DETERMINATION OF LACTATION CURVES IN DAMASCUS GOATS AND ASSESSMENT WITH REGARD TO HERD MANAGEMENT PRACTICE

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ABSTRACT

Lactation curves not only provide information on the temporal development of milk production in a herd during a specific lactation cycle, but also on the effects of care and feeding conditions and physiological status on milk yield. The aim of this study was to describe the lactation curve of Damascus goats and to determine the effects of herd management on lactation performance. In the study conducted in 2019, a total of 620 lactation records from 62 dairy goats of different ages and lactation orders kept under semi-intensive conditions were analyzed using Wood's gamma curve parameters. Since the gamma curve parameter intercept *lnA* was negative for all lactation groups, the analyzed lactations showed abnormal lactation curve characteristics. The coefficients of determination (R^2) of the lactation curves were 73.0 %, 72.5 %, 60.5 % and 61.7 % for the first, second, third and the average of all lactation groups. Therefore, the gamma function adequately described the lactation curves. The gamma curve parameters, including the intercept (*lnA*), slope coefficient (*b*), peak coefficient (*c*), persistency (*S*), time at which milk yield reached its maximum (T_{max}), and maximum daily milk yield (Y_{max}), were -2.53±0.16, 1.116±0.04, 0.015±0.00, 8.88±0.13, 73.67±1.34, and 3.31±0.06, respectively. Lactation order had a significant effect on the peak coefficient (c, $p \leq 0.05$) and on the maximum daily milk yield (Y_{max}, $p \leq 0.01$). In addition, the effects of litter size were significant on b ($p \leq 0.05$) and *lnA*, *S* and T_{max} ($p \leq 0.01$). The study of lactation curves of Damascus goats suggests that standardized feeding programs are associated with sustained high milk yield in the Iğdır region; however, causal conclusions cannot be drawn from this observational study.

Keywords: Damascus goat, lactation curve, Wood's model, management

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INTRODUCTION

The total number of small ruminants in Turkey is 48.48 million, of which 11.21 million are goats (FAO, 2022). The Damascus goat is one of the goat breeds considered within the scope of promoting the conservation and development of local animal genetic resources in Turkey. This breed is of great importance due to its high milk yield and potential for crossbreeding studies (Güney *et al.*, 2006; Mavrogenis *et al.*, 2006). For this reason, it is important to expand the production of Damascus goats with high milk yield and determine their adaptations to continue normal production under different climatic conditions. In this regard, Gipson and Grossman (1990) reported that the evaluation of the lactation curve in dairy goats will make an important contribution to the management and selection of goats. Knowledge of the lactation curve is important due to milk production and economic factors. Many models have been developed to describe the lactation curve. These models, usually developed for dairy cows, are also applied to lactation data of dairy goats and dairy sheep, although to a lesser extent (Çoban and Kayaalp, 2013). The shape and degree of continuity of the lactation curve can be determined by plotting the graph of daily milk yield during lactation through the days of lactation, or it can be determined by the parameters of a mathematical function. For this purpose, exponential, parabolic exponential, inverse polynomial and gamma functions are used (Akbulut, 1990; Akbulut and Emsen, 1994). The most used of these models is the so-called Wood's model (Yılmaz and Kaygısız, 2000; Oliveira *et al.,* 2020; Wood, 1967).

Lactation curve models, which describe the temporal evolution of milk production in ruminants well and are one of the most important applications of mathematical modeling in animal science, are also used in nutrition management software for various ruminant species (Boe *et al.,* 2005), and modeling is usually used to estimate the total milk yield of the animal in a lactation (Waheed and Khan, 2013; Marete *et al.,* 2014). The determined lactation curves provide information about the productivity of the goats and describe the milk production characteristics of the individual animals (Marete *et al*., 2014). In dairy goats, milk production normally peaks between the 4th and 8th postpartum weeks and declines thereafter (Wood, 1974; Waheed and Khan, 2013). It is undesirable for this decline to be more than 10% of the previous month's milk yield (Boztepe *et al*., 2015). The lactation curve can be described as a monitoring tool that graphically shows us the change in milk yield over time, from the first to the last milk yield period. It is necessary to understand the model in order to comprehend the production process, which is carried out with extreme precision every day under variable environmental conditions. With the lactation curve, it is possible to follow abnormal fluctuations in milk production due to diseases, management problems, care and feeding problems (Akbulut and Emsen, 1994; Orhan and Kaygısız, 2002).

In the present study, the characteristics of the lactation curve of Damascus goats were determined using nonlinear regression model and the environmental factors affecting these parameters were evaluated. The lactation curves of milk yield of two-, three- and four-year-old Damascus goats bred for the first time in Iğdır province were determined under semi-intensive conditions. The lactation curves express the change in milk yield in the period between the start of milk production and the time when the goat stops producing milk. If these curves are normal, it means that the flock has no problems in terms of management, husbandry, feeding or disease. It also allows the animals to adapt to the conditions of the region in which they are kept and to monitor normal production activities under these conditions. In this study, associations between environmental and physiological factors and the milk yield and lactation curve of Damascus goats were evaluated.

MATERIALS AND METHODS

Animal material: The animal material used for the study was reared on a goat farm in the province of Iğdır. All lactations were monitored from the beginning to the end of the milking period, and milk yield data were recorded on monthly control days throughout 2019 for a total of 62 goats, of which 21 were in their first lactation, 21 in their second lactation, and 20 in their third lactation. The births took place between February to March, and all births were completed by the end of March.

Care and feeding conditions: In general, the farm does not provide additional feed to the goats during the grazing season; however, in the winter months, they are fed according to the available feed resources, including hay, dried alfalfa, and barley groats. On days when the seasonal conditions are suitable for grazing, the animals are allowed to graze after the morning milking, while evening milking is carried out in open shelters once they return from the pasture. The animals are normally housed outdoors and are brought into covered shelters during extreme cold or heavy rain. The feeding program of the goats for each month at the farm is summarized in Table 1 (see Table 1).

Table 1. Information on the feeding program at the goat farm in Damascus

Months	**Daily feeding (g)**			**Grazing**	**Pasture**
	Clover	**Dried grass**	**Barley**		
December*	1000	1500	300	+	Clover stubble
January	1500	1000	300	-	-
February	1500	1000	300	-	-
March	1500	1000	300	-	-
April	1000	1000	200	+	Pasture
May	-	-	-	+	Pasture
June	-	-	-	+	Pasture
July	-	-	-	+	Pasture
August	-	-	-	+	Pasture
September	-	-	-	+	Pasture
October	-	-	-	+	Clover stubble
November	-	-	-	+	Clover stubble

*: December 2018. The other months belong to 2019.

Data collection: The milk yield was measured on site by the same researchers, and the checks were continued once a month, twice a day, morning and evening, until the animals were dried out. All data collected were recorded together with the ear tag number of each goat.

Lactation curve parameters: The lactation curve was described using the gamma function form of the Wood model (Wood, 1967), which also allows the assessment of lactation persistency. The model is expressed as:

$$Y_t = A\,t^b e^{-ct}$$

where Y_t is the milk yield on day t of lactation, t represents the number of days after parturition, and e is the base of the natural logarithm. In this model, A, b, and c describe the initial level of milk production, the increasing phase of lactation, and the decline after peak yield, respectively.

To facilitate estimation, the model was linearized by taking natural logarithms of both sides:

$$\ln Y_t = \ln A + b\ln t - ct$$

The parameters of the transformed model (ln A, b and c) were estimated using multiple regression analysis, as outlined by Draper and Smith (1998).

From these estimates, several biologically meaningful traits were derived. Lactation persistence (S), peak milk yield (Y_{max}), and the day of peak yield (T_{max}) were calculated as follows:

$$S = -(b+1)\ln c$$

$$Y_{max} = A(\frac{b}{c})^b e^{-b}$$

$$T_{max} = \frac{b}{c}$$

In biological terms, *lnA* reflects the initial production level, while b and c describe the rise and fall of the lactation curve, respectively. T_{max} indicates the timing of peak production, Y_{max} gives the expected maximum yield, and S is used as an indicator of how persistent milk production is throughout lactation.

All parameters were calculated separately for each goat using ten months of milk yield records. The inverse transformation $Y_t = \exp(y_t)$ was used when returning to the original scale.

The effects of different factors on lactation traits were evaluated using the following linear model:

$$Y_{ij} = \mu + \alpha_i + b_j + e_{ij}$$

where Y_{ij} is the observed trait, μ is the overall mean, α_i represents litter size (single or twin), b_j represents lactation number (1st, 2nd, 3rd), and e_{ij} is the random error term.

The data were analyzed using the least squares method. Differences among groups were tested using Duncan's multiple range test in Minitab (2014).

RESULTS AND DISCUSSION

It is desirable that the lactation curve has a normal shape, as this is a sign that the animals have a normal milk production. Knowing the shape of the lactation curve facilitates herd management decisions (Piccardi *et al*., 2017). Sudden increases, decreases and fluctuations in milk yield indicate that there is a problem with the care, nutrition and health of the animals (Lopes *et al*., 2016). In addition, the parameters of the lactation curve can be used as criteria in selection and monitoring instead the parameters of the curve help to carry out healthier and more economical breeding (Güler and Akmaz, 2020). For this reason, it is necessary to follow the lactation curves of the herds from which milk is produced over time. Therefore, it is essential to monitor the lactation curves of milk-producing herds over time and to identify and quantify the factors affecting these curves. In this study, the parameters of the lactation curve and relevant environmental factors potentially influencing them were analyzed.

Table 2. Least-squares means and standard errors of the lactation curve parameters

Trait/ efficiency	n	Curve parameters					
		A	***B***	***c***	***S***	T_{max}	Y_{max}
		$\overline{X}\pm S_{\bar{x}}$	$\overline{X}\pm S_{\bar{x}}$	$\overline{X}\pm S_{\bar{x}}$	$\overline{X}\pm S_{\bar{x}}$	$\overline{X}\pm S_{\bar{x}}$	$\overline{X}\pm S_{\bar{x}}$
Lactation order		NS	NS	*	NS	NS	**
1	21	-2.75±0.31	1.12±0.08	0.02±0.00[b]	9.07±0.25	77.49±2.28	2.88±0.08[b]
2	21	-2.60±0.25	1.18±0.06	0.02±0.00[a]	8.97±0.21	72.06±2.30	3.63±0.10[a]
3	20	-2.24±0.27	1.05±0.07	0.01±0.00[ab]	8.68±0.22	71.23±2.25	3.44±0.06[a]
Litter size		**	*	NS	**	**	NS
Single	32	-2.93±0.23[a]	1.21±0.06[a]	0.02±0.00	9.22±0.19[a]	77.91±1.75[a]	3.23±0.08
Twin	30	-2.10±0.20[b]	1.02±0.05[b]	0.01±0.00	8.52±0.16[b]	69.04±1.71[b]	3.39±0.09
Overall	62	-2.53±0.16	1.116±0.04	0.015±0.00	8.88±0.13	73.67±1.34	3.31±0.06

*: p≤ 0.05, **: p≤ 0.01, NS: Not significant, ***a, b, ab*:** The differences between the mean values, which are indicated with different letters in the same column, are statistically significant.

Table 3. Actual and predicted milk yield statistics for lactation groups

Control (days)	Lactation order							
	First		Second		Third		Average of all lactations	
	AY (kg)	PY (kg)	AY (kg)	PY (kg)	AY (kg)	PY (kg)	AY (kg)	PY (kg)
30	1,35	1,10	1,95	1,49	1,76	1,71	1,68	1,50
60	1,45	2,49	2,10	3,17	1,89	3,09	1,81	2,92
90	1,67	2,83	2,20	3,55	1,95	3,37	1,94	3,24
120	3,38	2,67	3,95	3,25	3,79	3,08	3,71	3,00
150	2,91	2,31	3,32	2,69	3,08	2,59	3,10	2,53
180	2,58	1,87	2,43	2,08	2,60	2,06	2,54	2,00
210	2,83	1,46	2,84	1,55	4,22	1,57	3,30	1,53
240	1,55	1,12	1,46	1,13	1,56	1,19	1,52	1,15
270	0,77	0,84	0,73	0,80	0,78	0,88	0,76	0,89
300	0,39	0,63	0,37	0,56	0,39	0,64	0,38	0,61

AY: Actual yield, PY: Predicted yield

As shown in Table 2, it was found that the lactation order, which is assumed to affect the parameters of the lactation curve, caused a variation in the *c* parameter at the significance level ($p \leq 0.05$), and according to the results of the multiple comparison, the total lactation orders had different values. It was also found that the lactation order caused a significant change in the Y_{max} value ($p \leq 0.01$). The results of the multiple comparison showed that the values in the second and third lactation were similar, while the value in the first lactation was lower. The effect of litter size on all parameters of the lactation curve proved to be significant for *A, S,* T_{max} ($p \leq 0.01$) and *b* values ($p \leq 0.05$).

The actual and predicted values determined in Damascus goats for all lactations and control months in the order of lactation are shown in Table 3. The coefficients of determination (R^2) of the gamma lactation curve were 73.0 %, 72.5 %, 60.5 % and 61.7 % for the first group, the second group and the third lactation group and for all lactation groups, respectively. Based on these results, the gamma function is compatible with the real lactation curves. The actual and predicted lactation curves by month for the first, second, third and all lactations are shown Figure 1.

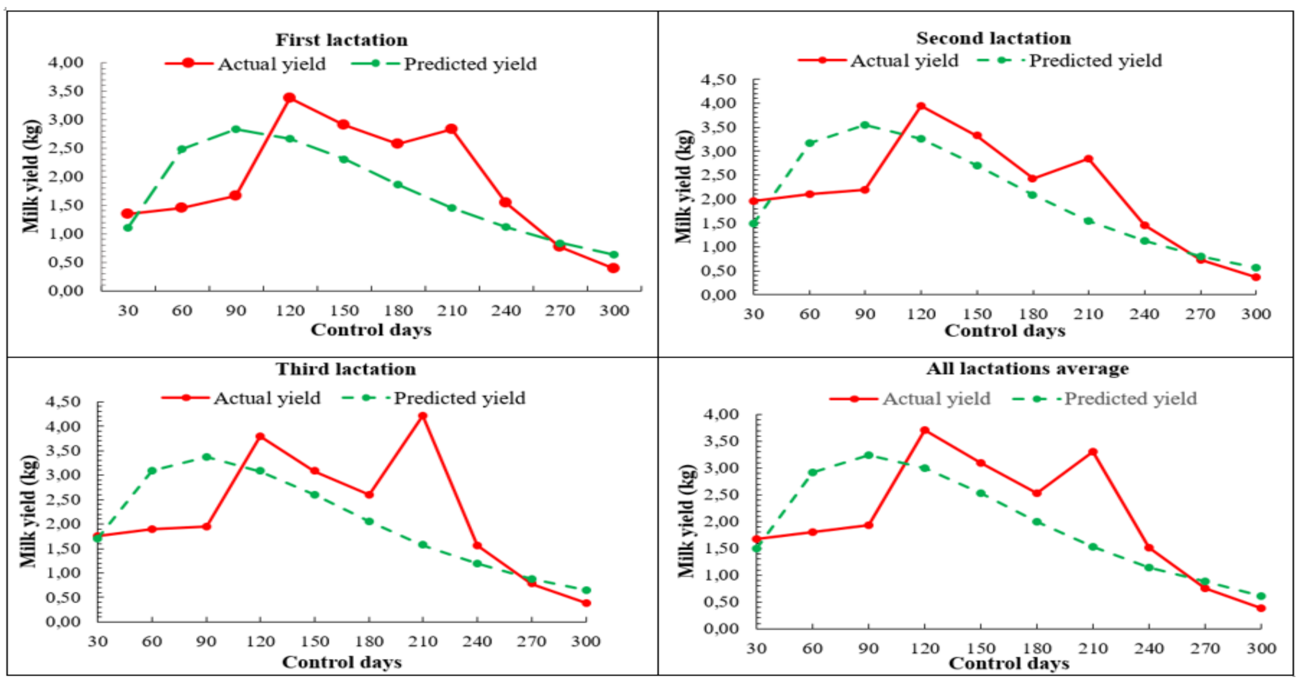

Figure 1. Actual and predicted curves for the average of all lactations.

This study shows that the lactations have an abnormal lactation curve type in relation to the lactation order and the average of all lactations. When all lactation curve shapes were examined, the lactation curve, which had a normal shape after the initial yield, showed a sharp increase at the 90-day control. The shape of the lactation curve, which took a normal course after this increase, began to rise again on the 180th control day and reached the peak level again on the 210th day and approached the average on the 240th day. These fluctuations in the lactation curve are strongly associated with the degree of pasture utilization by the goats in this observational dataset.

The rise in the lactation curve indicates an increase in milk yield when the animals received more high-quality pasture (Table 1). This suggests that the standard grazing and feeding program may support continuity of high milk yield, but further controlled studies are needed to confirm this relationship. These fluctuations in the lactation curve can be explained by the fact that milk yield increases when the goats are fed more green forage (wheat, maize, clover, sugar beet stubble and orchard floor) in the feeding program studied in Table 1.

In a previous study, Murney *et al*. (2019) reported in their study on Saanen goats in New Zealand that feeding goats with mixed forages such as clover, clover, meadow grass and rye increased milk yield. The province of Iğdır in Turkey is one of the provinces with the lowest annual rainfall. Irrigation in agriculture is carried out exclusively with water that is channeled through canals. However, the groundwater is very high and there are many canals to drain the water not used for irrigation. There is always green vegetation around the canals for animals. Savaş *et al*. (2019) reported that in the fall in Iğdır province, the meadow and pasture areas near the settlements, the stubble (clover, barley, wheat, corn plants, etc.) and the areas between the stubble and the areas in the vineyards and gardens are grazed by small livestock and provide quality green fodder for the animals until the snow falls. With the rains that fall in the fall months in the province of Iğdır, all areas become green again and prepare a suitable ground for grazing. It can be said that the fluctuations in the lactation curves are temporally associated with the provision of new green pastures or stubble; however, causality cannot be established from this study design. The relationships between the parameters of the lactation curve influence the level and continuity of milk yield. The phenotypic correlation values between the parameters and the milk yield elements estimated in the study using the gamma function are shown in Table 4.

Table 4. Correlations between the parameters of the Gamma lactation curve and some milk yield traits

Parameter	***A***	***b***	***c***	***S***	T_{max}	Y_{max}
B	-0.988**					
C	-0.873**	0.924**				
S	-0.994**	0.990**	0.862**			
T_{max}	-0.934**	0.894**	0.674**	0.945**		
Y_{max}	0.136	0.001	0.120	-0.053	-0.212	
LMY	0.458**	-0.382**	-0.421**	-0.363**	-0.353**	0.789**

*; $p \leq 0.05$, **; $p \leq 0.01$, LMY; lactation milk yield, S; persistence

When evaluating the parameters of the lactation curve, a strongly negative and significant ($P < 0.01$) correlation was found between the initial value *A* and the slope value *b*. Similar results were obtained for *c*, *S* and T_{max} with the parameter *A* ($P < 0.01$), and a moderately positive and significant correlation was found between *A* and the LMY values ($P < 0.01$). The correlations of these values were -0.988, -0.873, -0.994, -0.934 and 0.458, respectively (Table 4). Waheed and Khan (2013) in their study on Beetal goats found that the correlation between the *A* and *B* parameters was moderate and negative, and the results in this study were similar and also negative in terms of the degree of correlation. In the same study, the correlations between the *A* and *c* and *b* and *c* parameters were reported as low and positive ($p \leq 0.05$), but in the present results, in contrast, these parameters were found to be high and negative.

The correlations of *b* with the parameters *c*, *S* and T_{max} were positive and high ($p \leq 0.01$), and its relationship with LSV was moderate and significant ($p \leq 0.01$). It is important to note that parameter *b* has a significant correlation with parameters *c* and *S*. This is because the parameters lactation decline (*c*) and lactation persistence (*S*) are the parameters that largely determine the shape of the curve and milk yield. It was found that the relationship between *c* and the parameters *S* and T_{max} is strongly and significantly positive ($p \leq 0.01$), while the relationship with LSV is moderately negative ($p \leq 0.01$). The relationship between S and T_{max} is strong and significant ($p \leq 0.01$), while the relationship with LSV is moderately negative and significant ($p \leq 0.01$). The correlation between T_{max} and LSV was moderately negative ($p \leq 0.01$). The correlation between Y_{max} and LSV was high and positive ($p \leq 0.01$). However, no significant correlation was found between Y_{max} and the parameters *A, b, c, S* and T_{max}.

Conclusion: After the first breeding of Damascus goats in Iğdır province and analyzing the lactation curve data, it can be said that Damascus goats have adapted to the breeding, care and feeding conditions in this region. The study has shown that the lactation curves of the Damascus goats continue to fluctuate and that the daily milk yield is positively influenced by this situation, depending on the feeding. Finally, it was predicted that milk yield will increase significantly by implementing a balanced and sustainable feeding program in the herd.

Conflict of interest: As authors, we declare that there is no conflict of interest between us.

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