Genetic Relationship between Lactation Curve Traits in Dairy Cattle

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ABSTRACT: Dairy cattle selection strategy in Kenya prefers cows with good 305-day lactation milk yield (TMY) in previous parity. This has improved milk production although increased incidences of physiological disorders and reduced fertility have been reported in herds. Records on functional traits are scarce. Properties of lactation curves could indirectly explain reproductive efficiency in cows. This study assesses relationship between lactation curve traits, to evaluate effects of selection for TMY on lactation curve properties, to explain reduced physiological efficiency and fertility. Genetic correlations between peak milk yield (MYmax) and persistency (S), MYmax and Days in milk at peak (DIMP), TMY and DIMP were negative. Genetic correlations were positive between DIMP and S, TMY and MYmax implying that selection for high TMY increases MYmax and reduces DIMP. This shifts production pressure to early lactation aggravating negative energy balance thus compromising physiological integrity of cows

Key words: Correlation estimates, Lactation curve traits, Reproductive performance

Introduction

Selection of dams for national contract mating scheme in Kenya is on the basis of lactation performance across parities. At farm level, survival of the cow to the next lactation depends largely on its previous lactation performance. These selection strategies; on the basis of their milk production potential have resulted to considerable improvement in milk yield (Ojango and Pollott 2001). However, cases of increased infertility, reduction in production herd life, and metabolic and mammary disorders have also become common. It has been demonstrated that continuous selection for milk production traits may affect functional traits such as fertility, somatic cell count/score and mastitis depending on the correlation between them (Appuhamy et al. 2007; Jamrozik et al. 2010). Records on udder health and metabolic disorders in lactating animals are scarce. Consequently, the relationship between milk production and these traits cannot be directly estimated. On the basis of knowledge on lactation physiology, energy balance during lactation and reproductive efficiency in early lactation, explanations could be provided to the observed declining reproductive performance and increase in udder health problems in the Kenyan herds, indirectly by drawing inference from relationships between milk yield and lactation curve traits.

A lactation curve is useful in explaining the physiology of milk production in cows (Pollott 2000). The curve has three important components namely milk yield at peak lactation (MYmax), days in milk at peak milk yield (DIMP) and the extent to which the animal maintains peak milk yield also referred to as persistency (S), whose study provides insight into lactation physiology. Studies have shown that lactation curve traits are correlated with functional traits (Appuhamy et al. 2007; Jakobsen et al. 2002; Muir et al. 2004). Quantified estimates of association between lactation milk yield and lactation curve traits could explain physiological issues reported in Kenyan herds and guide future selection decisions. The correlation between milk yield and lactation curve traits has not been estimated in the Kenyan dairy cattle population and consequently, the relationship between these traits cannot be quantified. The objective of this study is to estimate the phenotypic and genetic relationship between lactation curve traits and 305 day milk yield in the dairy cattle population in Kenya in order to assess the effects of cow selection on the basis of lactation milk yield on lactation curve properties to provide an explanation to the declining functional performance reported in the herds.

Materials and methods

Milk yield records from the first three parities of Ayrshire, Holstein Friesian and Jersey cows were extracted from the national dairy cattle database at the Livestock Recording Centre (LRC) in Naivasha, Kenya. The records included test day milk yield (TDMY) and 305 days lactation milk yield (TMY) of cows that calved between 1994 and 2010. The TDMY records were from monthly milk yield samples collected on every 14th day evening and 15th day morning. The first test day record was taken on the 5th day post partum. For animals lactating beyond the 305 days, TMY was achieved by right truncation of records at 305 days in milk (DIM) resulting in a dataset that had 10 TDMY samples per lactation. The data were edited to remove records of lactations following abortions, lactation with missing test day yields and lactations with inconsistent dates of birth, calving and drying. Further edits involved removal of records of milk yield sampled earlier than the 5th day post partum in which case the subsequent milk sample was considered to be the first test day sample. In addition, extra milk records where sampling was done more than ones in a month were removed in favour of samples closer to the 14th and 15th days of sampling. A total of

61240 test day records were available for analysis after the edits. A summary of the structure and descriptive statistics of the data are presented in Table 1.

Lactation curve traits were computed from lactation curve parameters estimated from the TD data using the incomplete gamma function (Wood 1967).

$Y_t = at^b e^{-ct}$

where Y_t is the test day milk yield at DIM t, a, b and c are parameters representing a scaling factor associated with initial milk yield, the pre-peak and post-peak curvatures, respectively. The function was fitted to the TD data using PROC NLIN of SAS (SAS 2004), invoking a Marquardt computing algorithm. MYmax was calculated as $a(b/c)^b e^{-b}$, DIMP was expressed as b/c and S computed as $c^{-(b+1)}$.

The relationship between lactation curve traits and TMY was evaluated by estimation of phenotypic and genetic correlations using a multivariate repeatability animal model where; MYmax, DIMP, S and TMY records were fitted treating records from different lactations as repeated observations of the same trait. This yielded four traits in the analysis. The following model in matrix notation was used.

$\boldsymbol{y} = \boldsymbol{X\beta} + \boldsymbol{Za} + \boldsymbol{Wp} + \boldsymbol{e}$

where $\boldsymbol{y}$ is a vector of the observations for the various traits in the analysis (MYmax, DIMP, S and TMY), $\boldsymbol{\beta}$ is a vector of fixed effects including breed, parity, the contemporary group of herd year season of calving and linear and quadratic covariance of dam's calving age and days in milk at first test day; $\boldsymbol{a}$, $\boldsymbol{p}$ and $\boldsymbol{e}$ are vectors of random effect of the animal, permanent environmental effect and residual effects, respectively. $\boldsymbol{X}$, $\boldsymbol{Z}$ and $\boldsymbol{W}$ are incidence matrices that relate fixed effects, random animal and permanent environmental effects respectively, to the observations. Whereas matrix $\boldsymbol{Z}$ contains all animals (those with and those without records), matrix $\boldsymbol{W}$ contains only animals with records. The covariance between $\boldsymbol{a}$ and $\boldsymbol{p}$ was assumed to be zero. Estimates of phenotypic and genetic parameters were obtained using WOMBAT program (Meyer 2006).

Results and discussion

Estimates of genetic parameters for MYmax, DIMP, S and TMY are presented in Table 2. Genetic correlation between S and MYmax was negative but low. Negative genetic correlations were also observed between DIMP and MYmax, and TMY and DIMP. The negative genetic correlation between MYmax and S, MYmax and DIMP, and TMY and DIMP implies that genes that influence MYmax also influence S and DIMP, but in the opposite directions. Selection for increased MYmax would result in a reduction in S and DIMP, which implies sharper drop in post peak milk production and early attainment of peak milk yield. Due to the higher correlation estimate between MYmax and DIMP relative to MYmax and S, the magnitude of response to selection will be high in the former than the latter. Rekaya et al. (2000) similarly obtained negative correlation between MYmax and S, but reported positive estimates between MYmax and DIMP. Genetic correlation between DIMP and S, and TMY and MYmax were positive and high. The high positive genetic correlation between DIMP and S and, TMY and MYmax implies a strong genetic relationship between the traits due to pleiotropy. Therefore selection for genetic improvement of TMY would result in an increase in MYmax. Similarly, improvement in S could be achieved when selection aimed at increasing DIMP. Positive correlation estimates between TMY and MYmax, and DIMP and S were reported in the analysis of lactation curves of Spanish Holstein cattle (Rekaya et al. 2000). A positive correlation was observed between TMY and S, although this was low.

Phenotypic correlation between S and MYmax, and MYmax and DIMP were low and negative. S and DIMP, and MYmax and TMY had high positive phenotypic correlation estimates. Phenotypic correlations between S and TMY, and DIMP and TMY were positive but low. Phenotypic correlations depict a strong positive relationship between TMY and MYmax and, DIMP and S. This implies that cows with high TMY were highly likely to attain high MYmax while high S was closely associated with increase in DIMP. Similar results were observed in a study of phenotypic relationships of health disorders to lactation persistency (Appuhamy et al. 2007). Producers select breeding animals based on phenotypic value of TMY. This mode of selection is bound to result in improvement in MYmax. Considering the negative phenotypic relationship between MYmax and S, and DIMP, which is of greater magnitude than the positive correlation between TMY and S, and DIMP; the resultant of phenotypic selection for high TMY would be increased MYmax which is attained early as a result of reduction in DIMP and a steep post peak gradient due to a reduction in persistency.

Genetic or phenotypic selection to improve TMY would result in alteration of the shape of the lactation curve especially in early stages of lactation. This has a consequence on the lactation physiology energy balance and metabolic processes of the animal (Appuhamy et al. 2007; Muir et al. 2004; Negussie et al. 2008). Increased milk yield in early stages of lactation as a result of selection for high TMY would lead to high energy demand and consequently aggravating the condition of negative energy balance. This is because at this time the animal undergoes hormonal involution which depresses feed intake and energy metabolism. This may lead to reduced fertility in form of high non return rate and prolonged days open and silent heat (El-Sysy 2009).

Conclusion

Selection of cows to increase TMY would result in a positive correlated response of milk yield at peak lactation. Selection for high TMY would influence the shape of the lactation curve especially in early lactation and hence could be the course of the observed decline in fertility and increase in incidences of metabolic disorders.

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Table 1 Data structure and mean performances for the various traits[a]

		Number of records				Mean performance			
Breed	Parity	MYmax	DIMP	S	TMY	MYmax	DIMP	S	TMY
Ayrshire	1	214	214	214	325	13.48	63.79	1596.61	2991.47
	2	144	144	144	225	15.27	59.18	1441.71	3214.20
	3	130	130	130	183	15.70	57.71	1345.27	3425.36
Holstein	1	980	980	980	1414	18.94	67.04	1482.01	4516.58
	2	854	854	854	1154	22.99	49.84	1059.02	5109.81
	3	657	657	657	852	25.01	49.71	1049.09	5406.30
Jersey	1	200	200	200	264	15.99	56.51	1504.95	3939.67
	2	163	163	163	205	18.89	42.82	936.93	4224.90
	3	155	155	155	173	18.90	47.83	1094.30	4413.67

[a]S= persistency; MYmax= milk yield at peak lactation; DIMP= days in milk at peak lactation; TMY= 305 days lactation milk yield

Table 2 Estimates of heritability (h^2), permanent environmental variance as a proportion of phenotypic variance (c^2), repeatability (t), genetic (below the diagonal) and phenotypic (above diagonal) correlations between lactation curve traits and 305 days milk yield

Traits[a]	S	MYmax	DIMP	TMY	h^2	c^2	t
S	1	-0.120 (0.01)	0.747 (0.03)	0.048 (0.01)	0.171 (0.02)	0.077 (0.01)	0.248 (0.03)
MYmax	-0.093 (0.12)	1	-0.159 (0.02)	0.740 (0.02)	0.200 (0.04)	0.252 (0.05)	0.452 (0.03)
DIMP	0.983 (0.07)	-0.275 (0.02)	1	0.077 (0.01)	0.134 (0.05)	0.027 (0.02)	0.161 (0.04)
TMY	0.053	0.976 (0.05)	-0.129 (0.05)	1	0.171 (0.03)	0.328 (0.02)	0.499 (0.01)

[a]S= persistency; MYmax= milk yield at peak lactation; DIMP= days in milk at peak lactation; TMY= 305 days lactation milk yield