GENETIC PARAMETER ESTIMATES FOR SHAPE OF THE LACTATION CURVE IN DAIRY CATTLE

L.T. Gama, R.N. Carolino, A.A. Cruz and M.I. Carolino

Instituto de Estruturas Agrárias e Desenvolvimento Rural
R. Garrett, 80 - 1200 Lisboa - PORTUGAL

SUMMARY

Analysis of 5522 lactations by Wood's incomplete gamma function indicated important effects of lactation number and season of calving, with lower peak yield and higher persistency in first lactations and cows calving in the Summer. Curve parameters had heritability estimates ranging between .11 and .16, and their genetic correlation with total milk yield was low to intermediate. Peak yield and persistency at 270 days of lactation had heritability estimates of .28 and .17, respectively, and their genetic correlation with total milk yield was high.

INTRODUCTION

Lactation curves are important tools to be used by dairy farmers for management and selection decisions, as they smooth out random fluctuations occurring during lactation, allowing estimates of summary parameters to be analysed for the importance of different systematic effects. A frequent application of the lactation curve is to extend a lactation in progress to predict yield up to a standard length, thus allowing the inclusion of incomplete lactations in genetic evaluation schemes. Other possible applications may be considered in genetic evaluation for milk production, e.g., the inclusion of lactation shape parameters in an index combining them with milk yield.

Different non-linear models have been suggested to describe the shape of the lactation curve in dairy and beef cattle, as well as other species, of which the incomplete gamma function proposed by Wood (1967) has been the most frequently applied. The objectives of this work were a) to evaluate the influence of herd, lactation number and calving season on the shape of the lactation curve in Portuguese dairy cows, and b) to obtain estimates of genetic parameters for the coefficients of the curve and functions of these, such as peak yield and measures of persistency.

MATERIALS AND METHODS

Data included in the analysis were daily milk yields (**DMY**) collected over two years in 59 herds of Holstein Friesian cattle in Portugal, corresponding, after edits, to 5522 lactations in 4897 cows. Wood's incomplete gamma function was fitted to DMY up to 305 days for each individual lactation as:

$$\mathbf{DMY_t = a\, t^b\, e^{-ct}}$$

where DMY_t is predicted daily milk yield at day **t**; **a**, **b** and **c** are lactation shape parameters and e is the base of natural logarithms. Parameter estimates for each lactation were estimated with PROC NLIN in SAS (SAS Institute, 1985), using the secant method and a convergence criterion of 10^{-8}. Estimated production at (**PPY**) and day of (**DPY**) peak yield, as well as absolute persistency at 90, 180 and 270 days of lactation (**AP_{90}**, **AP_{180}** and **AP_{270}**), were obtained for each lactation as **PPY** = $a\ (b/c)^b\ e^{-b}$; **DPY** = b/c ; and **AP_i** = $a\ i^{(b-1)}\ e^{(-ci)}\ (b-ci)$, for $i=90$, 180 and 270.

Estimates of individual curve parameters, PPY, DPY, AP_{90}, AP_{180}, AP_{270} and total milk yield up to 305 d (**TMY**) were analysed by least squares procedures with PROC GLM of SAS. The following linear model was used:

$$Y_{ijkl} = \mu + H_i + L_j + S_k + LS_{jk} + e_{ijkl} \qquad (1)$$

where Y_{ijkl} is the trait of interest measured in the $ijkl^{th}$ lactation, μ is the overall mean, H_i is the effect of the i^{th} herd-year, L_j is the effect of the j^{th} lactation number ($j=1,2,3$ and ≥ 4), S_k is the effect of the k^{th} season of calving (k= Spring, Summer, Winter and Autumn), LS_{jk} is the effect of the interaction between lactation number and season of calving, and e_{ijkl} is the residual associated with the $ijkl^{th}$ observation.

Variance and covariance components were estimated by Method III with PROC VARCOMP of SAS, using a sire model which included the same fixed effects as in (1). These analyses were conducted with a subset of the original data set , including 2299 cows with known sires.

RESULTS AND DISCUSSION

The analysis of variance resulted in a significant ($P<.05$) interaction between lactation number and season of calving, for all traits except AP_{90} and TMY. Coefficients of determination ranged from 5 to 25% for curve parameters, 30 to 40% for measures of persistency, and were nearly 44% for PPY. Residual coefficients of variation ranged between 47 and 60% for curve parameters, and were about 18% for PPY, 51% for DPY, 81% for AP_{90}, 39% for AP_{180} and 31% for AP_{270}. Least squares means by trait, for combinations of lactation number and season of calving, are in Table 1. Means for parameters a and **c** were significantly lower in first lactations, and **b** tended to follow the same pattern, with the exception of Summer calvings where third lactations had the lowest mean for **b**. Within lactation number, means for **c** were similar among seasons, while generally **a** was lower and **b** higher in Summer calvings. The PPY was lower by 6 to 8 Kg, and occurred nearly 30 days later, in first lactation cows when compared to older cows in the same calving season, and was significantly lower in Summer calvings. Absolute persistency at 90, 180 and 270 days of lactation was significantly higher in first lactation cows and cows calving in the Summer.

Table 1. Least squares means (± standard error) for lactation shape parameters a, **b** and **c**, production at peak yield (**PPY**), day of peak yield (**DPY**), total milk yield (**TMY**) and absolute persistencies at 90, 180 and 270 days of lactation (**AP90**, **AP180** and **AP270**, respectively), by lactation number and season of calving[a].

		Calving season			
Variable	**Lactation**	**Winter**	**Spring**	**Summer**	**Autumn**
a	1	11.56^{a} ± .38	11.46^{a} ± .35	10.04^{b} ± .45	11.11^{ab} ± .48
	2	15.38^{cdfgl} ± .43	15.33^{cdfgl} ± .38	13.90^{e} ± .45	14.62^{cde} ± .48
	3	14.85^{def} ± .58	14.90^{def} ± .51	16.17^{fgi} ± .61	16.52^{gi} ± .61
	≥ 4	15.50^{dij} ± .44	15.06^{dfhj} ± .41	14.23^{ehl} ± .43	14.06^{eh} ± .51
b (x 100)	1	26.3^{ahj} ± .9	26.0^{a} ± .8	28.5^{abcd} ± 1.0	26.9^{abd} ± 1.1
	2	27.9^{acdfhi} ± 1.0	26.7^{adh} ± .9	29.0^{bcde} ± 1.0	28.1^{acdfhi} ± 1.1
	3	30.3^{ce} ± 1.3	30.4^{ce} ± 1.2	25.8^{abd} ± 1.4	26.0^{abd} ± 1.4
	≥ 4	30.4^{cei} ± 1.0	28.4^{bcj} ± .9	30.0^{cef} ± 1.0	31.9^{e} ± 1.1
c (x 1000)	1	3.63^{a} ± .11	3.59^{a} ± .10	3.60^{a} ± .13	3.58^{a} ± .14
	2	5.60^{bcd} ± .13	5.30^{b} ± .11	5.44^{be} ± .13	5.40^{bc} ± .14
	3	5.96^{dh} ± .17	6.22^{h} ± .15	5.38^{bg} ± .18	5.34^{bg} ± .17
	≥ 4	6.07^{h} ± .13	5.70^{cdeg} ± .12	5.86^{dh} ± .13	5.96^{dh} ± .15
PPY	1	23.5^{ab} ± .2	23.0^{ab} ± .2	22.8^{a} ± .3	23.6^{b} ± .3
	2	29.7^{cdg} ± .3	29.1^{g} ± .2	27.7^{i} ± .3	29.2^{cg} ± .3
	3	31.1^{ef} ± .4	31.2^{f} ± .3	29.3^{cdg} ± .4	30.9^{fh} ± .4
	≥ 4	31.7^{f} ± .3	29.8^{cd} ± .3	29.1^{cg} ± .3	30.2^{deh} ± .3
DPY	1	72.8^{a} ± 1.4	72.2^{a} ± 1.3	84.4^{d} ± 1.7	77.2^{e} ± 1.8
	2	47.1^{b} ± 1.6	47.8^{b} ± 1.4	53.0^{c} ± 1.7	49.3^{bc} ± 1.8
	3	49.4^{bc} ± 2.2	48.2^{bc} ± 1.9	46.5^{b} ± 2.3	47.7^{bc} ± 2.3
	≥ 4	47.3^{b} ± 1.7	49.1^{bc} ± 1.5	50.4^{bc} ± 1.6	51.0^{bc} ± 1.9
TMY	1	5765^{ab} ± 61	5624^{a} ± 57	5288^{g} ± 72	5651^{ab} ± 76
	2	6276^{cdf} ± 68	6205^{cd} ± 62	5639^{a} ± 72	6149^{c} ± 77
	3	6474^{ef} ± 93	6351^{cdef} ± 82	5825^{ab} ± 98	6424de ± 98
	≥ 4	6521^{e} ± 71	6194^{c} ± 65	5844^{b} ± 69	6227^{cd} ± 82
AP90 (x 100)	1	-1.56^{a} ± .20	-1.44^{a} ± .18	-.83^{b} ± .23	-1.25^{ab} ± .24
	2	-6.60^{cf} ± .22	-6.18^{chi} ± .20	-5.59^{d} ± .23	-6.07^{cdh} ± .25
	3	-7.28^{ef} ± .30	-8.00^{e} ± .26	-6.55^{cf} ± .31	-6.79^{cf} ± .31
	≥ 4	-7.70^{e} ± .23	-6.90^{fg} ± .21	-6.65^{cghf} ± .22	-6.76^{fgi} ± .26
AP180 (x 100)	1	-4.07^{a} ± .12	-3.90^{ab} ± .12	-3.64^{b} ± .15	-3.96^{ab} ± .16
	2	-7.67^{fg} ± .14	-7.28^{i} ± .13	-6.81^{c} ± .15	-7.41^{fgj} ± .16
	3	-8.34^{de} ± .19	-8.62^{d} ± .17	-7.28^{cfi} ± .20	-7.78^{fgj} ± .20
	≥ 4	-8.64^{d} ± .14	-7.78^{gh} ± .13	-7.63^{fgi} ± .14	-8.09^{ehj} ± .17
AP270 (x 100)	1	-3.89^{a} ± .08	-3.75^{ab} ± .07	-3.63^{b} ± .09	-3.85^{ab} ± .09
	2	-5.75^{ghij} ± .08	-5.52^{e} ± .08	-5.19^{c} ± .09	-5.67^{eh} ± .10
	3	-6.11^{df} ± .11	-6.08^{df} ± .10	-5.44^{ce} ± .12	-5.90^{fhj} ± .12
	≥ 4	-6.25^{d} ± .09	-5.71^{egij} ± .08	-5.60^{ei} ± .08	-5.96^{fg} ± .10

[a] Means for the same variable with different superscript differ at $P<.05$.

Estimates of curve parameters were correlated with each other (Table 2), with phenotypic correlations ranging, in absolute value, between .55 and .87. Taken individually, these parameters were poorly correlated with TMY, even though some functions of them, such as PPY, had high phenotypic correlations with TMY.

Heritability estimates for parameters **a**, **b** and **c** of the lactation curve (Table 2) ranged between .11 and .16, much lower than the heritability estimates of .28 for PPY and .38 for TMY. For measures of persistency, heritability estimates increased from .05 at 90 days to .17 at 270 days of lactation. Genetic correlations of curve parameters with TMY were, in absolute value, near .55 for a and c, but only .11 for b. The PPY had the highest genetic correlation with TMY, followed by AP_{270}, while correlations of TMY with earlier measures of persistency were intermediate, but of opposite sign. Curve parameters were genetically correlated with each other, with absolute values for genetic correlations ranging between .91 and .99.

Index selection based upon different combinations of milk yield and lactation shape traits could lead to slight improvements in accuracy of selection. For example, an index including TMY, **a**, **b** and **c** could increase accuracy of selection by about 3% for a sire selected on the performance of 25 daughters, and by more than 5% for a cow selected on her own first lactation performance. Other combinations of traits resulted in smaller increases in accuracy of selection.

Table 2. Heritabilities (diagonal), genetic correlations (above diagonal) and phenotypic correlations (below diagonal) for milk yield and lactation shape parameters[a]

	TMY	a	b	c	DPY	PPY	AP90	AP180	AP270
TMY	.38	.55	-.11	-.55	.11	.99	.34	-.37	-.82
a	.27	.15	-.91	-.99	-.71	.39	.22	.39	.00
b	-.13	-.87	.16	.96	.79	-.04	.04	-.57	-.33
c	-.33	-.55	.76	.11	.61	-.53	-.23	-.52	-.04
DPY	.07	-.69	.58	.07	.11	.18	.24	-.44	-.44
PPY	.74	.41	-.09	.08	-.23	.28	.34	-.52	-.93
AP90	.15	-.32	.10	-.52	.59	-.45	.05	.54	.11
AP180	-.14	.23	-.50	-.76	.14	-.57	.64	.15	.85
AP270	-.45	.30	-.52	-.46	-.07	-.60	.19	.83	.17

[a] See Table 1 for definition of abbreviations.

LITERATURE CITED

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