SHORT COMMUNICATION

Comparative Evaluation of Different Lactation Curve Models in Prediction of Monthly Test-Day Milk Yields in Murrah Buffaloes

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ABSTRACT

Present investigation was undertaken to compare the different lactation curve models for describing the shape of the lactation curve in Murrah buffaloes. Data for the present study included 9071 monthly test-day milk yield (MTDMY) from 965 Murrah buffaloes calved during 1977 to 2012 at the National Dairy Research Institute, Karnal. A total of 10 monthly test-day milk yield records were taken at an interval of 30 days. The data were used to estimate lactation curve parameters for four lactation curve models *viz*. Gamma type function (GF), Exponential function (EF), Mixed log function (MLF) and Polynomial regression function (MLF). The mean monthly test day milk yields (MTDMY) increased from 5.91 ± 0.13 kg on TD_1 to a peak yield of 7.41 ± 0.12 kg on TD_3. The estimates of coefficient of determination (R^2) and root mean square error (RMSE) for GF, EF, MLF, and PRF were 96.42%, 98.65%, 98.48%, 99.86% and 0.077, 0.049, 0.052, 0.015, respectively. PRF fitted best to the test day data followed by EF on the basis of higher R^2 and lower RMSE estimates, whereas GF fitted least.

Keywords: Comparative evaluation, Function**,** Lactation curve, Murrah, Monthly test-day

India is the largest milk producing country of the world with a production of 133 million tonnes of milk (BAHS, 2013). Buffalo population of the country is 108.5 million (Livestock Census, 2012) which contributes significantly (51.09 %) to the national milk production. Amongst various buffalo breeds found in India, Murrah is one of the best and important breed with superior genetic potential for milk production. In buffaloes milk production trait follows a curvilinear pattern over the complete lactation course. Understanding of the lactation curve of dairy animals provides an insight into the behavior of milk production traits, which could be better used for augmenting wet and herd average. Lactation curve can be defined as the graphical representation of milk yield against time (Brody,

1923) or it can also be referred as the curve representing the rate of milk secretion with advancement of lactation. The aim of modelling the lactation curve is to predict milk yield at any point of the lactation with minimum error. Many studies have been conducted in the past in dairy cattle and buffaloes using various lactation curve models to fit the lactation curve (Sahoo, 2014; Dongre, 2011 and Banu, 2012). However, information is scanty on fitting of lactation curve models using test-day milk yields in Murrah buffaloes. Therefore, the present investigation was undertaken to compare the different lactation curve models for describing the shape of the lactation curve in Murrah buffaloes and their efficiency in prediction of monthly test-day milk yields.

Table 1. Estimated lactation curve parameters of different functions

S.No.	Lactation curve functions	Parameters				
		a	b	c	d	e
1.	GF	7.28	0.69	0.23	-	-
2.	EF	10.78	-8.36	-0.73	-	-
3.	MLF	15.42	-9.60	7.98	-	-
4.	PRF	2.79	3.24	-0.13	-0.52	-3.73

Table 2. Different lactation curve functions with parameters for prediction of MTDMYs

S. No.	Function	Parameters of function	R^2 (%)	RMSE (kg)
1.	GF	$Y_t = 7.28\ t^{0.69}\ e^{-0.23t}$	96.42	0.077
2.	EF	$Y_t = 10.78 - 8.36\ e^{-0.70t} - 0.73t$	98.65	0.049
3.	MLF	$Y_t = 15.42 - 9.60\ t^{0.5} + 7.98\ \log(t)$	98.48	0.052
4.	PRF	$Y_t = 2.79 + 3.24\ (t/305) - 0.13\ (t/305)^2 - 0.52\ \log(305/t) - 3.73\ \log(305/t)^2$	99.86	0.015

Table 3. Predicted MTDMYs (kg) and error of different lactation curve functions

Test Day	MTDMY (Least Squares Mean)	PRF	Prediction Error	MLF	Prediction Error	EF	Prediction Error	GF	Prediction Error
TD_1	5.91	5.90	-0.004	5.81	-0.09	5.88	-0.02	5.75	-0.15
TD_2	7.29	7.31	0.02	7.37	0.08	7.24	-0.04	7.36	0.07
TD_3	7.41	7.38	-0.02	7.55	0.14	7.54	0.13	7.72	0.31
TD_4	7.20	7.16	-0.03	7.28	0.08	7.32	0.12	7.45	0.25
TD_5	6.82	6.81	-0.007	6.79	-0.02	6.84	0.02	6.88	0.06
TD_6	6.22	6.34	0.12	6.20	-0.01	6.23	0.01	6.18	-0.03
TD_7	5.82	5.76	-0.05	5.54	-0.27	5.55	-0.26	5.43	-0.38
TD_8	5.09	5.03	-0.05	4.85	-0.23	4.85	-0.23	4.71	-0.37
TD_9	4.15	4.16	0.01	4.15	0.001	4.13	-0.01	4.05	-0.09
TD_{10}	3.11	3.12	0.01	3.43	0.32	3.40	0.29	3.44	0.33

MATERIALS AND METHODS

Data Collection

The lactation records used in this study included 9071 monthly test-day milk yield (MTDMY) from 965 Murrah buffaloes calved during 1977 to 2012 at the ICAR-National Dairy Research Institute, Karnal. Data was collected from the history cum-pedigree sheets and daily milk yield recording registers maintained at Dairy Cattle and Breeding Division of this institute. The climate of the farm is subtropical in nature with lowest temperature around 2°C during the winter months, whereas the highest temperature goes upto 45°C during summer. The annual rainfall is about 760 to 960mm, out of which most of the rainfall is received during July and August. For the present investigation only those records of Murrah buffaloes were considered that had produced minimum of 500 kg for at least 100 days of lactation length. Culling in the middle of lactation, abortion, stillbirth or any other pathological causes which affected the lactation yield were considered as abnormalities and thus, such records were not considered for analysis. To ensure the normal distribution of data, the
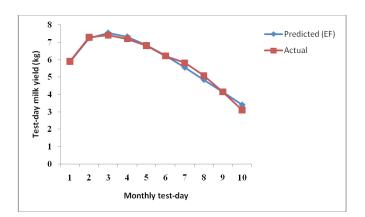
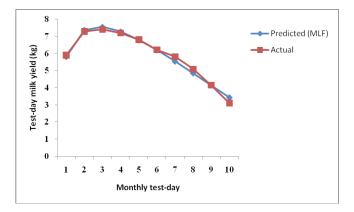**Figure 1. The observed and predicted MTDMYs from the exponential function.**

Figure 3. Observed and predicted MTDMYs from the gamma function.
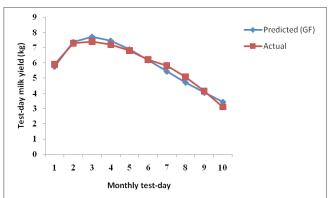

Figure 2. The observed and predicted MTDMYs from the mixed log function.
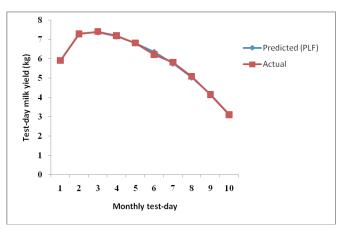

Figure 4. The observed and predicted MTDMYs from the polynomial regression function.

outliers were removed and data within the range of mean ± 3SD were considered for study.

Lactation Curve Models

A total of 10 monthly test-day milk yield records (15th day, 45th day,…, 285th day) were taken at an interval of 30 days. The data were used to estimate lactation curve parameters for the following four lactation curve models;

1. Gamma-type function (Wood, 1967)

$$Y_t = a t^b e^{-ct}$$

In its logarithmic form, this reduces to $\ln(Y_t) = \ln(a) + b\ln(t) - ct$

2. Exponential function (Catillo, 2002)

$$Y_t = a + b e^{-0.70t} + ct$$

3. Mixed log function (Guo and Swalve, 1995)

$$Y_t = a + b\sqrt{t} + c \log t$$

In the models, Y_t = average daily yield in the tth test day of lactation; a = initial milk yield just after calving; b= ascending slope parameter up to the peak yield; c = descending slope parameter and t = length of time since calving.

4. Polynomial regression function (Ali and Schaeffer, 1987)

$$Y_t = a + bx + cx^2 + d\log(1/x) + e\log(1/x)^2$$

In this model, Y_t = Average milk yield in t^{th} web of lactation, a = Associated with peak yield, b & c = Associated with the decreasing slope, d & e = Associated with the increasing slope, $\times$ = t / 305. The best fit model was identified on the basis of higher coefficient of determination (R^2) and lower root mean square error (RMSE). Residuals obtained by these functions were plotted graphically.

RESULTS AND DISCUSSION

The mean monthly test day milk yields (MTDMY) increased from 5.91 ± 0.13 kg on TD_1 (15th day of lactation) to a peak yield of 7.41 ± 0.12 kg on TD_3 (75th day of lactation) and subsequently declined to 3.11 ± 0.15 kg on TD_{10} (285th day of lactation). Geetha *et al.* (2006), Chakraborty *et al.* (2010) and Patil *et al.* (2012) who reported the peak MTDMY as 7.15 ± 0.15 kg, 8.11 ± 0.25 kg and 8.02 ± 0.09 kg, respectively on TD_3. The estimated lactation curve parameters (a, b, c, d and e) of four lactation curve models (Table 1) were using 9071 monthly test-day milk yield records of first lactation in Murrah buffaloes to fit into the mathematical models and obtain the predicting equation for monthly test-day milk yields (Table 2). The lowest R^2 value (96.42%) and highest RMSE value (0.07kg) was obtained by GF. In accordance with the present finding, R^2 value (96%) was reported by Kumar and Bhatt (1979) and Aziz *et al.* (2006) in Indian buffaloes and Egyptian buffaloes, respectively. Sahoo *et al.* (2014) also reported lowest R^2 value (93.13%) in Murrah buffaloes using this function. The EF gave a higher R^2 value (98.65%) with a comparatively lower RMSE value (0.04kg). Kumar (2007) reported similar R^2 value (99.16%) in Murrah buffaloes. MLF gave better R^2 and RMSE values i.e 98.48% and 0.05 kg, respectively in comparison to the above mentioned functions. The PRF gave the highest R^2 value (99.86%) and the lowest RMSE value (0.01kg) which were in accordance with the estimates Kumar (2007) and Sahoo *et al.* (2014). The peak MTDMY predicted by PRF was 7.38kg on TD_3 and GF, MLF and EF predicted the peak yield as, 7.72kg, 7.55kg and 7.54kg on TD_3, respectively. Kumar (2007) reported peak yield of 8.37kg, 8.27kg and 8.09 kg in Murrah buffaloes using EF, PRF and

MLF, respectively. Comparison of predicted with actual monthly test day milk yields using different functions have been presented in Table 3 and the overall observed and predicted MTDMY using all the four lactation curve functions were plotted graphically (Figure 1 to 4). The figures indicated that PRF was almost of similar order of magnitude as the actual curve. This may be due to the fact that this function accounted for rising and declining segments of the lactation curve.

In the present investigation it was found that on an average, the peak yield from all lactation curves functions was found to be highest in 3rd test day (TD_3) of lactation in Murrah buffaloes. Among four models studied PRF fitted best to the test day data followed by EF and therefore these two functions are recommended for prediction of MTDMYs in Murrah buffaloes.

ACKNOWLEDGEMENTS

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