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DESCRIBING THE LACTATION CURVE OF DAIRY CATTLE WITH MULTIPHASIC FUNCTION

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Abstract

An experiment to describe pattern of lactation curve using Multiphasic Function (MF) has been conducted. The MF is based on a sum of logistic functions:

$$Yt = \sum_{i=1}^{n} \{a_i b_i [1-\tanh^2(b_i(t-c_i))]\}$$

where Y_t is milk yield at time t (days in milk), n is the number of lactation phases, tanh is hyperbolic tangent and for each phase i: parameter a_i is half asymptotic total yield (liter), b_i is rate of yield relative to a_i (days^{-1}) , $a_i b_i$ is maximum (peak) yield and c_i is time of peak yield (days). In this study, the monophasic and diphasic function of MF was applied to adjust the pattern of lactation curve of Holstein cows in UPT Baturraden, Central Java. The milk yield data came from 236 first three lactations of 126 cows that had completed lactation and the data were collected weekly, beginning with day 5 after calving until day 301. Mean milk yield was used to estimate parameters of lactation curve. These parameters were fitted to the mean observed data. Goodness-of-fit was checked on two criteria proposed: 1) Adjusted coefficient of determination (Adj-R^2), and 2) Akaike's information criterion (AIC). Results showed that milk yield a day averaged about 10.4 liter with 2.79 standard deviation. Adj-R^2 both for monophasic and diphasic functions were 0.9798. AIC for monophasic function was –68.2245 while diphasic function –74.2246, which indicated that diphasic function revealed slightly better fit to mean milk yield data compared with monophasic function. Estimates for maximum yield was about 2.7 and about 7.9 liter for first phase and second phase, respectively. Time of peak yield was about 43 days for first phase and 180 days for second phase.

Keywords: Milk yield, Dairy cattle, Multiphasic function, Lactation curve

Introduction

The most common equation and well known to describe lactation curve is incomplete gamma function or Wood's function (Wood, 1967). The Wood's function is essentially a single-phase curve type, which the curve of lactation increases rapidly from calving to peak a few weeks later, followed by a more or less gradual decline until the animal goes dry in about 10 months.

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Rowlands *et al.* (1982) used four functions of single-phase lactation curve and observed that the peak yields occurred at a mean of 7.5 weeks. The lactation curve of each function depends on the initial rise in milk yield, the position of the peak and the rate of decline.

It has been proposed a model, namely Multiphasic Function (Koops, 1986), consisting more than one component function to describe curve in each phase of interest simultaneously. A number of papers deal with the fitting of Multiphasic Function to body weight data and to describe growth curve have been published (Koops, 1986; Grossman and Koops, 1988; Kurnianto *et al.*, 1999), but limited that deals with lactation curve. Based on this reason, therefore, it is important to use the Multiphasic Function for estimating parameters and for describing the lactation curve of cows.

Materials and Methods

The weekly-recorded Holstein milk yield data came from 236 first three lactations of 126 cows of UPT Baturraden, Central Java-Indonesia, which had completed lactation between 1997 to 2001. The data collected from each cow, beginning with day 5 after calving until day 301 (43 weeks of lactation). Records used for analysis were from cows having length of lactation from 280 days to 329 days.

Statistical analysis

All individual weekly data were used as material. Mean body weight was computed at each age from 1 to 301 days. The Multiphasic Function (MF) used to fit milk yield data and to describe lactation curve based on a sum of logistic function:

$$Yt = \sum_{i=1}^{n} \{a_i b_i[1-\tanh^2(b_i(t-c_i))]\}$$

where Y_t is milk yield at time t (days in milk), n is the number of lactation phases, tanh is hyperbolic tangent and for each phase i: parameter a_i is half asymptotic total yield (liter), b_i is rate of yield relative to a_i (days^{-1}), $a_i b_i$ is maximum (peak) yield and c_i is time of peak yield (days). In this study, the monophasic (n=1) and diphasic function (n=2) were used to adjust the pattern of lactation curve.

The 305-day milk yield as the cumulative yield from 0 to 305-day in milk was estimated by evaluating the integral of equation above at 305 and 0 day:

$$Y_{305} = \sum_{i=1}^{n} \{a_i[\tanh(b_i(305-c_i)) - \tanh(b_i(0-c_i))]\}$$

The parameters of lactation curve a_i, b_i and c_i was estimated by non linear regression (PROC NLIN using the DUD method of SAS, 1990). Goodness-of-fit was checked on two criteria proposed: 1) Adjusted coefficient of determination (Adj-R^2), and 2) Akaike's information criterion (AIC). A function in multiphasic analysis showing higher Adj-R^2 and lower AIC indicate better fit to observed data.

Results and Discussion

Parameter estimates

Both of monophasic and diphasic functions use iterative method to achieve convergence criterion. For analysis of estimating parameters of lactation curve in this study, monophasic function was faster to compute compared with diphasic function. Determining parameters under the model was also easier. Diphasic function, however, was more satisfied in result although it needs several times to meet convergence criterion.

Parameters of lactation curve for monophasic and diphasic function are in Table 1. For monophasic function, rate of yield was 0.0025 days^{-1}. Peak yield was 13.01 liter and time of peak yield was 36.20 days (5.17 weeks). This is in agreement with the statement of Bath *et al.* (1985) that at parturition milk production commences at relatively high rate, and the amount secreted continuous to increase for about 3 and 6 weeks. Higher producing cows usually take longer than lower producing cows to attain peak yield. After the peak is attained, milk production gradually declines. This study was not separate cows into production level. Peak yield attained by monophasic function was in the range of acceleration phase.

It has been pointed out by Keown *et al.* (1986) that the cows starting their lactations at higher production and maintain it throughout lactation, thereby being more persistent. Cows in the lower production herds do not peak as high.

Table 1. Parameters for monophasic and diphasic lactation curves

Function	Phase (i)	Parameters			
		Rate of Yield	Peak yield	Time of Peak Yield	305-d Milk Yield
Monophasic	1	0.0025	13.01	36.20	3520.74
Diphasic	1	0.0059	5.32	43.21	1047.29
	2	0.0034	8.38	180.02	2480.79
	Total		13.70		3528.08

For diphasic function, rate of yield in first phase (0.0059 days^{-1}) was larger than that of in second phase (0.0034 days^{-1}). About 38.8% of peak yield was contributed by the first phase (5.32 liter) and about 61.2% by the second phase (8.38 liter).

Time of peak yield in first phase and in second phase was 93.21 days and 180.02 days, respectively. Total 305-day milk yields was 3528.08 liter, which similar to that for monophasic function. First phase contributed about 38 % to 305-day milk yields, whereas second phase was about 70 %.

The pattern of diphasic lactation curve has a biological interpretation. Gipson and Grossman (1989) analyzed diphasic lactation curve in dairy goats and concluded that first phase could be interpreted as peak phase because of shorter 'duration', whereas second phase with its longer 'duration' could be interpreted as a persistency phase. 'Duration' is defined as time required for attaining about 75% asymptotic total yield during that phase.

Fit of lactation curve function

Of the data analyzed, mean of milk yield a day was 10.4 liter with 2.79 standard deviation. No analysis conducted to elucidate some factors affecting milk yield in this study. Monophasic and diphasic function was just fitted to mean yield at each age of successive week up to 301 days.

Results of analysis for criteria of goodness-of-fit showed that Adj-R^2 for both monophasic and diphasic functions were 0.9798. Meanwhile, AIC values for monophasic and for diphasic function were -68.2245 and -74.2246, respectively. Of two functions used, diphasic function with lower AIC value was slightly better than did monophasic.

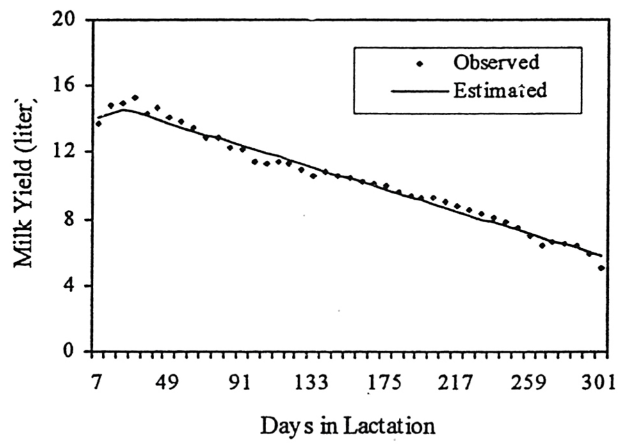

Figure 1. Fitted diphasic lactation curve

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Figure 1 illustrates the fitting diphasic lactation curve. This figure shows that the curve increased beginning from 7 to 21~ 28 days, declined gradually then until 301 days. Figure 2 shows the residual of the fitted data points (estimated value) from corresponding points on observed data by use of diphasic function. The diphasic function underestimated milk yield about 14 to 56 days in lactation, overestimated about 84 to 133 days and underestimated again about 154 to 252 days.

Conclusion

In conclusion, diphasic function with high Adj-R^2 and lower AIC value was better to fit a lactation data and sufficient to describe lactation curve compared with monophasic function.

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