ajava
Asian Journal of Animal and Veterinary Advances

Academic
Journals Inc.

www.academicjournals.com

Asian Journal of Animal and Veterinary Advances, 4 (3): 122-129, 2009
ISSN 1683-9919

Modeling Lactation Curves of Turkish Saanen and Bornova Goats

[1]Çiğdem Takma, [1]Yavuz Akbaş and [2]Turgay Taskin
[1]Unit of Biometry-Genetics, Department of Animal Science, Faculty of Agriculture, Ege University, Bornova 35100, İzmir, Turkey
[2]Unit of Animal Husbandry, Bornova 35100, İzmir, Turkey

Abstract: Lactation curves of 23 Bornova (25% White German×25% Maltase×50% Anglo-Nubian crossbreed) and 37 Turkish Saanen dairy goats were estimated in this study. Individnal 427 test-day milk yields were recorded monthly from lambing to drying off. The Wood (WD) and Cobby and Le Du (CL) models were applied to estimate lactation curve parameters of the two breeds. The WD model had greater a parameter (average milk yield at the beginning of the lactation) than CL model. The difference between breeds was significant ($p<0.05$) for the b parameter related to slope up to peak yield. The two models estimated significantly different pattern of the decline in milk production. Coefficient of determination values (R^2) of the models were high and ranged from 0.83 to 0.91. The CL model showed better performance than WD model. Lactation curve characteristics including Peak Yield (PY), Time to Peak Yield (TPY), Total Milk Yields (TMY) and Persistency (P) were also estimated using WD, CL and Fleischmann (FL) methods. WD and CL models forecasted higher PY and earlier TPY in comparison with the FL. TMY and P from two models were lower than those from FL. The effect of breed was significant ($p<0.05$) on TPY. Correlation coefficients among lactation curve characteristics were ranged from -0.29 to 0.78. The results suggest that CL model was better for the fitting of the test-day milk yields of Turkish Saanen and Bornova goats.

Key words: Lactation curve, test day milk yield, Bornova, Saanen, goat

INTRODUCTION

The lactation curve can be a valuable tool to the breeders for making management decisions such as feeding, mating and culling, which have an impact on the economics of milk production in dairy farms. The knowledge of lactation curve shape and effects of environmental factors on this curve can be used to evaluate the biological efficiency of production (Grossman and Koops, 1988). This information is also useful for determining milk strategies at the farm level. The lactation curves provide information about the pattern of milk production, which can be used to identify those breeds, group of animals or individnals with steady production throughout the lactation period and those with a high level of production until the peak, but a substantial decline thereafter. Moreover, it can help to identify sick animals before clinical signs appear such as those animals with decreased milk production from sub-clinical mastitis (Dudouet, 1982).

If the aim of the breeder is to manipulate characteristics of the lactation curve genetically, estimates of genetic parameters for individnal curves would be needed. Thus, it is important to determine whether or not there are genetic differences among shapes of the curves. It might be necessary to consider those differences into account for genetic evaluation and selection.

Corresponding Author: Çiğdem Takma, Unit of Biometry-Genetics, Department of Animal Sciences, Faculty of Agriculture, Ege University, Bornova 35100, İzmir, Turkey

On the other hand, improvement of the genetic models for evaluation of milk yields has produced new characteristics such as peak yield and persistency (Wiggans and Gengler, 1999). Such characteristics describe shape of the lactation curve (Pala and Savaş, 2005) and can be used as selection criteria (Togashi and Lin, 2004). In these respects, lactation curve has been proposed by EC governments to predict and monitoring milk production (Goodall, 1986; Goodall and Agnew, 1988). For this purpose, several noulinear models as Wood (1967), Cobby and Le Du (1978), Dhanoa (1981) and Wilmink (1987), Multiphasic logistic (Grossman and Koops, 1988) and Cappio-Borlino (Cappio-Borlino *et al*., 1995) models have been used to fit the goat lactation curves for milk yields (Gipson and Grossman, 1989; De Boer *et al*., 1989; Portolano *et al*., 1996; Franci *et al*., 1999; Chang *et al*., 2001; Fernandez *et al*., 2002). Particularly, most of the studies reported that Wood model adequately described the lactation milk yields of various dairy goats (Ruvuna *et al*., 1995; Montaldo *et al*., 1997; Fernandez *et al*., 2002; Rosa *et al*., 2006); dairy ewes (Wahome *et al*., 1994; Cappio-Borlino *et al*., 1995; Portolano *et al*., 1996). However, little research has been done on fitting lactation curve models in goats as compared with dairy cows. In addition, the predictions of peak yields, time at peak yield, total milk yield and persistency based on test-day milk yields using nonlinear models are not available for Turkish Saanen and Bornova goats. The aims of this study were modeling test-day milk yields of Turkish Saanen and Bornova goats using noulinear lactation curves and to estimate the breed difference in terms of lactation curve parameters.

MATERIALS AND METHODS

Data

The present study was conducted at Agricultural Faculty Experimental Farm of Ege University, Izmir, Bornova, located at the western part of Turkey at coordinates of 38°28 north latitude, 27°15 North longitude and an altitude of 27 m above sea level. Bornova has typical Mediterranean climate, with hot dry summers and warm wet winters. The average temperature is 18°C. Snow fall is extremely rare and approximately 148 days of the year are clear and sunny.

The experiment was took place on two goat breeds, Bornova (25% White German × 25% Maltase × 50% Anglo-Nubian crossbred) and Saanen. The average lactation length of Bornova goats is 193 days and average lactation milk yield is 246 kg (Sengonca *et al*., 2000; Akbas *et al*., 2006). The Turkish Saanen goats have average lactation length of 150-180 days and average lactation milk yield of 180-200 kg (Sengonca *et al*., 2000; Akbas *et al*., 2006). Goats were milked twice daily by hand (8:30 and 16:00 h) and the individual test-day milk yield was calculated by summing milk yields from these two milkings. Test-day milk records were collected monthly from kidding until drying off. A total number of 427 milk yield records of 60 goats (23 Bornova and 37 Saanen) from the time period 2000 to 2001 were used to fit lactation curve models. For test-day milk records, the genotype differences based on the factors of age, parity and month of kidding factors were found not statistically significant ($p>0.05$). Therefore, these factors were not considered in this study.

Kidding occurred in February and March. Free suckling was allowed and all kids were reared with their dam until 60±5 days of age, after that age kids were weaned as a common practice in the region. Therefore, most goats had their first test-day milk record nearly 60 days post partum. Kids were encouraged to consume roughage (Alfalfa) and concentrate mixture feed as ***ad-libitum*** to stimulate their rmminal activity. Concentrate mixture was containing 16% crude protein and 2600 kcal kg^{-1} ME. The goats used in this study were free brucellosis and tuberculosis. They were also vaccinated against enzootic abortion, para-tuberculosis, contagious agalactia and enterotoxaemia.

Statistical Analysis

The different lactation curve models mentioned before were fitted individually to test-day milk yields of goats. After the preliminary analysis, the Wood (WD) and Cobby and Le Du (CL) models with their parameters have been chosen to give fitting results of two breeds.

Table 1: Equations, peak yields (PY) and time at peak yield (TPY) functions of used models

Model	Equation	PY	TPY
Wood	$y_t = A.t^b \exp^{(-c.t)}$	$A(b/c)^b e^{-b}$	b/c
Cobby Le Du	$y_t = A\text{-}b.\ t\text{-}A^{\exp(-c.t)}$	$c^{-1}\ln(Ac/b)$	ln(Ac/b)

y_t: Milk production in month t, A: Constant associated with the average milk yield at the begiuning of the lactation, b: The slope parameter up to peak yield, c: The pattern of the decline in milk production, t: The test day (months), e: Base of natural logarithm (2.71828)

Equations of the models and explanations of their parameters were given in Table 1. The CL model was the same as the WD model, but weighed the logarithmic regression line with the inverse of the square of the untransformed production data (Landete-Castillejos and Gallego, 2000).

For the estimation of lactation curve parameters, Levenberg Marquardt iterative procedure (Marquardt, 1963) of non-linear regression was chosen by SPSS statistical program (SPSS, 2002). Starting values for all parameters of the models were taken from previous analyses. Convergence criterion was 1.0E-08. The goodness-of-fit statistics as coefficient of determination (R^2), the Mean Square Error (MSE) and the percentage of squared biases (PSB) were also determined for model comparison. PSB was calculated to obtain deviation values of predicted milk yields from actual one (Ali and Schaeffer, 1987).

$$PSB = \frac{\sum_{i=1}^{n}(y_{ij} - \hat{y}_{ij})^2}{\sum_{i=1}^{n}(y_{ij})^2} \times 100$$

where, n is the number of records, y_{ij} is observed milk yield, $\hat{y}_{ij}$ is predicted milk yield. Furthermore, various lactation curve characteristics, including peak yields (PY, kg), time at peak yield (TPY, wk), total milk yield (TMY, kg) and Persistency P (%) were also calculated. These characteristics were compared with those calculated from Fleischmann official method (FL), (centering date method) (Ruiz *et al*., 2000). General expression of FL method is:

$$TMY = P_1 \times D_1 + \sum_{i=2}^{k} \frac{P_i + P_{i+1}}{2} \times D_i + P_{k+1} \times 15$$

where, D_1 is interval between kidding and first recording, P_1 is milk yield of the record I, D_i is interval between the record I and the record (I+1) (I = 1,….,k) and 15 is assumed number of days between the last recording and the dry-off. For all models, persistency was calculated as:

$$\text{Persistency} = (100 \times TMY_{126\text{-}200}/TMY_{50\text{-}125})$$

where, $TMY_{126\text{-}200}$ is cumulated milk production for days 126-200, $TMY_{50\text{-}125}$ is cumulated milk production for days 50-125. Moreover, analysis of variance (ANOVA) was carried out to test the breed effect on the model parameters and lactation curve characteristics. Correlation among characteristics of WD, CL and FL were also performed.

RESULTS

Least square means of a, b and c parameters from the models are presented in Table 2. The WD model had greater a parameter values than CL. Furthermore, breed difference was detected for parameter b while only model effect was significant (p<0.05) for c (Table 2).

Table 2: Least square means and standard errors (between parentheses) for Bornova and Saanen goats as affected by parameters of models

Models	Breed	A	b	c
Wood (WD)	Bornova	5.78±0.34	0.14±0.007^{a}	0.12±0.53
	Saanen	6.49±0.26	0.13±0.005^{b}	0.14±0.41
	Overall	6.22±0.21^{A}	0.13±0.004^{A}	0.13±0.34^{A}
Cobby Le Du (CL)	Bornova	3.83±0.34	0.11±0.007^{a}	2.01±0.53
	Saanen	4.17±0.28	0.13±0.006^{b}	0.50±0.44
	Overall	4.00±0.22^{B}	0.12±0.004^{B}	1.26±0.35^{B}

^{A,B}The overall mean values within columns with different superscripts are significantly different ($p<0.05$). ^{a,b}The breed mean values within model in the same column with different superscripts are significantly different ($p<0.05$)

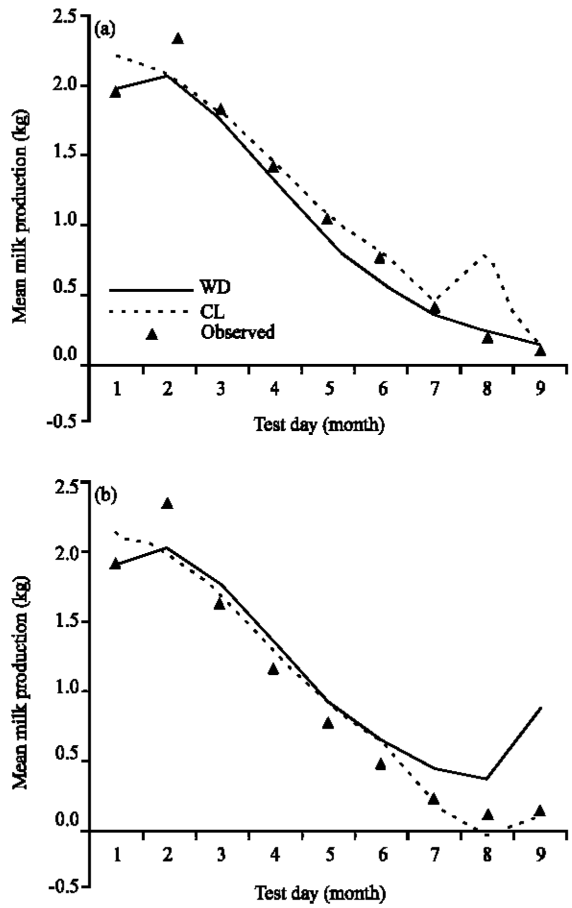

Fig. 1: Observed and estimated lactation curves for (a) Bornova and (b) Saanen goats

Figure 1 shows observed milk yields representing milk production tendency during lactation and lactation curves estimated from WD and CL models for Bornova and Saanen goats.

Observed and estimated lactation curves from WD and CL models for Bornova goats were generally similar (Fig. 1a). However, CL model overestimate milk yield at the first test day while second test day milk yield was underestimated by WD and CL models. The same tendency was valid for Saanen goats during initial part of lactation (Fig.1b). Considering the last part of the lactation, models show different behaviors for various breeds. CL for Bornova, WD for Saanen goats shows highly overestimated pattern after 6th test day (Fig. 1a, b). After 8th test day, overestimated milk production of Bornova goats was sharply decreased in CL model (Fig. 1a).

Table 3: R^2, MSE and PSB values of WD and CL model for Bornova and Saanen goats

	Model			
	Wood		Cobby Le Du	
Goodness-of-fit statistics	Bornova	Saanen	Bornova	Saanen
R^2	0.86	0.83	0.90	0.91
MSE	0.13	0.15	0.09	0.08
PSB	6.35	8.66	3.18	3.35

Table 4: Least square means, standard errors for Bornova and Saanen goats effects on PY, TPY, TMY and P

Model	Breed	PY (kg)	TPY (wk)	TMY (kg)	P (%)
Wood (WD)	Bornova	0.73±0.06	1.31±0.22^a	294.85±30.27	29.67±3.49
	Saanen	0.81±0.04	0.99±0.18^b	259.99±24.20	25.05±2.79
	Overall	0.77±0.04^B	1.06±0.14^C	277.42±19.37^B	27.36±2.24^B
Cobby Le Du	Bornova	1.29±0.06	2.58±0.23^a	349.84±30.27	52.48±3.49
(CL)	Saanen	1.22±0.05	1.91±0.19^b	320.15±26.08	49.41±3.00
	Overall	1.25±0.04^A	2.05±0.14^B	334.99±19.97^{AB}	50.95±2.30^A
Fleischmann	Bornova	0.37±0.06	3.39±0.22^a	376.61±30.27	59.22±3.49
(FL)	Saanen	0.28±0.04	3.09±0.18^b	330.17±24.20	52.61±2.79
	Overall	0.33±0.04^C	3.25±0.14^A	353.39±19.37^A	55.91±2.24^A

$^{A-C}$The overall mean values within columns with different superscripts are significantly different ($p<0.05$). ^{a,b}The breed means within model in the same column with different superscripts are significantly different ($p<0.05$)

Table 5: Correlations among PY, TPY, TMY and P in Bornova and Saanen goats by lactation curve model

		Bornova		Saanen	
Traits	Models	CL	FL	CL	FL
PY	WD	0.10	0.59**	0.01	0.64**
	CL		0.22		0.18
TPY	WD	0.02	0.08	0.133	0.34*
	CL		0.29		0.14
TMY	WD	-0.29	-0.20	0.38*	0.04
	CL		0.35		-0.08
P	WD	0.55**	0.78**	0.75**	0.65**
	CL		0.27		0.55**

* $p<0.05$; ** $p<0.01$

According to these comparison criteria, all models had high R^2 values ranged from 0.83 to 0.91. However, CL model had slightly higher R^2 values than WD model. WD model fit Bornova goat's milk production better than Saanen while CL fits milk production of Bornova and Saanen goats in equal performance. Contrary to R^2 values, MSE and PSB values of WD model were higher as compared with those from CL model (Table 3).

Model significantly affect all lactation curve characteristics. PY was changed from 0.28 to 1.29 and the highest in CL model and lowest in FL method. Irrespective of goat breed, the TPY were 3.25, 2.05 and 1.06 for FL, CL and WD, respectively. Moreover, TMY and P were similar in CL and FL. TMY from FL was higher than the estimated total milk yields from WD and CL models (Table 4).

Evidence for breed difference was found significant only on TPY (Table 4). Bornova goats had longer period to peak yield than Saanen goats.

The correlation coefficients among lactation curve characteristics in this study ranged between -0.29 to 0.78. The correlations among PY, TPY and P estimated from WD, CL and FL for the two breeds were positive and some of them statistically significant ($p<0.05$ or $p<0.01$). Correlation among models in terms of TMY were adverse in the two breeds (Table 5).

DISCUSSION

Several models fit differently the test day milk yields of goats. In this study, lactation curve parameters of WD and CL models are different. The a parameter, which represent estimated production after kidding, was higher for the Bornova and Saanen goat breeds from WD (5.78 and 6.49) than those from CL model (3.83 and 4.17), respectively. The b parameters, responsible for the rising phase of the curve, showed almost similar range (0.11-0.14) for all models. However, the c parameters, which represents the pattern of the decline in milk production, were higher (2.01 and 0.50) in CL model than WD. This agrees with findings from Fernandez *et al*. (2002) fit test day milk yields of Murciano-Granadia goats. The lactation curve parameters of Bornova and Saanen goats were generally similar. However, b parameter was different between the two breeds not ouly in WD but also in CL. Montaldo *et al*. (1997) reported that breed effect was significant on estimation of all WD model parameters. Moreover, Rosa *et al*. (2006) found that breed and type of birth had significant influence on a and b parameters of the WD model.

In generally, estimated shapes of the lactation curves of Bornova and Saanen goats were similar with the shape of observed milk production curve, except for the extremes parts of the lactation. The fitted curves from WD and CL models displayed underestimated milk yields at the beginning of the lactation. Sakul and Boylan (1992) explained this problem reporting that possible cause for such underestimation was resulted in delayed collection of milk data when the curve begins to decline. Likewise in this study, first milk record was taken nearly at 60 days after kidding when the curve had already begun nearly to decline. In Turkey, free suckling is allowed to all kids until 60±5 days of age, then they are weaned. For this reason, data records after about 60 days of age were considered in this study. This might directly affect the estimation of parameters a, b, TPY and TMY.

Moreover, CL model fit the Saanen yield data better than the WD model, in other words, WD model over predicted milk yields of Saanen goats at the late lactation. This finding is consistent with results of the Montaldo *et al*. (1997) revealed that the WD model over predicts milk production during early and late lactation.

Throughout the present study, R^2 values of two models were almost higher. This result is indicating that proportion of error variance is small in total variances and thus suggesting good fit of the models to the data. WD model showed lower R^2 and higher MSE and PSB values than those of obtained from CL model. R^2 values of WD model in this study were lower than those reported by Montaldo *et al*. (1997), Ruvuna *et al*. (1995), Fernandez *et al*. (2002) and Keskin and Dağ (2006) and were higher than the results found by Felix *et al*. (1999).

The goodness-of-fit statistics were also changed according to the breed. By fitting WD model, Saanen goats had worse fitting performance than Bornova. On the contrary, Saanen goats showed better fitting by using CL model. Different milk production levels and their variation throughout lactation of the Bornova and Saanen goats might be responsible for this discrepancy.

In the present study, outcomes of PY and TPY values were the nearly similar with those of Ruvuna *et al*. (1995), but lower than estimates of Montaldo *et al*. (1997) and Fernandez *et al*. (2002). Moreover, for the lactation curve characteristics, the WD and CL models forecasted peak yield higher and earlier in comparison with the FL method. Portolano *et al*. (1996) fit the lactation of Comisana sheep and found that the WD model forecasted peak yield earlier and lower when comparing to the Cappio-Borlino model.

Although breed difference was detected on TPY, there was no breed difference on PY and TMY in this study, contrary to Ruvuna *et al*. (1995) and Montaldo *et al*. (1997). At the same time, TMY and P from WD model were lower than the values from CL model. Also, TMY and P for WD and CL models were lower than values of the FL method. It could be as a result of 15 days longer productive period after last recording in FL method. The P estimates from WD model were almost 20% lower than FL and CL estimates. It can be seen how the total milk production was influenced by the P of lactation.

Though there was no breed difference on P in this study, Felix *et al*. (1999) demonstrated that breeds influenced on PY and P by using WD model. Evidence for a breed effect on P was also found by Ruvuna *et al*. (1995) and Montaldo *et al*. (1997).

In general, the PY, TPY and P characteristics for milk yields were positively correlated. Particularly, the correlations between real (FL) persistency and persistency of WD and CL were almost positive and significantly correlated and WD model showed higher coefficients than CL model for all characteristics. On the other hand, TMY from WD model was negatively correlated with TMY from CL and real TMY in Bornova goats, while these correlations were positive in Saanen goats. Similarly, Keskin and Dağ (2006) used the several lactation models on milk yield estimation of Akkaraman ewes and they had higher correlation among lactation curve characteristics.

CONCLUSION

It can be concluded that fitting performance of the WD and CL models to Bornova and Saanen goat's milk yields were sufficient. Although WD model is common in use and recommended for fitting milk yields of dairy cattle, goat and sheep, the CL model was found to be more powerful to estimate milk production of goats due to higher R^2 and lower MSE and PSB values. The positive correlations between real and CL for the lactation curve characteristics agree with this outcome as tendency. On the other hand, ouly the correlations between real and WD for the lactation curve characteristics were generally significant. These divergent results showed that both models could be use for the same purpose. In addition to that, breed might be significant effect on lactation curves parameters and characteristics. Further researches are needed to understand the predictive power of models and breed effect with more and complete lactation records of Bornova and Saanen goats.

REFERENCES

Akbaş, Y., Ç. Takma and T. Taskin, 2006. Variation in lactation curves of saanen and bornova goats. Proceedings of the 30th Conference on Research and Development in Agricultural Engineering, Jan. 24-25, Szent Istvan University, Gödöllö, Macaristan. Summary Book (30), pp: 8-8.

Ali, T.E. and L.R. Schaeffer, 1987. Accounting for covariance among test day milk yields in dairy cows. Can. J. Anim. Sci., 67: 637-644.

Cappio-Borlino, A., G. Pulina and G. Rossi, 1995. A non-linear modification of Wood's equation fitted to lactation curves of Sardinian dairy ewes. Small Rumin. Res., 18: 75-79.

Chang, Y., R. Rekaya, D. Gianola and D.L. Thomas, 2001. Genetic variation of lactation curves in dairy sheep: A Bayesian analysis of Wood's function. Lives. Prod. Sci., 71: 241-251.

Cobby, J.M. and Y.L.P. Le Du, 1978. On fitting curves to lactation data. Anim. Prod., 26: 127-133.

De Boer, J.A., J.I. Weller, T.A. Gipson and M. Grossman, 1989. Multiphasic analysis of milk and fat yield curves in Israeli Holsteins. J. Dairy Sci., 72: 2143-2152.

Dhanoa, M.S., 1981. A note on an alternative form of the lactation model of Wood. Anim. Prod., 32: 349-351.

Dudouet, E., 1982. Courbe de lactation theorique de la chevre et applications (Theoretical lactation curve of the goat and its applications). Le Point Veterinaire, 14: 53-61.

Felix, A., J. Detilleux and P.L. Leroy, 1999. Comparison of Holstein and Meuse Rhine Yssel lactation curves with three mathematical models. Proceedings of the 50th Annual Meeting of the EAAP, Aug. 22-26, Zürich, pp: 1-1.

Fernandez, C., A. Sanchez and C. Garces, 2002. Modeling the lactation curve for test-day milk yield in Murciano-Granadina goats. Small Rumin. Res., 46: 29-41.

Franci, O., C. Pugliese, A. Acciaioli, G. Parisi and M. Lucifero, 1999. Application of two models to the lactation curve of Massese ewes. Small Rumin. Res., 31: 91-96.

Gipson, T.A. and M. Grossman, 1989. Diphasic analysis of lactation curves in dairy goats. J. Dairy Sci., 72: 1035-1044.

Goodall, E.A., 1986. Prediction of milk and milk solids production. Agric. Syst., 21: 189-200.

Goodall, E.A. and E. Agnew, 1988. A computerized management information system to monitor annual milk production. Agric. Syst., 26: 231-240.

Grossman, M. and W.J. Koops, 1988. Multiphasic analysis of lactation curves in dairy cattle. J. Dairy Sci., 71: 1598-1608.

Keskin, I. and B. Dağ, 2006. Comparison of different mathematical models for describing the complete lactation of Akkaraman ewes in Turkey. Asian Aust. J. Anim. Sci., 19: 1551-1555.

Landete-Castillejos, T. and L. Gallego, 2000. Technical note: The ability of mathematical models to describe the shape of lactation curves. J. Anim. Sci., 78: 3010-3013.

Marquardt, D.W., 1963. An algorithm for least square estimation of non-linear parameters. J. Soc. Ind. Applied Math., 11: 97-109.

Montaldo, H., A. Almanza and A. Juarez, 1997. Genetic group, age and season effects on lactation curve shape in goats. Small Rumin. Res., 24: 195-202.

Pala, A. and T. Savaş, 2005. Persistency within and between lactations in morning, evening and daily test day milk in dairy goats (short communication). Arch. Tierz., 48: 396-403.

Portolano, B., F. Spatafora, G. Bono, S. Margiotta, M. Todaro, V. Ortoleva and G. Leto, 1996. Application of the Wood model to lactation curves of Comisana sheep. Small Rumin. Res., 24: 7-13.

Rosa, I.S., R.D. Rojero, G.T. Hernandez, C.M.B. Perez, A.A.M. Lagunas, J.S. Espinosa and M.R. Rubio, 2006. Milk production and lactation curves in three goat breeds in the dry tropic of Mexico. Vet. Mex., 37: 493-502.

Ruiz, R., L.M. Oregui and M. Herrero, 2000. Comparison of models for describing the lactation curve of Latxa sheep and an analysis of factors affecting milk yield. J. Dairy Sci., 83: 2709-2719.

Ruvuna, F., J.K. Kogi, J.F. Taylor and S.M. Mkuu, 1995. Lactation curves among crosses of Galla and East African with Toggenburg and Anglo Nubian goats. Small Rumin. Res., 16: 1-6.

Sengonca, M., M. Kaymakçi, N. Kosum, T. Taskin and J. Steinbach, 2000. Die Bornova-Ziege: Ein neuer milchziegentyp. In: Planck, U. (Ed.). Deutsch-Tür-Kische Agrarforschung. 6. Symposium vom, Sept. 27-Oktober 2, 1999 an der Justus-Liebig Universität Giessen, Germany, pp: 295-301.

SPSS INC., 2002. SPSS for windows release 11.5. Chicago.

Sakul, H. and W.J. Boylan, 1992. Lactation curves for several US sheep breeds. Anim. Prod., 54: 229-233.

Togashi, K. and C.Y. Lin, 2004. Efficiency of different selection criteria for persistency and lactation milk yield. J. Dairy Sci., 87: 1528-1535.

Wahome, R.G., A.B. Carles and H.J. Schwartz, 1994. An analysis of the variation of the lactation curve of small East African goats. Small Rumin. Res., 15: 1-7.

Wiggans, G.R. and N. Gengler, 1999. Strategies for combining test-day evaluations into an index for lactation performance. J. Dairy Sci., 82: 102-102.

Wilmink, J.B.M., 1987. Adjustment of test-day milk, fat and protein yield for age, season and stage of lactation. Livest. Prod. Sci., 16: 335-348.

Wood, P.D.P., 1967. Algebraic models of the lactation curves for milk, fat and protein production with estimates of seasonal variation. Anim. Prod., 22: 35-40.