A COMPARISON OF DIFFERENT EQUATIONS OF THE LACTATION CURVE IN HANWOO (*Bos taurus coreanae*)

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Summary

The objective of this research was to evaluate the suitability of six published equations to fit lactation curves to milk yield records of Hanwoo (Korean Beef Cattle) cows. Milk was collected from 102 heads of Hanwoo by milking machine from two teats every ten days for 180 days from 1986 to 1990, while the other two teats were suckled by her calf simultaneously. The following five lactation curve models were compared. 1) Wood, 2) Wood weighted, 3) Jenkins, 4) Nelder and 5) Multiphase (MP*i*). Two variants of multiphase curves (mono-phase (MP_1, n=1) and di-phase (MP_2, n=2)) were estimated. The mean deviations between observed milk yield and predicted equations by Wood, Nelder and mono-phase were ranged –0.2 to 0.2 kg during 10 days to 180 days after calving. The Wood weighted was over estimated, but MP_2 was under estimated during the whole period of lactation. The Jenkins showed markedly different shape of curve from the others. The multiphase estimated earlier day of peak yield than the others.

Introduction

Milk yield is an economically important trait in beef cattle because weaning weight of beef calves is influenced by dam's milk production more than by any other single factors. And the knowledge of the lactation curve shape in beef cattle is also important because the pattern of how a cow produces milk over time could determine her biological and economical efficiency for the purposes of feeding and selection. The Wood's incomplete gamma function is the predominant lactation curve used in model milk production of dairy cows (Scott *et al.*, 1996). However, the inverse polynomial has outperformed incomplete gamma function in some situation (Batra, 1986). Grossman and Koops (1988) proposed the multiphase lactation curve in order to overcome some of the limitations both the incomplete gamma function and the inverse polynomial have. On the other hand, Hohenboken *et al.* (1992) concluded that the Wood weighted equation was most suitable among four equations –Wood, Wood weighted, Jenkins and Morant – in characterizing variability among and within beef cows in milk production. The purpose of this research was to evaluate the suitability of six published equations to fit lactation curve to milk yield records of Hanwoo cows.

Materials and Methods

Data : Milk was collected from 102 heads of Hanwoo by milking machine from two teats every ten days for 180 days at the National Livestock Research Institute from 1986 to 1990, while the other two teats were suckled by her calf simultaneously. The observed milk yield was corrected by doubling the milk collected by milking machine, and the average milk yield of Hanwoo by ten-day intervals was shown in Table 1.

Table 1. Average milk yield of Hanwoo by ten-day intervals

Days after calving	Average yield(kg)	SD	Range (Min.~Max.)	Days after calving	Average yield(kg)	SD	Range (Min.~Max.)
10	4.80	1.0	2.2~7.8	100	3.4	1.0	1.3~6.0
20	4.78	1.0	2.3~7.7	110	3.2	1.0	1.2~6.6
30	4.6	0.9	2.2~7.3	120	3.1	1.0	0.9~6.2
40	4.6	1.0	2.6~6.9	130	2.9	1.0	0.8~6.3
50	4.3	1.0	2.6~6.7	140	2.7	0.9	0.6~5.7
60	4.1	1.0	2.3~6.4	150	2.6	0.9	0.4~5.7
70	3.9	1.0	2.1~6.4	160	2.4	0.9	0.3~5.7
80	3.8	1.1	1.8~9.0	170	2.2	0.9	0.2~5.2
90	3.5	1.0	1.6~6.1	180	2.0	0.9	0.1~4.7

Lactation Curve Equations : The three categories of lactation curve models were compared. The first category was the incomplete gamma function (Wood (Wood, 1967) and Wood weighted (Cobby and Le Du, 1978 and Rowlands *et al.*, 1982)), the second was inverse polynomial (Jenkins (Jenkins and Ferrel, 1984) and Nelder (Nelder, 1966)) and the third was the Multiphase (MP*i* (Grossman and Koops, 1988). The following five lactation curve models were compared. 1) Wood: $Y_t = At^b e^{-ct}$, 2) Wood weighted: each Y_t weighted by Y_t^2, 3) Jenkins: $Y_t = t/(ae^{bt})$, 4) Nelder: $Y_t = t/(b_0 + b_1 t + b_2 t^2)$, and 5) Multiphase (MP*i*): $Y_t = \sum_{i=1}^{n} a_i b_i [1 - \tanh^2(b_i(t - c_i))]$, where Yt = expected milk production on day t; A, a, b, c, b_0, b_1, b_2, a_i, , b_i and c_i are curve parameters; and n = number of phases in the multiphase lactation curve. Two variants of multiphase curves (mono-phase (MP_1, n=1) and di-phase (MP_2, n=2)) were estimated.

Statistical Analysis: The parameters of different lactation curves were estimated by DUD method using PROC NLIN of SAS (SAS, 1990).

Results and Discussion

Each estimated lactation curve equation was presented in Table 2. The lactation curve fitting

Jenkins equation differed markedly from the other five equations, and Hohenboken (1992) showed similar results. The lactation curve fitting Wood weighted equation was estimated to show milk production higher than the other equations. The mean deviations between the observed milk yields and the predicted milk yields by equations were shown in Figure 1. The Wood weighted equation showed over estimated during the whole lactation periods. On the other hand, the di-phase equation showed lower yield than the observed milk production. The deviations estimated by the equations of Wood, Nelder and mono-phase were ranged –0.2 to 0.2 kg during the whole periods.

Table 2. Lactation curve equations estimated

Method	Estimated equation
Wood	$Y_t = 4.033984t^{.1008}e^{-.006477t}$
Wood weighted	$Y_t = 4.729715t^{.060645}e^{-.004652t}$
Jenkins	$Y_t = t/(1.4310526e^{-.0447425t})$
Nelder	$Y_t = t/(.548464 + .14276t + .001587t^2)$
MP_1	$Y_t = 1165.47 \cdot 0.004515[1-\tanh^2(.004515(t+51.6353))]$
MP_2	$Y_t = 446.08 \cdot 0.005023[1-\tanh^2(.005023(t+91.1425))]$ $+ 302.37 \cdot 0.00999[1-\tanh^2(.00999(t-10.0477))]$

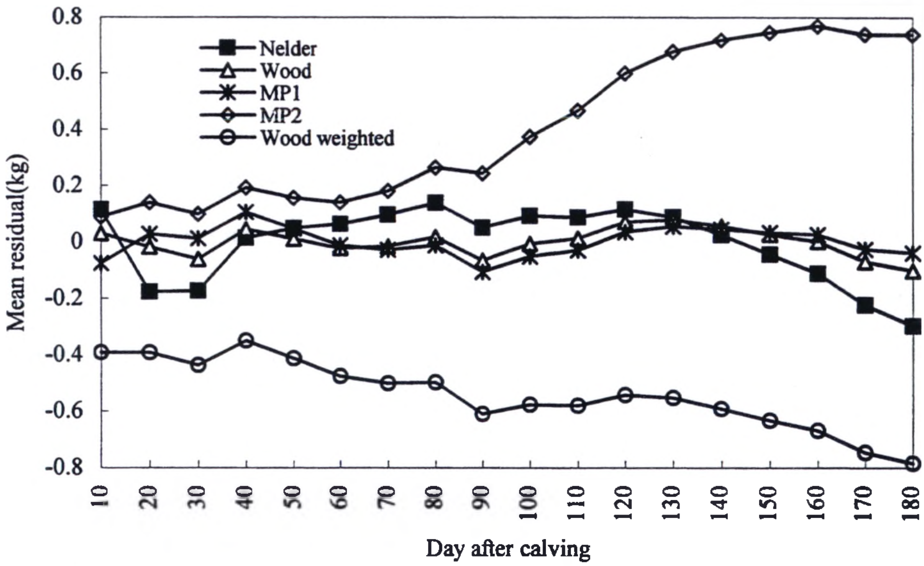

Figure 1. Mean deviations between the predicted and the observed milk production.

The day of peak production estimated by the equations fitting Wood, Wood weighted, Jenkins and Nelder was 14 to 22 days after calving (Table 3). On the other hand, the day of peak production in the mono-phase and the di-phase was one and three days after calving, respectively. The pattern of milk production in Hanwoo showed that the peak production was reached very rapidly. Milk yield at 10 days after calving was slightly higher than that at 20 days (Table 1). Because of characteristics of equations, it seemed that the day of peak yield of multiphase equations occurred earlier than that of the other equations. This means that incomplete gamma function and inverse polynomial has uncertainty in estimating early lactation (Rowlands *et al.*, 1982).

Table 3. Estimated peak days and yields and accumulated 180-day yields

Equation	Peak day	Peak yield(kg)	180-day yield(kg)
Wood	16	4.8	637.7
Wood-weighted	14	5.1	711.5
Jenkins	22	5.7	347.9
Nelder	19	5.0	629.5
MP_1	1	5.0	640.9
MP_2	3	4.8	635.4

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