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Original Research

Modeling Lactation Curve for Test Day Milk Yields in Holstein Friesian Crossbred Cattle

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Abstract

The present study was conducted on first lactation monthly test day milk yield records of 466 Holstein Friesian× Sahiwal crossbred cattle maintained at Directorate of Livestock Farms, GADVASU, Ludhiana. Four mathematical models viz. Mixed Log (MLF), Exponential (EF), Inverse Polynomial (IPF) and Polynomial Regression functions (PRF) were compared for monthly test day milk yield records. The adjusted R2 values of these functions were 88.80, 86.68, 99.90 and 99.31%, respectively; whereas the root means squares error (RMSE) with these functions were 0.161, 0.176, 0.172, and 0.035 kg, respectively. The PRF was adjusted best fit based on adjusted R2 and root mean squares error (RMSE) values. The best fit lactation curve functions will be helpful for milk yield prediction as well as genetic evaluation and selection of superior sires using records of their daughters.

Keywords: Holstein Friesian, Lactation Curve, Monthly Test Day, R2, RMSE

Introduction

The lactation curve can be defined as the graphical representation of milk yield against time (Sherchand *et al*., 1995). The typical shape of the lactation curve has two characteristic parts i.e. a rapid increase from calving to a peak period in early stage of lactation and a gradual decline from peak yield to the end of lactation (Leon-Velarde *et al.*, 1995). However, some workers suggested that there are three different stages of the lactation curve namely ascending phase, persistent phase and descending phase. Animals with more persistency are preferred over animals achieving higher peak lactation with low persistency having an abrupt decline as the later one increases production cost because yield is distributed less equally over the complete lactation. The cost of milk production depends to a large extent on the lactation yield and persistency. Lactation models can be used for sire evaluation thus helps in early selection and makes culling decisions easy (Vargas *et al*., 1998). Also, knowledge of the shape of the lactation curve in dairy cattle is useful in making management and breeding decisions (Amin, 2003). Accordingly, the present study was designed to fit and compare four different lactation curve models in Holstein Friesian crossbred (HF×Sahiwal) cattle.

Materials and Methods

The study was conducted on first lactation 4415 monthly test day milk (MTDMYs) yield records (6^{th}, 36^{th}, …., 306^{th}) of 466 crossbred (CB) cattle sired by 89 bulls during 2000 - 2018 maintained at Directorate of Livestock Farms, GADVASU, Ludhiana. The data were used to fit four lactation curve models i.e. mixed log function, exponential function, inverse polynomial function and polynomial regression function on monthly test day milk yields (MTDMYs). The models were-

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

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

Where, Y_t = Average daily yield in the t^{th} month of lactation, a = Approximate initial milk yield just after calving, b = Inclining slope parameter up to peak yield, c = Declining slope parameter, t = Length of time since calving.

2. Exponential function (Wilmink, 1987)

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

Where, Y_t = Average milk yield in t^{th} month of lactation, a = Initial milk yield after calving, b = Inclining slope parameter up to peak yield, c = Declining slope parameter, t = Length of time since calving.

3. Inverse Polynomial function (Nelder, 1966)

$$Y_t = \frac{t}{(a + bt + ct^2)}$$

Where, Y_t = Average daily yield in the t^{th} month of lactation, a = Approximate initial milk yield just after calving, b = Inclining slope parameter up to peak yield, c = Declining slope parameter, t = Length of time since calving.

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

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

Where, Y_t = Average milk yield in t^{th} month of lactation, a = Associated with peak yield, b & c = Associated with the decreasing slope, d & e = Associated with the increasing slope, x = t / lactation length.

Statistical Methods

The data was adjusted for non-genetic factors and least squares model was used for adjustment of non-orthogonal data. The least squares means of different monthly test day yields were calculated using SPSS software programme (IBM SPSS, 22.0). The means were then regressed on the day of lactation using Microsoft Excel, 2007. Various lactation curve models were fitted for assessing their ability to explain the lactation curve in HF × Sahiwal cattle.

Results and Discussion

The least squares means of observed and predicted first lactation MTDMYs estimated by four different functions has been presented in Table 1. In general, the MTDMYs increased till TD-2 and thereafter a gradual decline was noticed till the end of lactation.

Table 1: Predicted MTDMYs and error (kg) from different lactation curve functions in HF crossbred cattle

TD	Least squares mean (kg)	MLF		EF		IPF		PRF	
		Predicted (kg)	Error (kg)	Predicted (kg)	Error (kg)	Predicted (kg)	Error (kg)	Predicted (kg)	Error (kg)
TD - 1	12.05	12.69	0.64	12.74	0.69	13.73	1.68	12.05	0.01
TD - 2	15.65	14.56	-1.08	14.39	-1.25	15.06	-0.58	15.6	-0.04
TD - 3	15.38	14.84	-0.53	14.81	-0.56	14.86	-0.51	15.39	0.01
TD - 4	14.44	14.58	0.14	14.61	0.17	14.29	-0.14	14.56	0.13
TD - 5	13.79	14.07	0.28	14.11	0.32	13.62	-0.16	13.69	-0.09
TD - 6	12.88	13.43	0.55	13.46	0.58	12.94	0.06	12.9	0.03
TD - 7	12.27	12.72	0.45	12.73	0.46	12.3	0.03	12.22	-0.04
TD - 8	11.83	11.96	0.14	11.97	0.14	11.7	-0.12	11.63	-0.19
TD - 9	10.85	11.18	0.34	11.19	0.34	11.15	0.3	11.11	0.27
TD - 10	10.64	10.39	-0.24	10.39	-0.24	10.64	0	10.64	0.01
TD - 11	10.28	9.59	-0.68	9.6	-0.67	10.17	-0.1	10.21	-0.06

The estimated lactation curve parameters (a, b, c, d, and e) of different functions for prediction of monthly test day milk yields are presented in Table 2.

Table 2: Estimated lactation curve parameters of different functions for prediction of first lactation test day milk yield in HF crossbred cattle

Functions	Parameters of Function	Adjusted R^2 (%)	RMSE (kg)
MLF	$Y_t = 23.55 - 10.86*t^{0.5} + 9.20\log(t)$	88.8	0.161
EF	$Y_t = 18.42 - 9.81*e^{-0.70*t} - 0.80*t$	86.68	0.176
IPF	$Y_t = t / (0.02 + 0.05*t + 0.01*t^2)$	99.9	0.172
PRF	$Y_t = 7.35 + 4.79*(x) - 0.08*(x)^2 -4.79*\log(1/x) - 9.01*\log(1/x)^2$	99.31	0.035

Mixed log function explained high R^2 value (88.80%) with low RMSE (0.161 kg) value (Fig. 1). Bangar and Verma (2017) on working with primiparous Gir crossbred cows reported that the adjusted R^2 was highest for mixed log function (89.3%) with lowest RMSE. The best fit due to mixed log function was also reported by Dongre *et al.* (2012) while comparing gamma-type function, mixed log function and quadratic model in Sahiwal cows.

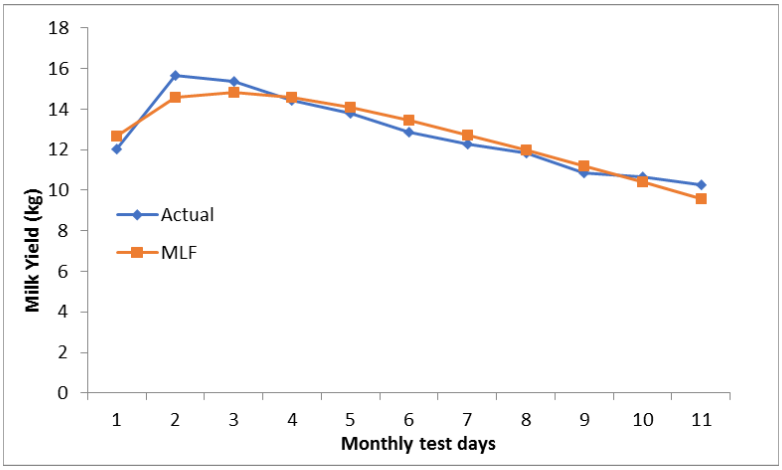

Figure 1: Observed and predicted monthly test day milk yields by Mixed Log Function

Exponential function explained high R^2 value (86.68%) with low RMSE (0.176 kg) value (Fig. 2). However, Gebreyohannes *et al.* (2003) obtained low mean R^2 (67.2%) value using the Exponential function including both crossbred and indigenous cows and for crossbreds sired by HF the R^2 value (70.5%) value by this function was also lowest among all models.

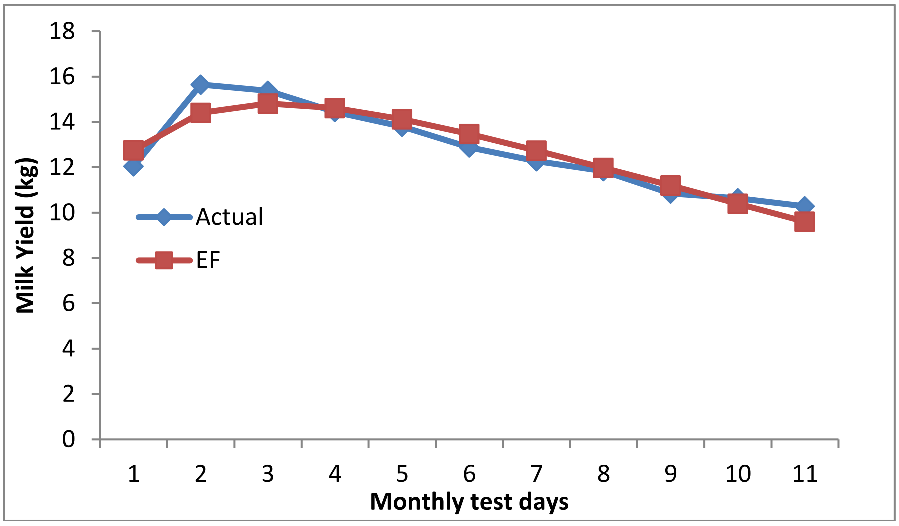

Figure 2: Observed and predicted monthly test day milk yields by Exponential Function

Inverse polynomial function explained highest R^2 value (99.90%) with low RMSE (0.172 kg) value (Fig. 3). Arya (2019) also obtained high R^2 value (99.97%) with low RMSE (0.07) and concluded that Inverse Polynomial model was the best fit based on monthly test day records in crossbred cattle. Sohal*et al.* (2019) also reported similar findings with 99.92% of R^2 and 0.0604 kg RMSE for fortnightly test day milk yields in first lactation Rathi cattle.

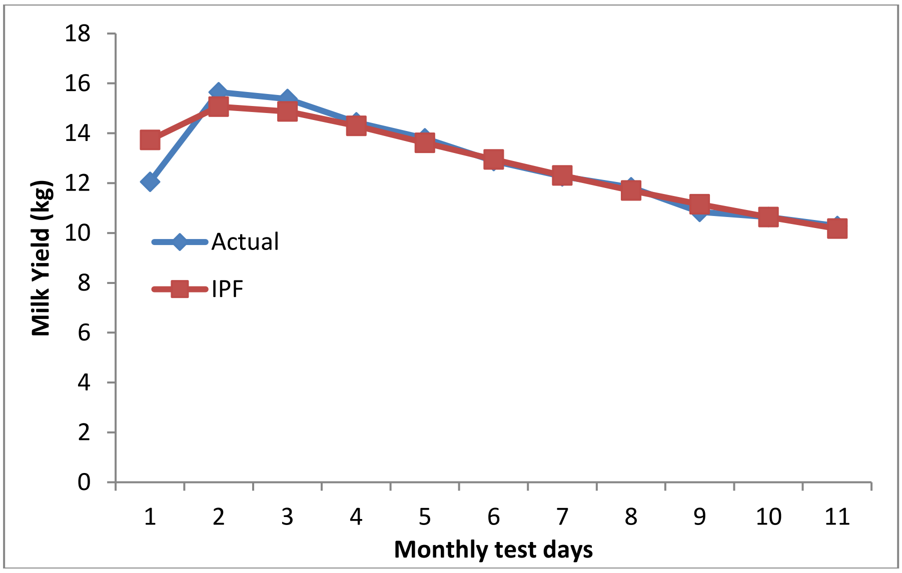

Figure 3: Observed and predicted monthly test day milk yields by Inverse Polynomial Function

Polynomial regression function explained high R^2 value (99.31%) with lowest RMSE (0.035 kg) value (Fig. 4). However, the R^2value is a little lower than Inverse polynomial model but the RMSE is significantly lower and therefore PRF was considered as the best fit. Olori*et al.* (1999) reported highest R^2 value (99.6%) and lowest RMSE (0.17%) value for HF cows by PRF. This was in accordance with Silvestre *et al.* (2006) who observed a superior fit by this model

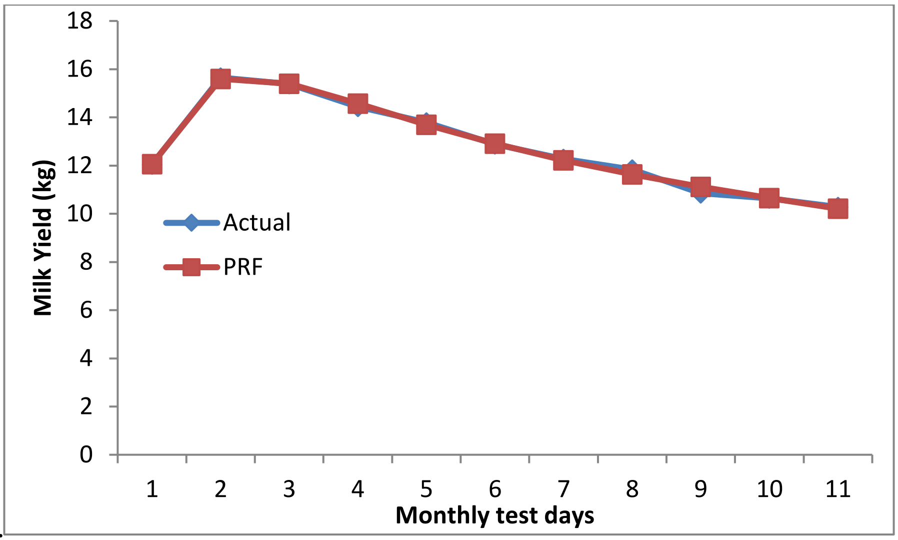

Figure 4: Observed and predicted monthly test day milk yields by Polynomial Regression Function

The residuals for overall observed and predicted MTDMYs from all four-lactation curve were plotted graphically (Fig. 5).

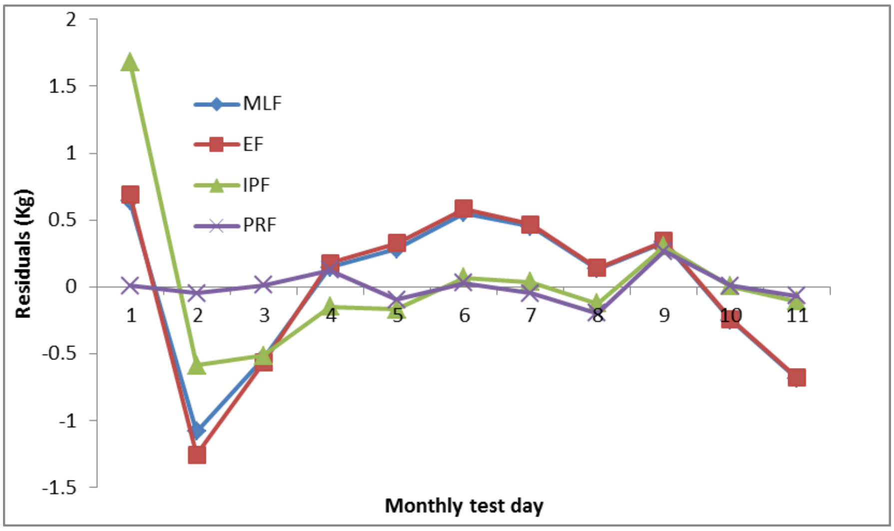

Figure 5: The residuals of MTDMYs for various lactation curve functions

The Polynomial Regression function model gave the best fit with high R^2 value and lowest RMSE. Although the R^2 value is slightly lower than Inverse polynomial function model but this model has the lowest RMSE. Therefore, this function was considered as the best fit among all the models. Similar findings were reported by Sahoo *et al.* (2016) in Murrah buffaloes.

Conclusion

All four lactation curve models fitted well for the MTDMYs in HF crossbred cattle. However, PRF was the best fit with lowest RMSE value and very high R^2 value for prediction of monthly test day milk yields in HF crossbred cattle. This model can be used further for subsequent sire evaluation using the predicted records of the daughters for early selection of crossbred cattle.

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Conflict of Interests

There is no conflict of interest.

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