The Relationship Between Parameters of Biological Models of Lactation and Milk Production

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Introduction

The use of models to fit the lactation curve of dairy cows, allows the prediction of milk yields as well as determining the effect of genetic and environmental factors, which influence a cow's performance.

The usefulness of each model relies on its accuracy to determinate factors affecting the lactation curve parameters. In general, the models provide parameters which are not well related biologically to what is occurring throughout the lactation and pregnancy (Pollott, 2000).

In recent years, Pollott (2000) proposed a biological approach to fit a lactation curve. This model is based on mammary cell proliferation, their differentiation into secretory cells, and the reduction in their number as a result of programmed cell death (apoptosis). The model describes two phases, the first representing the increase in milk production as a result of secretory cell proliferation, and second representing the decline in milk production during lactation because of apoptosis; these provided accurate values in order to estimate milk yields as well as its components.

The Pollott biological model has been shown evidence to be more accurate than some other widely used models (Pollott and Gootwine, 2000). Furthermore, the model provides new or additional parameters that contribute to a better understanding of the characteristics of the lactation curve.

The aim of this study was to determine the relationships between the parameters of the lactation curve, milk production and fertility.

Materials and Methods

The data analyzed in this study were provided by the National Milk Records Ltd. from 431 large British Holstein-Friesian herds. After validation, there were 392,958 lactations (ranging from 4 to 16 test day records), from 209,422 cows (calvings from 1^{st} to 8^{th}). Lactations were fitted using the 2-parameter reduce multiplicative model (model 1) describe by Pollott & Gootwine (2000), using NLIN Procedure (SAS, 1989).

$$\mathbf{M = [MS/(1 + a * \mathit{e}\ (-1 * \mathit{t} - 150))]\ (2 - \mathit{e}\ DR * \mathit{t})} \quad \mathbf{[1]}$$

Active cells ***Cells dying***

where MS= maximum secretion potential, a = constant DR = relative decline in cell numbers throughout lactation and t = day of lactation.

Lactation curve parameters were analyzed to determine the relationships between the parameters of the lactation curve, milk production and fertility. Model 2. was fitted to the 10 lactation traits shown in Table 1, with MANOVA using the GLM procedure of SAS (1989):

$$\mathbf{Y_{ijklm} = \mu + C_i(H_j) + S_k + Y_l + Lno_m + e_{ijklm}} \quad \mathbf{[2]}$$

where μ = overall least squares mean, $C_i(H_j)$ = cow i (C; I = 1 to 209,422) in herd j (H; j = 1 calving in season k (S; k = 1 to 4) of year l (Y; l = 1994 to 2004).

Results and Discussion

All factors consider in model 2 were highly significant (P<0.001). The squared correlation coefficient (R^2) (not shown) ranged from 0.62 to 0.88 for calving interval (CI) and persistency (P).Thus means that the model accounted for large proportion of the variance for all traits. Not surprisingly, the most important effects were cow, herd and lactation number each accounted for the variation in all traits: 0.39, 0.25 and 0.10 of the total sum of squares (TSS) respectively (not shown); while year and season of calving accounts for less than 0.02 of the TSS for the traits.

In Table 1 are shown the average values and standard deviations of curve parameters. The average lactation number was three, averaging 7,958 kg of calculated total milk yield. The average lactation length was 310 days and calving interval was 406 days. The average age at first calving was 28 months.

The values for curve parameters were as follow: the maximum secretion potential (MS) was 35.6 (kg/d), while the peak yield (PY) was 33.5 (kg/d). MS represent the upper limit to the amount of milk the animal is able to produce per day if there was no apoptosis during lactation (Pollott, 2000). The increasing rate in milk production midway between calving and PY (GM) was 201 g/d, reaching peak yield at 34 days.

The relative death rate in cell numbers (DR) was 0.0014, and persistency was 76.3 g/d. Total milk yield (TMY) was 7,843 kg corresponding to lactations no longer than 305 days; while calculated total milk yield (CTMY) was 8,153 kg. The average lactation length was 310 days and the calving interval was 406 days.

Correlations

Phenotypic correlations among traits are shown in Table 2. All correlations were highly significant (P < 0.001), even though some values are rather small. Parameters from the increasing phase of lactation such as MS, GM, PY, were well correlated amongst them. Important to highlight is the very high correlation between MS and PY indicating that these two traits are the virtually the same. Additionally, a reasonable correlation coefficient was found between MS and GM, DM, TMY and CTMY.

GM was moderately correlated with PY, DR and DM. Cows showing high increase rate of DM will reach PY early in lactation, implying a negative correlation between GM and DP. There was a good correlation between PY and P, TMY and CTMY. In general, it means that any increase in PY will increase milk yields. The correlations between DP and the rest of the parameters were poor but still significant (P>0.001). DR and persistency were well correlated. Not surprisingly, these two parameters were negatively correlated with TMY, CTMY LL and CI, with the exception of P and TMY that was positive. Finally, TMY, CTMY, LL and CI were either moderately or well correlated. However, was expect a higher correlation between these parameters with CI, due to the fact that high milk yields are associated with poor fertility, in this case CI is an estimator of fertility. The next step to address this particular point will be grouping cows according to their TMY and CTMY level into low (≤ 6,000 kg), medium (>6,000 to ≤8,000 kg) and high (>8,000 kg) in order to detect whether there is a negative correlation among milk yields and fertility traits. Parameters of first lactation are equally correlated with the lactation curve parameters from other age groups.

Conclusions

The adequate correlations among parameters from the increasing and decreasing phase of lactation curve, allow us to have clear idea about the interactions among productive traits and its implications on health and welfare for dairy cows. Hence, high peak yields are associated with high total milk yields, longer lactations and longer calving intervals; all were negative correlated with persistency.

Proposed new parameters, MS and DR, that have a biologically explanation of the lactation process were moderately correlated with the standard curve parameters highlighting its utility due to its biological meaning.

References

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Table 1. Means and standard deviations of the traits.

Parameter	Abreviation	Mean	SD
Maximum secretion potential (kg/day)	MS	35.6	9.17
Daily increase in milk production mid way between calving and peak (g/day)	GM	200.7	92.60
Peak yield (kg)	PY	33.5	8.49
Day of peak yield	DP	33.9	13.17
Relative death rate in cell numbers	DR	0.0014	0.0005
Persistency	P	76.3	57.20
Total milk yield (kg)	TMY	7843.5	2156.0
Calculate Total milk yield (kg)	CTMY	8152.7	2625.6
Lactation length (days)	LL	310	70.7
† Calving interval (days)	CI	406	78.6

†n= 220,977 lactations

Table 2. Partial correlation coefficients between traits.

	GM	PY	DP	DR	P	TMY	CTMY	LL	CI†
MS	0.75	0.99	0.06	0.20	0.59	0.71	0.56	0.04	0.02
GM		0.70	-0.39	0.64	0.66	0.25	0.10	-0.20	-0.10
PY			0.07	0.12	0.53	0.75	0.61	0.08	0.03
DP				-0.10	0.28	0.09	0.08	0.03	0.04
DR					0.78	-0.38	-0.47	-0.47	-0.23
P						0.03	-0.09	-0.28	-0.12
TMY							0.87	0.48	0.19
CTMY								0.76	0.46
LL									0.71

† n= 220,977 lactations

All significant (P<0.001)