Use of Lactation Curve Models for Prediction of Milk Yield in Sahiwal Cattle

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Abstract: A study was carried out on of 25499 weekly test day milk yield records of first lactation pertaining to 593 Sahiwal cows spread over 49 years located at National Dairy Research Institute, Karnal, India. The relative efficiency of three lactation curve models *via.* quadratic model, gamma type function and mixed log function were compared. Mixed log function described the best fit with highest coefficient of determination (97.9%) with root mean squares error (RMSE) of 0.025 kg which is followed by gamma type function. Least coefficient of determination (77.8%) was observed in quadratic model with maximum (0.081) RMSE. The peak yield of 8.08 kg in 8th week of lactation was observed by mixed log function. The predicted first lactation 305 day milk yields by quadratic model, gamma type function and mixed log function were 1993.23± 42.09, 1991.51± 40.38 and 1993.23± 42.10 kg, respectively.

Keywords: Gamma type function, Sahiwal cattle, test day milk yields.

INTRODUCTION

Milk production in dairy animals is a complex physiological process which follows a definite trend of milk secretion throughout the lactation. The phenomenon of milk production starts at parturition and continues until the dry-off of the lactating female. This is characterized by a peculiar pattern generally known as lactation curve. Lactation curve can be defined as the graphical representation of milk yield against time [1]. The lactation curve of indigenous cattle and cross bred cattle has been studied by several workers [2-4] but information on this aspect on Sahiwal breed which is considered to be one of the best milch breed of dairy cattle in India is very scanty. The knowledge of the trend of milk production across various stages of lactation would be application for the breeder to have an early sire selection, for prediction of total milk yield as well as designing suitable breeding and management strategies for dairy cattle [5]. The purpose of the present investigation was to compare the various lactation curve models to predict first lactation 305 day milk yield and also to predict weekly test day milk yields (WTDMYs) using lactation curve models.

MATERIALS AND METHODS

The data of 25499 weekly test day milk yields of first lactation pertaining to 593 Sahiwal cows sired by 51 bulls spread over 49 years (1961-2009) from National Dairy Research Institute, Karnal, India. The climate of the farm is subtropical in nature. The minimum temperature falls to 2ºC in winter months, whereas the maximum temperature goes up to 45 ºC in summer. The relative humidity ranges from 41 to 85 per cent. A total of 43 individual weekly test day milk yields were taken from daily milk yield at an interval of seven days from 6th day to 300th day of calving. The cows which had produced milk for less than 100 days and culled in the middle of lactation, abortion, still-birth or any other pathological causes which affected the lactation yield were not considered. To ensure the normal distribution, the outliers were removed and data within the range of mean ± 2SD were only considered for the study. The data were adjusted for the effect of non-genetic factors (season, period, age at first calving and first service period or days open) on all 43 weekly test day milk records (from 6th, 13th , 20th ,....., and 300th) and first lactation 305 day or less milk yield.

The data were used to estimate lactation curve parameters of the three lactation curve models *via*. quadratic model (QM), gamma type function (GF) and mixed log function (MLF) for developing the best model predictive model for prediction of first lactation 305 day and weekly test day milk yields.

1. Quadratic model [6]:

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

2. Gamma-type function [7]:

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

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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 [8]:

$$Y_t = a + bt^{½} + c \log t + e_t$$

In the models given above, Y_t = average daily yield in the t^{th} week of lactation; a = initial milk yield after calving; b = ascending slope parameter up to the peak yield; c = descending slope parameter; t = length of time since calving and e_t = residual error. The first lactation 305-day milk yield was obtained by addition of the predicted weekly test days (per day average x seven) up to 43 weeks.

RESULTS AND DISCUSSION

The actual average weekly test day milk yields ranged from 4.59 kg (TD-43) to 8.32 kg (TD-7). The weekly test day milk yield shows an increasing trend from TD-1 to TD-7 and thereafter decreasing trend was noticed till last test day (TD-43) of Sahiwal cows till 43rd week of lactation. Standard deviation and coefficient of variation of all the test days ranged from 1.97 (TD-40) to 2.55 (TD-6) and 29.03 (TD-9) to 44.67 (TD-43), respectively (Table **1**).

The estimated lactation curve parameters i.e. initial milk yield after calving (a), ascending slope parameter up to peak yield (b) and descending slope parameter (c) of different lactation curve models has been estimated to develop the prediction models (Table **2**).

The predicted weekly test day milk yields by gamma type function ranged from 4.60 ± 0.02 kg (TD-43) to 7.99±0.20 kg (TD-9). By quadratic model, it was ranged from 4.32±0.27 kg (TD-43) to 7.58±0.65 kg (TD-6). However, by mixed log function it was ranged from 4.55±0.04 kg (TD-43) to 8.08±0.02 kg (TD-8).

The mixed log function explained highest (97.9 %) coefficient of determination (R^2-value) with lowest (0.025) root mean square error. Thus, the best model

Table 1: Descriptive Statistics of Weekly Test Day Milk Yields

TD	Mean (kg)	SD	SE	CV (%)	TD	Mean (kg)	SD	SE	CV (%)
TD 1	4.94	2.02	0.08	40.88	TD 23	6.62	2.04	0.08	30.82
TD 2	6.67	2.38	0.10	35.69	TD 24	6.51	2.04	0.08	31.39
TD 3	7.52	2.52	0.10	33.56	TD 25	6.38	2.06	0.08	32.34
TD 4	7.93	2.50	0.10	31.57	TD 26	6.29	2.01	0.08	31.95
TD 5	8.12	2.52	0.10	31.03	TD 27	6.20	2.06	0.08	33.17
TD 6	8.23	2.55	0.10	31.01	TD 28	6.16	2.00	0.08	32.41
TD 7	8.32	2.49	0.10	29.87	TD 29	6.01	2.01	0.08	33.50
TD 8	8.28	2.48	0.10	29.98	TD 30	6.01	2.07	0.08	34.37
TD 9	8.27	2.40	0.10	29.03	TD 31	5.94	2.02	0.08	33.97
TD10	8.19	2.43	0.10	29.66	TD 32	5.87	2.04	0.08	34.71
TD11	8.09	2.40	0.10	29.64	TD 33	5.78	2.06	0.08	35.59
TD 12	7.94	2.34	0.10	29.46	TD 34	5.66	2.01	0.08	35.55
TD 13	7.82	2.31	0.09	29.53	TD 35	5.56	2.05	0.08	36.80
TD 14	7.69	2.31	0.09	30.08	TD 36	5.50	2.08	0.09	37.83
TD 15	7.59	2.25	0.09	29.57	TD 37	5.42	2.09	0.09	38.49
TD 16	7.47	2.22	0.09	29.78	TD 38	5.28	2.06	0.08	38.94
TD 17	7.34	2.26	0.09	30.74	TD 39	5.16	2.04	0.08	39.63
TD 18	7.22	2.16	0.09	29.94	TD 40	5.01	1.97	0.08	39.28
TD 19	7.04	2.13	0.09	30.21	TD 41	4.89	2.03	0.08	41.54
TD 20	6.90	2.06	0.08	29.92	TD 42	4.77	2.01	0.08	42.10
TD 21	6.83	2.09	0.09	30.57	TD 43	4.59	2.05	0.08	44.67
TD 22	6.73	2.05	0.08	30.41					

TD = test days; SD = standard deviation; SE = standard error; CV= coefficient of variation.

Table 2: Different Lactation Curve Functions with Parameters for Prediction of WTDMYs

Sl. No	Function	Lactation curve functions	R^2–value (%)	RMSE (Kg)
3	QM	$Y_t = 7.467 + 0.033*t + 0.002*t^2$	77.8	0.081
4	GF	$Y_t = 5.821 *t^{0.260051} e^{-0.02823 *t}$	95.6	0.037
5	MLF	$Y_t = 7.881306 + (-2.56075) *t^{½} + 8.24349 \log t + e_t$	97.9	0.025

(QM: quadratic model; GF: gamma type function; MLF: mixed log function; RMSE: root mean square error).

Table 3: Actual and Predicted First Lactation 305-Day or Less Milk Yield (kg) in Sahiwal Cows

Sl. No	Lactation curve models	Actual	Predicted	Error (kg)
1	Quadratic model	1951.14	1993.23	42.09
2	Gamma type function	1951.14	1991.51	40.38
5	Mixed log function	1951.14	1993.23	42.10

for predicting weekly test day and first lactation 305 day milk yield was mixed log function, which was better than other functions under study. However, quadratic model explained lowest (77.8 %) value of coefficient of determination with highest (0.081) root mean squares errors value for prediction of average first lactation weekly test day milk yield in Sahiwal cows. However, Olori *et al*. [9] and Cilek and Keskin [10] reported 96.4 and 92.7 % coefficient of determination values of mixed log function in Holstein Friesian and Simmental cows, respectively. Contrary to the present investigation, lower value (59.7 %) was reported by Kocak and Ekiz, [11] in Holstein Friesian cows.

Prediction of First Lactation 305-Day or Less Milk Yield

The first lactation 305-day or less milk yield was predicted from all the lactation curve models. However, comparatively, mixed log function explained less error. The first lactation 305-day milk yield was predicted using three different lactation curve functions via. quadratic model, gamma type function and mixed log function as 1993.23± 42.09, 1991.51± 40.38 and 1993.23± 42.10 kg, respectively. Actual and predicted first lactation 305-day milk yield have been presented in Table **3**.

CONCLUSION

It is concluded that mixed log function is the best function amongst three models studied which explained highest coefficient of determination with lowest root mean square error while quadratic model explain worst. On an average, the peak yield from all lactation curves functions was found to be highest in 7th week of lactation. Therefore, it is concluded that mixed log function could be a better function for predicting first lactation 305-day or less milk yield in Sahiwal cattle.

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