

Comparison of different lactation curve models in Sahiwal cows

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Abstract: The present investigation was carried out on 12,859 fortnightly test-day milk yield records of first lactation pertaining to 643 Sahiwal cows spread over a period of 49 years (1961–2009), maintained at the National Dairy Research Institute, Karnal, India. The comparison of 3 lactation curve models, i.e. the quadratic model, gamma-type function, and mixed log function, was done using fortnightly test-day milk yield records. The mixed log function was the best fit, with the highest (88.75%) coefficient of determination (R² value) and the lowest (0.08 kg) root mean square error (RMSE) value, whereas the lowest (56.93%) R² value was observed in the quadratic model with maximum (0.15 kg) RMSE value. The closeness of fit of the mixed log function and gamma-type function with the observed lactation curve was almost of the same order. However, the gamma-type function gave a low peak yield, and therefore it is recommended that this function can give the best fit for low-yielding cows.

Key words: Fortnightly test-day milk yields, gamma-type function, quadratic model

In dairy cows, milk production traits follow a curvilinear pattern over the course of lactation. Knowledge of the lactation curve can provide a worthwhile information source about the pattern of milk production traits, which in turn could be used for herd management decisions (1). However, test-day models have been used more frequently in the recent past for the genetic evaluation of dairy cows as a substitute for cumulative 305-day lactation yield. There are many advantages of evaluation of the lactation curve in dairy cows, such as designing suitable breeding and management strategies for dairy cattle, genetic evaluation of dairy cows, and the prediction of the total milk yield of cows (2). Various models have been tried by different researchers to fit the lactation curve in indigenous as well as exotic cattle (3–6). However, very few reports are available fitting the lactation curve in Sahiwal cattle, which is considered to be one of the best milch breeds of dairy

cattle in India. Therefore, the present investigation has been undertaken to fit and compare the lactation curve models for describing the shape of the lactation curve in Sahiwal cows and to determine the most important test days from different segments of the lactation curve.

The data on 12,859 fortnightly test-day milk yields (FTDMYs) during the first lactation of 643 Sahiwal cows, spread over 49 years (1961–2009), were collected from the National Dairy Research Institute, Karnal, India. The climate of the farm is subtropical in nature. The lowest temperature falls to 2 °C during the winter months, whereas the highest temperature goes up to 45 °C during the summer. The annual rainfall is about 760 to 960 mm, out of which most of the rainfall is received during the months of July and August. The relative humidity ranges from 41% to 85%.

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The data were used to fit 3 lactation curve models, i.e. the quadratic model, gamma-type function, and mixed log function, on fortnightly test-day milk yields to develop the best model. A total of 20 FTDMY records were considered (from days 6 through 291 of calving). The models were:

1. Quadratic model (7):

$$Y_t = a + bt - ct^2$$

2. Gamma-type function (8):

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

The constants can be derived by solving the above equation after transformation on the log scale:

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

3. Mixed log function (5):

$$Y_t = a + bt^{1/2} + c \log t = e_t$$

In these equations, Y_t = the average daily yield on the t th test day of lactation, a = the initial milk yield after calving, b = the ascending slope parameter up to the peak yield, c = the descending slope parameter, t = the length of time since calving, and e_t = the residual error.

The most suitable model was identified on the basis of the highest value of the coefficient of determination (R^2 value) and the lowest value of the

root mean square error (RMSE). Residuals obtained by these functions were plotted graphically.

The descriptive statistics of the fortnightly test-day milk yields are presented in the Table.

It was observed that the quadratic model gave the least fit of any other lactation curve function in the present study (Figure 1). It gave the lowest R^2 value (55.93%), with the highest RMSE value (0.15 kg). The quadratic model indicated a wide diversity between the observed and predicted yield, starting from the initial phase until the end of lactation. Therefore, this function does not explain the ascending peak yield or the descending phase of the lactation curve in Sahiwal cows. Similar findings have been reported by different researchers in different breeds of cattle (9–11).

The gamma-type function gave a higher R^2 value (82.73%) with a comparatively lower RMSE value (0.09 kg). Nearly same R^2 value (83%) for this function was reported in crossbred cows (12). However, higher R^2 values were reported in different breeds of cattle (3,4,11,13). Contrary to the present findings, lower R^2 values were reported by different researchers (14–16) in different breeds of cattle. In accordance with the present findings, an R^2 value of 87.9% and observed low peak yield estimates of

Table. Test day, mean of the test-day milk yields, standard deviation, standard error, and coefficient of variation for test-day milk yields.

TD	Mean	SD	SE	CV (%)	TD	Mean	SD	SE	CV (%)
1	4.96	2.55	0.42	48.98	11	6.62	1.75	0.29	24.16
2	7.51	2.49	0.41	27.94	12	6.45	1.78	0.29	25.66
3	8.20	2.58	0.42	27.69	13	6.21	1.90	0.31	29.01
4	8.28	1.95	0.32	26.84	14	5.97	1.83	0.30	28.56
5	8.22	2.30	0.38	25.49	15	5.98	2.08	0.34	33.99
6	7.95	2.39	0.39	27.74	16	5.82	1.83	0.30	30.18
7	7.72	2.26	0.37	27.02	17	5.78	1.88	0.31	31.19
8	7.42	1.81	0.30	23.33	18	5.58	1.94	0.32	31.90
9	7.15	2.01	0.33	26.50	19	5.45	1.77	0.29	29.00
10	6.94	1.95	0.32	26.66	20	5.49	1.30	0.21	22.09

TD = test day, SD = standard deviation, SE = standard error, CV = the coefficient of variation.

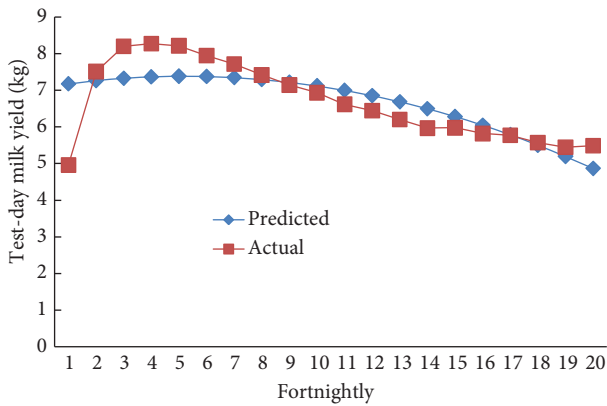


Figure 1. The observed and predicted FTDMYs from the quadratic model in Sahiwal cows.

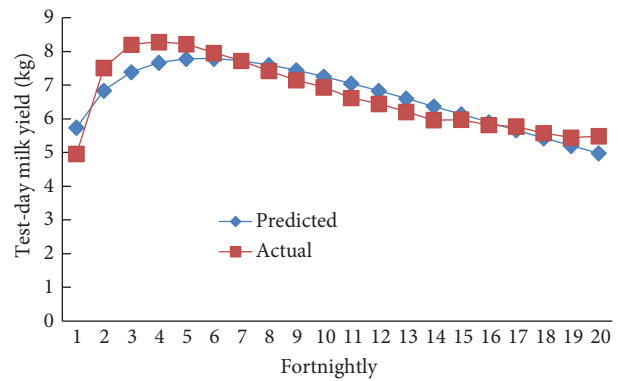


Figure 2. The observed and predicted FTDMYs from the gamma-type function in Sahiwal cows.

weekly test-day milk yields were reported in Karan Fries cows (6). Similarly, in the present study, the gamma-type function gave a lower peak yield (Figure 2). It is therefore suggested that this function can give the best fit for lower yielding cows.

The mixed log function was explored for the first time in indigenous cattle in the present study. The mixed log function gave the highest R^2 value (88.75%) and the lowest RMSE value (0.08 kg). A lower estimate (59.1%) was reported in Holstein-Friesian cows (16). The mixed log function gave a very close fit with the observed lactation curve throughout the whole lactation, except for the peak yield, which was slightly lower than the actual value (Figure 3).

The overall observed and predicted fortnightly test-day milk yields from all 3 lactation curve

functions were plotted graphically (Figure 4). On average, the peak yield from all of the lactation curve functions was 7.69 kg on day 66 of lactation. The closeness of the curves of the mixed log function and gamma-type function to the observed lactation curve was almost of the same order of magnitude. This may be due to the fact that both of these functions accounted for rising and declining segments of the lactation curve. The residuals of the first lactation fortnightly test-day milk yield estimated by 3 different lactation curve functions are graphically presented in Figure 5.

The mixed log function was found to be best fit among all of the models under study, giving the highest the R^2 value with the lowest RMSE in Sahiwal cattle. It was observed that at around the 8th test day

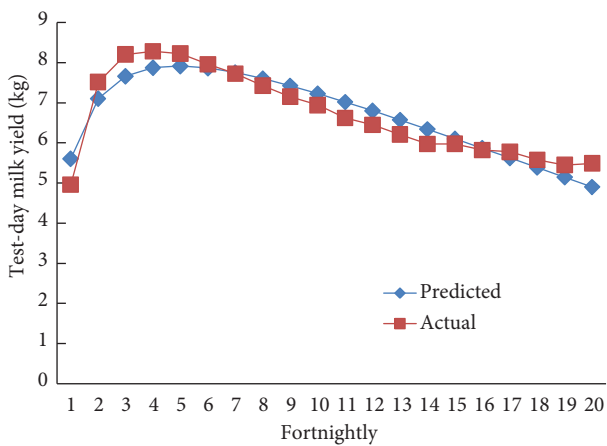


Figure 3. The observed and predicted FTDMYs from the mixed log function in Sahiwal cows.

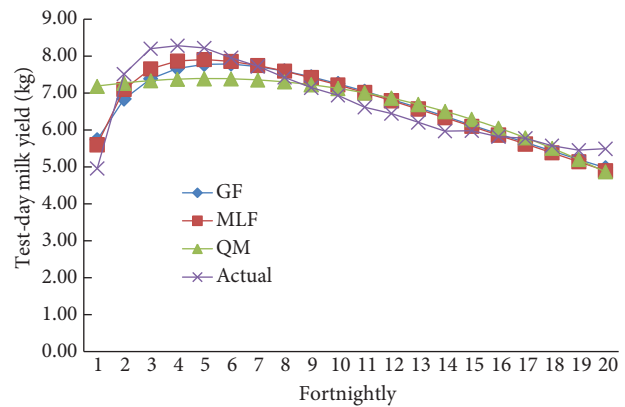


Figure 4. The observed and predicted FTDMYs from various lactation curve functions.

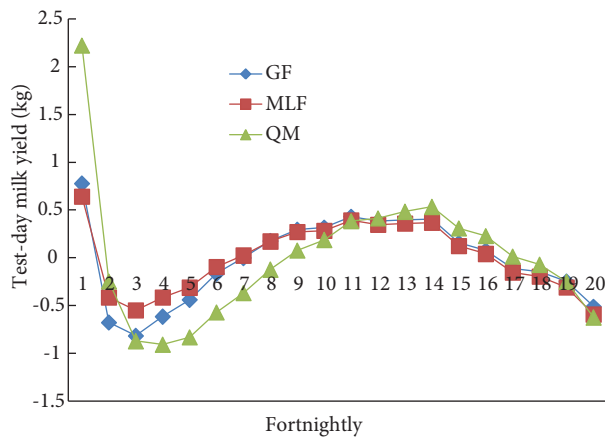


Figure 5. Residuals (kg) of the predicted FTDMYs for different lactation curves.

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of lactation, almost all of the lactation curve functions gave the closest fit to the lactation curve. However, the quadratic model gave a linear relation shift with the advancement of lactation, though a peak yield was predicted at a later stage of lactation.

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