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Lactation Curve and Persistency of Crossbred Dairy Cows in the Sudan

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Abstract: Data collected on Friesian and Ayrshire crossbred cows by Sudanese indigenous breeds of dairy cattle maintained at the University of Khartoum dairy farm, was analyzed according to fixed effect multiple regression model to study the effects of some environmental and genetic factors on the components of their lactation curve. That was being explained using the gamma function model (Wood[23]) as a method to determine the yield of the herd studied. The data showed that the difference between the actual and predicted yield of the gamma model (Bias) was -87.57 kg. Among the factors affecting the lactation curve was the lactation number, which revealed a significant variation on initial yield (a-parameter), decreasing slope of the curve (c-parameter), peak yield and degree of persistency ($p<0.01$). While the curve components that mostly affected by the percentage total foreign blood and sire breed were a-parameter ($p<0.05$), c-parameter ($p<0.01$), persistency of the yield ($p<0.01$), peak yield ($p<0.01$) and week of the peak yield ($p<0.01$). However, week of the peak yield affected variation among periods of calving. The study also, investigated the relationship among the components of the lactation curve.

Keywords: Gamma function model, lactation curve, persistency, initial yield, decreasing slope.

INTRODUCTION

A lactation curve depicts a cow's milk yield after colostrum to drying off Mason[11]. It is known to be the graphical representation of the relationship between milk yield and lactation length, and also assumed to represent the total milk yield of a single lactation. Analysis of lactation curve shape is important as it helps to identify feeding and management problems within a dairy herd Epaphras[4]. On the other hand persistency is defined as the slope of the decreasing phase of the curve or it is the extent to which peak yield is maintained Wood[23]. Therefore, peak yield and persistency are the only variables of the lactation curves which are influenced by many factors, although the general shape of the curve remains substantially unchanged. Whereas information on lactation curves in the developed countries is available Quinn[16]; Schnier[18], little is known about this trait in the developing countries. El-Amin[3] showed that month of calving did not influence persistency of Northern Sudan Zebu cattle. Moon[13] reported that winter calving cows had higher and later peak yield and lower persistency than cows calving in other seasons. Mudgal[14] found significantly different peak yields between farms and among periods, genetic groups and parities. However, Ibeawuchi[7] stated that parity, season of calving and daughter sire significantly ($p<0.05$) influenced persistency of lactation of Friesian x White Fulani F_1 cattle. Cue[1] showed that herd x year x season of calving interaction had a significant effect on all the parameters of the lactation curve.

The importance of the curve can be positioned in predicting the lactation yield by using both completed or part lactation length, depending on the method used to describe the underlying curve.

Based on the information obtained from the curve, it can be used as a tool for selecting the breeding herds and for evaluating the existing lactating herds.

The objectives of the current study were to characterize the milk production pattern of the crossbred dairy cows in the Sudan, including derivation of lactation curves at the University of Khartoum dairy farm; to assess the effects of parity, percentage foreign blood, sire breed, season and period of calving on

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lactation. And identifying the critical period along the lactation length.

MATERIALS AND METHODS

Lactation curve was described using the gamma function method (Wood[23]) according to the following statistical model:

- $Y_n = an^b e^{-cn}$

Where:

- Y_n= milk yield during the nth week.
- a = the initial yield.
- b = the increasing slope of the curve.
- c = the decreasing slope of the curve.

a,b, and c were constants that have been obtained sfter the following logarithmic transformation:

$$\ln Y_n = \ln a + b*\ln(-cn) + E_n$$

E_n = the residual error.

Gamma function had described the lactation curve using means of predicted yield, difference between predicted and actual yield (Bias) and coefficient of determination of variation R^2 and their respective standard deviations. Analysis of variance of gamma function parameters were performed on fixed effect multiple regression model, to study the effects of some factors viz, lactation number, percentage total foreign blood, sire breed, season of calving, period of calving and season X period of calving interaction. The data had been classified into five lactations, four grades of crossbred groups (25%, 37.5%, 50% and 62.5%), two sire breeds (Friesian and Ayrshire), three seasons (wet summer, dry summer and winter) and four periods of five years each. Means were compared using Duncan's multiple range test (DMRT). The following statistics were computed after fitting the curve:

- Persistency as $(1/c)^{b+1}$
- Peak yield as exp a $^{((a/c)\ b)\ exp-b}$
- Week of peak yield as b/c

Correlation coefficients were obtained among the curve components. All statistical analysis techniques were conducted using SAS[17] computer programme.

RESULTS AND DISCUSSIONS

Table (2) showed the overall means, standard deviation and coefficients of variations of the components of the lactation curve. The coefficients of determination of variation R^2 indicated that 68.56% of the total variation was accounted for the factors

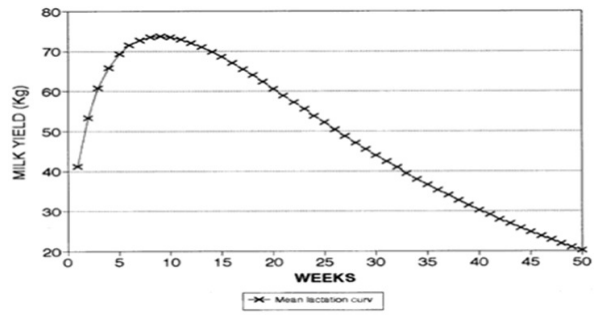

Fig 1: Mean lactation curve of crossbred cows at University of Khartoum farm.

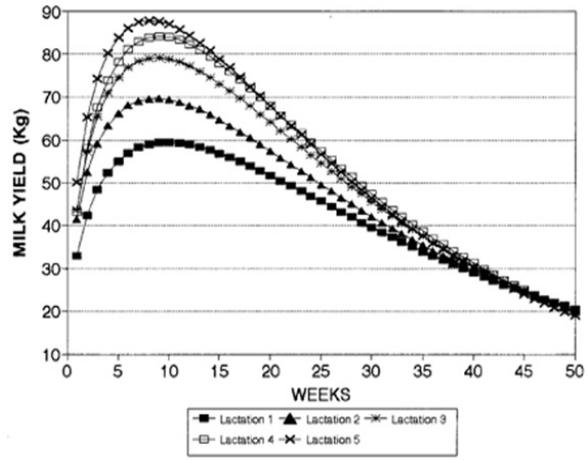

Fig 2: Lactation curves by lactation number of crossbred cows at University of Khartoum dairy farm.

studied. However, the bias estimated as the difference between predicted and actual yield was -87.57±295.32 kg. Figure (1) illustrated the average lactation curve of the pooled data.

Factors Affecting the Components of the Lactation Curve:

Lactation Number: The effect of parity number on the components of gamma function (a,b and c), degree of persistency of yield, peak yield and week to reach peak yield was presented in Table (1). Among which a-and c-parameters, persistency and peak yield showed significant variations ($p<0.01$). Table (3) indicated that the initial yield reached its maximum value in the 5th lactation, while the minimum value was obtained in the 1st lactation, with the means difference being significant ($p<0.05$). The decreasing slope of the curve (c-parameter) was significantly ($p<0.05$) lower in the 1st lactation.

Figure (2) expressed that the 1st lactation was significantly ($p<0.05$) more persistent than the

Table 1: Effect of the lactation number, percentage total foreign blood, sire breed, season of calving, period of calving and season x period of calving interaction on the components of the lactation curve of the crossbred cows

Source of variation	D.F.	a-parameter M.S.	b-parameter M.S.	c-parameter M.S.	Persistency M.S.	Peak yield M.S.	Week of peak yield M.S.
Lactation number	4	1.80**	0.11 N.S.	0.002**	2943.1**	11285.9**	12.92 N.S.
Percentage total foreign blood	3	0.56*	0.03 N.S.	0.002**	24152.2**	3897.8**	148.00**
Sire breed	1	0.10 N.S.	0.002 N.S.	0.0004 N.S.	11268.2**	84.59 N.S.	63.68*
Season of calving	2	0.34 N.S.	0.04 N.S.	0.002 N.S.	4162.2 N.S.	4964.74 N.S.	32.114 N.S.
Period of calving	3	0.66*	0.12 N.S.	0.002**	8634.2**	364.55**	28.83 N.S.
Season x period of calving interaction	6	0.28 N.S.	0.02 N.S.	0.0002 N.S.	2640.1 N.S.	364.12 N.S.	15.41 N.S.

** = Significant at $p<0.01$ N.S. = Not significant ($p>0.05$)
* = Significant at $p<0.05$ M.S. = Mean squares

Table 2: The overall means, standard deviation (S.D.) and coefficient of variation (C.V.) of the components of the lactation curve of the crossbred cows

Parameter	Mean	S.D.	C.V. (%)
Initial yield (a-parameter)	43.38	1.58	11.70
Increasing slope (b-parameter)	0.45	0.23	51.17
Decreasing slope (c-parameter)	0.05	0.02	39.22
Coefficient of determination of variation (R^2)	69	15	21.90
Predicted yield (kg)	2656	950.36	31.21
Actual yield (kg)	2743	986.32	31.43
Bias (kg)	-87.57	295.32	337.11
Persistency	75.89	47.50	48.98
Peak yield (kg)	79.40	22.30	27.10
Week of peak yield	09.04	03.69	38.83

Table 3: Effect of lactation number on the components of the lactation curve of the crossbred cows

Lactation number	Mean(a)	Mean(b)	Mean(c)	Mean persistency	Meanpeak yield	Week of peak yield
First	34.47^{c}	0.427^{a}	0.044^{c}	86.82^{a}	63.50^{d}	09.68^{a}
Second	43.38^{b}	0.409^{a}	0.047^{ab}	73.42^{b}	74.10^{c}	08.72^{a}
Third	46.06^{ab}	0.463^{a}	0.053^{ab}	73.92^{b}	84.40^{b}	08.96^{a}
Fourth	45.60^{ab}	0.509^{a}	0.057^{a}	76.41^{b}	89.70^{ab}	08.98^{a}
Fifth	52.98^{a}	0.459^{a}	0.055^{a}	68.65^{b}	94.70^{a}	08.70^{a}

Means with the same letters are not significantly different ($p>0.05$)

subsequent lactations which were similar in the mean persistency ($p>0.05$). Peak yield on the other hand, showed considerable increase along parities, it was minimum in the 1st lactation (63.5) and maximum in the 5th lactation (94.70) with the mean difference being significant ($p<0.05$) among lactations.

Percentage Total Foreign Blood and Sire Breed: The effects of these factors on the components of lactation curves were presented in Tables (1 and 4) and Figures (3 and 4). Mean comparisons test revealed that 25% and 50% total foreign blood obtaining the higher value for a-parameter that was significantly different ($p<0.05$) than 37.5% and 62.5% total foreign blood.

Table 4: Effect of percentage total foreign blood on the components of the lactation curve of the crossbred cows

Total foreign blood	Mean(a)	Mean(b)	Mean(c)	Mean persistency	Meanpeak yield	Week of peak yield
25 %	45.15[a]	0.429[a]	0.055[a]	62.77[c]	76.29[b]	07.70[b]
37.5 %	38.47[b]	0.464[a]	0.050[ab]	81.49[b]	72.48[b]	09.32[a]
50 %	45.15[a]	0.470[a]	0.048[b]	86.02[a]	88.09[a]	09.82[a]
62.5 %	40.95[ab]	0.454[a]	0.045[b]	90.25[a]	83.98[a]	10.30[a]

Means with the same letters are not significantly different (p>0.05)

Table 5: Effect of season of calving on the components of the lactation curve of the crossbred cows

Season of calving	Mean(a)	Mean(b)	Mean(c)	Mean persistency	Meanpeak yield	Week of peak yield
Dry summer	40.85[a]	0.466[a]	0.049[a]	82.47[a]	78.60[a]	09.60[a]
Wet summer	3.82[a]	0.432[a]	0.050[a]	72.96[a]	77.60[a]	08.80[ab]
Winter	45.15[a]	0.449[a]	0.052[a]	72.94[a]	81.90[a]	08.70[b]

Means with the same letters are not significantly different (p>0.05)

Table 6: Effect of period of calving on the components of the lactation curve of the crossbred cows

Period of calving	Mean(a)	Mean(b)	Mean(c)	Mean persistency	Meanpeak yield	Week of peak yield
First	31.50[b]	0.506[a]	0.0443[b]	109.27a	69.41[b]	11.40a
Second	44.70[a]	0.451[a]	0.0521[a]	72.76[b]	79.73[a]	08.66[b]
third	45.15[a]	0.473[a]	0.529[a]	75.92[b]	84.99[a]	08.96[b]
Fourth	38.86[ab]	0.392[a]	0.0427[ab]	80.62[ab]	68.41[b]	09.64[ab]

Means with the same letters are not significantly different (p>0.05)

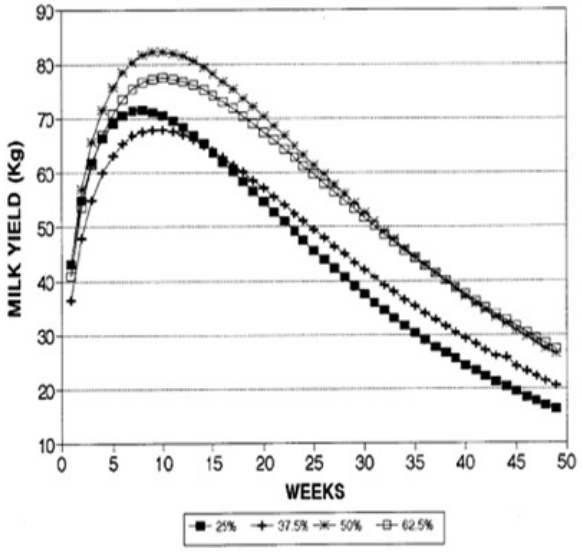

Fig 3: Lactation curves by percentage total foreign blood of crossbred cows at University of Khartoum dairy farm.

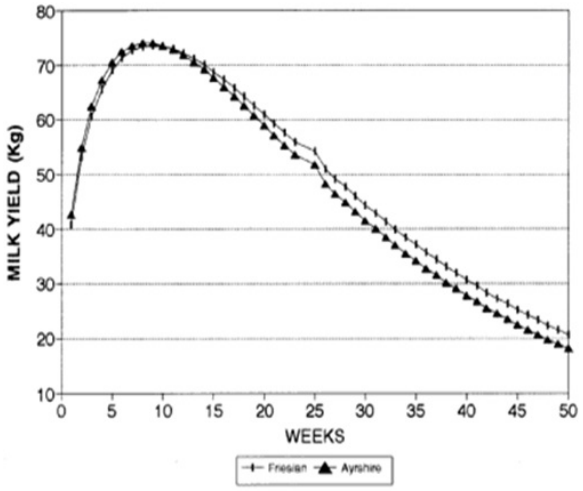

Fig 4: Lactation curves by sire breed of crossbred cows at University of Khartoum dairy farm.

However, sire breed has no effect on a-parameter. For c-parameter 25% total foreign blood was significantly (p<0.05) higher than other grades and no significant variation was encountered due to effect of sire breed.

Table 4 and Fig. (4) indicated that degree of persistency was significantly (p<0.05) higher for cows with 50% and 62.5% total foreign blood and those sired by Friesian bulls. Cows with 50% and 62.5% total foreign blood attained a significantly (p<0.05) higher peak yield than the two other grades, but there was insignificant (p>0.05) difference due to

Table 7: Correlation coefficients of the components of lactation curve of the crossbred cows

	(a)	(b)	(c)	Persistency	Peak yield	Week of peak yield
(a)	-	-	-	-	-	-
(b)	-0.674**	-	-	-	-	-
(c)	-0.184**	0.684**	-	-	-	-
Persistency	-0.702**	0.470**	0.0235**	-	-	-
Peak yield	0.523**	0.188**	0.232**	-0.113*	-	-
Week of peak yield	-0.715**	0.606**	-0.080 NS	0.934**	-0.039 NS	-

**=p<0.01
*=p<0.05
NS=Not significant

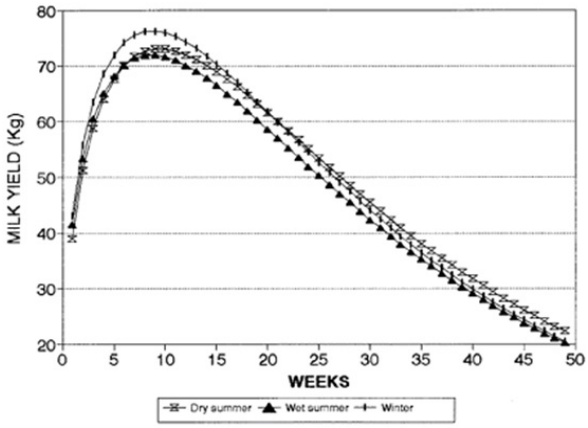

Fig 5: Lactation curves by season of calving of crossbred cows at University of Khartoum dairy farm.

effect of sire breed. The week of peak yield was attained earlier by 25% total foreign, then followed by 37.5%, 50% foreign blood cows, respectively.

The result also indicated that cows sired by Ayeshire bulls reached the peak yield significantly (p<0.05) earlier than those sired by Friesian bulls.

Season of Calving: Figure (5) presented that the lactation curves by season of calving were almost similar, however, observation on table (5) indicated that only week of peak yield showed variability due to season of calving. Summer calvers reached the maximum yield at latter time than other season calvers (p<0.05), while those calved during winter season attained the maximum yield at much earlier time than wet summer calvers (p<0.05).

Period of Calving: a-parameter, c-parameter, degree of persistency and peak yield were shown to be significantly (p<0.01) influenced by period of calving, while week of peak yield was significant at (p<0.05) (table 1).

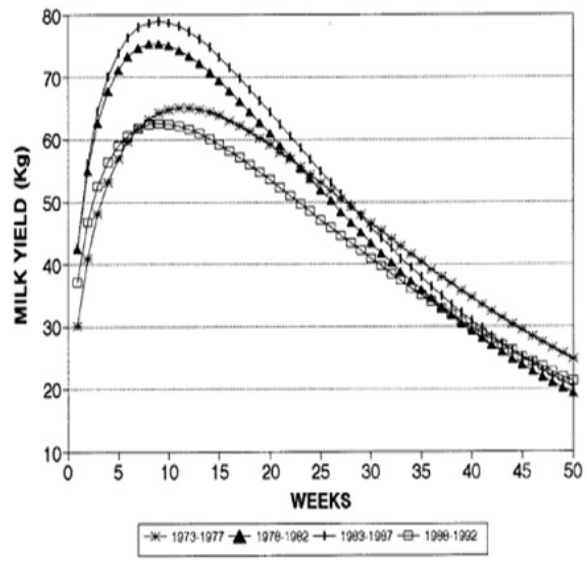

Fig 6: Lactation curves by period of calving of crossbred cows at University of Khartoum dairy farm.

DMRT (Table 6) revealed that a-parameter and c-parameter were significantly (p<0.05) higher at 2nd and 3rd periods, but significantly (p<0.05) lower at the 1st period. As shown by figure (6) cows calved in the 1st period were significantly (p<0.05) more persistent than cows calved during the other periods (table 7).

The 2nd and 3rd periods calvers were significantly (p<0.05) had a higher peak of yield that was attained at later time than other calvers.

Season X Period of Calving Interaction:
The interacted factors that comprised three seasons and four periods of calving were significantly (p<0.05) influenced the week to reach peak yield (table 1).

Relationship among the Components of the Lactation Curve: The correlation coefficients among

the components of the lactation curves are presented in Table (7). These results showed that a-parameter was positively ($p<0.01$) correlated with peak yield but negatively ($p<0.01$) with b- and c-parameters, persistency and week to attain peak yield. While b-parameter was positively ($p<0.01$) correlated with c-parameter, persistency peak yield and week to peak yield. However, c-parameter was positively ($p<0.01$) correlated persistency and peak yield and negatively ($p<0.05$) with week to attain peak yield. On the other hand, persistency showed positive ($p<0.01$) correlation with week to reach peak yield and negative ($p<0.05$) correlation with peak yield which revealed negative ($p<0.05$) correlation with week of peak yield.

Discussion: The Lactation yield presented by the lactation curve, described by gamma function consists of two segments: (a) rising segment (b) decline segment. Peak yield and persistency are the only variables of the lactation curve. The equation fitted the data well, and some of the parameter estimates were not significant. Compared to the study of Val-Arreola[21], who found that Wood equation explained much of the variation, and its parameters do not have direct biological interpretation.

Parity was positively associated with milk production. This finding tallies with other studies and may be partly explained by highest milk production capacity coupled with greater feed intake in older cows than young ones (Johnson[8], Gill[6] and Singh[19]). The studied curve showed less variation in the 1st lactation than in the subsequent ones indicating greater persistency in the 1st lactation. The genetic differences among groups and subsequent improvement of milk let down and/or change in management might be partially responsible for this variability. Both percentage total foreign blood and sire breed introduced significant ($p<0.01$) variation among some constants of gamma function, in addition to the degree of persistency and peak yield. This result was in agreement with those showed by Gahlot[5] for persistency of Rathi and Rathi crossbred, Mudgal[14] and Maarof[9] for peak yield and days to peak yield of Sahiwal x Friesian and Friesian cows respectively. The exhibited variability expresses the suitability of the parameters as selection criteria for improvement. Madalena[10] stated that breed type effect was significant for initial yield and increasing slope but not for the decreasing slope of Holstein Friesian and their crosses with Gir cows.

The effect of season of calving in this study was shown to be less important, but period of calving had been significantly influenced the initial yield, decreasing slope, persistency and peak yield. However, the interacted factors exhibited no significant ($p>0.05$) effect on the components of the lactation curve. These findings were different to those reported by Dèdwová[2] who found a highest influence on the shape of lactation curve for year of calving of Holstein cows. Whereas, Strandberg[20] indicated no seasonal variation of the parameters of the underlying lactation curve estimated by a 3-component function. Gill[6] showed that period of calving had significant effect on persistency and peak yield. Madalena[10] stated that year x season interaction had significant ($p>0.05$) effect on all parameters of the gamma function.

Winter calving cows had higher but later peak yield and moderate persistency than other seasons calving cows, this could be attributed to the favourable environmental conditions and the availability of green fodder during winter season. This finding could be compared with studies elsewhere which have shown that hot climate contributes significantly to reduced milk production indirectly through its effect on feed intake Mayer[12]; Payne[15] and West[22]). The 1st period calvers were favoured to other period calvers in the degree of persistency. Whereas, cows calved in the 3rd period were best than other periods calved cows in obtaining maximum yield. Variability in management and the differences in the genetic groups could probably be the cause of such variations.

On investigating the relationship among the components of the lactation curve, it can be concluded that the best fitted curve should have moderate persistency and higher but later peak. Results also indicated it is difficult to increase the persistency without adversely affecting the shape of the curve.

General conclusion of the study is that cows with 50% foreign blood are best suited to tropical environment under normal management. But management should be improved towards the increase in foreign blood. The lactation curve could be used as a method of evaluation and selection of lactating cows.

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