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PROOF
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Exploring the Economically Important Growth Traits and Environmental Influences on Akkaraman Lambs in Ankara

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Abstract

This study focused on the Akkaraman sheep breed, specifically examining the pre-weaning growth characteristics and Kleiber ratio, within the framework of Türkiye's National Community-Based Small Ruminant Breeding Program. The research involved Akkaraman lambs born between 2017 and 2021 across 20 farms in the Ankara province. The dataset comprised 19,119 observations, covering key attributes such as birth weight, weaning weight, average daily weight gain, and the Kleiber ratio. Statistical analyses were conducted to identify outliers, assess normality, and develop linear models to explore the impact of environmental factors on the traits. Birth weight was significantly influenced by sex, birth type, birth season, birth year, and flock size. Weaning weight exhibited significant variations based on the same factors, emphasizing the importance of gender, birth type, birth season, birth year, and flock size. Average daily weight gain was notably affected by gender, birth type, birth season, birth year, flock size, and environmental factors, emphasizing their impact on growth. The Kleiber ratio demonstrated significant variations influenced by gender, birth type, birth season, birth year, and flock size. The results highlighted the intricate interplay between environmental factors and pre-weaning growth traits in the Akkaraman sheep breed. The study contributes valuable insights to enhance productivity and underscores the potential of the Akkaraman breed in Türkiye's overall agricultural development, considering its adaptability to arid climates and challenging pasture conditions.

Introduction

Securing food resources for small ruminants holds paramount importance for several compelling reasons. In many regions, particularly in developing countries where alternative protein sources are mostly limited, small ruminants like sheep and goats play a crucial role in providing essential protein for numerous people. Smallholder farmers, whose livelihoods and income are closely tied to these animals, heavily rely on sheep and goats (Selçuk *et al.*, 2023). Thus, ensuring and contributing to food security for small ruminants becomes a pivotal factor in supporting the economic well-being of these farmers and their communities. Furthermore, the inexistent advantages of sheep and goats, requiring less feed, water, and labor compared to larger ruminants, make them adaptable to a diverse range of ecosystems (Joy *et al.,* 2020).

Türkiye with a population of 58 million sheep and goats (comprising 79.4% sheep and 20.6% goats), boasts diverse genotypes well-adapted to its varied geographic and climatic conditions (TUIK, 2023). Among these, the Akkaraman as fat-tailed sheep has the most ratio the small ruminant population in the country (Şirin *et al*., 2017; Unlusoy *et al*., 2016). It is well known that Akkaraman is an important breed and play a fundamental role the meeting the needs of people (Behrem & Gül, 2022; Gül *et al*., 2022; Mondal & Reddy, 2017). However, to enhance the meat production per individual, ensure a sustainable food supply, and address food security concerns (Yardımcı & Özbeyaz, 2001), it becomes imperative to focus on improving the Akkaraman sheep. (Ünal, 2002; Yalcin, 1986).

Sheep breeders practice in employing conventional production methods, and the persistently low predicted yield can be attributed primarily to deficiencies in record-keeping, suboptimal feeding practices, and inadequate herd health and management. Traditionally, breeders have based their selections on the morphological traits of lambs (Ceyhan *et al*., 2019). However, advancing sheep and goat breeding in the nation necessitates the adoption of suitable breeding strategies. The initial step in a systematic selection method involves characterizing and mitigating the effects of environmental factors, with genetic selection for cumulative gain following subsequently (Sönmez *et al.*, 2009). In sheep selection applications, it is imperative to consider lamb birth weight, weaning weight, feed efficiency, and average daily gain as key productivity indicators. Another vital trait employed for assessing feed efficiency is the Kleiber ratio, a metric that has been utilized extensively in sheep selection practices (Eskandarinasab *et al*., 2010; Mahala *et al*., 2020; Supakorn & Pralomkarn, 2012).

Many studies conducted within the scope of the national small ruminant breeding program revealed the developmental characteristics of many indigenous sheep and goat breeds such as İvesi, Hair goat, Akkaraman, and Pırlak (Bağkesen & Koçak, 2018; Biçer *et al*., 2019; Gül *et al*., 2019; Güngör *et al*., 2021; Kutlu *et al.,* 2022). Since the beginning of the Akkaraman community-based sheep breeding initiative in 2011, it has had significant success in Ankara. It is carried out in conjunction with numerous research institutions, universities, associations, and breeders of sheep and goats as a key stakeholder of small ruminant breeding. Lambs' average daily gain, weaning weight, and birth weight are all regularly reported as part of the study. Therefore, the purpose of this study was to characterize the distributions of birth weight, weaning weight, and average daily gain in Akkaraman sheep raised in the province of Ankara, as well as to estimate the influence of various environmental factors on these traits.

Materials and Method

Animals and Phenotype

The research was conducted on Akkaraman lambs born in 2017 and 2021, encompassing 20 farms participating in Türkiye's National Community-Based Small Ruminant Breeding Program within the Ankara region. Situated in the northwest of the Central Anatolian Region, Ankara province (39° 55' north latitude and 32° 50' east longitude). The climate in Ankara exhibits a steppe climate characterized by dry steppe conditions with hot, arid summers and cold, snowy winters. During the study, lambs typically stayed with their dams until the 90-day weaning stage. The ewes were nourished with roughage, including alfalfa, wheat straw, and vetch, supplemented with an average of 0.6 kg/day of concentrated feed, and housed in barns with a daily allowance of 1.5 kg per animal during the winter. In the spring and summer, they grazed on challenging pastures together with their lambs. Post-weaning, males underwent fattening, while females continued to graze on pasture.

A comprehensive dataset comprising approximately 19,119 observations was utilized to analyze key attributes such as birth weight (BW), weaning weight (WW), average daily weight gain (ADWG), and the Kleiber ratio at weaning (KR). Additionally, routine records encompassed information on birth and weaning dates, sex, birth type (singlets/twins), and the season of birth (Winter/Spring). Birth weight and weaning weight data for each animal were meticulously assessed and interpolated to the 90th-day weight. The calculation of average daily weight gain (ADWG) involved linear statistical methods utilizing BW and WW. Furthermore, the Kleiber ratio at weaning (KR) was derived from the ADWG and WW using the formula ($ADWG/\ WW^{0.75}$). A detailed breakdown of the data structure and sample size is provided in Table 1, following the removal of outliers.

Statistical Analyses

The identification and examination of outliers, defined as values deviating more than three standard deviations from the mean, were carried out on the observations and removed. Shapiro-Wilk tests were employed to assess the normality of the responses. Furthermore, a plot depicting the residuals versus fitted values of the responses was generated to visually assess the homogeneity of variance. In the development of the final linear mixed models, the impact of environmental factors (including sex, birth type, birth season, herd size, and birth year) was initially explored. Basic packages such as "lme4," "lmerTest," and various other foundational tools

Table 1. Descriptive statistics of the growth traits.

Trait	BW (kg)	WW (kg)	ADWG (g)	KR
Number of observations	19119	19119	19119	19119
Mean	4.44	27.14	252.18	20.99
Standard error	0.01	0.04	0.47	0.02
Minimum	1.40	11.09	68.23	11.00
Maximum	6.99	44.94	457.79	27.01
Coefficient of Variation	19.51	21.71	25.61	10.11

BW: birth weight. WW: weaning weight. ADWG: average Daily weight gain. KR: Kleibe within the R statistical environment were utilized for data management and all statistical analyses (R Core Team, 2020).

Following the fitting of the ultimate models for the traits, linear mixed models were employed to quantify the influence of environmental factors. These mixed models generated the least square means for the respective factors. To account for random variability, herd, and maternal persistent environmental effects were incorporated into the models. Subsequently, distinctions between groups about the significant factors were scrutinized using Duncan's Test. The ensuing paragraphs provide detailed descriptions of the final linear mixed models for the individual traits:

$$\mathbf{Y = \mu + X\beta + Z\alpha + \varepsilon}$$

Where **Y** are the variables that affect the values (BW, WW, ADWG, and KR); **μ** is the intercept; **β** is the fixed effects of sex, birth type (2 levels), birth season (2 levels), birth year (5 levels), heard size (3 levels); **α** is the random herd and maternal persistent environmental effects and **ε** is the residual error of observations in the models. **X** and **Z** are the design matrix for fixed and random effects respectively.

RESULTS AND DISCUSSION

Birth weight

As observed in Table 2, when examining the impact of fixed factors on birth weight, it was found that, except for the season, the effects of other factors were significant. Analyzing the results obtained based on least-square means, the influence of sex on birth weight was noteworthy, with male lambs weighing 4.31±0.01 kg, while female lambs weighing 4.09±0.01 kg (Table 2). Furthermore, a significant difference in birth weight between male and female groups was identified (P <0.001). Comparing these findings with a study conducted on Akkaraman breed lambs in Niğde province, the results align closely (Ceyhan *et al.,* 2019). However, in contrast to this study, the birth weights of male and female lambs in Çankırı province Akkaraman lambs were higher (Behrem, 2021). This consistency in results across various studies reaffirms the tendency for males to have higher birth weights than females. It is reported that the higher birth weight in males compared to females can be attributed to the greater effectiveness of endocrine factors in promoting growth in males and the limiting impact of estrogen hormone on bone growth in females. (Assan, 2020).

In the study, the birth weights of singleton and twin-born lambs were reported as 4.46±0.01 kg and 3.94±0.02 kg, respectively, as indicated in Table 2. The difference in birth weight between singleton and twin-born lambs was found to be significant (P < 0.001). Similar to this study, they have also determined that singleton lambs have a higher birth weight compared to twin-born lambs (Çolakoğlu & Özbeyaz, 1999; Ünal, 2002). It has been reported that the variability in birth weight is attributed to the effects of pregnancy care and nutrition during the gestation period of ewes (Koyuncu & Duymaz, 2017).

The least-square means for the birth season were determined to be 4.19±0.01 kg in winter and 4.21±0.02 kg in spring-born lambs (Table 2). The difference in birth weights between lambs born in winter and spring was found to be insignificant. Studies on Angora goats (Güngör *et al*., 2021) and Ivesi sheep (Gül *et al*., 2020) have identified the influence of season and birth month on birth weight. This observation underscores the variability in the impact of season on birth weight across different regions and breeds. However, it is noteworthy that the feeding system during pregnancy plays a critical role in regulating fetal and placental development in sheep, potentially affecting both short- and long-term health outcomes (Behrem *et al*., 2022; Heasman et al., 1999).

In the study, birth weights based on the birth year, namely 2017, 2018, 2019, 2020, and 2021, were observed to be 4.14±0.01, 4.06±0.02, 4.15±0.02, 4.31±0.02, and 4.34±0.02 kg, respectively, as depicted in Table 2. The highest birth weight was observed in 2021, while the lowest birth weight was recorded in 2018. When evaluating the groups by years, the difference in birth weights among lambs born in different years was found to be significant (P <0.001). Similar to this study, previous research has reported variations in birth weights across years (Ceyhan et al., 2019; Ünal, 2002). Factors influencing birth weight across years can be attributed to care, feeding, and flock management.

According to the results obtained in the study, as shown in Table 2, birth weights in farms categorized by flock size as 0-150, 150-300, and 300 or more heads were 4.04±0.02 kg, 4.06±0.01 kg, and 4.50±0.01 kg, respectively. Farms with 300 or more heads exhibited the highest birth weights, while those with 0-150 heads had the smallest birth weights. The impact of flock size on birth weight was found to be significant in our study (P <0.001). When considering the influence of flock size, it can be presumed that larger enterprises provide better conditions for the pregnancy, care, and feeding of sheep.

Weaning weight

When examining the results of weaning weight, it is observed that the impact of all fixed factors is significant. Detailed results based on the least square means are presented in Table 2. Upon scrutinizing the results of weaning weight obtained through least-square means, our study identified that male lambs had a weaning weight of 28.52±0.07 kg, while females had a weaning weight of 26.51±0.07 kg. The influence of gender on weaning weight was found to be significant for both male and female lambs (P<0.001). Studies conducted on Akkaraman and different

Table 2. The least mean squares (LSM) of the traits.

	BW (kg)			WW (kg)			ADWG (g)			KR		
Fixed Effects	**n**	**LSM ± SE**	**P-value**	**n**	**LSM ± SE**	**P-value**	**n**	**LSM ± SE**	**P-value**	**n**	**LSM ± SE**	**P-value**
Sex			***			***			***			***
Male	9574	4.31±0.01[a]		9574	28.52±0.07[a]		9574	268.97±0.81[a]		9574	21.57±0.03[a]	
Female	9545	4.09±0.01[b]		9545	26.51±0.07[b]		9545	249.08±0.81[b]		9545	21.04±0.03[b]	
Birth type			***			***			***			***
Single	15759	4.46±0.01[a]		15759	28.23±0.05[a]		15759	264.14±0.59[a]		15759	21.32±0.02[a]	
Twin	3360	3.94±0.02[b]		3360	26.79±0.10[b]		3360	253.91±1.11[b]		3360	21.29±0.04[b]	
Season			NS			***			***			***
Winter	15703	4.19±0.01		15703	25.24±0.06[a]		15703	233.83±0.66[b]		15703	20.58±0.02[b]	
Spring	3416	4.21±0.02		3416	29.79±0.10[b]		3416	284.23±1.08[c]		3416	22.03±0.04[c]	
Birth year												***
2017	4446	4.14±0.01[b]		4446	26.56±0.09[b]		4446	249.03±1.04[b]		4446	21.03±0.04[b]	
2018	4178	4.06±0.02[a]	***	4178	30.61±0.10[d]	***	4178	294.95±1.08[d]	***	4178	22.43±0.04[d]	
2019	3929	4.15±0.02[b]		3929	27.46±0.10[c]		3929	259.09±1.09[c]		3929	21.41±0.04[c]	
2020	3197	4.31±0.02[c]		3197	26.89±0.10[b]		3197	250.92±1.12[b]		3197	21.02±0.04[b]	
2021	3369	4.34±0.02[d]		3369	26.04±0.10[a]		3369	241.14±1.14[a]		3369	20.63±0.04[a]	
Herd Sıze			***			***			***			***
0-150	2578	4.04±0.02[b]		2578	25.93±0.11[a]		2578	243.23±1.23[a]		2578	20.92±0.04[a]	
150-300	6446	4.06±0.01[a]		6446	27.96±0.08[b]		6446	265.48±0.90[b]		6446	21.58±0.03[c]	
>300	10095	4.50±0.01[c]		10095	28.65±0.07[c]		10095	268.37±0.79[c]		10095	21.41±0.03[b]	
Intercept	19119	4.27±0.03		19119	27.72±0.17		19119	260.63±1.82		19119	21.19±0.06	

Notes: The mean values which have different superscripts are significantly different. ***P < 0.001. **P < 0.01. *P < 0.05. SE = standard error; n = number of observations.

genotypes show a similar trend, indicating that males tend to have higher weaning weights compared to females, with our findings showing weaning weights at 90 days surpassing results obtained by other researchers (Behrem, 2021; Ceyhan et al., 2019; Tüney Bebek & Keskin, 2021). The variability in weaning weights based on gender suggests that breeders may place greater emphasis on feeding male lambs, anticipating a significant portion of them going for slaughter.

When examining the results, it was determined that the weaning weights of singleton and twin-born lambs were 28.23±0.05 kg and 26.79±0.10 kg, respectively. The birth type significantly influences weaning weight (P<0.001). It is possible to attribute the better development of singleton animals in weaning weight to factors such as inadequate milking due to insufficient maternal milk for twins and the lack of necessary care by the breeder in raising twin-born lambs (Koyuncu & Duymaz, 2017). Numerous studies (Aksoy et al., 2023a; Çolakoğlu & Özbeyaz, 1999; Noyan & Ceyhan, 2021) have consistently reported that singleton lambs have higher weaning weights than twin-born lambs

In our study, least square means were calculated for weaning weights based on the fixed factor of season, reporting weights of 25.24±0.06 kg in Winter and 29.79±0.10 kg in Spring, as presented in Table 2. The difference between groups based on the birth season was found to be significant (P <0.001). It is observed that lambs born in Spring have higher weaning weights compared to those born in Winter. A study on Ivesi sheep reported changes in weaning weight based on birth months (Gül et al., 2020). The variability in weaning weight is evident in our study and other research, suggesting its dependence on birth month, region, care, feeding, and genotype.

Another influential factor, the birth year, was found to have a significant impact on weaning weight (P <0.001). The results by birth year were calculated as 26.56±0.09 kg in 2017, 30.61±0.10 kg in 2018, 27.46±0.10 kg in 2019, 26.89±0.10 kg in 2020, and 26.04±0.10 kg in 2021, according to least square means. The highest weaning weight was observed in 2018, while the lowest weaning weight occurred in 2021. Similar effects of years on growth have been noted in other studies (Aksoy et al., 2023b; Tüfekci, 2023). The COVID-19 pandemic disrupted global food and feed supply chains, leading to shortages and bottlenecks that subsequently drove up prices. Disruptions also resulted in decreased demand for some animal products such as wool and meat, impacting livestock and grazing industries, and making it difficult for sheep farmers to feed their flocks. The high increase in feed prices during the COVID-19 pandemic and afterward could be considered a fundamental reason for breeders not providing additional supplementary feed to ewes, leading to this situation in 2020 and 2021.

In our study, weaning weights were determined as 25.93±0.11 kg in 0-150, 27.96±0.08 kg in 150-300, and 28.65±0.07 kg in 300 or more head farms, based on flock size. The farms with 300 or more heads had the highest weaning weights, while those with 0-150 heads had the smallest, as presented in Table 2. The impact of flock size on weaning weight was found to be significant (P <0.001). It is observed in the study that larger farms show more careful management, care, and feeding, positively reflecting on weaning weight compared to medium and small farms.

Average daily weight gain

As seen in Table 2 based on least-square means, our study determined that males have a significantly higher average daily weight gain (ADWG) than females, and the difference between males and females is significant (P <0.001). When evaluated by birth type, we found a significant difference between singleton and twin groups (P <0.001), with singleton lambs exhibiting a higher ADWG than twin lambs in our study. Regarding the birth season, the highest ADWG was observed in lambs born in the Spring. The influence of the birth season on ADWG is statistically significant (P <0.001). Examining the ADWG increase over the years, the highest ADWG was observed in 2018, while the lowest ADWG was seen in 2021. Additionally, the impact of years on ADWG is significant (P <0.001). Analyzing ADWG based on flock size, the highest ADWG is observed in farms with 300 or more heads, similar to the pattern observed in weaning weight. The environmental factors play a crucial role in the ADWG increase, and their impact is significant (P <0.001).

Kleiber ratio

In our study, when determining the Kleiber ratio, we found that the ratio is 21.57±0.03 in male lambs and 21.04±0.03 in female lambs, with a significant difference between the two groups (P <0.001). The influence of sex is significant, consistent with results obtained in other studies (Mahala et al., 2020; Sofla et al., 2011). According to birth type, the Kleiber ratio for singleton and twin lambs is 21.32±0.02 and 21.29±0.04, respectively, as shown in Table 2. However, our results for singleton and twin lambs differ from those reported by Behrem (2021), with our study showing a lower Kleiber ratio. The slight but significant difference between singleton and twin lambs is consistent with results from other studies (P <0.001) (Sofla et al., 2011).

Analyzing the results according to the birth season, the highest Kleiber ratio is observed in lambs born in the Spring, with a ratio of 22.03±0.04, while in lambs born in the Winter, it is 20.58±0.02 (Table 2). The difference in the Kleiber ratio between groups born in Winter and Spring is significant (P <0.001), indicating a seasonal effect on the Kleiber ratio, similar to findings in other studies (Sofla et al., 2011). Examining the

Kleiber ratio based on birth years, the values for 2017, 2018, 2019, 2020, and 2021 are 21.03±0.04, 22.43±0.04, 21.41±0.04, 21.02±0.04, and 20.63±0.04, respectively. The highest Kleiber ratio was observed in 2018, consistent with GCAA and SKA results. The impact of birth years on the Kleiber ratio is significant (P <0.001), similar to findings in another study (Behrem, 2021). Regarding flock size, the highest Kleiber ratio is observed in enterprises with 150-300 heads, and the difference between groups based on flock size is significant (P <0.001).

The Kleiber ratio holds significant importance in sheep breeding as it functions both as an indirect selection criterion for feed conversion and an insightful indicator of growth efficiency. Breeding for an improved Kleiber ratio or growth rate in sheep has the potential to enhance the genetic composition of the breed. Health care and feeding practices are also closely tied to the Kleiber ratio, adding another layer of importance to its consideration in sheep breeding. Studies suggest that the Kleiber ratio in sheep is influenced by both genetic and non-genetic factors, underscoring the need to incorporate it into selection and management strategies to achieve desired growth rates. However, some research indicates that the variation in growth rate and the Kleiber ratio in certain sheep breeds may not be primarily linked to genetic factors. In a broader context, the Kleiber ratio plays a pivotal role in evaluating overall growth, as emphasized in studies by Eskandarinasab et al. (2010) and Mahala et al. (2020).

CONCLUSION

The observed influence of environmental factors on pre-weaning growth traits and the Kleiber ratio underscores their significant impact on the economic traits of the Akkaraman sheep breed. Enhancing these environmental factors holds the potential to positively influence productivity in terms of these traits. The study's outcomes emphasize the importance of not overlooking environmental factors when incorporating the Akkaraman breed into selection programs. The insights gained from this research offer valuable information for enhancing productivity and ensuring sustainability in the context of growth characteristics specific to the Akkaraman breed. Given its resilience to arid climates and challenging pasture conditions, coupled with its status as the most widely bred indigenous breed in Türkiye, increased recognition and further exploration of its genetic attributes, particularly in terms of growth and adaptation characteristics, are poised to make substantial contributions to Türkiye's overall development.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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