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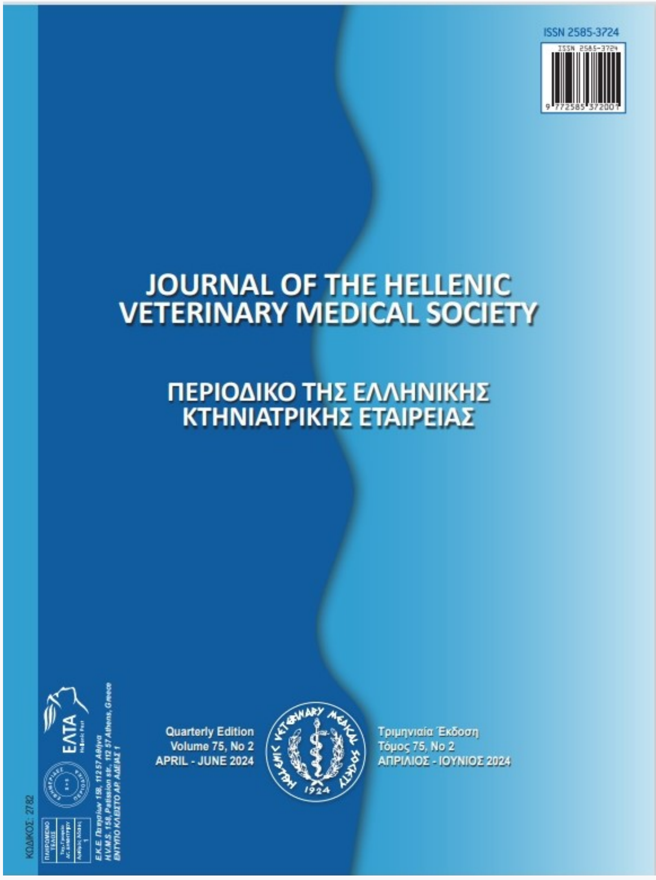
Journal of the Hellenic Veterinary Medical Society

Vol 75, No 2 (2024)



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doi: [10.12681/jhvms.35368](https://doi.org/10.12681/jhvms.35368)

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To cite this article:

Yıldırır, M. (2024). Factors effecting the lactation curve parameters of Brown Swiss and Jersey cows in Türkiye. *Journal of the Hellenic Veterinary Medical Society*, *75*(2), 7603–7610. https://doi.org/10.12681/jhvms.35368

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J HELLENIC VET MED SOC 2024, 75 (2): 7603-7610
ΠΕΚΕ 2024, 75 (2): 7603-7610

Research article
Ερευνητικό άρθρο

Factors effecting the lactation curve parameters of Brown Swiss and Jersey cows in Türkiye

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ABSTRACT: The explanatory capacity of lactation models depends on the successful prediction of the lactation curve and the regulation of environmental factors affecting production parameters. Therefore, in this study, six different lactation curve models (Wood, Wilmink, Sikka, Gou and Swalve, Nelder and Cobby and Le Du) were used to compare lactation milk yield data in individual monthly interval. Yield records for the first five lactations (1-5) were used a total of 61525 lactations data belonging to 22955 Brown Swiss (BS) and 5178 Jersey (JR) cows. Except for the Cobby and LeDu curve model, the explanatory capacity for the lactation curve models of the other models was high and the adjusted R^2 (between 0.95 and 0.99) and RSD (between 0.97 and 1.03) were found to be close to the others. EU origin of BS cows had higher observed and estimated milk yields than TR origin, while TR origin JR cows had higher observed and estimated milk yields than EU origin counterparts (P<0.01). Observed and estimated milk yield were higher for autumn-winter season compared to the spring-summer season in both breeds (P<0.01). With this approach, Wood's curve model was able to make a successful prediction in terms of lactation dynamics and environmental factors affecting production for both breeds. Moreover, results with sufficient accuracy were obtained with the Wood model in terms of breed-origin and environmental factors (breeding region, parity, calving season and year) affecting lactation curve parameters. The factors such as year of calving, season of calving and parity were the most important factors that accounted for the majority of the variation.

Keywords: Brown Swiss, Dairy cattle, Environmental factor, Jersey, Lactation curve

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Date of initial submission: 10-09-2023
Date of acceptance: 15-09-2023

INTRODUCTION

A successful prediction of the lactation curve and the effects of environmental factors affecting production parameters are crucial or decision-making in dairy production (Macciotta et al., 2005). Several mathematical models are suggested for fitting the estimated values of daily yields considering data from different regions and different dairy cattle breeds (Koncagül and Yazgan, 2008; M'Hamdi et al., 2021; Piccardi et al., 2017). Three parameters (a, b and c) are the popular and valid nonlinear models to date for describing lactation curves by Wood (1967). The inclusion of additional characteristics tries to capture specific variations in lactation curves, some of which influenced by genetics and others by environmental factors (Li et al., 2022; Macciotta et al., 2005). Better understanding of the gene effects can be gained by predicting them with production curves, which can be used to create genetic groupings (Strucken et al., 2011). Numerous studies highlighted the significance of environmental influences on lactation dynamics such as calving season, birth type, year of calving, parity, mastitis (Andersen et al., 2011; Atashi et al., 2012; Boujenane and Hilal 2012; Kopec et al., 2013; Ray et al., 1992; Yenilmez et al., 2022). Due to this feature, lactation curves exhibit significant variability that cannot be adequately modeled using traditional fixed effects models.

In terms of population, the Holstein and Simmental cattle breeds are followed by the Brown Swiss (BS) and Jersey (JR) breeds in Turkey. Therefore, the purposes of this research were to estimate the effects of environmental factors on lactation curve parameters of BS and JR cows in Türkiye. Only a few studies of the lactation curve in Türkiye BS and JR cattle have been conducted, using information from local data (Abacı et al., 2020; Cankaya et al., 2011; Çakıllı and Güneş, 2012; Kaygısız et al., 2003; Okuyucu et al., 2018). Therefore, this study aimed to compare and assess potential functions for their capacity to predict lactation curves from BS and JR cows raised in Türkiye under different geographical regions and the origin of cows.

MATERIAL AND METHOD

Data sources

In this study, a total of 22,955 head of BS (52,465 lactation) and 5,178 head of JR (9,060 lactation) cows were used. The total number of lactations were 61,525. Lactation data were obtained from 'Cattle Breeder Association' collected from commercial farms using milk recording system over a 23-year period (2000-2022). Animals with a lactation period ranging from a minimum of 150 days to a maximum of 400 days were included. Milk yield data used for 305 days in five lactations (1-5) and excluded less than 5 kg and more than 40 kg.

Environmental Factors

In the statistical model, two different breeds, BS (1) and JR (2) were divided into three regions according to variation of farm in geographical regions. Regions were grouped to ensure that animal numbers by region climate to provide meaningful results in statistical analysis. While the regions were grouped, three groups were formed that were similar in terms of climate. Reg-1: Aegean-Marmara-Mediterranean (AMM), Reg-2: Central-Eastern-Southeastern Anatolia (CESA), and Reg-3: Black Sea (BS). According to origin, cows are divided into two categories born in Europe (EU) and in Türkiye (TR). Lactation number, season of calving and year (2000-2022) were included in the statistical model. Calving season is divided into two categories: autumn-winter (AW) and spring-summer (SS). The least squares model was used in the analysis of the effects of environmental factors on the observed (OY) and estimated (EY) daily milk yield and model parameters (a, b and c). Statistical analyzes were performed with the Proc Glm/lsmeans (SAS, 2013) method and Tukey multiple comparison method was used to compare the subgroup means.

Statistical Model

The model was:

$$Y_{ijklmno}$$

$$\mu + B_i + O_j + R_k + CS_l + P_m + CY_n + (B*O)_{ij} + (B*R)_{ik} + (B*S)_{il} + (B*P)_I + (B*CY) + e_{ijklmno}$$

$Y_{ijklmno}$ a, b, c, OY or EY,

μ overall mean,

B_i= fixed effect of ith breed (i=1, 2),

O_j fixed effect of origin (J=1-2)

R_k fixed effect of jth region (k=1-3),

CS_l fixed effect of season (l=1-2),

P_m fixed effect of parity (m=1-5)

CY_n fixed effect of mth calving year (n=1-2)

$(B * \ldots)_{i\ldots}$ fixed effect of interaction between breed with the other fixed factors in the model,

$e_{ijklmno}$ random residual

Levels of factors in the model were defined as:

Breed (B): 2 groups as Brown Swiss and Jersey,

Origin (O): 2 groups as Europe, Turkey,

Region (R): 3 groups as, AMM, CESA, BS

Calving Season (s): 2 groups as autumn-winter (AW) and spring-summer (SS)

Parity (P): 5 groups as 1-5 lactation

Calving year (CY): 23 groups as 2000-2022,

Curve Models

In this study six different lactation curve models (Wood, Wilmink, Sikka, Gou and Swalve, Nelder ve Cobby ve Le Du) were used for fitting milk yield data in individual lactations (Table 1). Yt is the milk yield in lactation day t for all models. The scaling factor in parameter 'a' represents the yield at the start of lactation, while the factors in parameters 'b' and 'c' correspond, respectively, to the inclining and falling slopes of the lactation curve. The mean R^2 (the square of the correlation coefficient between the actual milk yield and the milk yield predicted by the model), the residual standard deviation (RSD), and the difference between the observed and estimated lactation milk yields were the metrics used to compare the models. Models with a lower RSD and greater R^2 were considered to be superior.

RESULTS AND DISCUSSION

Table 1. show the R^2 and RSD values for all lactation records for six models. Except for the Cobby and LeDu model, the explanatory capacity for the lactation curve models was quite high and the R^2 (0.95 to 0.99) and RSD (0.97 to 1.03) were found to be close to the others.

The R^2 and RSD values are the most important variables to take into account when assessing the applicability of various lactation curve models for expressing milk yield characteristics (Fernández et al., 2002). The ideal model is the one with the lowest RSD and highest R^2 coefficient. Although the RSD value is low (0.06) in the Nelder model, it was not preferred due to the deficiencies in parameter estimations. Similar outcomes have been reported in earlier studies despite the fact that the high level of accuracy of the models depends on how the data is organized (Cankaya et al., 2011). The Wood model appears to be superior as a good model for Brown Swiss and Jersey cows. Wood's model to successfully anticipate the dynamics of lactation and the effects of the environment on production for both breeds. Results using the Wood model were sufficiently accurate in terms of genetic (breed, origin) and environmental (region, parity, calving season, year) influences on lactation processes.

The calving season had effect ($P<0.01$) on the lactation curve in both breeds (Table 2). Milk yield of OY and EY levels were higher AW season compared to the SS season for the lactation starting in both breeds ($P<0.01$). Curve parameters of 'a', 'b' and 'c' values affected season and breed interaction. Lactation initial milk yield (a) was highest in AW for both breeds ($P<0.01$). The highest milk yield was reported during the winter in several research (Hamdi et al., 2021; Koncagül and Yazgan 2008; Li et al., 2022). Calving season findings of this investigation agree with Ray et al. (1992), Albarran-Portillo and Pollot (2011), and Barash et al. (2001) who reported that total milk production was higher in the fall and winter than in the spring and summer according to the study's findings. Li et al. (2022) reported that the estimates for the 305-day milk output for lactations beginning during the hot season, specifically from May to September, were lower than average which could result from neg-

Table 1. Model equations and criteria (R^2 and RSD) used for comparison of the mathematical models for the milk yield.

Model	Model Equation	R^2	RSD
Wood	$Y_{(t)}\ at^{b} e^{ct}$	0.99±0.001	1.03±0.002
Wilmink	$Y_{(t)}\ a + be^{-kt} + ct$	0.95±0.001	1.91±0.005
Sikka	$Y_{(t)}\ a\, e^{(bt-ct^{2})}$	0.99±0.001	1.02±0.002
Gou and Swalve	$Y_{(t)}\ a + b\, t^{1/2} + c\, \log(t)$	0.99±0.001	0.97±0.003
Nelder	$Y_{(t)}\ \frac{t}{a} + b\, t + c\, t^{2}$	0.99±0.001	0.06±0.020
Cobby and LeDu	$Y_{(t)}\ a - b\, t - a\, e^{(-ct)}$	0.71±0.001	4.90±0.011

ative effects of heat stress. Similarly, M'Hamdi et al. (2021) reported heat stress had a significant effect on the parameters of the lactation curve (*a, b,* and *c*). In this study, calving season took place in the SS, the rate of rise in the pre-peak period (b) was the lowest, similar to what M'Hamdi et al (2021) reported the parameter describing the ascending phase (b) of the lactation curve also tends to decrease with THI. The findings indicated that the calving season had an impact on the lactation curve parameters. Comparing the lactation parameters of cows that calved over different seasons should take this factor into account (Copec et al., 2013).

For both breeds, the BS region had the lowest OY and EY mean (P<0.01). However, while OY and EY

Table 2. Least square means and SE of observed (OY) and estimated (EY) daily milk yield, and Wood model parameters (a, b, c, R^2).

Region	Breed	n	OY	EY	a	b	c	R^2
AMM	BS	33,566	**22.3±0.04^{b}**	**22.3±0.19^{a}**	**24.6±0.06^{a}**	0.32±0.006^{b}	0.10±0.001^{c}	0.989±0.0001
	JR	18,497	20.8±0.08^{c}	21.0±0.43^{ab}	**23.8±0.13^{b}**	0.27±0.013^{cd}	0.09±0.003^{cd}	0.992±0.0002
CESA	BS	141,468	20.3±0.03^{d}	20.3±0.13^{b}	23.3±0.04^{c}	0.31±0.004^{bc}	0.11±0.001^{b}	0.991±0.0001
	JR	1,826	23.1±0.20^{a}	**23.3±0.97^{a}**	23.4±0.30^{bc}	**0.48±0.029^{a}**	**0.13±0.007^{a}**	0.994±0.0006
BS	BS	2,813	19.3±0.12^{e}	19.3±0.61^{bc}	21.6±0.19^{e}	0.23±0.018^{de}	0.08±0.005^{d}	0.991±0.0004
	JR	12,926	**17.6±0.07^{f}**	**17.6±0.38^{c}**	22.5±0.12^{d}	0.20±0.011^{e}	0.10±0.003^{bc}	0.993±0.0002
Origin								
EU	BS	49,597	**22.7±0.07^{a}**	**22.7±0.35^{a}**	**24.5±0.11^{a}**	0.28±0.011^{bc}	0.09±0.003^{c}	0.993±0.0002^{b}
	JR	20,264	19.9±0.05^{c}	19.9±0.44^{b}	22.8±0.14^{c}	0.25±0.013^{c}	0.09±0.003^{c}	0.992±0.0003^{b}
TR	BS	128,250	18.6±0.09^{d}	18.7±0.27^{b}	21.8±0.08^{d}	0.29±0.008^{b}	0.10±0.002^{b}	0.989±0.0002^{c}
	JR	12,985	21.1±0.13^{b}	21.3±0.64^{a}	23.6±0.20^{b}	0.39±0.019^{a}	0.12±0.005^{a}	0.994±0.0004^{a}
Season								
AW	BS	89,026	20.9±0.05^{b}	**21.0±0.24^{a}**	22.9±0.07^{c}	0.32±0.007^{b}	0.10±0.002^{b}	0.991±0.0001^{c}
	JR	15,207	**21.6±0.09^{a}**	**21.7±0.47^{a}**	**24.1±0.14^{a}**	**0.36±0.014^{a}**	**0.11±0.004^{a}**	0.993±0.0003^{b}
SS	BS	88,821	20.4±0.05^{c}	20.3±0.24^{b}	23.4±0.07^{b}	0.26±0.007^{c}	0.09±0.002^{c}	0.991±0.0001^{c}
	JR	18,042	19.5±0.09^{d}	19.6±0.46^{b}	22.4±0.14^{d}	0.28±0.014^{bc}	0.10±0.004^{bc}	0.994±0.0003^{a}

*Region; AMM; Aegean-Marmara-Mediterranean, CESA; Central-East-South-Anatolia, BS; Black Sea, Origin: EU; European origin and TR; Türkiye origin, Breed: BS; Brow Swiss, JR; Jersey, Season: AW; autumn-winter and SS; spring-summer. Means in the same column with different letters indicate significant differences (P < 0.05);

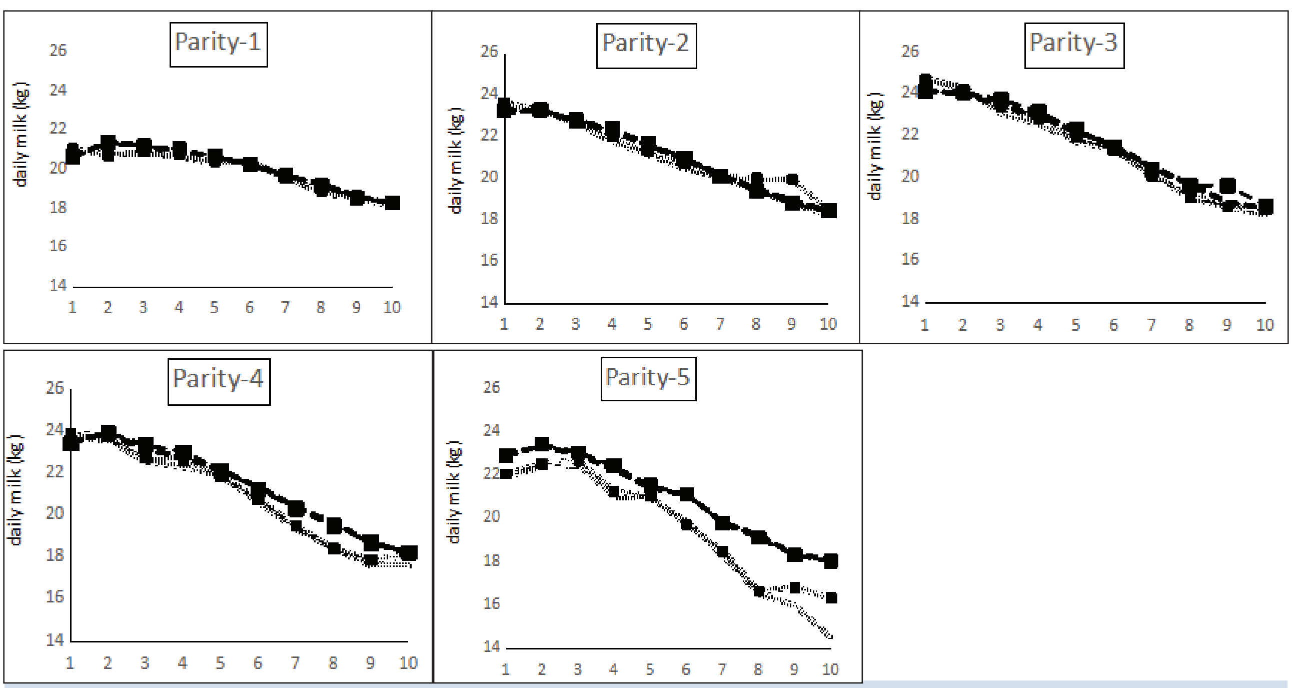

Figure 1. Lactation curves of observed and estimated milk yield (■) for Brown Swiss and (- -) and Jersey (. .) cows according to parity.

values were found to be highest in the AMM region for BS, they were highest in the CESA region for JR (P<0.01). Differences between lactation curve between intensive and small scale production systems has been reported by Val-Arreola et al. (2004) on shape of the lactation curve showed more pronounced for small-scale dairy systems. The large variations in herd characteristics found in this study appear to be the management practices of herds. This showed a wide range of diversity in the herd size and management practices, which affected how well each cow performed individually.

According to the results of OY and EY, EU origins had higher milk yield in BS, while TR origins had higher milk yield in JR cows (P<0.01). Initial milk yield (a) was highest in TR origin for JR cows while EU origin higher in BS cows (P<0.01). Lactation parameter coefficients of pre-peak slope (b) and af-

Table 3. Least square means and SE of observed (OY) and estimated (EY) daily milk yield, and Wood model parameters (a, b, c, R^2) by parity.

Breed	Parity	OY	EY	a	b	c	R^2
	1	**19.7±0.05^{f}**	19.6±0.25^{de}	**20.9±0.08^{f}**	**0.26±0.007^{ef}**	**0.08±0.002^{e}**	0.992±0.0001^{c}
	2	20.6±0.05^{d}	20.6±0.26^{bc}	23.4±0.08^{e}	0.26±0.008^{cde}	0.09±0.002^{d}	0.991±0.0001^{de}
BS	3	**21.2±0.05^{ab}**	**21.5±0.27^{a}**	**24.2±0.08^{b}**	0.28±0.008^{ac}	0.10±0.002^{abc}	0.990±0.0002^{f}
	4	21.1±0.06^{b}	21.0±0.30^{abc}	23.9±0.09^{c}	0.32±0.009^{b}	0.11±0.002^{ab}	0.990±0.0002^{f}
	5	20.7±0.07^{cd}	20.7±0.34^{abc}	23.4±0.10^{d}	0.31±0.010^{b}	0.10±0.003^{abc}	0.990±0.0002^{ef}
	1	**18.9±0.08^{g}**	18.9±0.41^{e}	**20.2±0.13^{g}**	0.33±0.012^{b}	0.10±0.003^{cd}	0.993±0.0002^{b}
	2	20.2±0.09^{e}	20.4±0.46^{abcd}	23.5±0.14^{de}	0.25±0.014^{ce}	0.09±0.004^{cd}	0.994±0.0003^{a}
JR	3	**21.5±0.12^{a}**	**21.6±0.60^{abcd}**	**24.8±0.19^{a}**	0.30±0.018^{abde}	0.11±0.005^{abcd}	0.992±0.0003^{bc}
	4	21.2±0.15^{ab}	21.4±0.77^{abcd}	24.3±0.24^{abc}	0.34±0.023^{abd}	0.12±0.006^{a}	0.992±0.0004^{bcd}
	5	20.6±0.22^{bcde}	20.8±1.12^{abcde}	23.3±0.35^{bcd}	**0.36±0.034^{abdf}**	**0.12±0.009^{a}**	**0.994±0.0006^{ab}**

*Region; AMM; Aegean-Marmara-Mediterranean, CESA; Central-East-South-Anatolia, BS; Black Sea, Origin: EU; European origin and TR; Türkiye origin, Breed: BS; Brow Swiss, JR; Jersey, Season: AW; autumn-winter and SS; spring-summer. Means in the same column with different letters indicate significant differences (P < 0.01);

ter-peak slope (c) were higher in TR origin comparing EU origin for both breeds (P<0.01).

There has been evidence that parity has an impact on the lactation curve's form (Lopez et al., 2015; Rekik and Ben Gara, 2004; Val-Arreola et al., 2004). In this study parity had an effect on the lactation curve parameters in BS and JR cows (P<0.01; Table 3). In both breeds, the third lactation had the highest milk yield, while the first lactation gave the lowest milk yield (P<0.01). In both breeds, the lactation curve differed depending on parity. Initial milk yield (a) increased with parity and the highest milk yield was reached in the third parity. Similar results from earlier studies were observed in the impact of parity on lactation curves. Val-Arreola et al. (2004) reported differences between parity related to the presence or absence of peak of production than to a more gradual decline in second and higher lactations. Lactation parameter coefficients of pre-peak slope (b) and after-peak slope (c) were increased with advancing (4-5) parity for both breeds (P<0.01). It has been reported that total milk yield reaches its maximum at third lactation (Ben Gara et al., 2006) and (Albarran-Portillo and Pollot, 2011) which agrees with findings in this study. Similarly, Ray et al. (1992) reported first lactation cows had lowest milk production, and highest production occurred in either lactation 4 or 5 parity.

An accurate modeling of lactation curves is important in the management and breeding of dairy cattle. Opposed to cows with a steep lactation curve, flat lactation curves have advantages for management and fertility qualities (Wood, 1967). Estimating dairy productivity indicators can be done with fitted lactation curves. Higher producing cows reach their peak production during the first several weeks of lactation, and the high energy requirement surpasses the energy in the feed (Strucken et al., 2011).

In conclusion, Wood's model successfully anticipate the dynamics of lactation and the effects of the environment on production for both Brown Swiss and Jersey cows. The lactation curve's form and an estimate of the milk yield at a specific stage of lactation are determined by the Wood's function's parameters. The factors such as year of calving, season of calving and parity were the most important factors that accounted for the large amount of the variation.

ACKONWLEDGEMENT

The author is grateful to Cattle Breeders Associations to access to the production data used in this study. I special thanks to Seyrani Koncagül for his valuable support to conduct this study.

CONFLICT OF INTEREST

The author declare have no competing interest.

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