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

Research Article

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ABSTRACT

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 (Y_{max}), 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 h^2 (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.

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 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 (Ødegard *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:

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

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_{max}) was defined as b / c and Y_{max} was calculated as: $a(b/c)^b e^{-b}$.

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:

$$s = -(b+1)\ln(c)$$

Table 1 Descriptive statistics for the phenotypic values[a]

Trait	Mean	SD	CV (%)	Min	Max
Milk (6-105) (kg)	3091.5	592.5	19.16	225	5864
Milk (106-205) (kg)	3215	528.8	16.45	1168.7	5913.8
Milk (206-305) (kg)	2758.9	582.6	21.12	400	5053.7
Milk (6-305) (kg)	9065.2	1521.5	16.78	3106.8	15243.3
a	15.084	8.884	58.9	0.000004	56.7
b	0.318	0.297	93.4	0.00036	3.77
c	0.00327	0.00223	68.19	0.0000001	0.0222
b / c (day)	91.61	32.97	35.99	20	179.98
Y_{max} (kg)	34.47	5.36	15.55	12.63	65.93
s	7.709	1.039	13.48	5.446	18.492
LL (day)	346.46	68.89	19.88	181	599
AFC (month)	25.92	2.43	9.38	20.03	39.97
CI (month)	13.287	2.223	16.71	9.67	20
AVG SCC$^{(*1000/mL)}$	245.1	343.8	140.27	9.67	6962
Ln SCC	4.869	1.109	22.78	2.269	8.848

[a] Milk (106-205): estimated first 100-day milk yield; Milk (106-205): estimated second 100-day milk yield; Milk (206-305): estimated third 100-day milk yield and Milk (6-305): estimated 305-day milk yield.

a: a scaling factor to represent yield at the beginning of lactation; b and c are factors associated with the inclining and declining slopes of the lactation curve; b/c: DIM at peak yield; Y_{max}: peak yield calculated as $a(b/c)^b e^{-b}$: persistency calculated as s= -(b+1)ln(c); LL: lactation length; AFC: age at firs calving; CI: calving interval; AVG SCC: mean somatic cell count and Ln SCC: mean $\log_e$ somatic cell count, Ln SCC= Ln $[{}^1/_n \sum_1^n [(SCC/1000\ ({}^{cells}/_{mL}))]]$.

SD: standard deviation and CV: coefficient of variation.

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}: $ijklmn^{th}$ observation of traits.

μ: population average.

R_i: fixed effect of region (i=1,…, 6).

HYS_j: fixed effect of herd-year-season of calving (j=1,…, 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:

$$Y_{ijklm} = \mu + R_i + HYS_j + bBL_k + a_l + e_{tijklm}$$

Where the definition of symbols are the same as the previous model.

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±8.884 or Ln(a)=2.362±1.219) than those reported by Rekik and Gara (2004) for Holstein–Friesian 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±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_{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.* 2007; Gradiz *et al.*2009). Similarly, persistency of lactation found in this study (7.709) was higher than those of other 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 h^2 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 Naeemipour, 2006). Among the 100-day milk yield periods, the second 100-day milk yield had the highest h^2 and the smallest residual variance, thus suggesting that the smallest fraction the phenotypic variance for milk yield due to the environmental effects occurred in mid-lactation. Our estimates of $h^2$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 h^2 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 h^2 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 h^2forLL, 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 Naeemipour, 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 h^2 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 Shahrbabakresult (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 reproductive 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 beenreported 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 2 Heritabilities (on diagonal), genetic (above) and environmental correlations (below) for the first, second and third 100-day milk yield, 305-day milk yield, lactation curve parameters, LL, AFC, CI, AVG SCC and Ln SCC in the first parity[a]

Trait	6-105	106-205	206-305	6-305	a	b	c	b / c
Milk (6-105) (kg)	**0.16±0.02**	0.89±0.02	0.78±0.04	0.91±0.02	0.70±0.08	-0.18±0.16	-0.34±0.11	0.18±0.10
Milk (106-205) (kg)	0.66±0.01	**0.29±0.02**	0.97±0.01	0.996±0.00	0.37±0.11	0.04±0.15	-0.48±0.15	0.57±0.07
Milk (206-305) (kg)	0.42±0.01	0.81±0.01	**0.27±0.02**	0.96±0.01	0.29±0.11	0.06±0.16	-0.62±0.09	0.71±0.06
Milk (6-305) (kg)	0.81±0.01	0.94±0.00	0.85±0.00	**0.29±0.02**	0.45±0.10	-0.02±0.15	-0.52±0.09	0.52±0.08
a	0.60±0.01	0.11±0.01	0.29±0.01	0.40±0.01	**0.04±0.01**	-0.80±0.10	-0.43±0.14	-0.30±0.13
b	-0.56±0.01	-0.01±0.01	-0.25±0.01	-0.34±0.01	-0.75±0.00	**0.02±0.01**	0.50±0.16	0.45±0.17
c	-0.33±0.01	-0.09±0.01	-0.53±0.01	-0.38±0.01	-0.68±0.01	0.88±0.00	**0.04±0.01**	-0.48±0.15
b / c (day)	-0.50±0.01	0.16±0.02	0.30±0.01	-0.03±0.02	-0.61±0.01	0.47±0.01	0.15±0.01	**0.10±0.02**
Y_{max} (kg)	0.77±0.01	0.87±0.00	0.52±0.01	0.83±0.00	0.18±0.01	-0.02±0.01	0.08±0.01	-0.13±0.02
s	-0.63±0.01	0.04±0.01	0.11±0.01	-0.09±0.02	-0.54±0.01	0.78±0.00	0.46±0.01	0.70±0.01
LL (day)	-0.04±0.01	0.02±0.01	0.14±0.01	0.05±0.01	0.06±0.01	-0.07±0.01	-0.16±0.01	0.10±0.011
AFC (month)	0.19±0.02	0.14±0.02	-0.01±0.02	0.12±0.02	0.06±0.01	0.04±0.01	0.12±0.01	-0.15±0.02
CI (month)	-0.07±0.01	-0.02±0.01	0.1±0.01	0.02±0.01	0.05±0.01	-0.06±0.01	-0.14±0.01	0.09±0.01
AVG SCC	-0.09±0.01	-0.16±0.01	-0.17±0.01	-0.15±0.01	-0.03±0.01	0.03±0.01	0.07±0.01	-0.04±0.01
Ln SCC	-0.08±0.01	-0.15±0.02	-0.16±0.01	-0.14±0.02	-0.03±0.01	0.03±0.01	0.07±0.01	-0.04±0.01
Additive variance	40749.8	58446.3	69223.1	323561	2.48566	0.001151	0.000000154743	93.2836
Residual variance	218906	143284	190454	793678	67.2042	0.067644	0.00000403589	848.118

Trait	Y_{max}	s	LL	AFC	CI	AVG SCC	Ln SCC
Milk (6-105) (kg)	0.96±0.01	0.07±0.12	0.66±0.09	-0.32±0.09	0.66±0.10	0.12±0.13	0.03±0.11
Milk (106-205) (kg)	0.96±0.01	0.49±0.09	0.78±0.07	-0.43±0.07	0.72±0.08	0.00±0.12	-0.08±0.09
Milk (206-305) (kg)	0.88±0.02	0.60±0.09	0.79±0.07	-0.48±0.07	0.67±0.09	-0.11±0.12	-0.16±0.09
Milk (6-305) (kg)	0.97±0.01	0.44±0.09	0.78±0.07	-0.44±0.07	0.71±0.09	-0.02±0.12	-0.08±0.09
a	0.50±0.11	-0.52±0.12	0.34±0.16	-0.14±0.14	0.35±0.16	0.04±0.19	-0.03±0.16
b	0.01±0.16	0.71±0.11	0.20±0.22	0.12±0.19	0.25±0.23	0.09±0.25	0.12±0.21
c	-0.33±0.10	-0.26±0.19	-0.39±0.15	0.46±0.12	-0.20±0.17	0.39±0.19	0.33±0.15
b / c (day)	0.37±0.08	0.97±0.03	0.48±0.12	-0.31±0.10	0.32±0.14	-0.23±0.15	-0.19±0.12
Y_{max} (kg)	**0.26±0.02**	0.35±0.10	0.73±0.08	-0.33±0.08	0.71±0.09	0.07±0.12	-0.02±0.09
s	-0.12±0.01	**0.05±0.01**	0.54±0.13	-0.31±0.12	0.43±0.14	-0.16±0.17	-0.14±0.14
LL (day)	-0.05±0.01	0.05±0.01	**0.05±0.01**	-0.35±0.11	0.97±0.01	-0.03±0.17	-0.06±0.14
AFC (month)	0.20±0.02	-0.04±0.01	-0.03±0.01	**0.13±0.02**	-0.27±0.12	0.02±0.15	-0.10±0.12
CI (month)	-0.08±0.01	0.05±0.01	0.93±0.00	-0.02±0.01	**0.04±0.01**	0.00±0.18	-0.05±0.14
AVG SCC	-0.10±0.01	-0.01±0.01	0.02±0.01	0.02±0.01	0.03±0.01	**0.03±0.01**	0.99±0.03
Ln SCC	-0.10±0.01	-0.01±0.01	0.04±0.01	0.03±0.01	0.05±0.01	0.77±0.00	**0.06±0.01**
Additive variance	5.426	0.0425813	197.477	0.604556	0.19723	3086.94	0.0567233
Residual variance	15.533	0.792954	3828.63	3.95437	4.32161	98284.2	0.832262

[a] Milk (106-205): estimated first 100-day milk yield; Milk (106-205): estimated second 100-day milk yield; Milk (206-305): estimated third 100-day milk yield and Milk (6-305): estimated 305-day milk yield.

a: a scaling factor to represent yield at the beginning of lactation; b and c are factors associated with the inclining and declining slopes of the lactation curve; b/c: DIM at peak yield; Y_{max}: peak yield calculated as $a(b/c)^{b}e^{-b}$: persistency calculated as s= -(b+1)ln(c); LL: lactation length; AFC: age at firs calving; CI: calving interval; AVG SCC: mean somatic cell count and Ln SCC: mean $\log_e$ somatic cell count, Ln SCC= Ln [$^{1}/_{n} \sum_{1}^{n}$ [(SCC/1000 ($^{cells}/_{mL}$))]].

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 Naeemipour (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 the305-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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