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Comparison of different lactation curve models in Karan Fries cattle of India*

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ABSTARCT

The first lactation weekly test day milk yield (WTDMY) records (57233) and monthly test day milk yield (MTDMY) records (11970) spread over a period of 23 years (1984– 2006) sired by 82 bulls of Karan Fries cattle were used to develop the best lactation curve model. The lactation curve parameters of Quadratic cum log model (QCLM), Gamma function (GF), Cobby Le Du model (CLDM), Polynomial regression function (PRF) and Multiphasic logistic function (MLF) were estimated. The average weekly test day milk yield was predicted with high degree of accuracy ($R^2 > 85\%$) by all the models with the maximum accuracy ($R^2 = 99.50\%$) obtained by polynomial regression function (PRF) and the least fit ($R^2 = 87.90\%$) was obtained by Gamma function (GF). However Quadratic cum log model ($R^2 = 99.20\%$) was almost equal to polynomial regression function and was better than Cobby Le Du model ($R^2 = 92.80\%$). The average root mean square error (RMSE) was found to be minimum with PRF (0.0121 Kg) followed by MLF (Triphasic). Thus the best fit model was polynomial regression function, which was better than other functions for prediction of first lactation WTDMY. The average monthly test day milk yield was predicted with high degree of accuracy ($R^2 > 75\%$) by all the models with the maximum accuracy ($R^2 > 99.41\%$) obtained by polynomial regression function (PRF) and the least fit was obtained with gamma function ($R^2 = 79.05\%$). However, quadratic-cum-log model ($R^2 = 99.28\%$) was almost equal to polynomial regression function and was better than CLDM ($R^2 = 89.50\%$). The average root mean square error (RMSE) was found to be minimum with PRF (0.0061 kg) followed by QCLM (0.0620). Thus the best fit model was polynomial regression function for prediction of both weekly and monthly test day milk yield of first lactation in Karan Fries cows.

Key words: Karan Fries, Lactation curve models, Milk yield, Monthly test day,Weekly test day milk yield

The Karan Fries - a synthetic cattle strain (Tharparkar × Holstein-Friesian) evolved at National Dairy Research Institute, Karnal with the aim of increasing milk yield and also retaining heat tolerant and disease resistant characters of indigenous cattle. For maintaining high level of milk production, it is necessary to have the accurate knowledge of the shape of the lactation curve of Karan Fries cattle. The lactation curve provides a summary of the pattern of milk yield and is quite useful for selection and feeding management. The lactation curve models can also be used to predict the milk yield at any point of the lactation and to predict future milk yields of an animal or of a herd for making decision on culling or keeping the breeding stock. Various models have been tried by different workers (Sherchand *et al.*1995, Olori *et al.*1999, and Catillo *et al.*2002) to fit the lactation curve of dairy animals. The objective of this study was to compare the properties of different models suitable for high milk yielders for their adequacy of fit to the lactation curves in Karan Fries cattle.

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MATERIALS AND METHODS

The daily milk yield and 305-day milk yield records of first parity of Karan Fries cattle spread over a period of 23 years (1984–2006) sired by 82 bulls were collected from the history-cum-pedigree sheets and daily milk recording registers maintained at Dairy Cattle Breeding Division of National Dairy Research Institute, Karnal, Haryana, India. The weekly test day milk yield (57,233) and monthly test day milk yield records (11,970) were used to develop the best lactation curve model for first lactation.

Khandekar (1956) proposed the quadratic-cum-log model

$$Y_t = a + bt + ct^2 + d \ln(t)$$

Y_t, Milk yield at t^{th} period; a, b, c and d are the lactation curve parameters.

The gamma function proposed by Wood (1967) is as under:

$$Y_t = at^b e^{-ct}$$

Y_t, Average daily yield in the t^{th} week; a, approximate initial milk yield just after calving; b, inclining slope parameter up to peak yield; c, declining slope parameter.

Cobby and Le Du (1978) proposed a model in which the exponential decline in the model of Brody (1924) is replaced by a linear decline.

$$Y_t = a - bt - ae^{-ct}$$

Y_t, Milk yield at t^{th} period; a, initial milk yield; b, persistency, measured in kg/day per week. It is a measure of the rate of decline of milk yield from peak lactation

Polynomial regression function proposed by Ali and Schaeffer (1987) is as under:

$$Y_t = a + bx_1 + cx_1^2 + dx_2 + e\,(x_2)^2$$

Y_t, Milk yield at t^{th} period; a, associated with peak yield; b & c, associated with the decreasing slope; d & e, associated with the increasing slope; x_1, t/305 ; x_2, log (305/t)

Grossman and Koops (1988) first proposed a Multiphasic logistic function, which gives total milk by adding each phase of the lactation

$$Y_t = \sigma_{i=1 \text{ to } n} \{a_i b_i [1 - \tanh^2 (b_i (t - c_i))]\}$$

Y_t, Milk yield at time t, a_i, half asymptotic total yield (kg), b_i, rate of yield relative to a_i ($days^{-1}$), n, number of lactation phases, tanh, hyperbolic tangent function.

RESULTS AND DISCUSSION

The lactation curve parameters of Quadratic-cum-log model (QCLM), Gamma function (GF), Cobby Le Du model (CLDM), Polynomial regression function(PRF) and Multiphasic logistic function(MLF) were estimated using 57233 WTDMY records of first lactation in Karan Fries cows for developing the best model (Table 1). The average weekly test day milk yield increased from 10.14 kg/day in lactation week-1 to a peak yield of 12.95 kg/day in week-6 and subsequently declined to 9.41 kg/day in week-43.

The average weekly test day milk yield was predicted with high degree of accuracy ($R^2 > 85\%$) by all the models with the maximum accuracy ($R^2 = 99.50\%$) obtained by polynomial regression function (PRF) and the least fit ($R^2 = 87.90\%$) was obtained by Gamma function (GF). However, Quadratic-cum-log model ($R^2 = 99.20\%$) was almost equal to polynomial regression function and was better than Cobby Le Du model ($R^2 = 92.80\%$) as presented in Table 1.

The observed and predicted first lactation weekly test day milk yield estimated by five functions has been depicted in Fig 1. The residuals of first lactation WTDMY estimated by functions is presented in Fig 2. It was observed that the errors in prediction of WTDMY using PRF were lowest in comparison to other models and ranged from –0.21 kg in week-15 to 0.16 Kg in week-6 in Karan Fries cows.

The average root mean square error (RMSE) was found to be minimum with PRF (0.0121 kg) followed by MLF (Triphasic). The average RMSE with QCLM, GF, CLDM, and MLF (Monophasic) were 0.0876 kg, 0.3324 kg, 0.3338 kg and 0.5213 kg respectively (Table 1). Thus the best fit model was polynomial regression function, which was better than other functions for prediction of first lactation WTDMY. Ali and Schaeffer (1987), Jamrozik and Schaeffer (1997), Olori *et al*. (1999) and Kocak and Ekiz (2008) also observed that the best fit was obtained with polynomial regression function in Holstein-Friesian cows. Out of all the five functions, MLF fitted worst for prediction of average first lactation weekly test day milk yield in Karan Fries cows. This observation was in conformation with the findings of Sherchand *et al.* (1995) on daily milk yields in Holstein cows.

A total of 11,970 monthly test day records of first lactation in Karan Fries cows were used for developing the best model

Table 1. Estimated lactation curve parameters of different functions for prediction of first lactation WTDMY

Functions	Parameters of Function	R^2 (%)	RMSE (Kg)
QCLM	Y_t= 6.295**–0.070**t+0.001**t^2+2.423** log (t)	99.2	0.0876
GF	Yt= 10.07** $t^{0.065**}$ $e^{-0.001**t}$	87.9	0.3324
CLDM	Y_t= 12.83+0.013 t-12.83$e^{-0.248\ t}$	92.8	0.3338
PRF	Y_t = 14.89**-13.05**x_1+7.63** $(x_1)^2$ +1.31×$_2$-2.35** $(×2)^2$	99.5	0.0121
MLF (Monophasic)	Y_t = 14020×0.001× [1-$\tanh^2$ (0.001×(t-(-408.3)))]	-	0.5213
MLF (Diphasic)	Y_t= 5633762×9.68× [1-$\tanh^2$ (9.68**× (t-(4))]+12527**×0.001× [1-$\tanh^2$ (0.001× (t- (-330)))]	-	0.5321
MLF (Triphasic)	Y_t = -864×0.43**× [1-$\tanh^2$ (0.43** × (t-(-36.36))]+12589**×0.001× [1-$\tanh^2$ (0.001 × (t-81.32))]+ (–3973**×0.003× [1-$\tanh^2$ (0.003× (t-167.7))]	-	0.0821

QCLM: Quadratic-cum-log model, GF: Gamma function, CLDM: Cobby Le Du model, PRF: Polynomial regression function and MLF: Multiphasic logistic function

Table 2. Estimated lactation curve parameters of different functions for prediction of first lactation MTDMY

Functions	Parameters of Function	R^2 (%)	RMSE (Kg)
QCLM	$Y_t = 6.210^{**} – 0.069t+0.001t^2+2.401 \log (t)$	99.28	0.062
GF	$Y_t = 8.912^{**} t^{0.039^{**}} e^{0.001t}$	79.05	0.4331
CLDM	$Y_t = 12.65-0.012 t-12.65e^{-0.270 t}$	89.5	0.3609
PRF	$Y_t = 15.624^{**}-14.291^{*}x_1+8.182^{**} (x_1)^2 +0.116x_2-1.877 (x2)^2$	99.41	0.0061
MLF (Mono-phasic)	$Y_t = 7002.6^{**}\times0.001\times [1-\tanh^2 (0.001\times(t-(-9.235))]$	-	0.814
MLF (Diphasic)	$Y_t = 291030000^{**}\times2.673\times [1-\tanh^2 (2.673\times (t-(40))]+5834\times0.001\times [1-\tanh^2 (0.001\times (t-56.09))]$	-	0.8421
MLF (Triphasic)	$Y_t = -836.90\times0.864^{**}\times [1-\tanh^2 (0.864^{**} \times (t-10))] +14207^{**}\times0.001\times [1-\tanh^2 (0.001 \times (t-123.4))]+ (–1506.7^{**}\times0.004\times [1-\tanh^2 (0.004\times (t-237.4))]$	-	0.2332

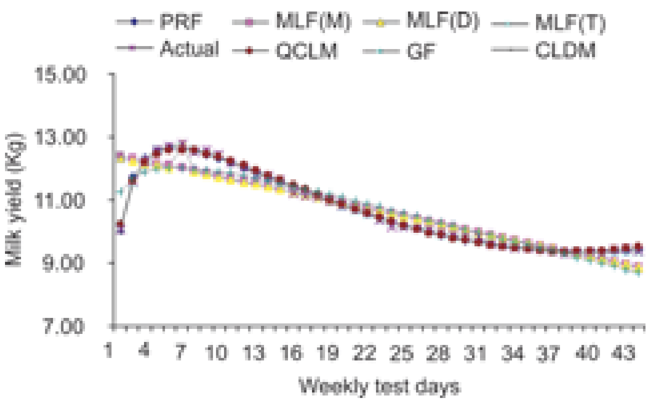

Fig. 1. Observed and predicted first lactation WTDMY for different lactation curve functions

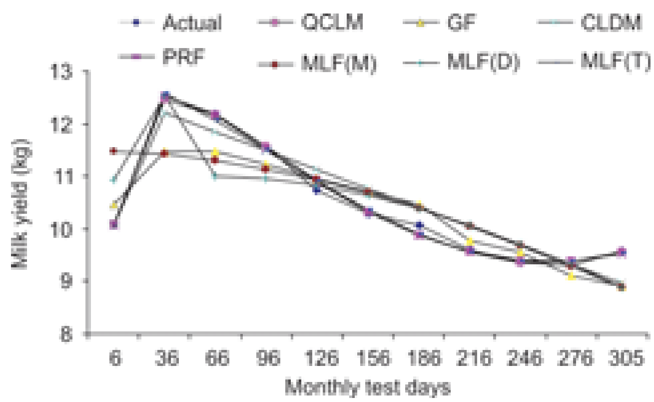

Fig. 3. Observed and predicted first lactation MTDMY for different lactation curve functions

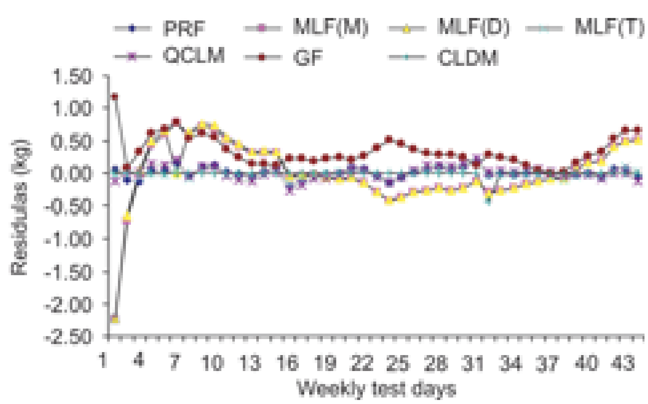

Fig. 2. Residuals (kg) of predicted first lactation WTDY for different lactation curve functions

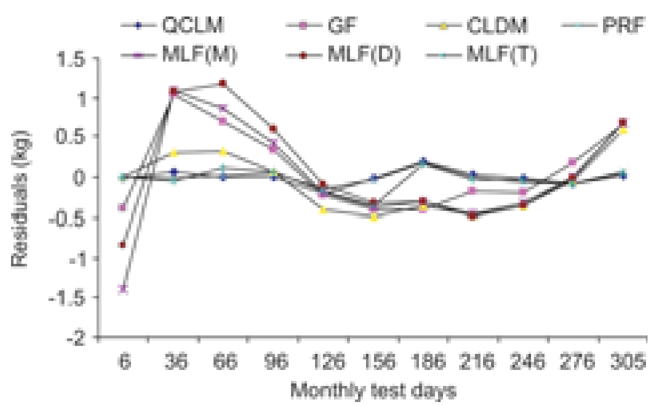

Fig. 4. Residuals (kg) of predicted first lactation MTDMY for different lactation curve functions

of lactation curve. The average monthly test day milk yield increased from 10.14 kg/day on 6th (first test day) day to a peak yield of 12.85 kg/day on 36th (second test day) day, and subsequently declined to 9.59 kg/day in 305th day (11th test day). The average monthly test day milk yield was predicted with high degree of accuracy ($R^2 > 75\%$) by all the models with the maximum accuracy ($R^2 > 99.41\%$) obtained by polynomial regression function (PRF) and the least fit was obtained with gamma function ($R^2 = 79.05\%$). However quadratic-cum-log model ($R^2 = 99.28\%$) was almost equal to polynomial regression function and was better than CLDM ($R^2 = 89.50\%$) in Table 2.

The observed and predicted first lactation monthly test day milk yield estimated by five functions has been depicted in Fig 3. The residuals of first lactation monthly test day milk yield estimated by different functions are shown in Fig 4. It was observed that the errors in prediction of monthly test day milk yield using polynomial regression function were in comparison to other models and ranged from –0.15 kg in 126th day to 0.18 kg in 186th day in Karan Fries cows.

The average root mean square error (RMSE) was found to be minimum with PRF (0.0061 kg) followed by QCLM (0.0620) and maximum (0.8421 kg) with MLF (Diphasic). The average RMSE with GF, CLDM, MLF (Monophasic) and MLF (Triphasic) were 0.4331 kg, 0.3609 kg, 0.8140 kg and 0.2332 kg respectively (Table 3). Thus the best fit model was polynomial regression function for prediction of monthly test day milk yield of first lactation in Karan Fries cows. This was in accordance with the findings (R^2=95 to 99%, RMSE= 0.041 to 0.238) of Ali and Schaeffer (1987) and Sharifi *et al*. (2009) in Holstein-Friesian cows and Cilek and Keskin (2008) in Simmental cows.

The polynomial regression function was found to be the best lactation curve model followed by quadratic-cum-log model based on coefficient of determination (R^2) and root mean square error (RMSE) for predicting weekly and monthly test day milk yield for first lactation in Karan Fries cattle.

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