ALTERNATIVE MODELS TO PREDICT LACTATION CURVES FOR DAIRY COWS

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Summary

Lactation curves of dairy cows were generated using three models, namely; incomplete gamma function (model 1), polynomial inverse function (model 2) and non-linear regression (model 3). Secondary milk yield data of 27 cows which had completed 6 lactations were used in this study. Milk yield records (once a week) throughout the lactation and from the first three months of lactation were fitted to the models. Estimation of total milk yield by model 3 using the data once a week throughout the lactation resulted in smaller % bias and standard error than those generated from model 1 and 2. But, model 2 was more accurate in predicting the 305-day milk yield equivalent closer to actual yields with smaller bias % and error using partial records up to 3 months. Also, model 2 was able to estimate the time to reach peak yield close to the actual data using both complete or partial lactation records. It is concluded that lactation characteristics predicted using partial records and model 2 could be used as a tool to advise farmers on appropriate feeding and management practices to be adopted.
(**Key Words**: Models, Lactation Curves, Cows)

Introduction

Performance recording is usually associated with selection and a well-known example is milk recording. The objectives of milk recording are (a) to help individual farmers in selecting both female and male animals according to their own performance (b) to help farmers in adjusting feeding levels and in taking day-to-day management decisions (c) to provide data for breeding and administrative decisions at regional level. Procedures for milk recording as used in developed countries can only be adopted by institutional herds and larger commercial farms in developing countries. Almost all farmers dislike keeping records, and therefore it is important that records are simple and easy to understand, and also suit the farmers' needs.

Mathematical models have been widely used to predict total yield of dairy cows and the data have been used in breeding and selection programmes (Van Vleck and Henderson, 1961; Lamb and McGilliard, 1967; McDaniel, 1969, Lindstrom, 1976a). However, the mathematical model approach requires continuous milk recording throughout lactation, while small scale dairy farmers do not commonly have the records of their individual cows. This is because farmers do not concern themselves much about the importance of the recording as they do not get any direct reward from it. To overcome this situation an approach through mathematical models using periodical data during lactation or partial data of a few months during lactation was carried out.

The objective of the study is to compare the suitability of three mathematical models, and to select an appropriate model which could predict the lactation characterisitcs of dairy cows with low % bias and error under the management practices commonly adopted by farmers in East Java.

Materials and Methods

Materials used for this study were secondary data on milk yield from 1980-1990, of 27 cows having milk recording from 1st-6th stages of lactation in a private dairy enterprise 'Sumber Susu Indonesia' Batu, Malang. Sumber Susu Indonesia is a private dairy cattle enterprise with a carrying capacity of 50-60 Holstein Friesian (HF)

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cows. Around 4-5 superior HF bulls are kept for breeding purposes for a period of more than 5 years, and thus inbreeding has been avoided. Artificial Insemination using imported semen has also been carried out. Selection of cows towards high production, good temperament and calving ease has also been practised. In general, the condition of the cows is relatively better than those of other farmers. This is because the fluctuation of feed quality and availability has been controlled throughout the year and feeding levels adjusted according to individual milk production.

Periodical data of milk yield once a week throughout lactation or partial data from the first three months of lactation were fitted to the models.

The lactation curve was generated using three models, namely:

1. Incomplete Gamma Function $Y = a x^b e^{-cx}$
2. Polynomial Inverse Function $Y = x(a + bx + cx^2)^{-1}$
3. Non-Linear Regression $Y = a - bx - ae^{-cx}$

Parameters of model 1 were estimated by linearizing the model with logarithmic transformation. Those of model 2 by weighed polynomial inverse and model 3 by non-linear least square methods.

Results and Discussion

The average milk yield observed in this farm was at optimal production levels. The mean lactation length (± standard error) of the first to the sixth lactation of the 27 cows studied were 319 ± 9.0 (range 257-439), 317 ± 12.3 (range 233-535), 329 ± 13.7 (range 245-517), 317 ± 10.7 (range 256-485), 348 ± 15.0 (range 162-541), 329 ± 17.8 (range 183-466) days, respectively.

Actual milk yields (total and 305-day equivalent), total yield estimation, % bias and standard error for the 1st, 3rd, 4th and 6th lactation generated by the three models using periodical data once a week throughout lactation or the first three months of lactation are presented in table 1.

TABLE 1. ACTUAL MILK YIELDS (TOTAL AND 305-DAY EQUIVALENT IN LITRES) AND THOSE PREDICTED USING PERIODICAL WEEKLY MILK RECORDS THROUGHOUT LACTATION OR THE FIRST THREE MONTHS OF LACTATION

Model*	Order of lactation	Data from complete lactation				Data from 3 months			
		Yield (Total)	Predicted yield	% Bias	SE*	Yield (305-day equivalent)	Predicted yield	% Bias	SE**
1	1st	4,140	3,785	8.6	1.4	3,368	2,146	36.3	0.7
	3rd	5,357	4,752	11.3	1.5	4,022	2,829	29.7	0.8
	4th	6,181	5,196	15.9	3.0	4,405	3,133	28.9	0.9
	6th	5,302	4,949	6.7	1.3	4,407	2,920	33.8	1.3
2	1st		4,698	13.5	1.7		3,212	4.6	0.7
	3rd		6,087	13.6	1.8		4,264	6.0	0.9
	4th		6,684	8.1	1.8		4,902	11.3	1.0
	6th		6,237	17.6	2.6		4,339	1.6	1.5
3	1st		4,186	1.1	1.3		3,221	4.4	0.3
	3rd		5,155	7.7	1.8		5,746	42.9	1.7
	4th		5,802	6.1	2.4		7,018	59.3	1.7
	6th		5,356	1.0	0.9		6,780	53.8	1.9

* See text for the equations.
** Standard error.

The mean actual milk yield in the first lactation was 4140 litres and gradually increased up to the fourth/fifth lactation (6181 litres in fourth lactation) and thereafter decreased. In general, the use of model 1 and 2 to predict of milk yields using the periodic data from the complete lactation resulted in higher % bias. Although for some stages of lactation (first and sixth with model 1, and fourth with model 2) the bias was below 10%, it was inconsistent between the different lactation periods. On the other hand, model 3 was able to estimate the total milk yield closer to the actual yield with very low bias (1.1-7.7%) using periodical data once a week throughout lactation. A number of studies conducted in Europe and North America (McDaniel, 1969) have shown that recording milk once a month is accurate enough for individual selection and once every two weeks for progeny testing. In a similar study conducted in Kenya, Lindstrom (1976b) concluded that weekly, biweekly and monthly testing for milk yield gave errors of −9 to +9, −9 to +12 and −15 to +18%, respectively. These results clearly indicate that for feeding and managerial purposes weekly or biweekly testing is advisable. In our study the use of weekly data and the non-linear regression function successfully predicted the lactation characteristics up to the sixth lactation with low bias and error. An example of the accuracy of prediction of the milk yields in the second lactation is shown in figure 1. Even so, under the highly diversified small scale crop-livestock systems that exists in tropical developing countries burdening the farmers to keep milk yield records once a week throughout the lactation period is not a practical solution. The low education level of the farmers, lack of qualified extension workers, lack of incentives provided to farmers to record their cows and the small average herd size are some of the other constraints which makes such a long term time consuming recording scheme unplausible.

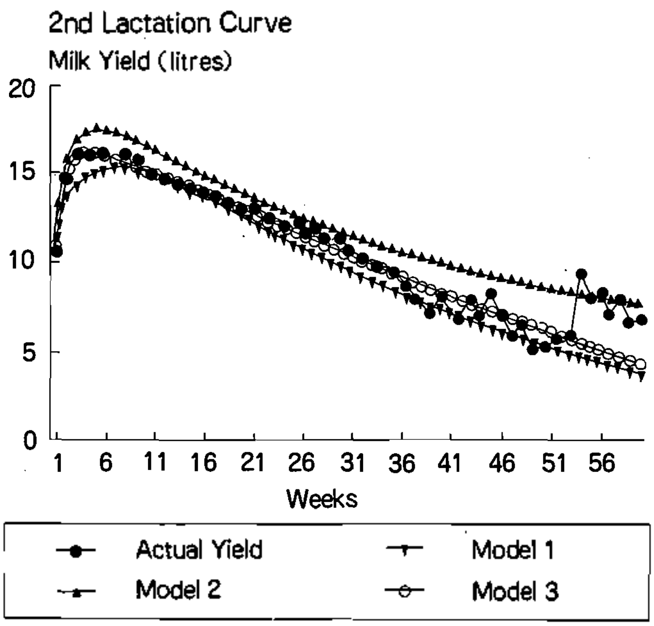

Figure 1. Actual milk yields in the second lactation and those predicted using the three mathematical models.

As regards the prediction of the 305-day milk yields using data from the first 3 months of the lactation, both model 1 and 3 resulted in either lower (model 1) or higher (model 3) prediction of milk yields with higher % bias (table 1). Model 2 was able to predict milk yields closer to the 305-day lactation equivalent as the average % bias and the error was small. Much of the published work on the use of part lactation records to predict milk production over a period of 305 days has been based on comparisons of the daily milk yields with monthly or bi-monthly test-day yields (Madden et al., 1959; Searle, 1963; Van Vleck and Henderson, 1961). Also, the scope of using these relationships was limited to breeding and selection programs (progeny testing, sire and bull selection). For this purpose, high genetic correlations were found between part records (5-7 months) and complete records. The results of our study indicates that fairly accurate predictions of the complete lactation yields and characteristics of the curve could be made by using part of the lactation records (up to 3 first months) and the polynomial inverse function (model 2). These findings not only lessen the burden on farmers and extension workers in maintaining records of the complete lactation, but also could be used as a valuable tool in advising farmers well in advance on the feeding practices to be adopted based on the availability of feed resources during different times of the year. Also, majority of the small scale dairy farmers in the tropical region do not rear their own replacement stock, as such training these farmers to maintain daily/monthly records of the complete lactation for breeding and selection purposes would be less meaningful. Such recording systems would be more appropriate to be introduced to institutional or commercial dairy enterprises from which replacement heifers are supplied to small farmers. For small farmers a monitoring scheme as suggested by Jackson (1982) implemented through a central body using village level extension workers seems to be a more appropriate solution. He proposed a comprehensive monitoring scheme where one day every month dates of breeding and calvings, identity of bulls of AI semen used, body weights, milk yields, dates and details of veterinary attention, feed consumption, and selling, buying and slaughtering of stock in each livestock-owning household should be collected and processed.

Estimation of peak yield using periodical weekly data throughout lactation or partial weekly data during the first three months of lactation is presented in table 2. The use of model 1 to estimate the time to reach peak yield using periodical weekly data throughout lactation was longer than the actual data. However, by using partial weekly data of the first three months of lactation, the estimation was close to the actual data. On the other hand, model 2 was able to estimate the time to reach peak yield close to the actual data using both complete or partial lactation data.

TABLE 2. ESTIMATION OF PEAK YIELD (WEEKS) OF LACTATION USING MILK YIELD DATA THROUGHOUT LACTATION (A) AND THE FIRST THREE MONTHS OF LACTATION (B)

Order of lactation	Actual yield	Model 1		Model 2		Model 3	
		A	B	A	B	A	B
1st	6	9	6	7	5	0.4	5
3rd	5	6	6	5	4	0.2	nd
4th	6	8	7	6	6	0.4	nd
6th	7	10	7	7	6	6.0	nd

nd : not defined.

Conclusions

Polynomial inverse function (model 2) is the most appropriate model to predict total milk yield and the time to reach peak yield by using partial data of the first three months of lactation.

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