Abstract T137

Fitness of Lactation Curve Functions to Daily and Test-Day Milk Data in an Ethiopian Dairy Cattle Population

Gebregziabher Gebreyohannes*, Skorn Koonawootrittriron*, Mauricio A. Elzo† and Thanathip Suwanasopee[1]

*Department of Animal Science, Kasetsart University, Bangkok 10900, Thailand
†Department of Animal Sciences, University of Florida, Gainesville, FL 32611-0910, USA

SUMMARY

The objective of this research was to identify a lactation curve function that best fit daily (**DD**) and monthly test-day milk (**MD**) data in an Ethiopian dairy cattle population. Three functions were compared: an incomplete gamma (**IG**), a modified incomplete gamma (**MIG**; b = 1) and an inverse polynomial (**IP**). Analyses used 6,707 lactation milk records of 2066 cows collected from 1979 to 2010 in the Bako, Debre-Zeit and Holetta Research Centers. Breed groups were Horro (**H**), Boran (**B**), B-Friesian, H-Friesian, B-Simmental, H-Simmental, B-Jersey and H-Jersey. The **IG** and **MIG** were first log-transformed to linear form before fitting. Goodness of fit of **IG**, **MIG** and **IP** functions were compared using R-squared values. Factors affecting R-squared values were analyzed using a model that contained herd-year-season, parity, data type (**DD** and **MD**), breed group, lactation curve function, and the interaction between data type and lactation curve function as fixed effects, and residual as a random effect. All factors in the model affected R-squared values (P < 0.001). Least squares means of R-squared values (**LSMR2**) were compared among subclasses of each factor. Milk data from cows in later parities (> 4 parities; range 0.84 to 0.85) showed significantly higher **LSMR2** (P < 0.001) than first parity cows (0.80 ± 0.002). The **LSMR2** of functions fitted to **MD** data (0.88 ± 0.001) was higher (P < 0.001) than the one for **DD** data (0.79 ± 0.001). Horro cows had higher **LSMR2** (0.86 ± 0.003) than other breed groups (0.77 to 0.85; P < 0.001). The **MIG** (0.90 ± 0.002) and **IP** (0.90 ± 0.002) functions had similar **LSMR2**, but both of them were significantly different from **IG** (0.71 ± 0.002; P < 0.001). The **MIG** function had the highest **LSMR2** for **DD** data (0.88 ± 0.002), while the **IP** function had the highest **LSMR2** for **MD** data (0.94 ± 0.002). The **MIG** and **IP** functions can be recommended for describing lactation patterns of Ethiopian dairy cattle using daily and test-day milk data, respectively.

INTRODUCTION

Lactation curves, defined as graphical representations of milk yield against time (Sherchand *et al.*, 1995), are used to adjust data for variation due to stage of lactation and to predict milk yield of individual animals (Olori *et al.*, 1999) and are also used in genetic evaluation of dairy cattle. Genetic evaluation of dairy cattle employs whole lactation or test-day milk data (Bilal and Khan, 2009). Test-day milk data has been used for genetic evaluation of dairy cattle using random regression models (Wiggans and Goddard, 1997; Druet *et al*., 2003). These genetic models considered the lactation function of Ali-Schaeffer, Wilmink, orthogonal polynomials, and regression splines (Druet *et al*., 2003). In addition, several other functions have been evaluated for their ability to describe lactation curves in a variety of breeds and locations (Dongre *et al*., 2011). The choice of an appropriate function to explain dairy data is crucial if functions are used for genetic evaluation (Pool and Meuwissen, 1999). In most instances, daily milk recording is not possible, but test-day milk yields are relatively easier to obtain. In such cases, test-day data could be used directly to genetically evaluate animals using test-day models or indirectly to predict milk yields using lactation curve functions. ***The objective of this study was to identify the best fit lactation curve functions to daily and test-day milk data and to evaluate factors that affected the goodness of fit of lactation curve functions in an Ethiopian multibreed dairy cattle population.***

MATERIALS AND METHODS

Description of the study area

The study utilized data from the Bako, Debre-Zeit and Holetta Research Centers in Ethiopia (**Figure 1**). The Bako Agricultural Research Center is located 250 km West of Addis Ababa at an altitude of 1,650 m above sea level. The center receives mean annual rainfall of 1,200 mm in a bimodal distribution, 80% of which falls from May to September. The area has a mean relative humidity of 59% and mean minimum and maximum temperatures of 13.5 and 27°C, respectively. The Debre Zeit Research Center is located 50 km South East of Addis Ababa at an altitude of 1,920 m above sea level and receives an annual rainfall of 850 mm in a bimodal distribution. About 84% rainfall falls during June to September and the remaining during March to May. The dry season extends from October to February. The station had mean minimum and maximum temperatures of 15 and 28°C, respectively and a mean relative humidity of 63% (Gebregziabher *et al.*, 2003). The Holetta Research Center is located 45 km west of Addis Ababa at an altitude of 2,400 m above sea level. The average annual rainfall is about 1,200 mm, most of it occurring between June and October. The dry season lasts from November to February followed by light showers during March to April (Demeke *et al*., 2003).

Data, lactation curve functions and statistical analysis

Milk data from Boran (**Figure 2**) and Horro (**Figure 3**) indigenous breeds (Albero and Hailemariam, 1982) and their crosses with Friesian, Jersey and Simmental sire breeds (Demeke *et al*., 2003) collected at the Bako and Holetta research centers, and milk data from

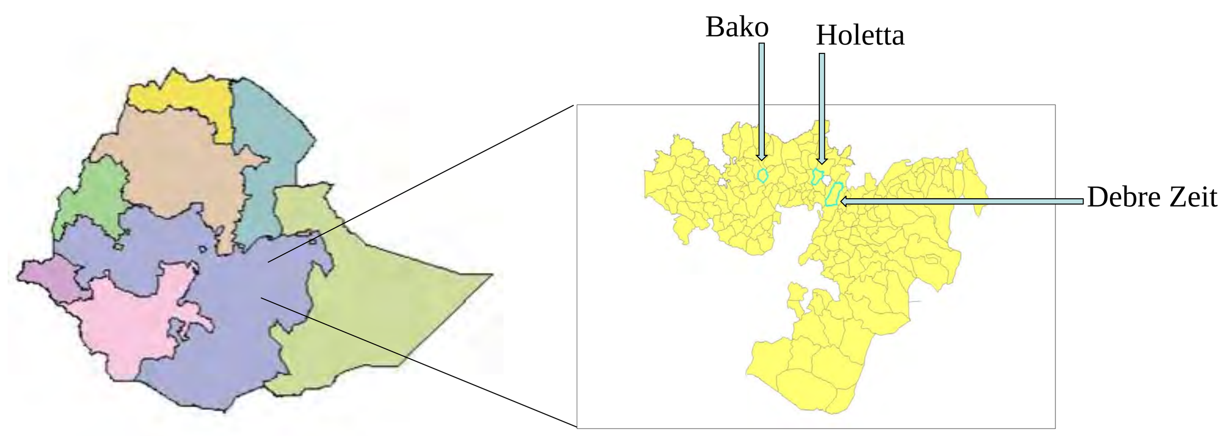

Figure 1. Map of Federal Democratic Republic of Ethiopia

Boran and Boran-Friesian crosses from the Debre Zeit research station were used in this study. The dataset included daily milk data (**DD**) of individual cows from the Bako (1977 to 2010), Holetta (1979 to 2010) and Debre Zeit research centers (1989 to 2006).

Daily milk yields collected on day 30, 60, 90, 120, 150, 180, 210, 240, 270 and 300 after calving were considered as monthly test-day (**MD**) milk yields. For cows with lactation length longer than 305 days, daily milk yield on days after 305 days in milk were not included in the study. Thus, the analysis was based on 6,707 milk records from 2,066 cows with lactation lengths greater than 90 days.

Three lactation curve functions, incomplete gamma (**IG**; Wood, 1967), modified incomplete gamma (**MIG**, with b = 1; Papajcsik and Bodero, 1988) and inverse polynomial (**IP**; Nelder, 1966) functions were compared for their ability to fit lactation data. These functions were chosen based on previous research (Gebregziabher *et al.*, 2003). The **IG** function (Wood, 1967) is described as $Y_t = at^b exp(-ct)$ where t represents the length of time since calving, Y_t represents milk yield at time t after calving and a, b and c are function parameters describing the shape of the curve. The **MIG** (Papajcsik and Bodero, 1988) is described as $Y_t = at^b exp(-ct)$, where the parameter b of Wood's function was set to 1. The **IP** function (Nelder, 1966) $Y_t = t(A_0 + A_1 t + A_2 t^2)^{-1}$, where Y_t is the milk yield at time t, A_0 is the rate of increase to peak production, A_1 is the average slope of the lactation curve and A_2 is the rate of decline after the peak.

Figure 2. Boran bull (left) and cow (right) from Holetta

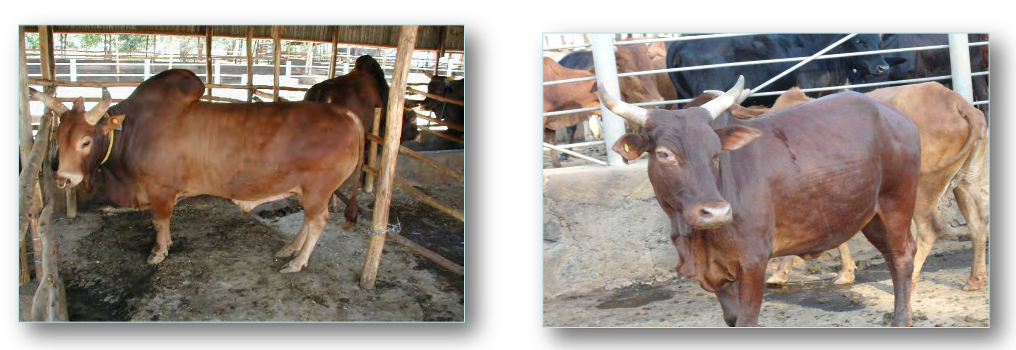

Figure 3. Horro bull (left) and cow (right) from Bako

The functions were fitted to **DD** and **MD** milk data. The **IG** and **MIG** were log-transformed to linear form before fitting to the data using regression analysis (PROC REG; SAS, 1999). The goodness of fit of the three lactation curve functions was compared based on least squares means of the coefficients of determination (**LSMR2**) that were estimated by fitting each function (**IG**, **MIG** and **IP**) to milk data (**DD** and **MD**) from each lactation of each cow (Olori *et al*., 1999).

The model used to analyze the coefficients of determination (**R2**) included the fixed effects of data type (**DD** or **MD**), function type (**IG**, **MIG** and **IP**), breed group (8 breed groups; Horro (**H**), Boran (**B**), B-Friesian (**BF**), H-Friesian (**HF**), B-Simmental (**BS**), H-Simmental (**HS**), B-Jersey (**BJ**), and H-Jersey (**HJ**)), parity (1 to 7), and herd-year-season of calving contemporary groups (333 classes), and a random residual effect. Computations were performed with PROC GLM (SAS, 1999).

RESULTS AND DISCUSSION

The **R2** values were significantly affected by herd-year-season, parity, breed group of cow, lactation curve function, data type and the interaction between data type and lactation curve function (P < 0.001; **Table 1**). Both **MIG** (0.90 ± 0.002) and **IP** (0.90 ± 0.002) functions had similar **LSMR2**, but they were significantly different from the IG (0.71 ± 0.002) function. The fitness of these functions to monthly test-day data was better than that of daily data (0.88 vs. 0.79). The interaction showed significantly (P < 0.001) higher **LSMR2** values for **MIG** when fitted to daily milk data (0.88 ± 0.002) and for **IP** when fitted to test-day milk data (0.94 ± 0.002). Milk data from cows in later parities (> 4 parities, range 0.84 to 0.85) showed significantly higher **LSMR2** values compared to cows in earlier parities (1 to 3), with first parity cows showing the lowest **LSMR2** value (0.80 ± 0.002).

Among breed groups, Horro cows had higher (0.86 ± 0.002) **LSMR2** values than the other breed groups (range 0.77 to 0.85). The **LSMR2** values for breed group (**Figure 4**) indicated that both **MIG** and **IP** were superior across all breed groups in both data types. The cumulative distribution of the **R2** values obtained by fitting the functions to daily milk data showed that 90.9, 78.4 and 33.0% of the **R2** values for **MIG**, **IP** and **IG** functions were within the range of 0.80 and above. The corresponding values for test-day milk data were 95.0, 95.3 and 58.5%, respectively (**Figure 5**).

The goodness of fit of the **MIG** and **IP** functions to daily and test-day milk data obtained in this study was comparable to other reports (Batra, 1986; Dongre *et al*., 2011). Although gamma type functions have been used in most comparison studies of lactation curve functions because of their desirable features to describe lactation curves (Dongre *et al*., 2011), their goodness of fit in the present and previous studies (Koonawootrittriron *et al*., 2001) was low. The better fit observed for **MIG** and **IP** might be associated with the short ascending phase of the lactation curve in the studied herds (Gebregziabher *et al*., 2003). Kumar and Bhat (1979) indicated that the **IP** had a good fit for lactations that started at a low level of milk and peaked earlier than average. Differences in fit of functions by data type observed here were also found elsewhere (Collins-Lusweti, 1991; Olori *et al*., 1999). Olori *et al*. (1999) reported a better fit for the **IG** function to weekly mean milk data compared to **IP**.

Table 1. Least squares means (± SE) of **R2** values

Factors	LSM ± SE
Lactation curve function	
Incomplete gamma (IG)	0.71 ± 0.002[a]
Modified Incomplete gamma (MIG; b = 1)	0.90 ± 0.002[b]
Inverse polynomial (IP)	0.90 ± 0.002[b]
Data type	
Daily milk data	0.79 ± 0.001[a]
Test-day milk data	0.88 ± 0.001[b]
Data type × Lactation curve function	
Daily milk data – IG	0.65 ± 0.002[f]
Daily milk data – MIG	0.88 ± 0.002[c]
Daily milk data – IP	0.85 ± 0.002[d]
Test-day milk data - IG	0.77 ± 0.002[e]
Test-day milk data – MIG	0.92 ± 0.002[b]
Test-day milk data – IP	0.94 ± 0.002[a]

[a, b, c, d] Least squares means within a column group with different letters differed significantly (P < 0.001)

FINAL REMARKS

- The **IP** and **MIG** lactation functions showed better fit than **IG**.
- Lactation curve function fit varied with data type. The **IP** best fitted monthly test-day milk data whereas the **MIG** best fitted daily milk data.
- The **IP** and **MIG** were superior to the **IG** lactation curve function when fitted to daily and test-day milk data from both indigenous and crossbred cows.
- Breed group, parity, data type, lactation function type, and interactions between data type and lactation curve function influenced R-square values.

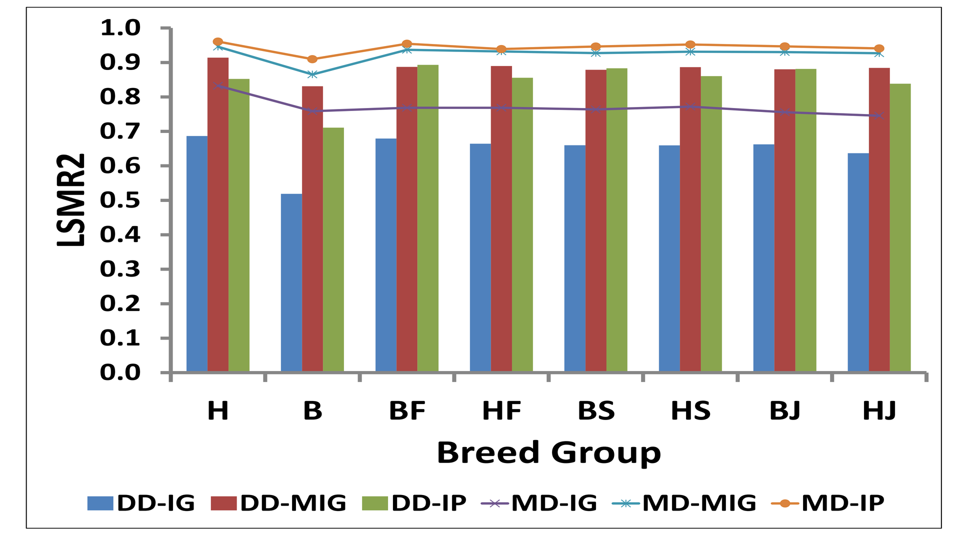

Figure 4. Least squares means for **R2** by breed group

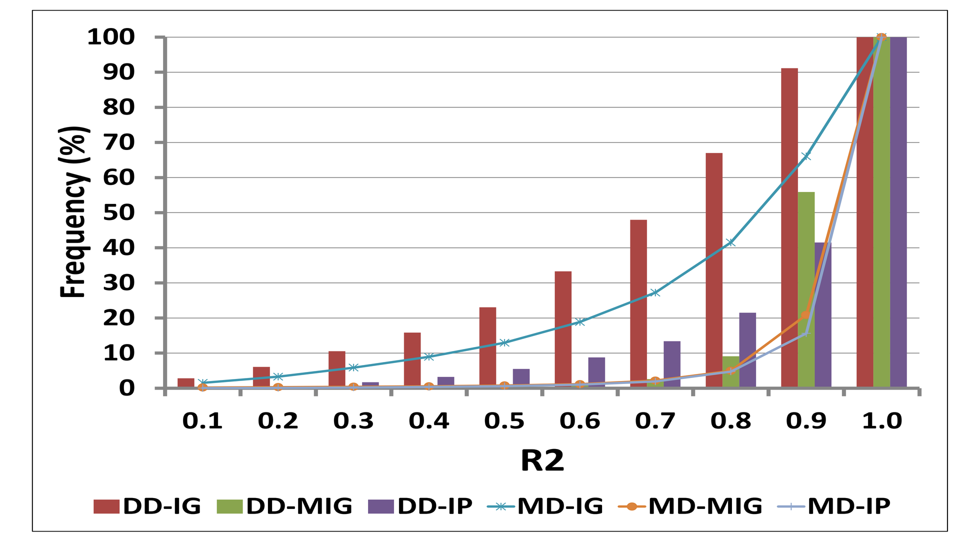

Figure 5. Cumulative distribution of **R2** across different classes for two data types and three lactation curve functions

LITERATURE CITED

Alberro, M. and S. Hailemariam. 1982. Wld. Anim. Rev. 41(1): 2-11.
Batra, T. R. 1986. Can. J. Anim. Sci. 66: 405 - 414.
Bilal, G. and M. S. Khan. 2009. Pakistan Vet. J. 29(1): 35-41.
Collins-Lusweti, E. 1991. S. Afr. J. Anim. Sci. 21 (1): 1 - 15.
Demeke, S., F. W. C. Neser and S. J. Schoeman. 2003. Livest. Prod. Sci. 84: 11-21.
Dongre, V. B., R. S. Gandhi, A. Singh and A. Gupta. 2011. Inter. J. of Agri. Research and Review. 1(1): 6-15.
Druet, T., F. Jaffrezic, D. Boichard and V. Ducrocq. 2003. J. Dairy Sci. 86:2480–2490.
Gebregziabher, G., T. Azage, M. L. Diedhiou and B. P. Hegde. 2003. Ethiopian J. Anim. Prod. 3(1): 53-70.
Koonawootrittriron, S., M. A. Elzo, S. Tumwasorn and W. Sintala. 2001. Thai J. Agri. Sci. 34 (3-4): 123-139.
Kumar, R. and P. N. Bhat. 1979. Indian J. Dairy Sci. 32: 156.
Nelder, J. A. 1966. Biometrics 22: 128-141.
Olori, V. E., S. Brotherstone, W. G. Hill and B. J. McGuirk. 1999. Livest. Prod. Sci. 58: 55-63.
Papajcsik, I. A. and J. Bodero. 1988. Anim. Prod. 47: 201-207.
Pool, M. H. and T. H. E. Meuwissen. 1999. J. Dairy Sci. 82:1555-1564.
SAS (Statistical Analysis System). 1999. SAS Institute Inc., Cary, NC, USA.
Sherchand, L., R. W. McNew, D. W. Kellogg and Z. B. Johnson. 1995. J. Dairy Sci. 78: 2507-2513.
Wiggans, G. R. and M. E. Goddard. 1997. J. Dairy Sci. 80: 1795-1800.
Wood, P. D. P. 1967. Nature 216: 164-165.

Acknowledgements

The authors would like to acknowledge the Ethiopian Agricultural Research Organization, Oromia Agricultural Research Institute and the International Livestock Research Institute for providing their highly valuable data for this study; The Tigray Agricultural Research Institute for the study leave offered to the first author and Ethiopian Ministry of Agriculture Rural Capacity Building Project for the financial support. The authors are grateful to Kasetsart University for hosting the study.