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Genetic Analysis of Body Condition Score and Productive Performance in Shami Does

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ABSTRACT

This study was conducted at the Ruminant Research Station of the Agricultural Research Directorate/Ministry of Agriculture using 50 Shami goat aged 2-3 years, aimed to studying the relationship between body condition score (BCS) and productive performance in Shami goat, as well as estimating genetic parameters, artificial intelligence models (MobileNetV2 network with Transfer Learning technology) were applied in the BCS estimation. The overall average of total milk yield, lactation length and period from parturition to peak for the highest BCS group (BCS:3.5-4.5) were 225.84±24.76 kg, 216.73±7.10 days and 40.05±2.53 days, respectively, followed by the medium BCS group (BCS:2.5->3.5) 155.87±16.54 kg, 192.50±11.04 days and 35.06±2.84 days, then the low BCS group (BCS:1.5->2.5) 77.27±5.09 kg, 13.140±1.81 days and 17.67±1.07 days for the above traits and in the same previous order respectively. Milk composition was affected by in production stage and the percentage of milk components. Changes Heritability estimates ranged from 0.11 to 0.28 for BCS and milk production traits, and ranged from 0.26 to 0.51 for milk components during production. Genetic and phenotypic correlations were positive and highly significant (P≤0.01) between BCS and milk production traits, ranged from 0.59 to 0.85. The BLUP values for BCS ranged from -0.139 to 0.492. We conclude that selection based on BCS is feasible in breeding programs based on the average genetic estimates and positive genetic and phenotypic correlations with milk production traits.

Key words: Automated evaluation, Genetic parameters, milk production traits, Shami deos.

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INTRODUCTION

Modern livestock farming systems face the challenge of meeting the increasing demand for milk and meat products while ensuring animal welfare. Regular assessment of the nutritional status of animals in modern livestock farming systems is an essential element of their good management. It is essential to ensure their health, welfare and overall productivity of the farm. Body condition scoring (BCS) is a vital process for assessing the body reserves of animals which influence their health and productivity (Temenos *et al*., 2024). Studies have shown that the BCS of goat is a management tool for assessing the nutritional status of animals and fat cover, which is an indicator of energy reserves in the animal. Its measurement is based on the subjective assessment of the level of fat and muscle thickness in the spine behind the last rib. Therefore, the BCS is one of the tools that goat farmers can use to achieve proper management of body fat reserves (Ghosh *et al*., 2019). The BCS is a term used to denote the body reserves of an animal. BCS refers to the amount of fat (lipid) and protein (muscle) stored and available for maintenance, reproduction and production. Determining the BCS in goat is a simple but useful procedure that can help farmers make management decisions regarding the quality and quantity of feed needed to improve production and

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reproduction, and can therefore play an important role in goat marketing (Gallego-Calvo *et al*., 2015; Figueiredo Filho *et al*., 2018; Desha *et al*., 2019; Widiyono *et al*., 2020; Sahoo *et al*., 2022b; Veliz-Deras *et al*., 2023; Tesema *et al*., 2025). The BCS for goat uses a range of 1.0 to 5.0, with an increment of 0.5. A healthy goat should have a BCS of 2.5 to 4.0. Goat, where a body condition score of 1.0, 1.5, or 2.0 indicates a management or health problem, while a body condition score of 4.5 or 5 indicates an excessive amount of condition that can be detrimental to the health of the goat, and these scores are rarely observed in goat herds under standard management (Ghosh *et al*., 2019; Sahoo *et al*., 2022a; Gupta *et al*., 2023; Sahoo *et al*., 2023; Shirke *et al*., 2024; Gafsi *et al*., 2025). The use of easily accessible body measurements in goat and their offspring, especially body condition score, can provide a practical way to improve goat production systems, especially in rural areas, as it enables breeders to make informed decisions regarding herd selection and management practices, which ultimately leads to improved productivity and economic returns, these insights are crucial to guide selective breeding strategies aimed at enhancing the resilience of livestock to environmental stresses such as heat, especially in arid regions where such conditions prevail (Venkata Reshma *et al*., 2021; Okere *et al*., 2022; Venkata Reshma *et al*., 2022; Atoui *et al*., 2023; Datt *et al*., 2023; Makamua *et al*., 2023; Misbah *et al*., 2023; Atoui *et al*., 2024). The BCS in goat is influenced by various factors including health factors (bacterial, viral and parasitic infections, wasting, metabolic diseases, and locomotion problems), physiological factors (milk production, stage of production, and age), and ordinal patterns, with lower-ranking goat showing lower BCS values (Ghosh *et al*., 2019). Differences in BCS can impact production outcomes and economic sustainability at the animal and farm levels (Mullins *et al*., 2019), with both overweight and wasted goat showing reduced productivity and health problems (Koyuncu & Altincekic, 2013). Although the available information in goat production systems about body condition score measurements and their relationship with body weight, productive and reproductive performance is scarce, but no work has been carried out on BCS systems in Iraq for goat, as the scarcity of feed and water and adverse climatic conditions under the country's conditions lead to low BCS, which limits goat production, so there is a need to evaluate the condition of goats using the BCS scoring system to maintain the optimal productivity of the goat herd under field conditions by relying on the traditional BCS assessment method using tactile and visual cues, and the automated evaluation method using the Mobile-NetV2 network and Transfer Learning technology, note research is still underway to develop techniques for predicting BCS in goats, technological advances allow for assessment of body weight and BCS through imaging techniques, making the process faster, more accurate, and non-invasive (Ma *et al*., 2024; Goncalves *et al*., 2025). Studies have shown the potential of using digital images, along with artificial intelligence tools (deep learning and machine learning), to obtain morphometric data from cattle, goats, and sheep (Zhang *et al*., 2018; Iqbal *et al*., 2022; Li & Teng, 2022; Atoui *et al*., 2023). Machine learning and deep learning methods and algorithms have also provided different accuracy rates for predicting BCS in goats (Temenos *et al*., 2024; An *et al*., 2025) and cows (Rodriguez Alvarez *et al*., 2018; Huang *et al*., 2019; Rodriguez Alvarez *et al*., 2019; Yukun *et al*., 2019; Cevik, 2020; Liu *et al*., 2023; Xiong *et al*., 2023; Zhao *et al*., 2023; Li *et al*., 2025). Therefore, the current study aimed to evaluate the performance of Shami goat under field conditions by studying the relationship of body condition score with productive performance in Shami goat raised under field conditions in Iraq, in addition to estimating the genetic parameters (heritability, genetic and phenotypic correlation, and genetic merit) of body condition score and the studied traits in Shami goat due to their importance in goat breeding and improvement programs as they aim to improve productivity and economic return.

MATERIALS AND METHODS

Experimental design and studied traits: The study was conducted at the Ruminant Research

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Station of the Agricultural Research Directorate/Ministry of Agriculture on 50 Shami goat aged 2-3 years during the period from 12/1/2023 to 1/1/2025. They were divided based on the BCS at birth into three groups according to the 1-5 score evaluation system used to evaluate the BCS of goat, which was indicated by Ghosh *et al*. (2019), Gupta *et al*. (2023) and Vall *et al*. (2025). The BCS scale was used for each group within a range of 1.0 degrees according to the reality of the studied goat sample. The application of the MobileNetV2 network with Transfer Learning technology achieved an overall accuracy of 98.3% in BCS classification, surpassing traditional methods in which variance between assessors was recorded at a rate of κ=X according to Cohen's Kappa coefficient. This is the highest accuracy rate compared to the models used in previous studies for assessing BCS in cattle, especially VGG-16, ResNet50 and Inception (Temenos *et al*., 2024; An *et al*., 2025; Goncalves *et al*., 2025). The groups were as follows: the low BCS group 15 animals (BCS: 1.5->2.5), the medium BCS group 16 animals (BCS: 2.5->3.5), and the highest BCS group 19 animals (BCS: 3.5-4.5). Total milk yield was calculated based on daily milk yield, which was measured twice a month for each doe by hand milking using a graduated cylinder to determine the amount of milk produced, after isolating the newborns from their mothers in the evening for 12 hours and then milking them early in the morning. Based on the morning milking, the daily production of each doe was estimated after multiplying its production by 2. The length of the milk season and the period from birth to peak production were measured. Total milk yield was calculated by multiplying the daily milk yield rate by the length of the milk season. Milk composition were analyzed according to the production stages suggested by Chauhan *et al*. (2020) beginning of production (Upto 30 days of lactation), middle of production (31 to 60 days of lactation), and end of production (above 61 days of lactation) with the aim of studying the relationship between BCS was evaluated in productive performance of Shami goat raised under field conditions in Iraq, as well as estimating the genetic parameters (heritability, genetic and phenotypic correlation, and genetic merit) of BCS score and studied traits in Shami goat .

Statistical analysis: The Statistical Analysis System - SAS program (SAS, 2018) was used to analyze the data to study the effect of BCS on the studied traits according to a completely randomized design (CRD), and the significant differences between the means were compared using Duncan's (Duncan, 1955) multinomial test. Mathematical model of the experiment was: Yij = μ + Bi + eij. Where: Yij: The value of the observation j that is due to the degree of body condition i

μ: The general average of the studied trait.

Bi: The effect of the degree of body condition i

eij: The random error that is normally distributed with a mean equal to zero and a variance of σ2e.

The variance components of the random effects in the studied traits were estimated, from which the heritability, genetic and phenotypic correlations, and genetic fitness estimates (Best Linear Unbiased Prediction-BLUP) were estimated using the Restricted Maximum Likelihood (REML) method, according to the following mathematical models. The variance and covariance (VCV) matrix of the parent and the error was created for each trait for the purpose of conducting the positive definite test. This matrix must have real values (Exist) and the eigenvalues matrix associated with it must be positive and definite for the purpose of obtaining estimates of the genetic parameters that must be within the permissible limits. The test was conducted on the variance and covariance matrices of the parent and the error for each group of the studied traits by calculating the eigenvalues associated with the test matrix. It was found that some of them were negative. Therefore, the binding process had to be conducted to obtain new matrices of modified variances and covariances from which the heritability of the studied traits was estimated using the paternal half-sib method and the genetic and phenotypic correlations between them. The second mathematical model (estimation of genetic parameters).

Yijk = μ + Bi + S + eijk

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Where: Sj: the effect of the father (Sire) j (since the study included 5 shami bucks) to estimate the variance components. The rest of the symbols are as in the first mathematical model.

RESULTS AND DISCUSSION

Relationship between body condition score of Shami goat and milk yield traits: The results in Table (1) indicate a highly significant differences (P≤0.01) in milk yield traits among the three studied groups for BCS (BCS:1.5->2.5, BCS:2.5->3.5, and BCS:3.5-4.5), The highest BCS group (BCS:3.5-4.5) recorded the highest total milk yield and lactation season length of 225.84 ± 24.76 kg and 216.73 ± 7.10 days, respectively, compared to the low and medium groups in body condition score (BCS:1.5->2.5 and BCS:2.5->3.5), and did not differ significantly in the period from birth to peak production from the medium group in BCS. The medium group in BCS had the highest total milk yield and lactation season length of 155.87±16.54 kg and 192.50±11.04 days respectively compared to the low BCS group, and lower than the high BCS group (BCS:3.5-4.5). It did not differ significantly in the period from birth to peak production, namely 35.06±2.84 days, while the BCS group (BCS:1.5->2.5) recorded the lowest total milk yield and length of the lactation season and the period from birth to peak production reached 77.27±5.09 kg and 13.140±1.81 days and 17.67±1.07 days respectively compared to the medium and high body condition groups (BCS:2.5->3.5 and BCS:3.5-4.5). Therefore, it can be concluded that goat groups with good body condition score are more productive of milk because they have energy reserves in the body that enable them to increase milk production for the longest possible period. Accordingly, the relationship is inverse between milk production and body condition score, as animals with high production have a low BCS during the production stages. As the production stage progresses, milk yield will decrease and BCS will gradually increase. Therefore, the BCS must be relatively high during the dry period to compensate for the loss during the production stage. Venkata Reshma *et al*. (2022) suggested that the optimum BCS is 3.50 to 4.00 at parturition so that the animal can maintain its optimum body condition during production and replenish its body fat stores to restore its body condition score more efficiently. Body fat storage during the dry period positively affects milk yield at the beginning of production (Ghosh *et al*., 2019; Sahoo *et al*., 2022a). The importance and impact of body fat stores in goat on milk production is more evident in lean goat as they are low-yielding because their body fat stores are low and insufficient to support milk yield (Koyuncu & Altincekic, 2013). Studies have shown that Saanen goat with BCS of 2.5 produced more milk at the beginning of production (0-60 days) with a significant decrease in BCS (2.20 and 2.19) to reach peak production (Graff *et al*., 2014). The positive relationship between BCS and milk production is due to the transmission of the hormone leptin to the hypothalamus, which controls the body's metabolism. Leptin acts as a signal to stimulate appetite for food by primarily affecting brain regions associated with the regulation of energy metabolism (Roche *et al*., 2009; Sahoo *et al*., 2022a). Note that the body condition of does at mating may affect feeding patterns and productive performance during forthcoming lactation (Sharma *et al*., 2018).

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Table 1. Relationship between the body condition score of Shami goat and milk yield traits.

Group	Mean ± Standard Error		
	Total milk yield (kg)	lactation length (day)	Period from birth to peak production (days)
Thin BCS:1.5->2.5 (15 animal)	77.27±5.09 c	140.13±1.81 c	17.67±1.07 b
Normal BCS:2.5->3.5 (16 animal)	155.87±16.54 b	192.50±11.04 b	35.06±2.84 a
Fat BCS:3.5-4.5 (19 animal)	225.84±24.76 a	216.73±7.10 a	40.05±2.53 a
Significant level	**	**	**

**** (P≤0.01). The means with different letters within one column differ significantly from each other.**

Relationship between the body condition of Shami goat and milk components according to the production stages: Beginning of production (Upto 30 days of lactation): The results in Table (2) show significant differences (P≤0.05) in the percentage of lactose and total solids and highly significant differences (P≤0.01) in the percentage of solids non-fat at the beginning of production among the three groups of body condition score. The low body condition score group (BCS:1.5->2.5) recorded the highest lactose percentage (4.37±0.06%) compared to the high BCS group (4.14±0.07%). The medium BCS group did not differ significantly from the low and high BCS groups, in lactose percentage (4.26±0.07.%). The low body condition group recorded the highest percentage of solids non-fat and total solids, reaching 8.50±0.02 and 11.00±0.13%, respectively, compared to the medium body condition group, which recorded the lowest percentage of solids non-fat and total solids, reaching 8.06±0.10 and 10.42±0.22%, respectively. The high body condition group did not differ significantly with the low body condition group in percentage of solids non-fat (8.39±0.05%). The high body condition group did not differ significantly with the low and medium body condition groups in percentage of total solids (10.72±0.19%). Non-significant differences were observed in the percentage of protein and fat among the three groups for body condition score. Studies have shown that in the case of a negative energy balance during the early and middle stages of production, body fat and protein must be used to compensate for this energy deficit, as at this stage BCS and milk production in goat decreases to 60-80% of peak production levels, The production stage affects BCS, glucose, and milk components (Darwesh *et al*., 2013). While Susilorini *et al*. (2014) in their study on goat with BCS between 2 and 4, indicated that BCS had a positive association with milk yield, a negative association with milk protein, and no association with milk fat during early production. Hafsa *et al*. (2014) observed that milk yield, fat, protein, lactose, non-fat solids, and total milk solids contents increased significantly (P<0.05) with increasing BCS up to 4, and that protein, fat, non-fat solids, and total milk solids contents increased significantly (P<0.05) with increasing BCS up to 3, while lactose content decreased significantly (P<0.05) with BCS 1. Note that increasing the percentage of milk components according to the BCS of goat will contribute to increasing the production of dairy products, and therefore if goat can produce milk containing a higher percentage of components, we will be able to increase the production of dairy products which will bring more economic benefits.

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Table 2. Relationship between the body condition score of Shami goat and milk components at start of production (Upto 30 days of lactation).

Group	Mean ± Standard Error (%)				
	Lactose	Protein	Fat	Solids non-fat	Total solids
Thin BCS:1.5->2.5 (15 animal)	4.37±0.06 a	3.07±0.02	2.50±0.12	8.50±0.02 a	11.00±0.13 a
Normal BCS:2.5->3.5 (16 animal)	ab 4.26±0.07	3.09±0.08	2.36±0.18	8.06±0.10 b	10.42±0.22 b
Fat BCS:3.5-4.5 (19 animal)	4.14±0.07 b	3.18±0.08	2.34±0.17	8.39±0.05 a	10.72±0.19 ab
Significant level	*	N.S.	N.S.	**	*

****(P≤0.01), * (P≤0.05), NS: not significant. The means with different letters within one column differ significantly from each other**

Mid of production (31 to 60 days of lactation): The results in Table (3) indicated that there were highly significant differences (P≤0.01) in the percentage of lactose, protein, solids non-fat and total solids in the production medium among the three groups of BCS score. The low BCS group recorded the highest percentage of lactose, protein, solids non-fat and total solids, amounting to 4.74±0.02, 3.04±0.03, 8.71±0.05 and 10.94±0.12%, respectively, compared to the medium and high BCS groups. Note that no significant differences were observed in the percentage of fat among the three groups for body condition score, as the percentage of fat was 2.23±0.11, 2.18±0.18, and 2.33±0.21 % for the three groups, respectively. Assan (2014) indicated that milk components do not follow the same trend as milk yield during the production stages, as milk production increases from the beginning of early production to mid-production (peak production) and then begins to decline until the end of production, but milk yield and composition are affected by different factors, among these factors is the production stage, as the percentage of protein, lactose, fat and total solids changed slightly with the progress of production with a steady decrease in milk production. This may be attributed to the fact that milk production depends on the number of secretory cells of the mammary gland and the change in their metabolic activity during the production stage. The production stage has actual effects in determining the optimal feeding management to enhance total milk production and milk composition. Therefore, knowledge of physiological activities during the different production stages is important in feeding dairy cattle and supporting management system decisions to improve dairy goat herd production processes. Improvement in reproductive performance in goat has been achieved by improving the level of nutrition and/or hormonal treatment (Assan, 2022; Zamuner *et al*., 2023).

Table 3. Relationship between the body condition of Shami goat and milk components at medium of production (31 to 60 days of lactation).

Group	Mean ± Standard Error (%)				
	Lactose	Protein	Fat	Solids non-fat	Total solids
Thin BCS:1.5->2.5 (15 animal)	a 4.74±0.02	a 3.04±0.03	2.23±0.11	a 8.71±0.05	a 10.94±0.12
Normal BCS:2.5->3.5 (16 animal)	b 4.05±0.09	b 2.59±0.08	2.18±0.18	b 7.04±0.22	9.22±0.29 b
Fat BCS:3.5-4.5 (19 animal)	b 4.07±0.14	b 2.66±0.09	2.33±0.21	b 7.43±0.27	9.76±0.36 b
Significant level	**	**	N.S.	**	**

****(P≤0.01), NS: not significant. The means with different letters within one column differ significantly from each other**

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End of production (above 61 days of lactation): The results in Table (4) indicated that there were highly significant differences (P≤0.01) in the percentage of lactose, protein, non-fat solids, and total solids at the end of production among the three groups of body condition score. The group with low BCS recorded the highest percentage of lactose, protein, non-fat solids, and total solids, amounting to 5.27±0.06, 3.53±0.04, 9.60±0.11, and 12.04±0.14% respectively, compared to the groups with high body condition score, which recorded 4.56±0.08, 3.01±0.07, 8.36±0.14 and 10.92±0.22% for the above components and in the same previous order, while it did not significantly differ with the group with medium BCS, which recorded 5.09±0.22, 3.41±0.15, and 9.27±0.39 and 11.87±0.43% for the above components and in the same previous order. Note that no significant differences were observed in the percentage of fat between the three groups for body condition score. Contrary to the current, results Graff *et al*. (2018) in their study to analyze the composition of milk and evaluate BCS of dairy goat in the last third of production, indicated that there is a relationship between body condition and composition of goat milk with increasing BCS, as the percentage of fat, protein and minerals in milk increased (6.01%, 3.55% and 0.98%) in goat with good body condition score (BCS 3.5) compared to goat with lean body condition score (BCS 1.5-2) which recorded (4.56%, 3.11%, 0.77%) for the same components respectively, and the concentration of milk sugar was similar between the two groups. We concluded that there is a difference in the percentage of milk composition according to the different body condition scores of the goats, as the percentage of composition are higher in the milk of goats with a low BCS because they are at the end of production and produce less milk compared to the group with a high body condition score. An *et al*. (2025) reported that milk yield showed no significant variation among different BCS groups, but milk protein content was highest in the average condition group.

Table 4. Relationship between the body condition of Shami goat and milk components at end of production (above 61 days of lactation).

Group	Mean ± Standard Error (%)				
	Lactose	**Protein**	**Fat**	**Solids non-fat**	**Total solids**
Thin BCS:1.5->2.5 (15 animal)	a 5.27±0.06	a 3.53±0.04	2.44±0.08	a 9.60±0.11	a 12.04±0.14
Normal BCS:2.5->3.5 (16 animal)	a 5.09±0.22	a 3.41±0.15	2.72±0.13	a 9.27±0.39	a 11.87±0.43
Fat BCS:3.5-4.5 (19 animal)	b 4.56±0.08	b 3.01±0.07	2.50±0.16	b 8.36±0.14	b 10.92±0.22
Significant level	**	**	N.S.	**	**

****(P≤0.01), NS: not significant. The means with different letters within one column differ significantly from each other**

Genetic parameters: Heritability: The results in Table (5) showed the estimates of the heritability of the BCS and the studied traits. The heritability of the BCS reached 0.28, which is close to what was recorded by Figueiredo Filho *et al.* (2018) in the only study in which the heritability of the BCS in goat was estimated (0.29). The heritability of milk yield traits was low to medium, reaching 0.18, 0.11, and 0.26 for each of the total milk yield, length of the milk season, and the period from birth to peak production, respectively. This was confirmed by previous studies that the heritability estimates for all milk traits (production, peak production, and persistence) were low and close to medium (Miranda *et al*., 2019). The heritability estimate for milk production was lower than that recorded by Hermiz *et al.* (2004) in their study to estimate the genetic parameters of milk yield in local goat, stated that heritability reached 0.46, 0.83, and 0.53 for each of the total and daily milk

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yield and milk yield after weaning, respectively, and also lower than that recorded by in their study to estimate the genetic parameters of milk production in Shami goat, as the heritability reached 0.22, 0.17, 0.17 and 0.26 for total and daily milk yield and milk production for the pre-weaning and post-weaning periods, respectively. The milk components at the beginning of production, the heritability was from medium to high, reaching 0.34, 0.26, 0.41, 0.38 and 0.44 for each of lactose, protein, fat, solids non-fat and total solids, respectively. Likewise, for the milk components in the middle of production, the heritability was from medium to high, reaching 0.29, 0.26, 0.46, 0.40 and 0.51 for each of lactose, protein, fat, solids non-fat and total solids, respectively. Also, for the milk components at the end of production, the heritability was from medium to high, reaching 0.35, 0.31, 0.38, 0.38 and 0.41 for each of lactose, protein, fat, solids non-fat and total solids, respectively. Previous studies have reported that heritability estimates ranged from 0.10 to 0.50 for both milk yield and fat content (Teissier *et al*., 2024). Hermiz *et al*. (2020) in a review of the genetic and phenotypic parameters of some economic traits in goat indicated that heritability is a characteristic of the population trait and the environmental conditions to which the animals are exposed, and therefore any change in the components of variance is likely to change the heritability estimate, which could explain the differences in estimates related to different studies. It can be concluded that heritability estimates for the same traits vary from one study to another depending on the breed, sample size, estimation method, statistical model, and whether or not the variance component matrix is tested, as well as everything related to the study in terms of space and time. Therefore, significant genetic progress in production rate can be achieved by selecting goat according to medium to high heritability, as a large part of the superiority in milk traits will be inherited due to the effect of population genes (Hermiz *et al*., 2020).

Table 5. Estimates of heritability of the body condition score with studied traits of Shami goat in Iraq

Studied traits		Number of animals	Heritability
BCS		50	0.28
Milk yield traits	Total milk production	50	0.18
	lactation length	50	0.11
	Period from birth to peak production	50	0.26
Components at start of production-1	Lactose-1	50	0.34
	Protein-1	50	0.26
	Fat-1	50	0.41
	Solids non-fat-1	50	0.38
	Total solids-1	50	0.44
Components at medium of production-2	Lactose-2	50	0.29
	Protein-2	50	0.26
	Fat-2	50	0.46
	Solids non-fat-2	50	0.40
	Total solids-2	50	0.51
Components at end of production-3	Lactose-3	50	0.35
	Protein-3	50	0.31
	Fat-3	50	0.38
	Solids non-fat-3	50	0.38
	Total solids-3	50	0.41

1, 2, 3: Milk component ratios at Start, Medium and End of lactation respectively
Number of animals = 50, number of sires = 5 sires

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Genetic and phenotypic correlations: The results in Table (6) showed the genetic and phenotypic correlation between BCS and the studied traits. The genetic and phenotypic correlation was positive and highly significant (P<0.01) for milk production traits, as the genetic correlation reached 0.59, 0.62 and 0.78 for each of the total milk yield, length of the milk season and the period from birth to reaching peak production, respectively. The phenotypic correlation reached 0.67, 0.59 and 0.85 for each of the total milk yield, length of the milk season and the period from birth to reaching peak production, respectively. The positive and highly significant genetic and phenotypic correlations indicate that these traits were affected in the same direction, i.e., the selection of one trait can lead to an indirect genetic improvement in the other trait. Hermiz *et al*. (2004) indicated in their study to estimate the genetic parameters of milk yield in local goat that the genetic correlations for milk yield traits were positive and ranged between 0.46 and 0.80. Likewise, indicated in their study to the genetic parameters of milk production in Shami goat that the genetic correlations ranged between 0.52 and 0.91 and were positive and highly significant (p<0.01) between any pair of the studied traits (total and daily milk yield, and milk yield for the pre-weaning and post-weaning periods). The genetic and phenotypic correlation of milk components at the beginning of production was negative insignificant for each of lactose -0.08 and -0.05, fat -0.07, -0.02 and -0.08, solids non-fat -0.08 and total solids -0.11 and -0.08, and was insignificant for protein 0.11 and 0.16 for both correlations respectively. As for the middle of production, the genetic correlation of milk components was highly significant negative (P<0.01) for lactose -0.36 and significantly negative (P<0.05) for protein -0.25 and solids non-fat -0.31 and total solids -0.26 and insignificant for fat 0.02, and the phenotypic correlation was highly significant negative (P<0.01) for lactose -0.42 and solids non-fat -0.38 and significantly negative (P<0.05) for protein -0.27 and total solids -0.28 and insignificant for fat 0.07. The end of production the genetic and phenotypic correlation for milk components was highly significant negative (P<0.01) for lactose -0.51 and -0.42, protein -0.45 and -0.57, solids non-fat -0.36 and -0.44 and significantly negative (P<0.05) for total solids -0.32 and -0.30 and insignificant for fat 0.07 and 0.11. It is worth noting that the genetic and phenotypic correlations between BCS and the studied traits in goat have not been previously studied. We conclude that selection based on BCS is feasible in breeding programs based on the average genetic estimates and positive genetic and phenotypic correlations with milk production traits.

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Table 6. Genetic (rG) and phenotypic (rP) correlations between body condition score and studied traits of Shami goat in Iraq.

Studied traits		Genetic correlation-rG	Phenotypic correlation-rP
Milk yield traits	Total milk production	0.59 **	0.67 **
	lactation length	0.62 **	0.59 **
	Period from birth to peak production	0.78 **	0.85 **
Components at start of production-1	Lactose-1	-0.08 NS	-0.05 NS
	Protein-1	0.11 NS	0.16 NS
	Fat-1	-0.07 NS	-0.02 NS
	Solids non-fat-1	-0.08 NS	-0.08 NS
	Total solids-1	-0.11 NS	-0.08 NS
Components at medium of production-2	Lactose-2	-0.36 **	-0.42 **
	Protein-2	-0.25 *	-0.27 *
	Fat-2	0.02 NS	0.07 NS
	Solids non-fat-2	-0.31 *	-0.38 **
	Total solids-2	-0.26 *	-0.28 *
Components at end of production-3	Lactose-3	-0.51 **	-0.42 **
	Protein-3	-0.45 **	-0.57 **
	Fat-3	0.07 NS	0.11 NS
	Solids non-fat-3	-0.36 **	-0.44 **
	Total solids-3	-0.32 *	-0.30 *

**(P≤0.01), * (P≤0.05), NS: not significant

1, 2, 3: Milk component ratios at Start, Medium and End of lactation respectively
Number of animals = 50, number of sires = 5 sires

Estimates of best linear unbiased prediction (BLUP) on body condition score (BCS): Table (7) shows the estimates of genetic merit of buck according to the body condition score. The maximum genetic merit reached 0.307±0.06, 0.422±0.07, and 0.492±0.06, respectively, while the lowest genetic merit was -0.139±0.02. The BLUP values for total milk production in goat ranged from -130.65 to 224.77. We concluded that the high and positive genetic correlations between BCS and productive performance improve the genetic worth of goat, and that the wide range in genetic worth estimates of buck according to body condition score may be due to a population genetic variation that can be exploited in selection programs. Recent studies have indicated that the most effective method for estimating breeding values and enhancing genetic gains in goat is the single-step genomic best linear unbiased prediction (ssGBLUP), as it provides many advantages in terms of the computational process and the accuracy of the estimated breeding values, in line with the development or reliance of many countries at present on genomic selection in the dairy goat sector (Liu *et al*., 2020), as the greatest gain is for animals nominated for breeding in the community, especially female goat (doe) that do not have production records and bucks that do not have daughter records, and therefore it is expected that the increased selection accuracy through the implementation of genomic selection will accelerate the genetic improvement of milk yield traits and increase production efficiency in the dairy goat industry (Massender *et al*., 2022, Negro *et al*., 2024). Note that the genetic merit of bucks (BLUP) according to the body condition score in goat has not been previously studied.

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Table 7. Estimates of best linear unbiased prediction (BLUP) on body condition score (BCS) of Shami goat in Iraq

No.	Sire Number	Number of offspring	Estimates of BLUP on BCS	Rank (weight)
1	23667	8	0.307±0.06	3
2	**23759**	**11**	**0.492±0.06**	**1**
3	23831	9	-0.139-±0.02	4
4	351	17	0.422±0.07	2
5	755	5	-0.265-±0.04	5

Total number of animals: 50 heads

CONCLUSION

It seems necessary to consider environmental (BCS) and genetic influences that affect milk production traits in Shami goat. The average genetic estimates and positive genetic and phenotypic correlations with some traits provide insights for enhancing productive performance in goats and predicting for the implementation of BCS-based selection in breeding programs. Note that enabling goat farmers to achieve sound management of body reserves according to the different stages of reproductive and productive performance by applying artificial intelligence (AI) as an accurate tool in sustainably assessing BCS and meeting the nutritional needs of animals is of paramount importance for improving management methods and increasing goat productivity by supporting reliable evidence-based decision-making processes.

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CONFLICT OF INTEREST

Regarding this manuscript, the authors disclose no conflicts of interest.

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التحليل الوراثي لدرجة حالة الجسم والأداء الإنتاجي لدى اناث الماعز الشامي

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[2]قسم الإنتاج الحيواني، كلية علوم الهندسة الزراعية، جامعة بغداد، العراق.

المستخلص

أجريت الدراسة في محطة بحوث المجترات التابعة لدائرة البحوث الزراعية/وزارة الزراعة باستخدام 50 معزة شامية تتراوح أعمارها من 2-3 سنوات، بهدف دراسة علاقة درجة حالة الجسم (BCS) بالأداء الإنتاجي لدى الماعز الشامي، فضلاً عن تقدير المعالم الوراثية، اذ تم تطبيق نماذج الذكاء الاصطناعي (شبكة MobileNetV2 مع تقانة نقل التعلم) في تقديرBCS. بلغ المتوسط العام لإنتاج الحليب الكلي وطول موسم الحليب والمدة من الولادة إلى بلوغ قمة الإنتاج للمجموعة الأعلى بدرجة حالة الجسم (BCS:3.5-4.5) 24.76± 225.84 كغم و7.10±216.73 يوم و2.53±40.05 يوم على التوالي، تلتها المجموعة المتوسطة بدرجة حالة الجسم (BCS:2.5->3.5) 16.54±155.87 كغم و11.04±192.50 يوم و2.84±35.06 يوم، ثم المجموعة المنخفضة بدرجة حالة الجسم (BCS:1.5->2.5) 5.09±77.27 كغم و1.81±13.140 يوم و1.07±17.67 يوم للصفات أعلاه وبنفس الترتيب السابق على التوالي. تأثر تركيب الحليب بمرحلة الإنتاج وتغيرت نسبة مكونات الحليب خلال مراحل الإنتاج. تقديرات المكافئ الوراثي تراوحت من 0.11 إلى 0.28 لدرجة حالة جسم وصفات إنتاج الحليب، وتراوحت من 0.26 إلى 0.51 لمكونات الحليب خلال مراحل الإنتاج. كانت الارتباطات الوراثية والمظهرية موجبة وعالية المعنوية($P\leq0.01$) بين BCS وصفات إنتاج الحليب وتراوحت من 0.59 إلى 0.85. كذلك تراوحت قيم BLUP لدرجة حالة جسم من -0.139 إلى 0.492. نستنتج بإمكانية الانتخاب على أساس درجة حالة الجسم في برامج التربية وفق التقديرات الوراثية المتوسطة والارتباطات الوراثية والمظهرية الموجبة مع صفات إنتاج الحليب.

الكلمات المفتاحية: التقييم الآلي، المعالم الوراثية، صفات انتاج الحليب، اناث الماعز الشامي.