MINIMUM NUMBER OF SAMPLES TO ADEQUATELY FIT LACTATION CURVES IN BEEF CATTLE

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INTRODUCTION

Milk production (MP) is a trait economically important in beef cattle. The high positive correlation between the dams' MP and the weaning weights of their calves shows that MP is the major factor influencing the pre-weaning gain of calves (Montaño-Bermudez and Nielsen, 1990; Meyer *et al*., 1994 ; Myers *et al*., 1999). In beef cattle, the measurement of MP is an uncommon practice in commercial situations, due to the difficulty in obtaining records. However, MP data and estimation of lactation curves are utilized in beef cattle experimentation (Akers, 2000 ; Brown *et al*., 2001). For domestic animals such as beef cattle, it is important to find the fewest number of samples required to appropriately fit lactation curves.

Accurate description and prediction of lactation curves on cows of different genotypes is important because it allows for a better understanding of a production system, gives useful information in development of selection strategies, helps to determine optimum strategies of production and management to improve cow/calf production efficiency, and allows to modify genetically lactation curves of the animals (Varona *et al*., 1998 ; Ruiz *et al*., 2000 ; Vargas *et al*., 2000).

Ramírez *et al*. (1998) compared eight equations to estimate lactation curves in Angus, Brown Swiss, and reciprocal-cross cows; concluding that incomplete gamma function (Wood, 1967) and parabolic exponential function (Sikka, 1950) provided the best fit for lactation curves of these genotypes. However, it may be useful to know if the fit of the equations is maintained when it is carried out with few number of daily MP samples. The objective of this study was to find the minimum number of samples of daily MP to adequately fit lactation curves in Angus, Brown Swiss and their crosses, using gamma incomplete and exponential parabolic functions.

MATERIAL AND METHODS

Data came from a complete diallel crossbreeding experiment at the research station of the University of Chapingo, in a temperate climate using Angus (A) and Brown Swiss (B) breeds. Calves had access to cow's feed all the time, but intake of solid feed began approximately after three to four months of age, and weaning was at 180 days.

Daily MP was collected weekly up to 180 d by the weigh-suckle-weigh technique. Cows were separated from their calves late in the afternoon and joined again approximately 12 h later for milk recording. The weight difference of calves before and after suckling for about 15 to 30 minutes, was considered MP of 12 h. Daily MP was calculated as twice of the 12 h milk

recorded. Residual milk was obtained manually when required, and added to milk consumed by the calf. Incomplete lactations or MP of cows with twin calves were discarded. Lactation records were obtained from 1981 to 1993. Numbers of cows and lactation records for A, B, and reciprocal crosses (AB) were respectively, 36 and 111, 40 and 109, and 24 and 52.
The following equations were evaluated for each lactation record :

1. $Y_t = a \exp(bt + ct^2)$ (Sikka, 1950)
2. $Y_t = a\, t^b \exp(-ct)$ (Wood, 1967)

where Y_t is the daily MP at day t, and *a*, *b*, and *c* are parameters to estimate. Parameter estimates of the equations were obtained by least squares of nonlinear forms (SAS, 1985). Equation 1 is an exponential function, proposed by Sikka (1950) to consider the initial increase in MP, and equation 2 is an incomplete gamma function, proposed by Wood (1967) to estimate typical lactation curves of dairy cattle.

These equations were evaluated with four sampling frequencies of daily MP, simulating the following four strategies during lactation: 1) twenty six measurements, 2) thirteen measurements, 3) seven measurements, and 4) four measurements. Strategy 1 used daily MP from weekly samples. Strategies 2, 3, and 4 were generated by deleting observed daily MP data for some weeks of lactation. Strategies 2 and 3 considered daily MP records at intervals of 14 and 28 days, respectively. Strategy 4 used daily MP obtained in weeks 1, 5, 13, and 25 after calving, to simulate sampling at early, intermediate, and final stages of the lactation.

To determine the minimum number of samples to fit a lactation curve properly, the invariance of parameter estimates on weekly sampling strategy was compared to the other sampling strategies. The parameters considered were *a*, *b*, and *c*, and total milk production (TMP), maximum daily milk production (MMP), day at maximum milk production (DMMP), and persistency (PER, defined as the ratio of daily MP in last day of lactation over MMP). These variables were analyzed within equation using the GLM procedure of SAS (SAS, 1985), with the following linear mixed model (after removing non significant two-way interactions, $P > 0.05$) :

$$Y_{ijklm} = \mu + F_i + G_j + V_{k(j)} + L_l + GL_{jl} + e_{ijklm}$$

where Y_{ijklm} is the response variable to analyze of the sampling frequency i, in genotype j, of cow k in lactation l; μ is a constant; F_i is a fixed effect of sampling frequency i (i = 1, 2, 3, 4); G_j is a fixed effect of cow's genotype j (j = 1, 2, 3); $V_{k(j)}$ is a random effect of cow k within genotype j (k = 1, 2, …,40); L_l is a fixed effect of lactation number l (l = 1, 2, 3, 4, ≥5); GL_{jl} is a fixed effect of interaction between genotype j and lactation number l, and e_{ijklm} is the residual error. Least square means for significant ($P < 0.05$) differences were compared using Tukey's multiple range test.

RESULTS AND DISCUSSION

Table 1 shows the results from analyses of variance of parameters *a*, *b*, and *c*; and TMP, MMP, DMMP, and PER considering the four sampling strategies; for parabolic exponential and incomplete gamma equations (equations 1 and 2, respectively). Cow nested in genotype, lactation number, and the interaction genotype*lactation number influenced ($P < 0.01$) all response variables studied, for the two equations studied.

Table 1. Level of significance (probabilities) for genetic and environmental effects on parameters *a*, *b*, and *c* of lactation curves, and total milk production (TMP), maximum daily milk production (MMP), day at maximum milk production (DMMP), and persistency (PER) obtained with exponential parabolic[A] and incomplete gamma[B] equations

Source of variation	Parameters *a*	*b*	*c*	TMP	MMP	DMPP	PER
			Exponential parabolic				
Sampling frequency	0.9099	0.8064	0.9673	0.6887	0.0238	0.0743	0.0881
Genotype (G)	0.0001	0.0004	0.0027	0.0001	0.0001	0.0001	0.0270
Lactation number (LN)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cow: Genotype	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
G*LN	0.0001	0.0021	0.0046	0.0001	0.0001	0.0001	0.0001
			Incomplete gamma				
Sampling frequency	0.4370	0.3015	0.6964	0.0225	0.1372	0.6880	0.0136
Genotype (G)	0.4545	0.0176	0.1169	0.0001	0.0001	0.0001	0.0001
Lactation number (LN)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cow: Genotype	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
G*LN	0.0025	0.0025	0.0002	0.0001	0.0001	0.0001	0.0001

[A] Sikka [$Y_t = a \exp(bt + ct^2)$].
[B] Wood [$Y_t = a\, t^b \exp(-ct)$].

The parameter estimates for *a*, *b*, and *c*; and the DMMP obtained with both, equations 1 and 2, did not change ($P > 0.30$) with the four sampling frequencies studied, and their least square means are given in Table 2. Equation 1 slightly overestimated the predicted MMP with four daily samples during lactation compared with the other sampling strategies (11.0 and ≤ 10.7 kg, respectively), and equation 2 underestimated the prediction of TMP and PER with four samples compared to the others sampling strategies (1512.9 and ≥ 1553.8 kg, and 0.58 and ≥ 0.62, respectively).

The similar values of the parameters for both, equations 1 and 2, suggests the possibility of using the lowest sampling frequency (four samples during lactation) to estimate lactation curves in genotypes similar to those evaluated in this study. However, the changes occurred in MMP with equation 1, and in TMP and PER with equation 2 when using four samples of daily MP during lactation, restrict their use with this sampling frequency. Therefore, these results indicate the advantage of taking monthly samples of daily MP during lactation when using equations 1 or 2, as a practical alternative for studies of lactation curves under similar conditions to the present research.

Table 2. Least square means of parameters *a*, *b*, and *c* of lactation curves, and total milk production (TMP), maximum daily milk production (MMP), day at maximum milk production (DMMP), and persistency (PER) obtained with exponential parabolic[A] and incomplete gamma[B] equations, with different sampling frequency of daily milk production during lactation

Sampling Frequency	Parameters *a*	*b*	*c*	TMP (kg)	MMP (kg/d)	DMPP (d)	PER
			Exponential parabolic[C]				
26 samples	8.7 a	0.0036 a	-0.0000031 a	1569.4 a	10.5 a	54.8 a	0.61 a
13 samples	8.7 a	0.0037 a	-0.0000031 a	1573.8 a	10.6 a	58.0 a	0.61 a
7 samples	8.6 a	0.0040 a	-0.0000032 a	1558.7 a	10.7 a	64.1 a	0.61 a
4 samples	8.7 a	0.0034 a	-0.0000031 a	1553.1 a	11.0 b	58.8 a	0.62 a
			Incomplete gamma[C]				
26 samples	6.2 a	0.2166 a	0.005199 a	1557.8 a	11.6 a	48.1 a	0.63 a
13 samples	6.9 a	0.1973 a	0.004853 a	1567.8 a	11.8 a	51.3 a	0.63 a
7 samples	7.0 a	0.1893 a	0.004753 a	1553.8 a	11.9 a	51.0 a	0.62 a
4 samples	7.6 a	0.1735 a	0.004893 a	1512.9 b	12.2 a	47.9 a	0.58 b

[A] Sikka [$Y_t = a \exp(bt + ct^2)$].
[B] Wood [$Y_t = a\, t^b \exp(-ct)$].
[C] Within equation, different letters in columns indicate significant differences ($P < 0.05$).

CONCLUSIONS

The results of minimum number of samples of daily milk production during lactation indicate that monthly sampling is adequate to obtain predictions of lactation curves in beef cattle.

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