen of rams of the Southern Karaman breed was lower than that of the other breeds. However, it is known that the variability in the abnormal sperm rate between different breeds and even between different animals within the same breed is high, and many individual and environmental factors are effective on the difference in this rate.

The present study revealed that the average blood serum testosterone level of Southern Karaman rams was 4.91 ± 0.74 ng/ml. In a study that evaluated the effect of breeding season, the testosterone level in Kangal Akkaraman rams was 6.46 ± 1.31 ng/ml during the breeding season and 1.77 ± 0.53 ng/ml outside the breeding season (Koçyiğit *et al*., 2021). In a study conducted by Yeni and Gündoğan (2018) with Pırlak breed rams, blood serum testosterone content was found to be 5.24 ± 0.42 ng/ml on average. The reasons for these differences in testosterone levels may include factors such as breed, age, care and nutrition conditions, climatic characteristics of the region in which they live, whether they are in the breeding season or not, and time and place of blood sampling.

According to the Pearson correlations (Table 3), semen quality may be low in heavier individuals. The existence of a strong relationship between scrotum circumference and testicular volume indicates that scrotum circumference can be considered an indicator of testicular development. The high correlation between mass activity and motility shows that these two parameters are parallel and can be considered in fertility evaluations. A completely negative correlation between the live and dead sperm ratio is an expected biological result and confirms the reliability of the measurement.

Table 3. Pearson's correlation coefficients between morphometry and spermatological traits.

	Right testis length	Right testis width	Right testis thickness	Left testis length	Left testis width	Left testis thickness	Scrotum thickness	Scrotum girth	Testis volume	Semen volume	Mass activity	Motility	Concentration	Live sperm rate	Dead sperm rate	Abnormal sperm rate	Testosterone
Body weight	0.798*	0.036	0.174	0.707	0.319	0.240	0.535	0.557	0.643	−0.505	−0.977***	−0.984***	−0.473	0.173	−0.173	−0.506	0.660
Right testis length		0.384	0.581	0.977***	0.503	0.632	0.541	0.819*	0.867*	0.032	−0.850*	−0.820*	−0.470	0.110	−0.110	−0.089	0.161
Right testis width			0.767*	0.514	0.900**	0.797*	−0.352	0.791*	0.760*	0.436	−0.071	−0.039	0.105	−0.119	0.119	−0.098	−0.578
Right testis thickness				0.681	0.572	0.982***	0.121	0.739	0.769*	0.333	−0.160	−0.192	−0.191	−0.326	0.326	−0.117	−0.294
Left testis length					0.604	0.743	0.472	0.871*	0.928**	0.107	−0.774*	−0.723	−0.430	0.043	−0.043	−0.038	0.000
Left testis width						0.639	−0.312	0.842*	0.809*	0.301	−0.346	−0.296	0.192	0.213	−0.213	−0.267	−0.348
Left testis thickness							0.188	0.760*	0.821*	0.305	−0.243	−0.233	−0.144	−0.230	0.230	−0.100	−0.302
Scrotum thickness								−0.004	0.181	−0.311	−0.533	−0.493	−0.423	0.068	−0.068	0.130	0.451
Scrotum girth									0.966**	0.216	−0.589	−0.599	−0.294	−0.041	0.041	−0.231	−0.150
Testis volume										0.080	−0.671	−0.654	−0.327	−0.056	0.056	−0.268	−0.060
Semen volume											0.405	0.467	0.442	0.275	−0.275	0.643	−0.847*
Mass activity												0.968**	0.491	−0.215	0.215	0.330	−0.534
Motility													0.579	−0.084	0.084	0.468	−0.637
Concentration														0.656	−0.656	0.086	−0.390
Live sperm rate															−1.000***	0.126	−0.011
Dead sperm rate																−0.123	0.011
Abnormal sperm rate																	−0.657

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Conclusion

Information about the reproductive performance of rams of the Southern Karaman breed is insufficient. As a result of this study, the testicular, spermatological, and hormonal characteristics of Southern Karaman rams were revealed and added to the literature. The results of this study will shed light on future studies on the short- and long-term storage and fertility of Southern Karaman ram semen.

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Conflict of interest

The authors declare no conflict of interest.

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Authors' contribution

Tutku Can Acısu and Emine Yüksel: Conceptualization, supervision, methodology, writing–original draft preparation, review, and editing. Tülay Canatan Yılmaz, Aslıhan Çakır Cihangiroğlu and Nida Badıllı; Methodology, data curation. Yasin Baykalır, Emre Kaya, and Ülkü Gülcihan Şimşek; Methodology. conceptualization, and validation.

Data availability

All data supporting the findings of this study are available within the manuscript.

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