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Original Contribution

A STUDY OF THE LACTATION BIOMETRY OF BLACK AND WHITE DAIRY COWS RAISED IN PRIVATE FARMS IN TURKEY

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ABSTRACT

Generally, dairy cattle, as controls, are used in estimating lactation yields in dairy cattle farms. But this is a source of additional cost, especially in family scale operations. This study aims at providing the Wood model, Goodall model and Grossman model as alternative solutions and as models for estimating lactation yields by use of lactation curves. The differences between expected and observed lactation curves, obtained from data grouped according to the number of lactation, were used as a test criterion for choosing best-fitted models. The relevant parameters of lactation curves were processed mathematically. Two different populations of Turkish cattle were used in this research: 25 heads of Black and White cattle and another 48 heads of Black and White cattle, the two groups obtained from different parts of the country. The Grossman model had highest coefficient of determination. Goodall and Wood methods had second and third highest values of coefficient of determination, respectively. The highest and lowest non-standard lactation curves obtained in all models and populations were 36,20 % and 17,40 %, respectively.

Key Words: Lactation Yield, Lactation Curve, Wood Model, Goodall Model, Grossman Model.

INTRODUCTION

Genotype and environment are main factors affecting lactation yield in the cow. Other important factors include, breed, age, number of lactation, dry period, season of pregnancy and birth, health,management, feeding, etc. Lactation can be defined as production of milk from birth until its cessation. Milk yield is generally standardised as milk produced in a 305-day period.

Generally milk yield is increased until first 60 – 90 days during lactation, gets to peak and then relatively stable for a month. From this time the amount of milk produced daily decreases until the end of lactation. This general trend of the curve formed by amount of milk yield during the lactation is also called lactation curve.

The measure of variation in the daily milk yield is obtained by expressing variations as mathematical equations. The shape and type of lactation curve can be described by several models. Most of the functions describing lactation curves contains the components of the coefficient of beginning yield (a), coefficient of rising (b), coefficient of decreasing (c), coefficient of persistency (S), average maximum daily peak yield (Y_{max}) and the time after parturition when the peak yield occurs (T_{max}).

The independent and dependent variables of lactation curves given above are as the time [is shown (n) or (t) and] lactation yield in (n) th day of lactation respectively. In the equations developed the coefficients which may be derived directly from the model of lactation curves are the maximum daily yields, the time when maximum (peak) milk yield is attained, the persistency of lactation which expresses the rate of decline.

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Wood (1967) classified the lactation curves into two types, namely, flat lactation curves (relatively homogenous fluctuations), which are more advantageous than those of the second type, the steep lactation curves (no homogenous fluctuations).

The mathematical expression of lactation curve is called biometry of lactation. Wood (1967) examined the daily milk yield variations, as the daily yield was the function of time; the proposed non-linear mathematical equations were as below:

$y=a.t^{b}\ e^{-ct}$

The logarithmic transformation of this model is as follows:

ln (y)= ln (a)+bln(t) -c(t)

This function is called Gamma function or Wood model. In this model persistency is obtained using the following formula S=-(1+b)lnc. Several different methods are available for obtaining the value for persistency.

Schneeberges (1978) divided the methods for determining the shape of lactation curves by means of persistency of lactation into the three main groups. First method for measuring persistency of lactation consists of ratio calculations. Sanders (1923) called this ratio Shape Figure. Second method group of measuring the persistency of lactation curve utilizes the milk yield's variation in three parts of lactation period as early (till to peak), middle (from peak to the noticeable decline in milk yield due to pregnancy) and late part of lactation.

Osterkorn (1974) claimed early middle and late lactation curves follow the parabolic, linear and hyperbolic variation respectively. The third group of calculation methods of measuring persistency uses total lactation periods and utilizes the linear regression and inverse polynomial regression. Second non-linear model of lactation curve is called the Grossman Model.

Grossman et al (1986) modified the Wood (1967) model by taking into consideration the effect of calving season. The differences between the Grossman model and that of Wood were, the coefficient of the day of year of the yield obtained as measured radian (u) and the coefficient of calving season (v).

Grossman model is as shown below:

$Y= a.t^{b}.e^{-ct.}\ (1+u\ Sin\ (x)+v\ Cos\ (x))$

The persistency values of Grossman models are obtained using following formulas:

$S= (1+b)\ln(C)$ or $S=c^{[-b+1]}$

The major aim of investigating lactation curve is its use as whole prediction and partial lactation yield.

Goodall (1986) has also developed non-linear function describing the lactation curves as shown below:

$Y=a.t^{b}.e^{[-ct+dD]}$

The linear transformation of this model is as ln (y)=ln (a)+nln(t)-ct+dD

Grossman et al (1986) developed new equations modifying the Woods original models called modified gamma function. This model is as follows:

$Y=an^{b}e^{-ct}[1+u\ Sin(x)+v\ Cos(x)]$

The linear transformation of this model is:

ln (Y)=ln(a)+b ln(t)-ct+usin(x)+vcos(x)

Where (x) represents the day of year of the daily yield measured calculated as radian. This model takes into account the influence of season to the lactation curve [for October - March=0 and for April - October: D=1], (d) is representing the coefficient of season.

Panda, (1983) used exponential, parabolic, inverse polynomial and gamma function in order to investigate the lactation curve of exotic breeds.

Batra, (1986), had researched the fitness of modified gamma (Wood) invert polynomial function to the observed lactation curve. Batra has shown that the coefficient of determination obtained by applying inverse polynomial function and modified gamma function were 91.3 %; 90.2% and 87%; 67,9% and 76,9%; 74,7%; for 1, 2, 3th lactation respectively.

Kayaalp, (1988), had investigated the lactation curves of Brown Swiss population of Eskişehir Seed Production Farm by Wood, Goodall and Grossman models. He found that coefficient of determination of Grossman model was higher than that of the other model.

Akbulut et al (1991) also showed in their review that the heritability of the coefficient of ln (a) ,(b),(c) and (s) were low in general and ranged from 0,05 to 0,35.

Kaygısız, (1999), had determined the shape of lactation curves of yellow pied cattle by gamma function. It is shown the variation according to the seasons were significant for 42% of atypical lactation curves of population.

Orman ve Ertuğrul, (1999), calculated coefficient of determination of lactation curves of Black and White cows raised in Ceylanpınar State Farm using three different models of Wood, Schaeffer and Grossman as 70,62% minimum and 79,47% maximum. It was concluded that Wood model were fitted best.

Papaljcsik and Bodero (1988) compared the efficiency of 20 different mathematical models describing lactation curve using the magnitude of mean square of error (differences between predicted and observed milk yield). They concluded that Wood model had the lowest mean square of error.

Several studies were also conducted to clear the genetic properties of lactation curves parameters.

Akbulut (1998) reviewed the studies conducted for obtaining heritability, genetic and phenotypic correlations of persistency. According to this review, heritability ranged from (0,14) to (0,50) showing the possibilities of being as good selection criteria. This study also showed that the phenotypic correlation between lactation milk yield and persistency was relatively low and mostly positive in contrast to the relatively high and positive genetic correlation between the same traits. The heritability of the (c) coefficient was higher than other coefficients.

Soysal, and Gürcan (2000), had also studied several lactation biometric characteristics of Black and White cattle raised in Turkey. They had showed that the data obtained from their studies fitted the Grossman model.

Vargas et al (2000, investigated the lactation curves of Costa Rica cow population by 9 different models of Wood, Cobby, Wilmink, Morank, Rook, single stage, multiple stage LPM and RLPM. Highest and lowest coefficients of determination were obtained from LPM double stage (0,987) and Wood model (0.957).

Yılmaz and Kaygısız, (2000), investigated lactation curves of Black and White cattle of Reyhanlı State Farm by gamma function. They found that distribution of typical and atypical lactation curves and its parameters according to the seasons and number of lactation were significant.

Soysal et al (2004), examined the lactation curves of Black and White cattle of Kumkale State Farms by Wood, Goodall, Grossman and found that the Grossman model fitted best to the real yield.

Val-arreola et al (2004), examined the lactation curves of Mexican Dairy Cattle by Wood, Gaines, Rook, Dijkstra and Pollott models and found that Dijkstra was fitted to the variation observed.

MATERIAL AND METHODS

Research materials consisted of 25 heads of lactation record of Black and White cattle belonging to the period of 2000 – 2004 registered by Dairy Cattle Breeder Association of Tekirdağ and lactation record of 48 heads of Black and White cattle of private farms belonging to the period of 2003-2004 years.

Three non linear equations were used in this study (Wood, 1967; Goodall, 1986; Grossman, 1986). The meanings of the coefficients in the formula have been explained in the **Introduction**. The original data were converted to the value required for the working formulae for obtaining the various parameters of models used.

The persistency values were calculated by using the formula given below,

$S=[[-(1+b)][\ln c]]$or $S=c^{(-b+1)}$

The time required to reach peak yield (T_{max}) was estimated as the ratio (b/c). The peak yield (Y_{max}) was estimated using the following formula,

$Y_{max}=a.(b/c)^{b}e^{-b}$

Obtained curves were classified typical and atypical according to the sign of parameters.

The correlation coefficient (r) between the observed milk yield and predicted milk yield, according to the equations used for test day yield data were also calculated. The square of correlation coefficients (r^2) were used to compare the models .The data were analysed by means of Statistica Program of Quasi-Newton method (Statsoft inc, 1994).

RESULTS AND DISCUSSION

The estimation of parameters was done for the Wood models by using the data of lactation yield of Tekirdağ and Bolu for the Black and White cattle population. The a, b, c, r, r^2, values were calculated for each record. Then the average value of the constants of a, b, c, r, r^2, values were determined. The results were grouped according to the number of lactation. The results are given on **Table 4**.

The results of analysis of variance for the variation observed for number of lactation showed that this factor was not significant The coefficient of persistency (S), maximum daily yield (Y_{max}) time at maximum daily yield obtained (T_{max}) were calculated and showed on **Table 1**.

Table 1. *The S, T_{max}, Y_{max}, r^2 values of material according to the models and region for Wood model*

Region	Number of Lactation	S	T_{max}	Y_{max}	r^2
Tekirdağ	**1. Lactation**	6,7634	37,2581	35,2695	0,6587
Tekirdağ	**2. Lactation**	6,2005	35,5007	28,5763	0,7587
Tekirdağ	**3. Lactation**	6,0312	31,0361	38,2949	0,7470
Tekirdağ	**4. Lactation**	6,5799	48,4137	84,8693	0,7554
Bolu	**1. Lactation**	7,2993	79.080	34.988	0,7114
Bolu	**2. Lactation**	6,4893	43,011	39,393	0,6426
Bolu	**3. Lactation**	6.8673	60,762	41,960	0,6876
Bolu	**4. Lactation**	6.7230	53,829	39,497	0,7574

The estimations of parameter for Goodall model in the data of Tekirdağ and Bolu population were done similarly; the parameters for the curves of each individual were determined. The results were grouped according to the number of lactation for the model investigated. It is concluded that the variation observed in the parameter of curves due to number of lactation was not significant for the Goodall model. The results obtained for Goodall model are shown on **Table 2**.

Table 2. *The S, T_{max}, Y_{max}, r^2 values of material according to the models and region for Goodall model*

Region	Number of Lactation	S	T_{max}	Y_{max}	r^2
Tekirdağ	**1. Lactation**	6.4486	27,8841	25,9314	0,7111
Tekirdağ	**2. Lactation**	6,5612	46,8799	36,2724	0,8105
Tekirdağ	**3. Lactation**	6,6897	52,9504	34,6345	0,8071
Tekirdağ	**4. Lactation**	4,7721	12,0185	35,7598	0,8137
Bolu	**1. Lactation**	4,1359	76,9871	43,2869	0,7707
Bolu	**2. Lactation**	6,6294	50,3964	48,9620	0,6734
Bolu	**3. Lactation**	7,0139	60,6051	92,9373	0,7815
Bolu	**4. Lactation**	6,3462	40,0816	54,6064	0,8473

The parameters of Grossman model for the materials belonging to the Tekirdağ and Bolu provinces were also determined similarly. This model takes into account the lactation due to seasons before and after peak yield of (u) and (v) constants respectively which is not used in other equations. The results of parameters of Grossman model obtained are shown on **Table 3**.

Table 3. *The S, T_{max}, Y_{max}, r^2 values of material according to the models and region for Grossman model*

Region	Number of Lactation	S	T_{max}	Y_{max}	r^2
Tekirdağ	**1. Lactation**	6,4165	15,8335	23,7926	0,8827
Tekirdağ	**2. Lactation**	6,5293	46,3428	41,9585	0,8956
Tekirdağ	**3. Lactation**	5,2621	12,2149	38,1288	0,8557
Tekirdağ	**4. Lactation**	7,3936	78,4129	120,4539	0,8518
Bolu	**1. Lactation**	7,0744	49,6242	60,5409	0,8675
Bolu	**2. Lactation**	7,5601	67,1662	160,5213	0,8658
Bolu	**3. Lactation**	8,3259	70,5496	82,2265	0,9084
Bolu	**4. Lactation**	7,4946	57,0152	184,5024	0,9059

Lactation parameters and curves of lactation were determined for Wood, Goodall, and Grossman models. The estimations of 0,30,60,90,120,150,180,210,240,270-day milk yield were done by using the parameters of constant of a, b, c, u, v, calculated from the observed and expected milk yield for the mentioned day yield when compared. Most of the constants, such as a (starting yield), b (coefficient of increase) and c (coefficient of decline), were positive values as classified typical curves except one non-typical curve. The results are shown on **Tables** below:

Table 4. *The parameters of lactation curves of material investigated according to the models*

Region	***Wood Model***
Tekirdağ	1. Lactation: $Y=29{,}7457\ n^{0,0650}\ e^{-0,0017n}$
	2. Lactation: $Y=16{,}7715n^{0,2073}\ e^{-0,0058n}$
	3. Lactation $Y=18{,}3939\ n^{0,3011}\ e^{-0,0097n}$
	4. Lactation: $Y=43{,}2703\ n^{0,2339}\ e^{-0,0048n}$
Bolu	1. Lactation: $Y = 11{,}1910.n^{0,3382}.e^{(-0,0042.n)}$
	2. Lactation $Y = 25{,}3351.n^{0,1598}.e^{(-0,0037.n)}$
	3. Lactation: $Y = 19{,}2023.n^{0,2515}.e^{(-0,0041.n)}$
	4. Lactation: $Y = 17{,}7998.n^{0,2669}.e^{(-0,0049.n)}$
Region	***Goodall Model***
Tekirdağ	1. Lactation: $Y=22{,}2558\ n^{0,0656}\ e^{(-0,0023n+0,0272D)}$
	2. Lactation: $Y=21{,}5729\ n^{0,1824}\ e^{(-0,0038n+0,1295D)}$
	3. Lactation: $Y=17{,}8011\ n^{0,2241}\ e^{(-0,0042n-0,0061D)}$
	4. Lactation: $Y=21{,}0652\ n^{0,3560}\ e^{(-0,0296n+0,0274D)}$
Bolu	1. Lactation $Y=11{,}0528.n^{0,4082}.e^{(-0,0053.n+0,0392.D)}$
	2. Lactation: $Y=24{,}7580.n^{0,2335}.e^{(-0,0046n-0,0017.D)}$
	3. Lactation: $Y=27{,}6945.n^{0,3899}.e^{(-0,0064.n+0,1777.D)}$
	4. Lactation: $Y=28{,}3522.n^{0,3435}.e^{(-0,0060.n+0,1582.D)}$
Region	***Grossman Model***
Tekirdağ	1. Lactation: $Y=22{,}5090n^{0,0314}e^{(-0,0019n)}$ [1+0,1239sin(x)+0,0375cos(x)]
	2. Lactation: $Y=23{,}0087n^{0,2118}e^{(-0,0045n)}$ [1+0,0103sin(x)-0,1207cos(x)]
	3. Lactation: $Y=32{,}6159n^{0,1039}e^{(-0,0085n)}$ [1-0,0565sin(x)+0,0193cos(x)]
	4. Lactation: $Y=23{,}8139n^{0,4821}e^{(-0,0061n)}$ [1+0,0380sin(x)+0,0836cos(x)]
Bolu	1. Lactation: $Y=10{,}4247.n^{0,6056}.e^{(-0,0122.n}$)[1+0,0720sin(x)-0,1088cos(x)]
	2. Lactation: $Y=23{,}0220.n^{0,6055}.e^{(-0,0090.n}$)[1+0,0704sin(x)-0,1145cos(x)]
	3. Lactation: $Y=4{,}1484.n^{0,2515}.e^{(-0,9172.n}$)[1+0,1110sin(x)-0,2288cos(x)]
	4. Lactation: $Y=21{,}4291.n^{0,7074}e^{(-0,0124.n}$)[1-0,0091sin(x)-0,07867cos(x)]

Table 5. *The distribution of typical and non-typical lactation curves for models and region.*

Models	**Wood Model**		**Goodall Model**		**Grossman Model**	
Type of lactation curves	Typical lactation curves	Non-Typical lactation curves	Typical lactation curves	Non-Typical lactation curves	Typical lactation curves	Non-Typical lactation curves
Tekirdağ	**%77,77**	**%22,22**	**%79,04**	**%20,96**	**%63,80**	**%36,20**
Bolu	**%75**	**%25**	**%72,92**	**%27,08**	**%82,60**	**%17,40**

CONCLUSION

It is concluded that best fitted models according to the amount of coefficient of determination was the Grossman model. The coefficient of determination for Wood model was the smallest.

These values were consistent with the results obtained by Soysal (2004) but higher than those of Kayaalp (1988). Our results were lower than those obtained by Keskin and Tozluca (2004).

The percentages of typical and non-typical lactation curves for the Goodall model in Tekirdağ and Bolu were: 79,04%, 20,96% and 72,92%, 27,08%, respectively. The percentages of typical and non-typical lactation curves for the Grossman model in Tekirdağ and Bolu were: 63,80%, 36,20% and 86,20%, 17,40%, respectively. The percentages of typical and non-typical lactation curves for the Wood model in Tekirdağ and Bolu were: 77,77%, 22,22% and 75%, 25%, respectively.

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