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Factors Affecting Lactation Curves of Friesian Cows in Saudi Arabia

M.A. Sharaby and M.A. Aziz
Department of Animal Production, Faculty of Agriculture, Alexandria University Shatby, Alexandria, Egypt

Abstract. First lactation records of 203 Friesian cows were utilized to estimate parameters of the lactation curve using the incomplete gamma function and to determine the importance of sex, season of calving and the regression of these parameters on coefficients of dam weight, calf weight and age at first calving. Sex of calf had nonsignificant effects on the estimated parameters of the lactation curve. However, aborted cows had lactation curves different from the normally delivered cows. Season of calving had a significant effect on the initial milk yield (Log (a)) and rate of increase to peak production (b). Dam weight had a highly significant effect ($P<0.01$) on log (a) and a significant ($P<0.05$) effect on the seasonal variation other than season of calving (cosine (v)). Its regression coefficients for both parameters were 0.004 ± 0.001 and 0.0005 ± 0.0003, respectively. However, dam age had no effect. Calf weight had a highly significant effect ($P<0.01$) on all parameters, but the value of v. The regression coefficients for initial yield (log a), rate of increase to peak production, rate of decrease after peak and seasonal variation (sin u) were -0.091 ± 0.014, 0.090 ± 0.011, -0.0055 ± 0.0020 and -0.0097 ± 0.0028, respectively. It could be concluded that seasonality, dam weight and calf weight had an important effect on the shape of the lactation curve.

Introduction

Dairy cow lactation curves have been investigated extensively and several attempts were made to change their characteristics [1,2]. Several algebraic equations have been proposed and compared [3,4]. With this respect, Wood [5] has shown that the incomplete gamma function can give a good fit to the lactation curve, accounting for at least 73.8% of the variation in log weekly milk yield. Furthermore, Kuck, *et al.* [6] modified Wood's equation by adding sine and cosine terms to account for seasonal variation other than season of calving and reported that this equation accounts for 92.8% of the variation in log 10 day milk yield. On the other hand, factors affecting the shape of the lactation curve have also been studied [6-8].

The success of importing Friesian cows to Saudi Arabia should mainly depend on the awareness of the potential for increasing milk production in the country through the introduction of exotic genes. It is thus important to obtain more information on the factors influencing milk production under local conditions.

The objectives of this study were to estimate the lactation curve parameters using the incomplete gamma function and to determine the importance of some environmental factors on the coefficients of the lactation curve obtained.

Materials and Methods

First lactation records from 203 newly imported Friesian cows of a dairy herd located in the Qassim region of central Saudi Arabia were utilized in this study. Records were collected during the years of 1984-1985. The cows were kept under stable management regimes and fed on alfalfa and concentrate mixed throughout the year. Individual animal observations were used to estimate the parameters of the lactation curve. The modified gamma function defined by Kuck, *et al.*, [6] was proposed as follows:

$$Y_n = a\, n^b\, e^{-cn}\,(1 + u \sin(x) + v \cos(x))$$

where Y_n is the average daily milk yield in the n^{th} week of lactation; a,b,c, u and v are coefficients to be estimated; e is the base of the natural logarithm and x is the day of year computed as radians. In this function, a is a constant representing the level of initial yield of the cow, b is a parameter representing the rate of increase to peak production, c represents the rate of decrease after peak, u and v represent the seasonal variations other than season of calving. Taking natural logarithms gives the following equation for each cow:

$$\text{Log}(Y) = \log(a) + b\log(n) - cn + u\sin(x) + v\cos(x)$$

This equation is linear with respect to the coefficients to be estimated. Therefore, it can be fitted by multiple linear regression.

A least-square analysis was performed on the coefficients of the lactation curve using SAS PROC GLM (Generalized Linear Model Procedure) [9]. The mathematical model used was:

$$Y_{ijk} = u + S_i + SE_j + b_1(D) + b_2(CWT) + b_3(A) + e_{ijk}$$

where:

Y_{ijk} = a regression coefficient of the lactation curve of the 1^{th} daughter calved the i^{th} sex in the j^{th} year-season,

u = population mean,

S_i = an effect due to the i^{th} sex of calf,

SE_j = an effect due to the j^{th} season of calving within each year,

b_1 = partial regression coefficient of dependent variable on dam weight at calving (D) (kg),

b_2 = partial regression coefficient of dependent variable on calf weight at birth (CWT) (kg),

b_3 = partial regression coefficient of dependent variable on age of cow at calving (A) (month),

e_{ijk} = random error assumed to be normally and indpendently distributed with mean zero and constant variance.

All five regression coefficients of the lactation curve were analyzed separately. All factors in the model were considered to be fixed, except the error term. Sex was either male or female. Abortions and stillborn cases were included as a third category. Each year was divided into two seasons of calving. Summer calvings were from May to October and winter calvings were from November to April.

Results and Discussion

The analysis of variance for the coefficients of the lactation curve is in Table 1. Least-square means, regression coefficients and their standard errors for the coefficients of the lactation curve are shown in Table 2.

Sex of calf had a nonsignificant effect on the coefficients of the lactation curve. However, the least-square means of the coefficients of lactation curve of cows aborted were significantly ($P<0.05$) lower than those of cows that gave birth of either male or female, except the rate of increase to peak which it was higher, i.e. aborted cows went to peak with faster rate. Jenkins and Ferrell [10] noted that without calf nursing stimulus, the oxytocin levels would be reduced resulting in smaller quantities of milk obtained. This might be an explanation for the significant differences among least-square means of normally delivered and aborted cows.

Season of calving had a significant ($P<0.05$) effect on log (a) and b. Similar results were obtained by Mainland [11] who reported considerable seasonal differences in the shape of the lactation curve. Furthermore, Goodall [12] emphasized the importance of the seasonality effect. He noted that the addition of that categorical variable (season effect) to the original model provided a significant improvement on the regression fit of the data. However, Abubakar and Buvanendran [8] reported a nonsignificant season effect. Dam weight had a significant effect ($P<0.01$ or $P<0.05$) on log (a) and v values. Calf weight had a highly significant ($P<0.01$) effect on log (a),b,c and u values. Age of cow was not an important source of variation for the coefficients of lactation curve. Similarly, Kuck *et al.* [6] reported a nonsignificant effect of age at calving on the coefficients of the lactation curve. On the other hand, Batra [13] found that age at calving effect was not significant on the coefficients of lactation curve except log (a), a result which is in a partial agreement with the results of this study.

It could be concluded that seasonality, weight of dam and calf weight were important factors affecting the shape of lactation curve. Although sex of calf was not an important factor for the shape of the lactation curve, aborted cows might have a different lactation curve from those gave births.

Table 1. Mean square of the coefficients of the first lactation curve

Source of Variation	df	Log (a)	b	c	u	v
Sex of Calf	2	0.173	0.300	0.006	0.002	0.014
Year-Season	2	0.692*	0.417*	0.003	0.009	0.033
Dam Weight	1	2.690**	0.265	0.009	0.006	0.040*
Calf Weight	1	7.368**	7.092**	0.027**	0.083**	0.021
Age at Calving	1	0.311	0.269	0.004	0.010	0.050
Residual	195	0.165	0.107	0.003	0.007	0.015

* $P<0.05$

** $P<0.01$

Log (a) : Level of initial milk yield.

b : Rate of increase to peak production.

c : Rate of decrease after peak.

u & v : Seasonal variations other than calving season.

Table 2. Least-squares means (±SE) for coefficients of the first lactation milk yield (kg)

Class	No. of cows	log (a)	b	c	u	v
Sex of Calf						
Aborted	37	0.94 ± .39^{a}	3.15 ± .32^{a}	−0.20 ± .06^{a}	−0.28 ± .08^{a}	−0.13 ± .12
Male	66	4.02 ± .11^{b}	0.13 ± 09^{b}	−0.04 ± .02^{b}	0.07 ± .02^{b}	0.05 ± .03
Female	100	3.86 ± .09^{b}	0.28 ± .07^{b}	−0.03 ± .01^{b}	0.06 ± .02^{b}	0.03 ± .03
Year-Season						
Summer	32	3.02 ± .10^{a}	1.12 ± .08^{a}	−0.08 ± .01	−0.05 ± .02	−0.01 ± .03
Winter	113	2.83 ± .08^{b}	1.28 ± .07^{b}	−0.10 ± .01	−0.05 ± .02	0.01 ± .03
Summer	58	2.97 ± 09^{a}	1.16 ± .07^{a}	−0.10 ± .01	−0.07 ± .02	−0.04 ± .03
			Regression coefficients			
Dam weight (kg)	0.004 ± 0.001**	−0.001 ± 0.001	0.0002 ± 0.0001	−0.0002 ± 0.0002	0.0005 ± 0.0003*	
Calf weight (kg)	−0.091 ± 0.014**	0.090 ± 0.011**	−0.0055 ± 0.0020**	−0.0097 ± 0.0028**	−0.0049 ± 0.0041	
Age of Dam (mo.)	−0.022 ± 0.012	0.020 ± 0.010	−0.0022 ± 0.0017	0.0023 ± 0.0025	0.0062 ± 0.0036	

Means with different superscripts differ significantly ($P<0.05$).

* $P<0.05$.

** $P<0.01$.

Log (a) : Level of initial milk yield.

b : Rate of increase to peak production.

c : Rate of decrease after peak.

u & v : Seasonal variations other than calving season.

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العوامل المؤثرة على منحنى الحليب لأبقار الفريزيان في المملكة العربية السعودية

محمود شرابي و محمود محمد عبدالعزيز

قسم الإنتاج الحيواني، كلية الزراعة، جامعة الاسكندرية

الاسكندرية، جمهورية مصر العربية

ملخص البحث. استخدم موسم الحليب لأبقار الفريزيان (٢٠٣ بقرة) لتقدير معايير منحنى الحليب باستخدام توزيع جاما غير الكامل وكذلك التقويم أهمية جنس النتاج، موسم الولادة، ومعاملات اعتماد معايير منحنى الحليب على وزن الأم، وزن النتاج، العمر عند أول ولادة وجد أن جنس النتاج ليس له تأثير معنوي على معاملات منحنى الحليب على الرغم من أن شكل منحنى الحليب للأبقار التي أجهضت كان مختلفًا عن شكل منحنى الحليب للأبقار التي ولدت ولادة طبيعية. كان موسم الولادة له تأثير معنوي على كل من بداية إنتاج اللبن حتى أقصى إنتاج له. وزن الأم كان له تأثير معنوي على بداية إنتاج اللبن والتأثير الموسمي وكانت معاملات الاعتماد لهما هي: 0.001 + 0.004 ,0.0003 + 0.0005 على التوالي أو 0.001-0.004 ,0.0003 - 0.0005 على التوالي، بينما عمر الأم لم يكن له تأثير معنوي على أي من معايير منحنى الحليب. كان وزن النتاج من العوامل ذات الأهمية على معايير منحنى الحليب فقد وجد أن تأثيره كان معنويًا على كل المعاملات وكانت معاملات الاعتماد هي:

0.091 + 0.014, 0.090 + 0.011, -0.0055 + 0.0020, -0.0097 + 0.0028

لكل من بداية إنتاج الحليب، معدل الزيادة حتى أقصى إنتاج، معدل النقص بعد أقصى إنتاج والتأثير الموسمي على التوالي.