Genetic Parameter Estimates for Lactation Curve Parameters, Milk Yield, Age at First Calving, Calving Interval and Somatic Cell Count in Holstein Cows

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INTRODUCTION

In most developing countries, milk production is the main objective in dairy cattle genetic improvement programs. However, in addition to milk yield, reproductive and health traits are among the major traits that should be improved genetically in dairy cattle. In recent years intensive selection for milk yield has depressed reproductive performance of cows (Pedron et al. 1989). Deficient reproductive performance, exhibited as longer calving intervals and increased involuntary culling, may result in less milk and fewer calves per cow per year, lower voluntary culling and consequently increased replacement costs and finally, reduced returns (Bagnato and Oltenacu, 1994). Suitable fertility performance can result in higher income from milk sales and reduced input costs (Dekkers, 1991). Two measurements of reproductive efficiency frequently taken in Iranian farms with intensive management systems are age at first calving and calving interval. Genetic improvement of these traits could have a major impact on dairy production costs. Shortening of age at first calving would decrease the cost of raising replacement heifers and shortening of calving intervals would decrease them early production costs per calf (Vergara et al. 2009). Mastitis is the most costly disease in

The objective of this study was to estimates the genetic and environmental components for the lactation curve parameters, milk yield, age at first calving (AFC), calving interval (CI) and somatic cell count (SCC) in Iranian Holstein cows. The dataset consisted of 210625 test day records from 25883 cows with milk yield in the first parity recorded from July 2002 to September 2007 in a total of 97 herds in Iran. The lactation curve and the selected lactation parameters were the scaling factor to represent yield at the beginning of lactation (a), the factor associated with the inclining (b) and declining (c) slopes of the lactation curves and the first 100-day milk yield, second 100-day milk yield, third 100-day milk yield, peak yield (Ymax), days in milk at peak yield (b/c), persistency (s), lactation length (LL) and the 305-day milk yield. The incomplete gamma function (Wood function) was used to estimate lactation curve and lactation parameters from daily milk records. Among the 100-day milk yield periods, the second 100-day milk yield had the highest heritability (0.29±0.024) and the highest genetic correlation with the 305-day milk yield (0.996±0.00). Lactation curve parameters had low h² (0.017±0.007 to 0.051±0.011). The b / c had a relatively high genetic correlation with the 305-day milk yield (0.52±0.08), a moderate genetic correlation with CI (0.32±0.14) and negative genetic correlations with measures of somatic cell count. This suggested that b / c could be used as a criterion to improve 305-day milk yield and resistance to subclinical mastitis.

KEY WORDS heritability, lactation curve, subclinical mastitis, Wood function.
dairy cattle, and lowering its incidence is important to reduce costs of treatment, improve animal welfare, reduce consumption of antibiotics and reduce the risk of antibiotic residues in milk. One option is to select for improved mastitis resistance by direct selection, using clinical mastitis records. An alternative approach is indirect selection on traits genetically correlated to mastitis, e.g., somatic cell count (SCC) and measuring the inflammatory response in the udder (Odegard et al. 2003). Other characters, such as shape of lactation curve, having a complex relationship with production and health traits, could also be considered to optimize production and profitability. “Knowledge of the probable shape of the lactation curve would make feeding trials more efficient because differences between treatments could be more easily detected when animals are grouped according to the expected curve shape” as stated by Tekerli et al. (2000). Assessment of the genetic components for the shape of lactation curves, would allow selecting for these traits and thus to improve cattle yield efficiency. The heritability and genetic correlation among economic performance traits are needed for the development of an effective genetic evaluation and breeding system. Although variance components and genetic parameters have been estimated for lactation curve parameters (Moradi Shahrbabak, 2001), milk yield (Moradi Shahrbabak, 2001), age at first calving (Berry and Cromie, 2009), calving interval (Toghiani Pozveh et al. 2009) and somatic cell count (Haile-Mariam et al. 2003) in previous studies, none of them estimated genetic relationships between all the aforementioned traits in a single study. Thus, the objectives of this study were 1) to estimate heritabilities as well as genetic and environmental correlations between lactation curve parameters (a, b, c, b/c, Y_max and s), milk yield, age at first calving (AFC), calving interval (CI) and somatic cell count (AVG SCC and Ln SCC) in Iranian Holstein cows, and 2) to investigate the effect of age at first calving on lactation curve parameters, milk yield, calving interval and somatic cell count.

MATERIALS AND METHODS

Dataset
Test-day records of milk yield, somatic cell count and calving events in Holstein cows were obtained from the National Animal Breeding Center and Promotion of Animal Products. The dataset included herds with more than 500 test-day records from daughters of at least four different sires. Only first lactation cows calving between 20 and 40 months of age with a minimum of 6 test-day records were considered in the analysis. Tests before 6 days in milk (DIM) or after 305 DIM were excluded. Also, cows with calving intervals outside the interval from 290 to 600 days were excluded from the data set. Daily milk production records below 10 kg and above 80 kg were deleted because these records most likely represented sick cows or recording mistakes. Records of cows with unknown parents or cows with pedigree errors were also discarded. The final dataset comprised 210625 test-day records from the first lactation of 25883 cows from 97 herds, for the period between July 2002 and September 2007. The average number of daughters per sire was 23.28 and about 6% of the sires had more than 100 daughters. The total number of sires was 1112. A summary of descriptive statistics of phenotypic values for 305-day milk yield, lactation curve parameters, AFC, CI and measures of SCC is shown in Table 1.

Statistical methods
Test-day records of milk yield were used to compute the first 100-day milk yield, second 100-day milk yield, third 100-day milk yield and 305-day milk yield using Wood’s gamma function (Wood, 1967). MATLAB 7.7.1 software (MathWorks, 2008) was used for fitting the Wood’s gamma function and obtaining the corresponding parameters. Wood’s gamma function can be described as follows:

\[ y_t = a e^{bt} \]

Where:

- \( y_t \): milk yield on day \( t \).
- \( a \): a scaling factor to represent yield at the beginning of lactation.
- \( b \) and \( c \): factors associated with the inclining and declining slopes of the lactation curve.

The typical lactation curves have positive \( b \) and \( c \), and curves with negative \( b \) or \( c \) are considered to correspond to atypical lactations (Tekerli et al. 2000). Atypical lactation curves in our dataset constituted 20.6% of the records and were excluded from further analysis. The DIM at peak yield (\( Y_{\text{max}} \)) was defined as \( b / c \) and \( Y_{\text{max}} \) was calculated as:

\[ a(b/c)e^{-b} \]

A disadvantage for Wood’s gamma function is that even of atypical lactations are excluded, after calculation of its parameters (\( a, b \) and \( c \)) when computing DIM at peak yield (i.e., \( b/c \) for individuals, it produces abnormal DIM at peak yield for some animals (less than 1 day or more than 1000 days) that are not justifiable. In our study, DIM at peak yield shorter than 20 days \( (n=479) \) and longer than 180 days \( (n=1076) \) were excluded, leaving 18,989 records for DIM at peak yield. Persistency was evaluated using the following expression derived from Wood’s gamma function:

\[ s = -(b+1)\ln(c) \]
The lactation length (LL) was calculated by subtracting the calving date from the date of the first day of the subsequent dry period.

The WOMBAT1.0 software (Meyer, 2007) was used to estimate the variance and covariance components. The following mixed linear model was used for the analysis of all traits except AFC:

\[ Y_{ijklmn} = \mu + R_i + HYS_j + b_1(AFC)_k + b_2(BL)_l + a_m + e_{ijklmn} \]

Where:

- \( Y_{ijklmn} \): \( i,j,k,l,m \)th observation of traits.
- \( \mu \): population average.
- \( R_i \): fixed effect of region (\( i = 1,\ldots, 6 \)).
- \( HYS_j \): fixed effect of herd-year-season of calving (\( j = 1,\ldots, 1324 \)).
- \( AFC_k \): covariate effect of age at first calving in months.
- \( BL_l \): blood percentage from the Holstein breed.
- \( b_1 \) and \( b_2 \): linear regression coefficient of traits on age at first calving and percent of the genetic contribution from the Holstein breed, respectively.
- \( a_m \): random genetic effect of the animal.
- \( e_{ijklmn} \): random residual error.

The following mixed linear model was used for the analysis of AFC:

\[ Y_{ijklm} = \mu + R_i + HYS_j + b(BL)_k + a_l + e_{ijklm} \]

Where: \( Y_{ijklm} \) is the AFC.

### RESULTS AND DISCUSSION

#### Descriptive statistics

The traits’ descriptive statistics are summarized in Table 1. As expected, milk yield in second 100-day period was higher than first and third 100-day periods. In the present study, the overall mean of the initial lactation value estimates was lower (\( a = 15.084 \pm 8.884 \) or \( \ln(a) = 2.362 \pm 1.219 \)) than those reported by Rekik and Gara (2004) for Holstein–Frisian cows (\( a = 16.57 \)) in Tunisia or by Tekerli et al. (2000) for Holstein cows (\( \ln(a) = 2.71 \)) in Turkey; but it was higher than reports of Gradiz et al. (2009) for Holstein × Brahman, Holstein × Brown Swiss and Brown Swiss × Brahman crossbred cows (\( a = 4.67 \pm 3.35 \)) in Honduras. The differences in “a” values may be attributable to differences in the genetic groups or in herd management (Osorio-Arce and Segura-Correa, 2005).

The mean for \( b \) and \( c \) (0.318 and 0.00327 respectively) were within the range of previous reports (Ferris et al. 1985; Tekerli et al. 2000; Rekik and Gara, 2004; Gradiz et al. 2009).

The predicted peak milk yield (\( Y_{\text{max}} \)) and the DIM at peak yield (\( b/c \)) were 34.47 ± 5.36 kg and 91.61 days, respectively, with an estimated 305-day milk yield of 9065.2 kg. The DIM at peak yield and 305-day milk yield estimated in the present study was higher than earlier available reports for Holstein cows (Tekerli et al. 2000; Atashi et al. 2006; Atashi et al. 2007).
The differences in those parameters are likely the result of a combination of genetic, management and nutritional effects among these studies. The largest coefficient of variation (CV) among the lactation curve traits was for s and the smallest for b. The mean age at first calving in this population (25.9 months) was greater than the estimated mean in Ireland (25 months; Berry and Cromie, 2009) and smaller than the estimated mean in the US (26.9 months; Hare et al. 2006) and in the Isfahan Province of Iran (26.84 months; Nilforooshan and Edriss, 2004).

Variance components and genetic correlations
Estimates of variance components and heritabilities using single-trait analyses are presented in Table 2. Heritability for 305-day milk yield was 0.29. The h² for 305-day milk yield was within the range of estimates reported in previous research (Moradi Shahrbabak, 2001; Haile-Mariam et al. 2003; Atashi et al. 2006; Farhangfar and Naemipour, 2006). Among the 100-day milk yield periods, the second 100-day milk yield had the highest h² and the smallest residual variance, thus suggesting that the smallest fraction of the phenotypic variance for milk yield due to the environmental effects occurred in mid-lactation. Our estimates of h² for parameters of the Wood’s function were lower than the reported by Rekaya et al. (2000) who stated that the model used in their study reduced residual dispersion, as a consequence of a better fit. The also concluded that the point estimates of heritabilities for the parameters of the lactation curve are suggestive of important genetic differences existing in the shape of the lactation curve.

The h² estimates for Y max (0.259), s (0.051) and b / c (0.099) were similar to those reported by other authors (Ferris et al. 1985; Rekaya et al. 2000). Estimates of h² for AVG SCC and Ln SCC were 0.03 and 0.064, respectively; they were slightly lower that estimates for Australian (0.14) and Norwegian (0.11 to 0.13) dairy cattle (Haile-Mariam et al. 2003; Ødegard et al. 2003), which could be due to differences in the recording accuracy.

The estimated h² for LL, AFC and CI were 0.049, 0.133 and 0.044, respectively, indicating that AFC has a relatively low heritability alike other reproductive traits. Thus, under the current conditions, changes in environmental factors (such as management, nutrition or health care) would likely have a higher impact than the selection for these traits. Heritability of AFC in the present study is within the range (0.086 to 0.15) for those estimated for Angus-Blanco Orejinegro-Zebu straightbred and crossbred cattle in the Colombia (Vergara et al. 2009) and Holstein cattle in Iran (Nilforooshan and Edriss, 2004; Farhangfar and Naemipour, 2006). Heritability of CI is similar to that in the report by Haile-Mariam et al. (2003), who also reported an heritability of 0.03 for LL in the Holstein-Friesian cattle in Australia.

Estimates of genetic and environmental correlations among traits are shown in Table 2. Besides presenting the highest h² amongst the different milk yield periods, the second 100-day period showed the highest genetic correlation with the 305-day milk yield (0.996), thus agreeing with Moradi Shahrbabak result (2001). The genetic correlations between initial yield (a) with increasing (b) (-0.8) and decreasing (c) (-0.43) slopes were similar to estimates from Tekerli et al. (2000) (-0.902 and -0.529 for the correlations between initial yield with increasing and decreasing slopes, respectively). The negative correlation between the parameters a and b implies that a higher initial yield is associated with a slower rate of increase until peak yield. Tekerli et al. (2000) suggested (based on amoderate to large positive correlation estimates of the lactation yield with peak yield and persistency) that one of these traits should be used as a criterion to improve all the three traits. Similarly, considering the large negative correlation among initial yield with increasing and decreasing slopes, Moradi Shahrbabak (2001) recommended to select based on the initial yield to decrease the increasing slope and the decreasing slope of the lactation curve to produce steadier lactation and reach peak yield later. Although Y max had a favorable high genetic correlation with 305-day milk yield (0.97), it also presented an unfavorable genetic correlation with CI (0.71) suggesting that selection based on Y max could decrease reproductivity performance by increasing CI. The b / c presented a relatively high genetic correlation with 305-day milk yield (0.52) and the lowest genetic correlation with CI (0.32), as well as a negative genetic correlation with AVG SCC and Ln SCC (-0.23 and -0.19, respectively). Thus, cows with Y max later in lactation had a lower mean somatic cell count and they probably were more resistant to subclinical mastitis. The positive genetic and environmental correlations between b and c (0.5 and 0.876, respectively) indicated that cows that peaked more rapidly also had a quicker decline after peak. Similar results have been reported in previous research (Schneeberger, 1981; Shanks et al. 1981; Ferris et al. 1985; Batra et al. 1987; Tekerli et al. 2000). Genetic correlation between b / c and s (0.97) suggested that cows that reached their peak yield later during their lactation had higher persistency. The genetic correlations between c with b / c and s (-0.48 and -0.26, respectively) indicated that selecting for Y max later in lactation would improve persistency by lowering the rate of decrease after peak yield. The genetic correlation between 305-day milk yield and s (0.44), suggested that cows with higher EBV for persistency would be expected to have higher EBV for 305-day milk yield.
<table>
<thead>
<tr>
<th>Trait</th>
<th>6-105</th>
<th>106-205</th>
<th>206-305</th>
<th>6-305</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>b / c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk (6-105) (kg)</td>
<td>0.16±0.02</td>
<td>0.89±0.02</td>
<td>0.78±0.04</td>
<td>0.91±0.02</td>
<td>0.70±0.08</td>
<td>-0.18±0.16</td>
<td>-0.34±0.11</td>
<td>0.18±0.10</td>
</tr>
<tr>
<td>Milk (106-205) (kg)</td>
<td>0.66±0.01</td>
<td>0.29±0.02</td>
<td>0.97±0.01</td>
<td>0.996±0.00</td>
<td>0.37±0.11</td>
<td>0.04±0.15</td>
<td>-0.48±0.15</td>
<td>0.57±0.07</td>
</tr>
<tr>
<td>Milk (206-305) (kg)</td>
<td>0.42±0.01</td>
<td>0.81±0.01</td>
<td>0.27±0.02</td>
<td>0.96±0.01</td>
<td>0.29±0.11</td>
<td>0.06±0.16</td>
<td>-0.62±0.09</td>
<td>0.71±0.06</td>
</tr>
<tr>
<td>Milk (6-305) (kg)</td>
<td>0.81±0.01</td>
<td>0.94±0.00</td>
<td>0.85±0.00</td>
<td>0.29±0.02</td>
<td>0.45±0.10</td>
<td>-0.02±0.15</td>
<td>-0.52±0.09</td>
<td>0.52±0.08</td>
</tr>
<tr>
<td>a</td>
<td>0.60±0.01</td>
<td>0.11±0.01</td>
<td>0.29±0.01</td>
<td>0.40±0.01</td>
<td>0.04±0.01</td>
<td>-0.80±0.10</td>
<td>-0.43±0.14</td>
<td>-0.30±0.13</td>
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<tr>
<td>b</td>
<td>-0.56±0.01</td>
<td>-0.01±0.01</td>
<td>-0.25±0.01</td>
<td>-0.34±0.01</td>
<td>-0.75±0.00</td>
<td>0.02±0.01</td>
<td>0.50±0.16</td>
<td>0.45±0.17</td>
</tr>
<tr>
<td>c</td>
<td>-0.33±0.01</td>
<td>-0.09±0.01</td>
<td>-0.53±0.01</td>
<td>-0.38±0.01</td>
<td>-0.68±0.01</td>
<td>0.88±0.00</td>
<td>0.04±0.01</td>
<td>-0.48±0.15</td>
</tr>
<tr>
<td>b / c (day)</td>
<td>-0.50±0.01</td>
<td>0.16±0.02</td>
<td>0.30±0.01</td>
<td>-0.03±0.02</td>
<td>-0.61±0.01</td>
<td>0.47±0.01</td>
<td>0.15±0.01</td>
<td>0.10±0.02</td>
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<tr>
<td>Y max (kg)</td>
<td>0.77±0.01</td>
<td>0.87±0.00</td>
<td>0.52±0.01</td>
<td>0.83±0.00</td>
<td>0.18±0.01</td>
<td>-0.02±0.01</td>
<td>0.08±0.01</td>
<td>-0.13±0.02</td>
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<tr>
<td>CI (month)</td>
<td>-0.07±0.01</td>
<td>-0.09±0.01</td>
<td>0.11±0.01</td>
<td>-0.09±0.02</td>
<td>-0.54±0.01</td>
<td>0.78±0.00</td>
<td>0.46±0.01</td>
<td>0.70±0.01</td>
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<tr>
<td>SCC (100-305) (kg)</td>
<td>0.50±0.01</td>
<td>-0.01±0.01</td>
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<td>0.37±0.11</td>
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<td>0.29±0.02</td>
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</table>
These findings are supported by previous research (Ferris et al. 1985; Rekaya et al. 2000). Genetic correlations among measures of somatic cell count and other traits were low and with high standard errors. The exceptions were the positive genetic correlation between AVG SCC and Ln SCC with c (0.39 and 0.33, respectively), which suggested that a higher rate of decrease in milk yield after peak yield would increase somatic cell count. Similarly, the absolute values for the genetic correlations between measures of somatic cell count and third 100-day milk yield were the highest among the milk yield periods analyzed. Strong genetic and environmental correlations were detected between CI and LL were (0.976 and 0.93, respectively; Table2) as well as the genetic correlation between LL and the average.
305-d milk yield (0.78). However, weak environmental correlations existed between 305-d and LL or CI (0.05 and 0.02, respectively). The AFC had moderate and negative genetic correlations with all traits (except for the small genetic correlation with high standard errors with a, b and the number of somatic cell count). This suggested that selection for smaller AFC would improve the lactation curve traits and also adversely lengthen CI. Conversely, Vergara et al. (2009) reported a moderate and positive genetic correlation between AFC and CI (0.33) whereas Gressler et al. (2005) estimated a negative value (-0.92) for Nellore cattle in Brazil, and Farhangfar and Naemipour (2006) obtained a zero correlation between AFC and CI (-0.01). Vergara et al. (2009) suggested that the differences in sign and magnitude of the estimates for the genetic correlation between AFC and CI may be due to differences in breed composition, environmental conditions, methods of estimation, and accuracies of variance and covariance components. Still, these authors state that it may also be an indication that sets of genes affecting these traits differ across populations, and also may have different additive genetic values.

Environmental and phenotypic correlations were lower in magnitude (data not shown). The environmental correlations between AFC and 100-day milk yield periods suggested that cows with higher AFC had higher milk yield especially early in lactation, which might be due to increased body condition score and reduced negative energy balance in comparison to cows with lower AFC (Loker et al. 2012). Tamminga (2000) explained that early in lactation, cows are usually in negative energy balance, which means they need to mobilize body adipose reserves to meet the increased nutrient demand for milk yield.

To depict the trend of first-lactation 305-day milk yield and calving interval over AFC, AFC were categorized into 20 age classes (ranging from 20 months to 39 months). By increasing age at first calving from 20 to 23 months, 305-day milk yield increased, but delaying the onset of first lactations beyond 23 months of age did not significantly change the 305-day milk yield. Similar results were reported by Nilforooshan and Edriss (2004) and Froidmont et al. (2013). They obtained a non-linear association between age at first calving and first lactation milk yield with maximum milk yield achieved in heifers calving at 24 months of age. An Italian survey on national Holstein cows revealed that milk yield increases with the increase of age at first calving from 20 to 36 months, but the authors remarked that a reduction of age at first calving to 24 and 23 months of age seemed to be more profitable than reducing it to 22 months of age (Pirlo et al. 2000). Berry and Cromie (2009), investigating seasonal calving production in Ireland, reported that 305-day milk yield for the first lactation decreased almost linearly by 55.5 kg for each month of younger age at first calving. In direct contrast, Bewley et al. (2001) reported that US herds that calved heifers at an older age produced less milk. Calculating the regression of AFC on CI it was showed that for each month increase in age at first calving the calving interval in creased by 1.26 days. However, the phenotypic correlation between AFC and CI was near zero (-0.04; data not shown). Pedron et al. (1989) investigating factors affecting calving interval concluded that CI was not affected by AFC. Additionally, Berry and Cromie (2009) refer to a non significant linear association between CI and AFC, but they stated that heifers calving at 22 months of age had longer CI than heifers calving at 24, 25, 29 and 34 months of age. This indicated that traits like CI that have low heritability do not follow a clear pattern and are highly influenced by environment and management factors.

**CONCLUSION**

The genetic correlation between initial yield (a) with increasing slope (b) and decreasing slope (c) was favorable, but unfavorable with persistency and CI. Genetic correlation between b / c and s suggested that cows that reached peak yield later during lactation would have higher persistency. Among persistency similar traits, b / c had relatively high genetic correlation with 305-day milk yield and had the lowest genetic correlation with CI. Also, b / c had negative genetic correlation with udder health traits (measures of somatic cell count); therefore it can be recommended as a criterion to improve milk yield and udder health. Although the phenotypic correlation between AFC and CI was near zero, each month of increase in age at first calving increased calving interval by 1.26 days.

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**REFERENCES**


