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Comparison of four different lactation curve models for prediction of weekly test day milk yields in Murrah buffalos

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Lactation curve is the graphical representation of milk yield against time (Brody *et al*. 1923). Dairy cattle and buffaloes with more stable lactation curve are more persistent than those which show a rapid increase in the daily milk yield from calving to peak followed by a rapid decline. Several lactation curve models have been tried by different workers to fit the lactation curve in indigenous as well as in exotic cattle. However, very scanty work on lactation curve is available on Murrah buffaloes, the best dairy buffalo breed of India. Hence, the present investigation was proposed to fit and compare the lactation curve models for describing the shape of the lactation curve in Murrah buffaloes for prediction of weekly test day milk yields.

Data collection: Data of 39,059 weekly test day milk yield (WTDMY) records during first lactation of 961 Murrah buffaloes calved during 1977 to 2012 at the National Dairy Research Institute, Karnal were collected from the history-cum-pedigree sheets and daily milk yield recording registers. Culling in the middle of lactation, abortion, still-birth or any other pathological causes affecting the lactation yield were considered as abnormalities and thus, such records were not taken for the study. Records of buffaloes with less than 800 kg of milk production and less than 100 days lactation length were not considered in the present investigation. To ensure the normal distribution, the outliers were removed and data within the range of mean±3SD were only considered for the study.

Lactation curve models: A total of 43 weekly test day milk yield records (6^{th} day, 13^{th} day, 20^{th} day,…, 300^{th} day) were taken at an interval of 7 days. The data were used to estimate lactation curve parameters of the 4 lactation curve models as described best fit in Italian water buffaloes (Catillo *et al*. 2002) for developing the prediction model for estimation of weekly test day milk yields in Murrah buffaloes.

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1. Gamma-type function: (Wood 1967)

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

In its logarithmic form, this reduces to

$$\ln(Y_t) = \ln(a) + b\ln(t) - ct$$

2. Exponential function (Catillo 2002)

$$Yt = a + be^{-0.70t} + ct$$

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 t^{th} 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)

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

In this model, Y_t, average milk yield in t^{th} week of lactation; a , associated with peak yield ; b and c, associated with the decreasing slope ; d and e, associated with the increasing slope ; x , t/305.

The least squares means of the WTDMYs were calculated for adjustment of effect of non-genetic factors. The average WTDMYs increases from 3.84±0.08 kg in first test day (sixth day of lactation) to a peak yield of 7.81±0.09 kg on test day 8 (55^{th} day of lactation), and subsequently declined to 2.50±0.09 kg in last test day. Comparatively higher estimates of peak monthly TDMY as 8.11±0.25kg and 8.02±0.09kg on TD3 were reported by Chakraborty *et al*. (2010) and Patil *et al*. (2012) in Murrah buffaloes, respectively.

Various lactation curve parameters (a, b, c, d and e) were estimated to fit into the mathematical models and obtain

Table 1. Different lactation curve functions with estimated parameters for prediction of WTDMY

Function	Parameters of function	Adjusted R^2 (%)	RMSE (kg)
EF	$Y_t = 9.13–11.74*e^{-0.70*t} -0.13*t$	88.50	0.08
GF	$Y_t = 3.98*t^{0.54}e^{-0.05*t}$	92.78	0.06
MLF	$Y_t = 6.97–3.72*t^{0.5}+5.54\log(t)$	95.61	0.05
PRF	$Y_t= 3.41+0.25*(t/305)-0.01*(t/305)^2-3.44*\log(305/t)-1.07*\log(305/t)^2$	99.30	0.02

the predicting equation for WTDMYs. The 4 lactation curve functions were developed after fitting the values of the lactation curve parameters for predicting WTDMYs (Table 1).

The EF gave the lowest R^2 value, with the highest RMSE value. Using this function, Dimauro *et al.* (2005) and Singh *et al*. (2015) reported comparatively higher R^2 value (94.4% and 98.7%) in Italian water buffaloes and Murrah buffaloes, respectively. The GF gave a higher R^2 value (92.78%) with a comparatively lower RMSE value (0.06 kg). Similar R^2 value (93.7%) was reported by Dimauro *et al.* (2005) in Italian water buffaloes using this function, whereas an R^2 value of 96% was reported by Kumar and Bhat (1979) and Aziz *et al*. (2006) in Indian buffaloes and Egyptian buffaloes, respectively. The R^2 and RMSE values from MLF were still better i.e. 95.61% and 0.05 kg, respectively. Comparatively higher R^2 values of 98.48% were reported by Singh *et al*. (2015) in Murrah buffalos. The PRF gave the highest R^2 value (99.30%) and the lowest RMSE value (0.02 kg) for Murrah buffaloes in the present study. Singh *et al*. (2015) also reported highest accuracy of prediction using this function in Murrah buffaloes. However, Dimauro *et al*. (2005) reported comparatively lower R^2-value of 96.7% in Italian water buffaloes.

Table 2. Predicted WTDMY and error (kg) of different lactation curve functions

FTDMY	Observed value (LS means)	GF		EF		MLF		PRF	
		Predicted	Error	Predicted	Error	Predicted	Error	Predicted	Error
TD 1	3.84	3.78	–0.07	3.17	–0.67	3.25	–0.59	3.66	–0.18
TD 2	5.44	5.21	–0.23	5.98	0.54	5.55	0.11	5.77	0.33
TD 3	6.38	6.15	–0.23	7.31	0.93	6.61	0.23	6.61	0.23
TD 4	7.03	6.82	–0.20	7.91	0.88	7.21	0.18	7.05	0.02
TD 5	7.44	7.31	–0.13	8.14	0.71	7.56	0.13	7.31	–0.13
TD 6	7.66	7.66	0.00	8.19	0.54	7.78	0.12	7.47	–0.19
TD 7	7.79	7.90	0.11	8.16	0.36	7.90	0.11	7.57	–0.22
TD 8	7.81	8.06	0.25	8.07	0.27	7.96	0.15	7.63	–0.18
TD 9	7.73	8.16	0.43	7.97	0.24	7.98	0.25	7.66	–0.07
TD 10	7.77	8.20	0.43	7.86	0.08	7.95	0.18	7.67	–0.10
TD 11	7.68	8.20	0.52	7.73	0.06	7.91	0.23	7.66	–0.01
TD 12	7.62	8.16	0.54	7.61	–0.01	7.84	0.22	7.64	0.03
TD 13	7.58	8.09	0.51	7.49	–0.09	7.76	0.18	7.61	0.03
TD 14	7.52	8.00	0.47	7.36	–0.16	7.66	0.14	7.57	0.05
TD 15	7.46	7.88	0.42	7.24	–0.23	7.55	0.09	7.52	0.05
TD 16	7.38	7.75	0.36	7.11	–0.27	7.44	0.05	7.46	0.07
TD 17	7.29	7.60	0.31	6.98	–0.31	7.32	0.02	7.39	0.09
TD 18	7.21	7.45	0.24	6.86	–0.35	7.19	–0.02	7.31	0.10
TD 19	7.13	7.28	0.15	6.73	–0.40	7.05	–0.08	7.22	0.09
TD 20	7.02	7.11	0.09	6.61	–0.41	6.92	–0.10	7.13	0.11
TD 21	6.90	6.93	0.03	6.48	–0.42	6.78	–0.13	7.02	0.12
TD 22	6.80	6.75	–0.05	6.36	–0.44	6.63	–0.17	6.91	0.11
TD 23	6.69	6.56	–0.13	6.23	–0.46	6.49	–0.21	6.79	0.10
TD 24	6.59	6.38	–0.21	6.10	–0.49	6.34	–0.25	6.66	0.07
TD 25	6.47	6.19	–0.28	5.98	–0.49	6.19	–0.28	6.53	0.06
TD 26	6.34	6.01	–0.34	5.85	–0.49	6.04	–0.31	6.38	0.04
TD 27	6.23	5.82	–0.41	5.73	–0.51	5.88	–0.35	6.23	0.00
TD 28	6.08	5.64	–0.44	5.60	–0.48	5.73	–0.35	6.07	0.00
TD 29	5.95	5.46	–0.50	5.47	–0.48	5.58	–0.38	5.90	–0.05
TD 30	5.82	5.28	–0.55	5.35	–0.48	5.42	–0.40	5.73	–0.10
TD 31	5.68	5.10	–0.58	5.22	–0.46	5.26	–0.41	5.54	–0.13
TD 32	5.50	4.93	–0.57	5.10	–0.40	5.11	–0.39	5.35	–0.15
TD 33	5.31	4.76	–0.56	4.97	–0.34	4.95	–0.36	5.15	–0.17
TD 34	5.11	4.59	–0.51	4.84	–0.26	4.80	–0.31	4.94	–0.17
TD 35	4.84	4.43	–0.41	4.72	–0.12	4.64	–0.20	4.72	–0.12
TD 36	4.56	4.27	–0.28	4.59	0.04	4.48	–0.07	4.49	–0.06
TD 37	4.34	4.12	–0.22	4.47	0.13	4.33	–0.01	4.26	–0.08
TD 38	4.07	3.97	–0.11	4.34	0.27	4.17	0.10	4.01	–0.06
TD 39	3.75	3.82	0.07	4.22	0.46	4.01	0.26	3.76	0.01
TD 40	3.44	3.68	0.24	4.09	0.65	3.86	0.42	3.50	0.06
TD 41	3.13	3.54	0.41	3.96	0.83	3.70	0.57	3.23	0.10
TD 42	2.82	3.40	0.59	3.84	1.02	3.55	0.73	2.95	0.13
TD 43	2.50	3.27	0.77	3.71	1.21	3.39	0.89	2.66	0.16

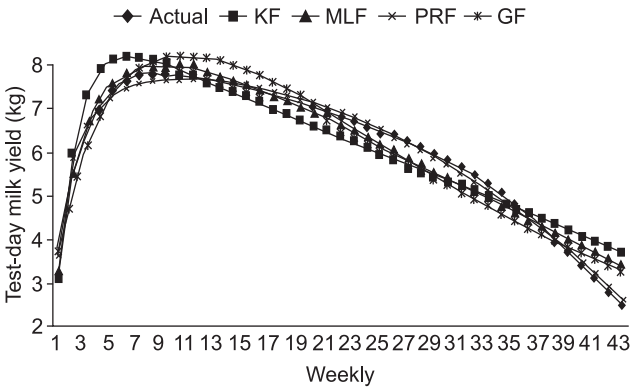

Fig. 1. The observed and predicted WTDMYs from various lactation curve functions.

The peak weekly TDMY predicted by PRF, GF, MLF and EF were 7.67 kg, 8.20 kg, 7.98 kg and 8.19 kg, respectively. Singh *et al*. (2015) reported peak monthly TDMY as 7.38 kg, 7.72 kg, 7.55 kg and 7.54 kg on TD3 (75th day) using these functions, respectively in Murrah buffaloes. However, in Italian water buffaloes using GF, EF and PRF, Dimauro *et al*. (2005) reported peak yield of 10.9 kg, 11.3 kg and 11.5 kg in 33rd, 26th and 29th day, respectively. The predicted and actual WTDMY records of different functions are presented in Table 2.

The overall observed and predicted WTDMYs from all 4 lactation curve functions were plotted graphically (Fig. 1). The EF showed an early peak by 41st day (TD6) of lactation, whereas GF indicated a late peak by 69th day (TD10). The closeness of the curves to the actual lactation curve was almost of the same order of magnitude which may be due to the fact that all these functions accounted for rising and declining segments of the lactation curve in Murrah buffaloes and PRF explained best fit as reported by Catillo *et al.* (2002) in Italian water buffaloes.

In the present investigation, polynomial regression function (PRF) was the best fit lactation curve model among 4 models studied with highest coefficient of determination and lowest root mean square error and therefore this function is recommended for prediction of WTDMYs in Murrah buffaloes.

SUMMARY

The present investigation was carried out using data on 39,059 weekly test day milk yield (WTDMY) records during first lactation of 961 Murrah buffaloes calved during 1977–2012 maintained in an organized farm at the Institute. The least squares means of the WTDMY ranged from 2.50±0.09 kg to 7.81±0.09 kg. The relative efficiency of 4 lactation curve models via gamma-type function (GF), exponential function (EF), mixed log function (MLF) and polynomial regression function (PRF) were compared. PRF described the highest coefficient of determination (99.30%) and with least value (0.02 kg) of root mean squares error (RMSE), whereas, least coefficient of determination (88.50%) was observed in EF having maximum (0.08 kg) RMSE value suggesting PRF the best mathematical model for prediction of WTDMYs in Murrah buffaloes.

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REFERENCES

Ali T E and Schaeffer L R. 1987. Accounting for covariances among test day milk yields in dairy cows. *Canadian Journal of Animal Science* **67** (3): 637–44.

Aziz M A, Shalaby N A, El-Shafie O M, Mahdy A T and Nishida A. 2006. Comparison between the shapes of lactation curve of Egyptian buffalo milk yield estimated by the incomplete gamma function and a new model. *Livestock Research for Rural Development* **18** (5).

Brody S, Ragsdale A C and Turner C W. 1923. The rate of decline of milk secretion with the advance of the period of lactation. *Journal of General Physiology* **5**: 441–44.

Catillo G, Macciotta N P P, Carretta A and Cappio Borlino A. 2002. Effects of age and calving eeason on lactation curves of milk production traits in Italian water buffaloes. *Journal of Dairy Science* **85** (5):1298–306.

Chakraborty D, Dhaka S S, Pander B L, Yadav A S, Singh S and Malik P K. 2010. Prediction of lactation milk yield from test day records in Murrah buffaloes. *Indian Journal of Animal Sciences* **80** (3): 244–45.

Dimauro C, Catillo G, Bacciu N and Macciotta N P P. 2005. Fit of different linear models to the lactation curve of Italian water buffalo. *Italian Journal of Animal Science* **4** (2): 22–24.

Guo Z and Swalve H H. 1995. Modelling of the lactation curve as a sub-model in the evaluation of test day records. journal.interbull.org/index.php/ib/article/view/237/237.

Kumar R and Bhat P N. 1979. Lactation curves in Indian buffaloes. *Indian Journal of Dairy Science* **32** (2):156–60.

Patil C S, Chakravarty A K, Kumar V, Sharma R K and Kumar P. 2012. Average performance of various first lactation 305–day and test day milk yield in Murrah buffaloes. *Indian Journal of Animal Research* **46** (3): 310–12.

Singh M, Singh A, Gupta A K, Dash S K, Gupta A, Sahoo S K, Dash S and Shivahre P R. 2015. Comparative evaluation of different lactation curve models in prediction of monthly test-day milk yields in Murrah buffaloes. *Journal of Animal Research* **5** (1):189–93.

Wood P D P. 1967. Algebraic model of lactation curve in cattle. *Nature* **216**: 164–65.