Black Sea Journal of Agriculture
doi: 10.47115/bsagriculture.1563898

Open Access Journal
e-ISSN: 2618 – 6578

Research Article
Volume 8 - Issue 2 : xxx-xxx / March 2025

MODELLING CHANGES IN MILK COMPONENTS OF DAMASCUS GOATS DURING LACTATION

Nazire MİKAİL[1]*, Ayhan YILMAZ[2], Muhammet Ali KARA[1], Figen CERİTOĞLU[1], Ercan GÜNEŞ[3]

[1]Siirt University, Faculty of Agriculture, Department of Animal Husbandry, Siirt, Türkiye
[2]Bitlis Eren University, Faculty of Health Sciences, Department of Nutrition and Dietetics, Bitlis, Türkiye
[3]Provincial Directorate of Agriculture and Forestry, Animal Health Breeding and Fisheries Branch Directorate, Siirt, Türkiye

Abstract: In this study, the possibilities of determining the changes of lactation milk components in Damascus goats by mathematical models were investigated. The animal material of the study consisted of 47 Damascus goats raised in Gökçebağ village of Siirt province. Milk components were analyzed in milk samples acquired at 2-week intervals after parturition. Milk components were analyzed using the Lactoscan Milk Analyzer. Wood and Ali-Schaeffer models, which are assumed to be the most appropriate for the definition of lactation curves, were applied to the milk component data obtained to describe the change in milk components, the best fitting model was determined, mathematical and biological relationships were solved in protein and fat content, and the relationship between the parameters was examined. Samples taken from dairy goats in the local enterprise were expressed with mathematical models and the change in milk content during lactation was tried to be learned. The results are intended to form the basis for the improvement of goat milk content and breeding projects in Siirt.

Keywords: Milk component, Protein, Fat, Wood model, Ali Schaeffer model

***Corresponding author:** Siirt University, Faculty of Agriculture, Department of Animal Husbandry, Siirt, Türkiye
E mail: naziremikail@siirt.edu.tr (N. MİKAİL)
Nazire MİKAİL https://orcid.org/0000-0002-8996-9330
Ayhan YILMAZ https://orcid.org/0000-0002-5990-7550
Muhammet Ali KARA https://orcid.org/0000-0003-3203-8364
Figen CERİTOĞLU https://orcid.org/0000-0003-4016-0394
Ercan GÜNEŞ https://orcid.org/0009-0001-1843-4734

Received: July 2, 2024
Accepted: November 17, 2024
Published: March 15, 2025

Cite as: Mikail N, Yılmaz A, Kara MA, Ceritlioğlu F, Güneş E. 2025. Modelling changes in milk components of Damascus goats during lactation. BSJ Agri, 8(2): xxx-xxx.

1. Introduction

Goat breeding is an important component of small ruminant production worldwide and in Türkiye. Türkiye's geographic structure, soil characteristics, and vegetation provide a favorable environment for goat farming. Additionally, goat breeding plays a significant economic role in rural areas due to its minimal land requirements and adaptability to harsh conditions (Park and Haenlein, 2006; Paksoy, 2007; Kaymakçı and Engindeniz, 2010). According to FAO (2014), goats contribute 2.4% of the world's milk production. In Türkiye, 90.8% of milk production comes from cattle, 8.88% from small ruminants, and the remainder from buffaloes."Of the small ruminants' contribution, 6.28% comes from sheep and 2.60% from goats (Semerci and Çelik, 2016).

Milk composition, particularly fat and protein content, varies significantly in goat milk depending on factors such as breed, season, lactation period, and nutrition. Goat milk contains approximately 4.5% fat and features a higher proportion of short and medium-chain fatty acids compared to cow milk, offering distinct nutritional benefits (Yadav et al., 2016; Tüfekçi, 2023). The taste and composition of goat milk are highly dependent on the breed and feeding practices (Raynal-Ljutovac et al., 2005). Proper maintenance and feeding conditions, particularly in intensive farming systems, can help achieve desired milk quality parameters. Milk content is a critical determinant of milk prices and is linked to quality standards (Raynal-Ljutovac et al., 2008). Variations in milk components, such as fat and protein, are influenced by the lactation stage. For instance, the beginning, middle, and end of lactation may show significant differences in milk composition (Daşkıran et al., 2022). However, studies addressing lactation curves for goats remain limited, despite extensive research on this topic for cattle (e.g., Dağ et al., 2003; Keskin et al., 2004; Çilek and Keskin, 2008; Zülkadir et al., 2008 Çilek et al., 2009; Keskin et al., 2009a; Keskin et al., 2009b; Gök et al., 2019).

Lactation curves are mathematical representations of milk production patterns throughout the milking period. These curves are essential for evaluating milk yield and determining selection criteria. Knowledge of lactation curves and their parameters in goats are very important for changing the shape of lactation curves and improving these parameters in order to optimize production and benefits (Mousa et al, 2016). Parity had a large effect on the characteristics of the lactation curve in dairy goats. It was found that peak yield increased with increasing parity up to about the third or fourth parity, while time of peak yield is later for first-parity does than for later parity does (Groenewald and Viljoen, 2003). Models such as Wood, Dhanoa, Wilmink, Cobby and Le Du, Dave, and Inverse Polynomial have been widely used to describe lactation curves (Masselin et al., 1987, Gaddour et al, 2009). Animals with flatter lactation curves are preferred for their consistent yield, efficient maintenance, and reproductive advantages (Wood, 1967; Madsen, 1975; Akbulut, 1990). Incomplete gamma function of Wood was sufficient in describing lactation curve for Damascus goats. The Wood's model explained the variation quite accurately and described the shapes of lactation curves (Ayasrah et al., 2013). These models have been applied in diverse goat populations, including Alpine goats (González-Peña et al., 2012), Damascus goats in Jordan (Ayasrah et al., 2013), and crossbred goats in Saudi Arabia (Mousa et al, 2016). Each model offers unique advantages in terms of accuracy and applicability, depending on the production environment and specific traits of the studied population.

Protein and fat content in goat milk are also influenced by factors like lactation stage, season, and nutrition. Comparative studies on goat and cow milk proteins have highlighted significant differences due to species genetics and feeding practices (Haenlein, 2004; Min et al., 2005). Protein content, an important quality criterion for milk payment systems in many countries, is determined by lactation stage and season (Raynal-Ljutovac et al., 2005; Pirisi et al., 2007).

The aim of this study is to model changes in milk components during the lactation period of Damascus goats raised in Siirt, Türkiye. By focusing on Damascus goats in Siirt, the study also provides insights into local production dynamics, helping optimize goat milk yield and quality in the region. Specifically, the Wood and Ali-Schaeffer models, which are widely regarded as appropriate for describing lactation curves, were applied to protein and fat content data."By identifying the best-fitting model, this study seeks to elucidate the mathematical and biological relationships underlying these variations and analyze the connections between model parameters.

2. Material and Method

The animal material of this study consisted of 47 Damascus goats raised in Gökçebağ village of Siirt province. The animals were raised in extensive conditions and there were no special management practices for housing, feeding kidding etc. Milk samples were acquired every two weeks during the parturition season and 7 test days were performed in total (April 1-July 1, 2021). In total 274 test-day records were used in the study. The samples were brought to Siirt University, Faculty of Agriculture, Laboratory of Animal Husbandry with milk preservatives in 50 cc tubes and analyzed with Lactoscan Milk Analyzer (MILKOTRONIC LTD, Bulgaria) on the same day.

2.1. Mathematical Models

Wood and Ali-Schaeffer models are widely used lactation curve models. In this study, these mathematical models were applied to control day records. The models are as follows (Silvestre et al., 2006)

Wood $$Y_t = at^b e^{-ct} \tag{1}$$

Ali-Schaeffer $$Y_t = a + b\delta_t + c\delta_t^2 + d\theta_t + g\theta_t^2 \tag{2}$$

From the terms in equation 1,
Y_t : milk yield on day t of lactation (kg),
t : the time from kidding to the test day (days),
e: denotes the base of the natural logarithm.
a, b, c: parameter estimates of the lactation curve;
a: is an intercept,
b: curve increase at the beginning of lactation,
c: is the coefficient indicating the decline of the curve after reaching the highest level.
From the terms in equation 2,
$\delta_t = t/305$,
$\theta_t = \ln(305/t)$ and
t: indicates any day of lactation,
a: parameter refer to the peak yield,
d and g: parameters refer to the increase in the curve,
b and c: parameters refer to the decrease in the curve.

2.2. Comparison of the Models

The following criteria were used to compare the models (Burnham and Anderson, 2002).

a) Coefficient of Determination,

$$R^2 = 1 - \sum_{i=1}^{n}(y_i - \tilde{y}_i)^2 / \sum_{i=1}^{n}(y_i - \bar{y})^2 \tag{3}$$

b) Adjusted Coefficient of Determination,

$$R^2_{adj} = 1 - (1 - R^2)\frac{n-1}{n-p} \tag{4}$$

c) Mean Squared Error (MSE),

$$MSE = \sqrt{\frac{1}{n-p}\sum_{i=1}^{n}(y_i - \tilde{y}_i)} \tag{5}$$

d) Wellmont Agreement Criteria

$$D = 1 - \frac{\sum(y_i - \tilde{y}_i)^2}{\sum\{|y_i - \bar{y}| + |\tilde{y}_i - \bar{y}|\}^2} \tag{6}$$

e) Mean Absolute Percentage Error (MAPE)

$$\bar{\varepsilon} = \frac{\sum_{i=1}^{n}\left|\frac{y_i - \tilde{y}_i}{y_i}\right|}{n} 100\% \tag{7}$$

f) Akaike Information Criterion

$$AIC = \ln\left[\frac{1}{n}\sum_{i=1}^{n}(y_i - \tilde{y}_i)^2\right] + \frac{2p}{n-(p+1)}\ ,\ \left(\frac{n}{p} < 40\right) \tag{8}$$

g) Bayesian Information Criterion

$$BIC = \ln\left[\frac{1}{n}\sum_{i=1}^{n}(y_i - \tilde{y}_i)^2\right] + \frac{p}{n}\ln n \tag{9}$$

h) Hannan-Quinn Information Criterion (HQC)

$$HQC = \ln\left[\frac{1}{n}\sum_{i=1}^{n}(y_i - \tilde{y}_i)^2\right] + \frac{2m}{n} \cdot [\ln(\ln n)] \quad (10)$$

Where,
n : Number of observations,
p : Number of parameters in the model,
y_i : milk yield in the i^{th} week,
$\bar{y}$: average daily milk yield,
$\tilde{y}$: the predicted milk yield.

In determining the best model, it was taken into consideration that the coefficient of determination, adjusted coefficient of determination and Wellmont Agreement Criterion were high, while the other criteria were low. In the study, R statistical package (R Core Team, 2021) was used to calculate the parameters in the models. The nlsLM() function from the minpack.lm package in R estimates model parameters using the Levenberg-Marquardt algorithm.

3. Results and Discussion

Means and standard errors of milk components according to control days are given in Table 1. Statistically significant differences were observed in milk components on individual control days ($p<0.01$), and this results highlighting the dynamic nature of milk composition throughout lactation). The findings revealed that milk fat content exhibited notable fluctuations, peaking at the end of the 1st and 3rd months, as well as at the beginning of the 4th month. This result is consistent with previous studies indicating that milk fat content varies due to physiological changes in lactation stages (Zeng and Escobar, 1995; Park et al., 2007). Protein content started to increase at the end of the 1st month. The changes and distribution of milk components throughout the control period are given in Figure 1-9.

Table 1. Means and standard errors of milk components according to control days

N	Control day	Fat (%)**	SNF (%)**	Density**	Lactose (%)**	Salts (%)**	Protein (%)**	Freezing point**	pH**	EC**
1	01.04.2021	3.75 ± 0.18^{a}	8.22 ± 0.17^{cd}	29.09 ± 0.56^{ef}	3.69 ± 0.07^{de}	0.61 ± 0.01^{d}	3.89 ± 0.08^{de}	-0.46 ± 0.01^{a}	6.69 ± 0.02^{b}	6.44 ± 0.17^{a}
2	22.04.2021	3.83 ± 0.21^{a}	9.10 ± 0.17^{ab}	32.45 ± 0.61^{bc}	4.08 ± 0.08^{ab}	0.67 ± 0.01^{b}	4.31 ± 0.08^{ab}	-0.51 ± 0.01^{cd}	6.64 ± 0.02^{c}	5.46 ± 0.15^{b}
3	06.05.2021	2.47 ± 0.18^{c}	9.27 ± 0.29^{a}	35.17 ± 0.65^{a}	4.26 ± 0.08^{a}	0.71 ± 0.01^{a}	4.49 ± 0.08^{a}	-0.53 ± 0.01^{d}	6.66 ± 0.01^{bc}	5.24 ± 0.13^{b}
4	19.05.2021	2.29 ± 0.16^{c}	9.02 ± 0.16^{ab}	33.36 ± 0.60^{b}	4.04 ± 0.07^{b}	0.67 ± 0.01^{b}	4.27 ± 0.08^{b}	-0.49 ± 0.01^{bc}	6.63 ± 0.02^{c}	5.47 ± 0.12^{b}
5	03.06.2021	3.07 ± 0.18^{b}	8.48 ± 0.09^{cd}	30.65 ± 0.37^{de}	3.81 ± 0.04^{cd}	0.63 ± 0.01^{cd}	4.02 ± 0.04^{cd}	-0.47 ± 0.01^{ab}	6.55 ± 0.02^{d}	6.30 ± 0.09^{a}
6	17.06.2021	3.65 ± 0.17^{a}	8.72 ± 0.16^{bc}	31.12 ± 0.57^{cd}	3.91 ± 0.07^{bc}	0.65 ± 0.01^{bc}	4.13 ± 0.07^{bc}	-0.49 ± 0.01^{b}	6.65 ± 0.02^{bc}	6.46 ± 0.09^{a}
7	01.07.2021	3.77 ± 0.18^{a}	8.08 ± 0.09^{d}	28.57 ± 0.31^{f}	3.61 ± 0.04^{e}	0.60 ± 0.01^{d}	3.83 ± 0.04^{e}	-0.44 ± 0.01^{a}	6.77 ± 0.02^{a}	6.58 ± 0.10^{a}

**p<0.01 (SNF: Non fat solids, EC: Electrical conductivity)

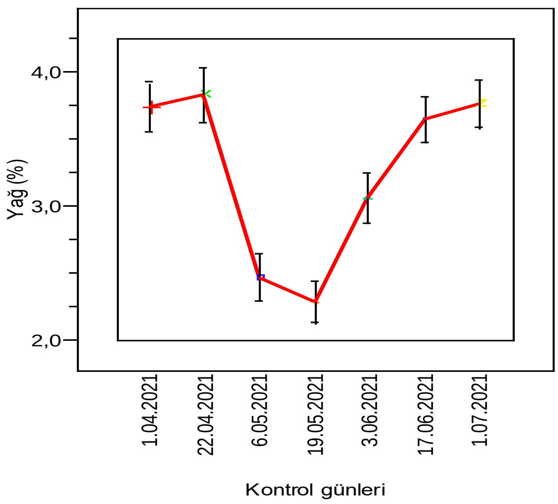

Figure 1. Variation of fat in milk.

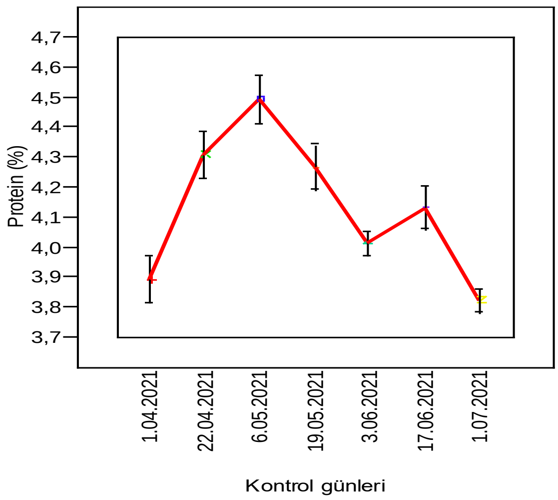

Figure 2. Variation of protein in milk.

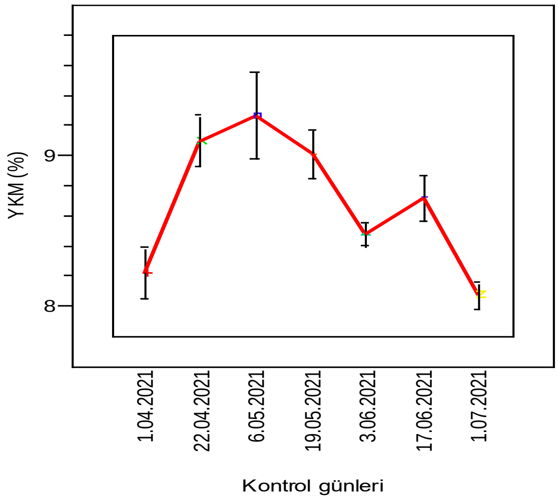

Figure 3. Variation of SNF in milk

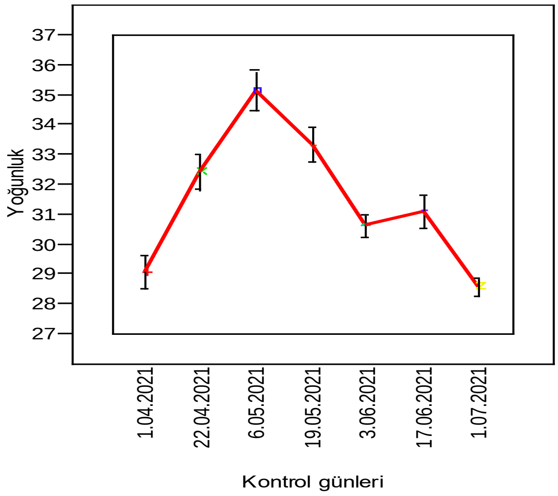

Figure 4. Variation of density in milk

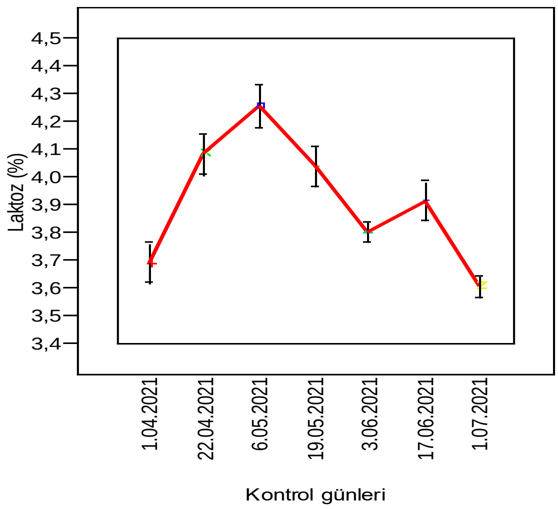

Figure 5. Variation of lactose in milk

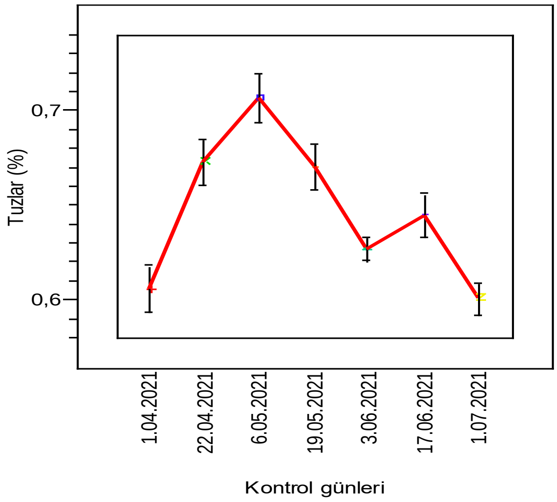

Figure 6. Variation of salts in milk

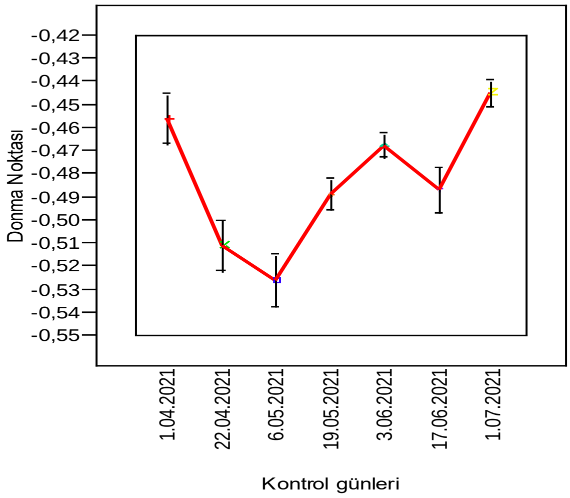

Figure 7. Variation of freezing point in milk

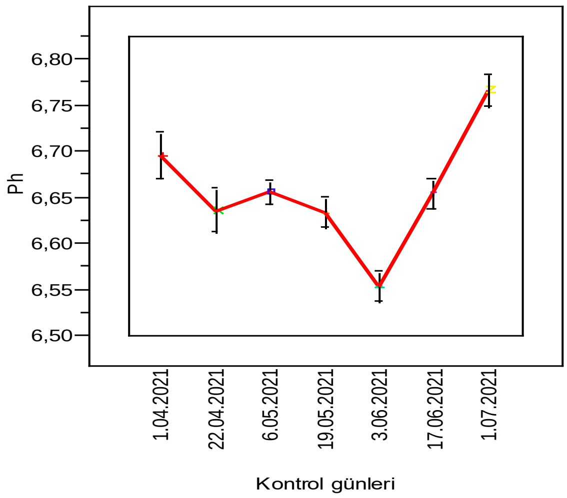

Figure 8. Variation of pH in milk

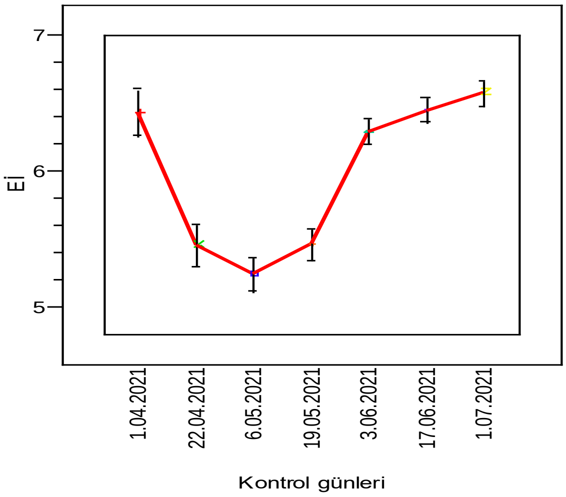

Figure 9. Variation of electrical conductivity in milk

The correlation between milk components is given in Table 2. When Table 2 is analyzed, the correlations of milk components with the others except the correlations with fat and pH were found to be statistically significant. Accordingly, there was a highly significant correlation between SNF and milk density, lactose, salt and protein ($p<0.01$) and a significant correlation between freezing point and electrical conductivity ($p<0.05$). There was no statistically significant correlation between milk fat content and other components. However, the correlation between milk protein content and density, lactose and salt was very significant ($p<0.01$). Zeng and Escobar (1995) reported that there was a significant correlation between milk fat content and SNF content in Alpine goats ($p<0.001$). In the same study, it was found that there was a significant correlation between milk lactose and protein content ($p<0.05$) and a very significant correlation between milk lactose content and SNF in accordance with the findings of the present study.

Table 2. Correlations between milk components

Milk components	Fat	SNF	Density	Lactose	Salt	Protein	Freezing point	pH
SNF	-0.570							
Density	-0.736	0.966**						
Lactose	-0.597	0.991**	0.982**					
Salt	-0.627	0.985**	0.988**	0.996**				
Protein	-0.597	0.990**	0.982**	0.999**	0.998**			
Freezing point	0.448	-0.972**	-0.933**	-0.983**	-0.973**	-0.983**		
pH	0.411	-0.453	-0.428	-0.421	-0.379	-0.407	0.385	
EC	0.634	-0.917**	-0.923**	-0.918**	-0.925**	-0.919**	0.873*	0.326

*p<0.05, **p<0.01

3.1. Fitting Lactation Curves

In the present study, Ali-Schaeffer and Wood models were applied to the data obtained for milk components. The parameters calculated as a result of the application of the models to the data are given in Table 3. In the Wood model, the coefficient a indicates the point where the curve crosses the y-axis, the coefficient b indicates the rise of the curve at the beginning of lactation and the coefficient c indicates the decline of the curve after reaching the highest level. In the Ali-Schaeffer model, the a parameter indicates the peak value, the d and g parameters indicate the rise in the curve, and the b and c parameters indicate the descent in the curve (Silvestre et al., 2006).

Table 3. Calculated parameters of the models

Milk component	Models	Parameters				
		a	b	c	d	g
Fat	Ali-Schaeffer	-38.097**	43.315**	-1.472**	76.321**	-174.653**
	Wood	3.139**	-0.733	-0.231	-	-
SNF	Ali-Schaeffer	7.271	0.981	-0.033	-3.114	-9.808
	Wood	8.992**	0.245*	0.083**	-	-
Density	Ali-Schaeffer	82.348	-55.268	1.973	-118.704	191.116
	Wood	32.747**	0.362**	0.121**	-	-
Lactose	Ali-Schaeffer	5.216	-1.589	0.061	-5.174	3.113
	Wood	4.069**	0.270*	0.092*	-	-
Salts	Ali-Schaeffer	1.136	-0.552	0.021	-1.398	1.565
	Wood	0.669**	0.281*	0.095*	-	-
Protein	Ali-Schaeffer	5.772	-1.957	0.076	-5.995	4.227
	Wood	4.289**	0.267*	0.091*	-	-
Freezing point	Ali-Schaeffer	-0.291	-0.169	0.005	0.036	1.149
	Wood	-0.504**	0.256*	0.089*	-	-
pH	Ali-Schaeffer	9.979*	-3.426	0.143	-6.152	12.006
	Wood	6.635**	-0.034	-0.011	-	-
EC	Ali-Schaeffer	-9.056	16.117	-0.626	34.917	-51.823
	Wood	5.521**	-0.401*	-0.142*	-	-

*p<0.05, **p<0.01

As can be seen from Table 3, the Ali-Schaeffer model has 5 parameters and the Wood model has 3 parameters. The graphs of the application of the Ali-Schaeffer and Wood models to the observation values are given in Figures s1-s18 (Supplementary material).

3.2. Model Comparison Results

When the models applied to the data obtained for milk components were evaluated with the comparison criteria, the changes in milk fat content, pH and electrical conductivity were best explained by the Ali-Schaeffer model, while the changes in SNF content, density, protein, lactose, salt and freezing point were better explained by the Wood model (Table 4). The curves fitted to the milk components are shown comparatively in the graphs between Figures 10-18.

Table 4. Evaluation criteria for the models

Milk component	Model	p	R^2	R^2_{adj}	MSE	D	$\overline{\mathcal{E}}$	AIC	BIC	HQC
Fat	Ali-Schaeffer	5	0.99	0.99	0.01	0.99	1.06	53.45	-5.16	-5.59
	Wood	3	0.51	0.27	0.65	0.82	10.6	6.28	-0.88	-1.15
SNF	Ali-Schaeffer	5	0.88	0.63	0.39	0.97	1.29	56.19	-2.42	-2.85
	Wood	3	0.85	0.78	0.25	0.96	1.41	4.38	-2.79	-3.05
Densıty	Ali Schaeffer	5	0.90	0.69	1.86	0.97	1.81	59.29	0.68	0.25
	Wood	3	0.86	0.80	1.23	0.96	1.87	7.56	0.39	0.13
Lactose	Ali Schaeffer	5	0.86	0.57	0.21	0.96	1.68	54.96	-3.65	-4.09
	Wood	3	0.83	0.75	0.13	0.95	1.64	3.11	-4.06	-4.32
Salts	Ali Schaeffer	5	0.86	0.59	0.04	0.96	1.67	51.36	-7.25	-7.69
	Wood	3	0.82	0.74	0.02	0.95	1.75	-0.38	-7.55	-7.81
Protein	Ali Schaeffer	5	0.86	0.57	0.22	0.96	1.66	55.05	-3.56	-4.00
	Wood	3	0.83	0.74	0.14	0.95	1.67	3.23	-3.94	-4.20
Freezing point	Ali Schaeffer	5	0.81	0.44	0.03	0.95	2.05	51.09	-7.51	-7.95
	Wood	3	0.75	0.62	0.02	0.93	2.38	-0.60	-7.77	-8.03
pH	Ali Schaeffer	5	0.91	0.72	0.05	0.96	0.2	51.99	-6.61	-7.05
	Wood	3	0.46	0.19	0.07	0.77	0.53	1.77	-5.40	-5.66
EC	Ali Schaeffer	5	0.98	0.93	0.22	0.99	1.03	54.99	-3.63	-4.06
	Wood	3	0.84	0.76	0.33	0.95	3.05	4.91	-2.25	-2.52

p= number of parameters in the model, R^2= coefficient of determination, R^2_{adj}= adjusted coefficient of determination, MSE= mean squared error, D= Wellmont Agreement Criteria, $\overline{\mathcal{E}}$ = mean absolute percentage error, AIC= Akaike Information Criterion, BIC= Bayesian Information Criterion, HQC= Hannan-Quinn Information Criterion.

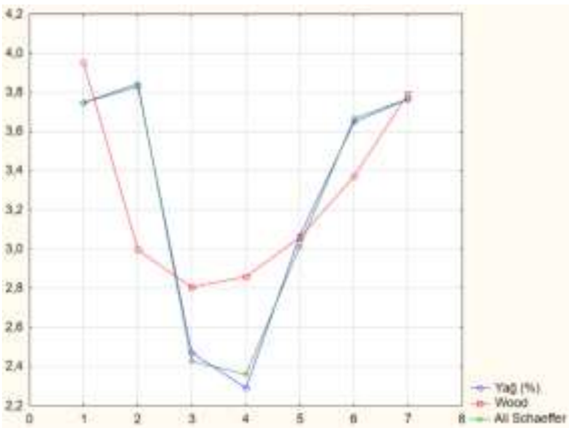

Figure 10. Plot of Ali-Schaeffer and Wood model fitting to fat content data

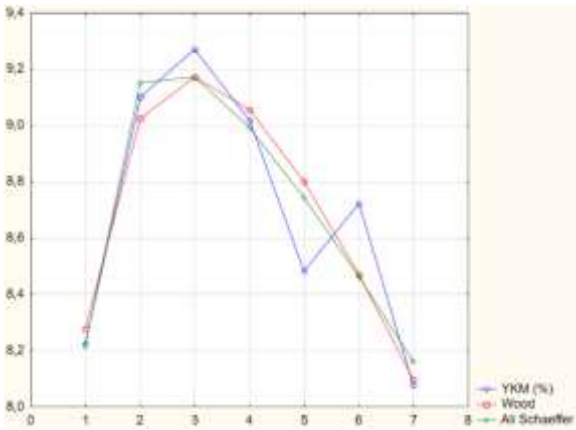

Figure 11. Plot of fitting Ali-Schaeffer and Wood models to the data for the SNF content

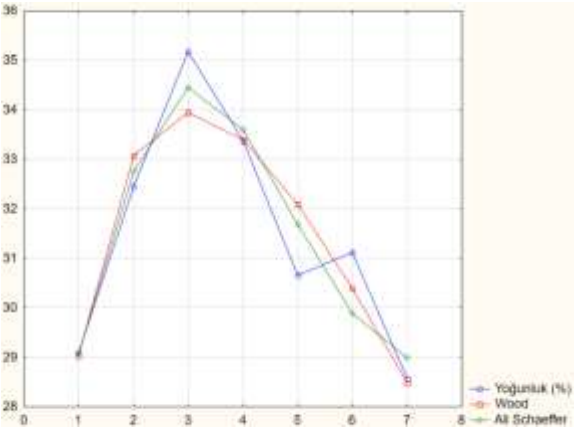

Figure 12. Plot of fitting Ali-Schaeffer and Wood models to density content data

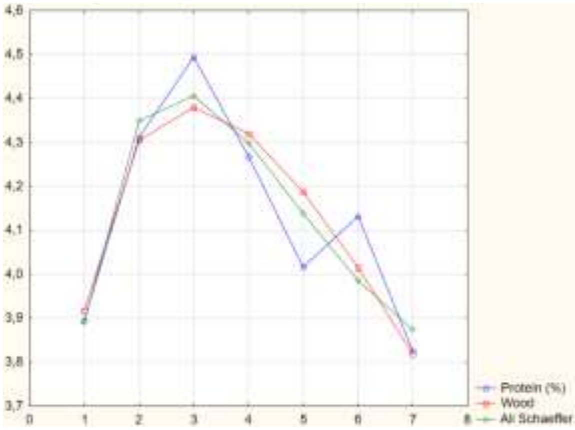

Figure 15. Plot of fitting Ali-Schaeffer and Wood models to protein content data

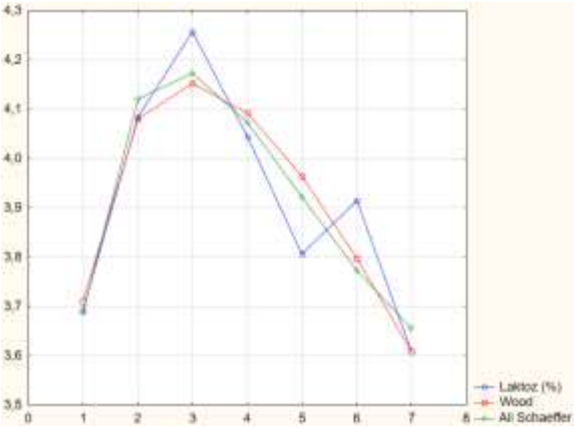

Figure 13. Plot of fitting Ali-Schaeffer and Wood models to lactose content data

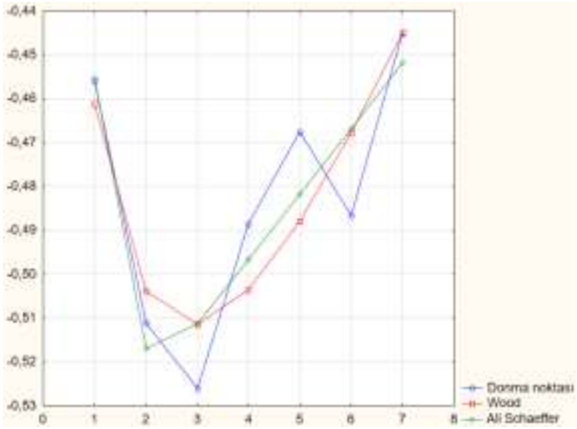

Figure 16. Plot of fitting Ali-Schaeffer and Wood models to freezing point data

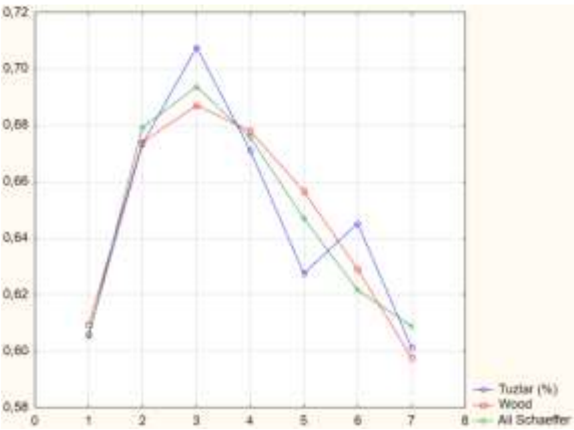

Figure 14. Plot of fitting Ali-Schaeffer and Wood models to salt content data

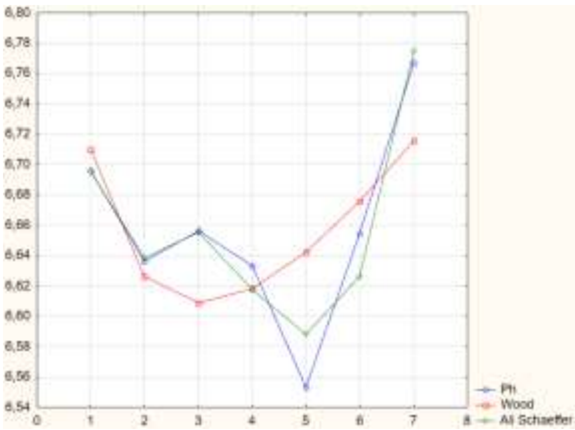

Figure 17. Plot of fitting Ali-Schaeffer and Wood models to pH data

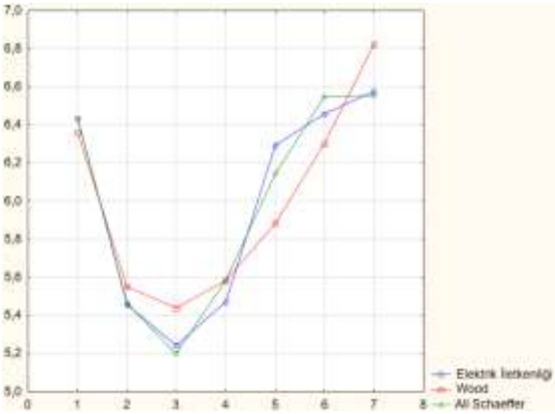

Figure 18. Plot of fitting Ali-Schaeffer and Wood models to EC data

Regarding lactation curve modeling, the comparison of Ali-Schaeffer and Wood models demonstrated varying performance across different milk components. The Ali-Schaeffer model, which includes five parameters, was found to better explain variations in milk fat, pH, and EC, likely due to its ability to capture complex fluctuations over time. In contrast, the Wood model, with its simpler three-parameter structure, provided a better fit for SNF, density, protein, lactose, salts, and freezing point. These results suggest that while the Wood model is effective for general trends, the Ali-Schaeffer model may be more suitable for components exhibiting pronounced early and late lactation variations.

5. Conclusion and Recommendations

In animal breeding, the prediction of some yields is of great importance in terms of breeding economics. Especially in economically important livestock, the time until the animals reach the productive age is an issue to be considered in terms of cost. This is an important issue in animal breeding applications and must be overcome. Therefore, the estimation method with mathematical models offers us benefits in terms of time and cost. In the case of determining the best prediction method, it will contribute to time and profitable production by making a good selection at the beginning, preparing a suitable ration considering the lactation curve and planning the appropriate strategies required by predicting the yield of the flock in advance. Most of the basic elements of lactation are similar in all species and especially between dairy goats and dairy cows, but there are some differences. Some of these are due to the higher metabolic rate in the goat.

In this study, two mathematical models commonly used in lactation curves were applied to milk components in the case of Damascus breed dairy goats, curves were drawn and parameters were calculated. The Wood and Ali-Schaeffer functions analyzed in the study were evaluated with AIC, BIC, HQC, MAPE, D, MSE, R^2_{adj} and R^2 methods used to compare different models, and the statistics obtained showed that different models gave better results in different components.

Author Contributions

The percentages of the authors' contributions are presented below. All authors reviewed and approved the final version of the manuscript.

	N.M.	A.Y	M.A.K.	F.C.	E.G.
C	40	20	20	10	10
D	50	30	20		
S	30	50	20		
DCP		30	40	20	10
DAI	100				
L	60			40	
W	60	20		20	
CR	60	20		20	
SR	50			50	
PM	30	30	30		10
FA	20	20	20	20	20

C= concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because there was no study on animals or humans.

Acknowledgments

This study was supported by the Project No 2020-SİÜZİR-010 of the Scientific Research Council of Siirt University.

References

Akbulut Ö. 1990. Atatürk Üniversitesi Tarım İşletmesinde yetiştirilen Esmer, Esmer melezleri ile Siyah Alaca sığırların süt verim özellikleri ve laktasyon eğrisi parametrelerine etkili faktörler. Doktora Tezi, Atatürk Üniversitesi, Fen Bilimleri Enstitüsü, Erzurum, Türkiye.

Ayasrah EM, Abou-Bakr S, Ibrahim MAM. 2013. Characteristics of lactation curve in Damascus goats in Jordan. Journal of Animal and Poultry Production, 4(8), 479-491.

Burnham KP, Anderson DR. 2002. Model Selection and Multimodel Inference. A practical information-theoretic approach. Springer-Verlag, New York, USA, 2nd Edition, pp: 1-488.

Çilek S, Keskin I. 2008. Comparison of six different mathematical models to the lactation curve of Simmental cows reared in Kazova State Farm. J. Anim. Vet. Advan, 7: 1316-1319.

Çilek S, Keskin İ, İlhan F, Hesna EŞ. 2009. Lactation curve traits of Anatolian population of Brown Swiss cows in Turkey. Archiva Zootechnica, 15(2): 53-60.

Dağ B, Keskin İ, Zülkadir U, Boztepe S. 2003. Çumra Ziraat Meslek Lisesinde yetiştirilen esmer ineklerin süt verim özellikleri ve bu özelliklere ait tekrarlanma dereceleri. S.Ü. Ziraat Fakültesi Dergisi, 17(1): 13-17.

Daşkıran İ, Yılmaz A, Günbey VS. 2022. A study on lactation milk yield and milk qualtiy characteristics of Kilis goats in farm conditions. Journal of Tekirdag Agricultural Faculty, 19(03):

678-687.
FAO. 2014. FAOSTAT. URL: https://www.fao.org/faostat/en/#data (Erişim tarihi: Eylül 11, 2024).
Gaddour A, Najari S, Ferchichi A. 2009. Lactation curve of local goat, pure breds and crosses in southern Tunisia. J of Applied Animal Research, 36(1), 153-157.
González-Peña D, Acosta J, Guerra D, González N, Acosta M, Sosa D, Torres-Hernández G. 2012. Modeling of individual lactation curves for milk production in a population of Alpine goats in Cuba. Livestock Science, 150(1-3), 42-50.
Gök T, Mikail N, Akkol S. 2019. Analysis of the first lactation curve in Holstein cows with different mathematical models. KSU J. Agric Nat, 22(4): 601-608.
Groenewald PC, Viljoen CS. 2003. A Bayesian model for the analysis of lactation curves of dairy goats. Journal of Agricultural, Biological and Environmental Statistics, 8, 75-83.
Haenlein GFW. 2004. Goat milk in human nutrition. Small Rumin. Res, 51, 155-163.
Kaymakçı M, Engindeniz S. 2010. Türkiye'de Keçi Yetiştiriciliği; Sorunlar ve Çözümler. Ulusal Keçicilik Kongresi Tam Metin Bildiri Kitabı, 24 Haziran, Çanakkale, pp. 1-25.
Keskin İ, Tozluca A. 2004. Süt sığırlarında laktasyon eğrilerinin farklı matematik modellerle belirlenmesi ve kontrol aralığının tespiti. S.Ü. Ziraat Fakültesi Dergisi, 18(34): 11-19.
Keskin İ, Dağ B, Sariyel V. 2009a. Fitness of four different mathematical models to the lactation curve of Brown Swiss cows in Konya Province of Turkey. Canadian Journal of Animal Science, 89(2): 195-199.
Keskin İ, Çilek S, İlhan F. 2009b. Polatlı tarım işletmesinde yetiştirilen Siyah Alaca siğirlarin laktasyon eğrisi özellikleri. Kafkas Üniversitesi Veteriner Fakültesi Dergisi, 15(3): 437-442.
Madsen OA. 1975. Comparison of some suggested measures of persistency of milk yield in dairy cows. Anim. Prod, 20: 191-197.
Masselin S, Sauvant D, Chapoutot P, Milan D. 1987. Les modèles d'ajustement des courbes de lactation. Ann. Zootech, 36: 171-206.
Min BR, Hart SP, Sahlu T, Satter LD. 2005. The effect of diets on milk production and composition, and on lactation curves in pastured dairy goats. J. Dairy Sci, 88: 2604-2615.
Mousa E, Elzarei MF. 2016. Prediction of lactation curve in Saudi Arabia, Damascus and their crossbred goats. Journal of Agricultural and Veterinary Sciences, 267(3724), 1-22.
Paksoy M. 2007. Kahramanmaraş ilinde süt üretimine yönelik keçi yetiştiriciliğine yer veren tarım işletmelerinin ekonomik analizi. Doktora Tezi, Ankara Üniversitesi, Fen Bilimleri Enstitüsü, Ankara, Türkiye.
Park YW, Haenlein GFW. 2006. Overview of milks of minor species. In: Park YW, Haenlein GFW. Editors, Handbook of Milk of Non-Bovine Mammals. Blackwell Publishers. Ames, Iowa and Oxford, England. pp. 3-10.
Pirisi A, Lauret A, Dubeuf JP. 2007. Basic and incentive payments for goat and sheep milk in relation to quality. Small Rumin. Res, 68: 167-178.
R Core Team 2021. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/ .
Raynal-Ljutovac K, Gaborit P, Lauret A. 2005. The relationship between quality criteria of goat milk, its technological properties and the quality of the final products. Small Ruminant Research, 60: 167-177.
Raynal-Ljutovac K, Lagriffoul G, Paccard P, Guillet I, Chilliard YY. 2008. Composition of goat and sheep milk products: An update. Small Ruminant Research, 79(1): 57-72.
Semerci A, Çelik AD. 2016. Türkiye'de küçükbaş hayvan yetiştiriciliğinin genel durumu. Mustafa Kemal Üniversitesi Ziraat Fakültesi Dergisi, 21(2): 182-196.
Silvestre A, Petim-Batista F, Colaço J. 2006. The accuracy of seven mathematical functions in modeling dairy cattle lactation curves based on test-day records from varying sample schemes. J. Dairy Sci, 89: 1813-1821.
Wood PDP. 1967. Algebraic model of lactation curve in cattle. Nature, 218: 164-165.
Tüfekçi H. 2023. Keçi sütü üretimi ve önemi. Osmaniye Korkut Ata Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 6(1): 970-981.
Yadav KA, Singh J, Yadav KS. 2016. Composition, nutritional and therapeutic values of goat milk: A review. Asian J Dairy Food Res, 35(2): 96-102.
Zeng SS, Escobar, EN. 1995. Effect of parity and milk production on somatic cell count, standard plate count and composition of goat milk. Small Ruminant Research, 17: 269-274.
Zülkadir U, Aytekin İ, Keskin İ. 2008. Relationship between persistency values defined with various methods and some lactation traits of Brown Swiss cattle in Turkey. Journal of Applied Animal Research, 34(1): 137-141