 Genetic and environmental parameters and trends for milk production of Holstein cattle in Turkey

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Abstract

Data from 4143 Holstein cattle from three herds in Turkey were used to study the influences of genetic and environmental factors on milk production traits as well as genetic and environmental trends over 20 years from 1987 to 2006. First lactation mean values for 305-day milk yield, actual lactation milk yield, and lactation length were 6222±35.8 kg, 6651±42.6 kg, and 327±13 days. Second and third 305-day lactation yields were proportionately 8% and 11% greater, respectively. The effects of herd and calving year were the largest sources of variation for all traits. Heritabilities of actual lactation milk yield, 305-day milk yield, and lactation length for first lactation records were 0.24±0.007, 0.23±0.007, and 0.08±0.035. Estimates of variances and genetic parameters were consistent with estimates reported throughout the literature. Trends were inconsistent with some phenotypic increase in yields during the period between 2001 and 2005. This improvement was associated with increased environment parameter estimates during that period. No consistent genetic improvement was observed.

Introduction

With growing world populations, increases in the quantity and quality of animal products are needed. This is particularly true for Turkey, which has a relatively low number of dairy cattle per capita and is a culture that relishes dairy products in the diet (Ozhan et al., 2009; FAO, 2010; TUIK, 2010). Since the early years of the republic in Turkey, producers worked to improve the genetic potential of dairy cattle. Little is known about how these efforts have affected the productivity of Turkish cattle. Increased per cow productivity and efficiency is needed to meet future demands in Turkey. Knowledge of genetic and environmental influences and relationships for production traits in Turkey is essential for proper planning and evaluation of dairy improvement programs. Proper genetic selection techniques as well as the part the environment plays must be understood and included in these programs.

Milk yield traditionally has been the single most important trait considered in dairy selection programs (Grosshans et al., 1997; Demateewa and Berger, 1998; Haile Mariam et al., 2003). It is generally considered the major trait of economic importance in dairy breeds and research done in developed countries has indicated that selection for production will increase profitability (Simm, 2000; Haile Mariam et al., 2003). The ultimate aim of most dairy producers is to maximize profitability. While there is no reason to suspect that this will be different for Turkey, research is needed to determine if the genetic and environmental forces at work are similar.

Accurate production records for animals producing in Turkey are required to answer these questions. Once such records are in hand, genotypic and phenotypic parameters can be estimated. Using appropriate statistical methods, sources of variation can be identified and quantified and important parameters such as, variances, correlations, and covariances estimated (Tosh and Kemp, 1994; Saatci et al., 2000).

Development of animal breeding plans requires knowledge of heritabilities, repeatabilities, and phenotypic and genetic correlations of the traits included. These parameters are needed to evaluate the breeding plan itself as well as to predict breeding values of the animals. Breeding plans for dairy cattle have to account for repetitive performance of cattle, i.e. the potential for more than one lactation per cow. Lifetime production is an important trait economically when defining breeding objectives. This importance raises the question of whether milk production in subsequent lactations is repeatable enough genetically so that first lactation production can contribute useful genetic information about later lactations. Another question is what the best method could be to combine records for evaluation purposes, if information on more than one lactation is available.

Often, performance in later lactations is assumed to be genetically due to genes that influenced performance in first lactation. The majority of procedures for predicting breeding values in dairy cattle either consider only first lactations or imply a genetic correlation of one between all lactations. With data typically available, the validity of this assumption is difficult to test because selection has occurred based on knowledge of part of the data (Swalve and Van Vleck, 1987).

First lactation is the first complete lactation to base a selection decision on. Delayed selection increases generation interval and thereby slows rate of progress. Many authors have presented the argument that milk production in all lactation is determined more or less by the same genes (Meyer 1984; Bagnicka et al., 2004). Selection decisions are often based on first lactations (Da et al., 1992). First parity yields are therefore considered to be an efficient selection criterion.

The objectives of this study were to identify important causes of variation in milk production traits and to estimate genetic and phenotypic parameters. Genetic, environmental, and phenotypic trends were estimated in order to assess the results of breeding programs practiced and environmental changes across the years.

Materials and methods

Data consisted of 5439 305-day milk yield (2334 first, 1834 second, and 1271 third), 5448 actual lactation milk yield (2339 first, 1836 second, and 1273 third), and 5439 lactation lengths (2334 first, 1834 second, and 1271...
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Model 2 (for the first lactation)

\[
Y_{ijkl} = \mu + a_i + b_j + c_k + d_l + b_1(Y_{ijkl} - \mu_1) + b_2(X_{ijkl} + \mu_2) + e_{ijkl}
\]

where all components of the model are as defined for Model 1. Since the linear and quadratic regressions on lactation length were not significant, they were subsequently left out of Models 1 and 2.

Genetic parameters, variance components, breeding values and genetic correlations were estimated using the DXMUX sub-program developed by Boldman et al. 1995 to perform single and multi-trait analysis in MTDFREML. Single trait animal models were used to estimate genetic parameters, variance components (for all records) and breeding values (only first lactation 305-day milk yield and lactation length). Multiple traits animal models were used to estimate genetic correlations among the traits (for first three lactation records). The convergence criteria for all analyses was 1x10^{-9}.

For first lactation records a single trait animal model was used with animal as the only random effect (Model 4 below). This model included fixed effects (year, season, and herd). Linear and quadratic effects of the covariates calving age (for actual milk yield and 305 day milk yield) and lactation length (only actual milk yield) were included.

For analysis of the first three lactations, multiple trait animal models included the permanent environmental effect of the animal itself, fitted as a random effect, and considered uncorrelated with all other effects in the model (Model 3). In Model 3, year, season, parity and herd were fixed effects, as were linear and quadratic effects of the covariates at age first calving (for all traits) and lactation length (only for actual milk yield).

Model 3 (used for three lactation data):

\[
Y_{ijklmn} = F_{ijkl} + a_m + e_{ijklmn}
\]

where:
- \(Y_{ijklmn}\) is the observed milk yield;
- \(F_{ijkl}\) is fixed effects (year, season, parity and herd);
- \(a_m\) is the direct additive genetic effect of the \(m^{th}\) animal;
- \(P_c\) is permanent environmental effect of the \(n^{th}\) animal;
- \(e_{ijklmn}\) is the random residual error (\(\sigma^2_e\)).

Model 4 (for first lactation records)

\[
Y_{ijklm} = F_{ijkl} + a_m + e_{ijklm}
\]

where:
- \(F_{ijkl}\) is fixed effects (year, season, and parity);
- \(a_m\) is the direct additive genetic effect of the \(m^{th}\) animal;
- \(e_{ijklm}\) is the random residual error (\(\sigma^2_e\)).

Repeatabilities (\(r\)) were calculated using the following equation (Meyer et al., 1990):

\[
r = \frac{\sigma^2_A + \sigma^2_P}{\sigma^2_A + \sigma^2_P + \sigma^2_e}
\]

where:
- \(\sigma^2_A\) is the additive genetic variance;
- \(\sigma^2_P\) is the permanent environmental variance;
- \(\sigma^2_e\) is the residual variance;
- \(A\) is the additive genetic relationship matrix; \(I\) and \(I\) are identity matrices of order equal to the number of cattle and the number of records, respectively.

Model 3 is represented in matrix form as:

\[
y = Xb + Za + Wp + e
\]

where \(y\) is a vector of observation, \(b\) is a vector of fixed effects with incidence matrix \(X\), \(a\) is a vector of random animal effects with incidence matrix \(Z\), \(p\) is a vector of random permanent environmental effects with incidence matrix \(W\), and \(e\) is a vector of random residual effects.

The distributional properties were assumed to be as follows:

\[
E[y] = Xb, \quad \text{and} \quad V[y] = \begin{bmatrix} \sigma^2_A & 0 \\ 0 & \sigma^2_p \\ 0 & 0 & \sigma^2_e \end{bmatrix}
\]
Genetic and environmental trends were estimated by averaging the estimated breeding values (EBVs) by birth year of cattle and regressing the averages against birth year. Phenotypic trends were estimated by regressing the average of unadjusted records on year of calving. Graphs that show genetic, phenotypic, and environmental trends were produced using Excel®. The regression procedure in Minitab Version 12.1 was used to determine genetic, phenotypic, and environmental trends.

### Results and discussion

Frequencies of data are in Table 1 and descriptive statistics of the data are in Table 2. Figures 1 and 2 are the distributions of 305-day milk yield and lactation length for first lactations. Average first lactation 305-day milk yield was 6222±35.8 kg, while second and third lactation yields were 8% and 11% greater, respectively.

Means in Table 2 show that 305-day milk yield increased by 666 kg from 1st to 3rd lactation while the corresponding increase in actual lactation milk yield was 644 kg (P<0.05). Coefficients of variation in Table 2 show the relative variation in 305-day milk yield, actual milk yield, and lactation length across 1st, 2nd, and 3rd lactations. Differences in coefficients of variation were small to moderate, ranging from 27.66 to 32.00 across lactations for milk yield traits and 18.62 to 19.54 for lactation length. Effect of parity on milk yield was significant (P<0.05). Similarly, significant effect of parity on milk yield was reported by some authors working on different herds of Holstein cattle (Topaloglu and Günes, 2005; Sehar and Ozbeyaz, 2005; Erdem et al., 2007; Kocak et al., 2007).

The effect of herd on milk yield was significant (P<0.05). Similar results were reported for Holstein calves raised in different herds (Kim et al., 2001; Topaloglu and Günes, 2005; Ozkök, 2006). Year of calving had a significant effect on milk yield (P<0.05). The present results are in close agreement with those reported by Bilgic and Alic, (2005), Topaloglu and Günes, (2005), Erdem et al., (2007). Changes in milk yield traits from one year to another can be attributed to changes in herd size, age of animals, improved management

### Table 1. Frequencies of first lactation 305-day milk yield records.

| Item | 305-day milk yield |
|------|-------------------|
| Number of animals in A-1 | 4143 |
| Number of records for 305-day milk yield | 5439 |
| Number of records for actual milk yield | 5448 |
| Number of records for lactation length | 5439 |
| Number of dams | 1735 |
| Number of sires | 350 |
| Seasons | 4 |

### Table 2. Descriptive statistics of milk production data.

| Trait | N | Mean | SE | CV | Min | Max |
|-------|---|------|----|----|-----|-----|
| 305-day milk yield, kg | 2334 | 6222 | 35.8 | 27.80 | 2000 | 13,403 |
| Lactation 1 | 1834 | 6710 | 45.6 | 29.09 | 2000 | 14,484 |
| Lactation 2 | 1271 | 6888 | 53.4 | 27.66 | 2182 | 17,208 |
| Lactation 3 | 2339 | 6651 | 42.6 | 30.99 | 2000 | 15,521 |
| Actual lactation milk yield, kg | 1836 | 7124 | 53.2 | 32.00 | 2000 | 17,040 |
| Lactation 1 | 1273 | 7295 | 62.2 | 30.44 | 2182 | 17,208 |
| Lactation 2 | 2334 | 327 | 1.33 | 19.54 | 220 | 550 |
| Lactation 3 | 1834 | 317 | 1.38 | 18.62 | 220 | 550 |
| Lactation length, days | 1271 | 316 | 1.66 | 18.69 | 220 | 550 |

Mean, arithmetic average; CV, coefficient of variation; Min, minimum value; Max, maximum value.
practices introduced from one year to another, and phenotypic trend. The effect of season of calving on milk yield was significant (P<0.05). Previous studies of Topaloglu and Günes (2005), Sehar and Öz beyaz (2005), Erdem et al. (2007), and Koç ak et al. (2007) with different herds of Holstein cattle reported significant effect of season of calving on milk yield.

The majority of lactation records were between 3000 kg and 10,000 kg with the distribution appearing approximately normal (P-value (approx):<0.0100 and R: 0.9911; Figure 1). The majority of lactation lengths fell between 250 days and 350 days with the distribution being skewed to the left (Figure 2).

Genetic parameters
Heritability estimates for actual lactation milk yield, 305-day milk yield, and lactation length are in Table 4. Heritabilities of actual milk yield, 305-day milk yield, and lactation length were 0.35, 0.34, and 0.05. Repeatabilities of the same traits were 0.35, 0.34, and 0.10. As the heritabilities were about the same for the traits, the results indicate that the permanent effect of the cattle was larger for milk yield traits than for lactation length.

Heritability estimates ranged from 0.22 to 0.23 for first lactation milk yield traits, while the estimates were generally higher for second lactation and lower for third lactation. Heritability estimates are in agreement with results from the literature for Holsteins. Van Vleck and Dong (1988) using REML methods with an animal model reported a heritability of 0.36 for milk yield in the first lactation. The heritabilities of 305-day milk yield was determined 0.23±0.000, 0.31±0.000 and 0.27±0.000 for first, second and third lactations milk yields, respectively.

Unalan and Cebeci (2004) reported heritability estimates of 0.297±0.025, 0.369±0.027, and 0.359±0.034, for milk yield in 1st, 2nd, and 3rd lactations. Albuquerque et al. (1994) reported heritability estimates of 0.34, 0.31, and 0.27 for milk yield in 1st, 2nd, and 3rd lactations. Teepeker and Swalve (1988) reported heritabilities of 0.29, 0.23, and 0.25 for milk yield in 1st, 2nd, and 3rd lactations.

The heritability estimates for lactation length were 0.08±0.035, 0.07±0.042, 0.09±0.060 for 1st, 2nd, and 3rd lactations. Heritabilities for first, second and third lactation milk yield were 0.24±0.070, 0.30±0.000, and 0.22±0.000, respectively.

The largest heritability estimates were found for second lactation 305-day milk yield and actual milk yield, while the smallest was for lactation length (Table 4). Variance component estimates for \( \sigma_a^2 \) were largest for second lactation traits, while \( \sigma_c^2 \) estimates were small. Environmental effects due to cattle were not large for the investigated herds. Standard errors were lower than 0.0001 for all lactation traits and therefore shown as 0.000 in Tables 2 and 3.

### Table 3. Estimates of additive (\( \sigma_a^2 \)), residual (\( \sigma_e^2 \)) and phenotypic (\( \sigma_y^2 \)) variances, heritabilities (h²), standard deviations (S), residual error (e²) for milk yield traits by lactation.

| Trait                        | Lactation | \( \sigma_a^2 \) | \( \sigma_e^2 \) | \( \sigma_y^2 \) | h²   | S     | e²   | S     |
|------------------------------|-----------|------------------|------------------|------------------|------|-------|------|-------|
| 305-day milk yield, kg       | 1         | 491,902.95       | 1,659,048.64     | 2,150,981.85     | 0.23 | 0.0070| 0.77 | 0.000 |
|                              | 2         | 954,216.98       | 1,617,134.20     | 3,069,074.31     | 0.31 | 0.0000| 0.53 | 0.000 |
|                              | 3         | 847,441.21       | 1,219,147.92     | 3,153,540.56     | 0.27 | 0.0000| 0.68 | 0.000 |
| Actual lactation milk yield, kg | 1       | 505,623.53       | 1,565,738.75     | 2,071,386.81     | 0.24 | 0.0070| 0.76 | 0.000 |
|                              | 2         | 1,279,569.01     | 1,490,124.48     | 4,306,830.06     | 0.30 | 0.0000| 0.35 | 0.000 |
|                              | 3         | 630,760.41       | 1,342,751.00     | 2,920,417.95     | 0.22 | 0.0000| 0.46 | 0.000 |
| Lactation length, day         | 1         | 302.12            | 3,352.78         | 3,960.27         | 0.08 | 0.0350| 0.85 | 0.270 |
|                              | 2         | 246.40            | 3,410.79         | 3,936.55         | 0.07 | 0.0420| 0.10 | 0.072 |
|                              | 3         | 326.17            | 2,963.85         | 3,478.93         | 0.09 | 0.0600| 0.85 | 0.482 |

### Table 4. Estimates of additive (\( \sigma_a^2 \)), permanent environmental (\( \sigma_{pe}^2 \)), residual (\( \sigma_e^2 \)) and phenotypic (\( \sigma_y^2 \)) variances, heritabilities (h²), repeatabilities (r), standard deviations (S), ratios of permanent environmental variance (c²) due to animal and (co)variances, residual errors (e²) and repeatabilities for the tree lactation traits.

| Trait                        | \( \sigma_a^2 \) | \( \sigma_{pe}^2 \) | \( \sigma_e^2 \) | \( \sigma_y^2 \) | h²   | S     | c²   | S     | e²   | S     | r    |
|------------------------------|------------------|---------------------|------------------|------------------|------|-------|------|-------|------|-------|------|
| 305 day milk yield           | 992,173.20       | 36.50               | 1,844,782.80     | 2,836,992.50     | 0.35 | 0.0070| 0.65 | 0.000 | 0.000 | 0.35|
| Actual lactation yield       | 910,319.89       | 37.29               | 1,755,199.80     | 2,665,556.98     | 0.34 | 0.0000| 0.66 | 0.000 | 0.000 | 0.34|
| Lactation length             | 178.98           | 208.91              | 3,332.21         | 3,715.20         | 0.05 | 0.0180| 0.056| 0.000 | 0.23 | 0.90 |

### Table 5. Genetic (\( r_g \)) and phenotypic (\( r_p \)) correlations of lactation traits with their standard errors (S) from multivariate analysis.

| Lactation number | Trait 1 | Trait 2 | \( r_g \) | S     | \( r_p \) | S     | \( r_g \) | S     | \( r_p \) | S     | \( r_g \) | S     |
|------------------|---------|---------|----------|-------|----------|-------|----------|-------|----------|-------|----------|-------|
| 305 day milk yield| Actual lactation milk yield | 0.95 | 0.000 | 0.97 | 0.000 | 0.97 | 0.000 | 0.97 | 0.000 |
| 305 day milk yield| Lactation length | 0.50 | 0.000 | 0.40 | 0.171 | 0.40 | 0.52 | 0.242 | 0.38 |
| Actual lactation milk yield| Lactation length | 0.45 | 0.000 | 0.57 | 0.65 | 0.56 | 0.91 | 0.000 | 0.56 |
and 3. Parameter estimates agree with those reported using REML procedures (Ulutas et al., 2008).

Heritability and repeatability estimates for lactation length found in this study are supported in the literature (Ojango and Pollott, 2001; Attil and Khattab, 2005). With lactation length considered to be a genetically controlled trait, heritability estimates in this study were low (0.07 to 0.09). Proportions of phenotypic variation in lactation length due to permanent environmental effects of animal $c^2$ were also low. Genetic and phenotypic correlations between first lactation 305-day milk yield and lactation length were 0.50 and 0.40. Genetic and phenotypic correlations between 305-day milk yield and actual lactation milk yield were close to one (Table 5). Correlations between the milk yield traits and lactation length were slightly lower and decreased with lactation number, except for the third lactation.

Tuzemen et al. (1999) reported that genetic and phenotypic correlations between actual milk yield and 305 day milk yield were 0.92 and 0.86, respectively. Dong and Van Vleck (1989) reported that genetic correlation between first and second lactations was 0.82. Unalan and Cebeci (2004) reported that genetic correlation between first and second lactations was 0.73; between first and third was 0.63; between second and third was 0.74; while phenotypic correlations for the same lactations were 0.56, 0.48 and 0.36, respectively. Unalan and Cankaya (2010) reported that the genetic correlation between first and second lactations was 0.68; between first and third was 0.67; between second and third 0.75; phenotypic correlations for the same lactations were 0.54, 0.52 and 0.73, respectively.

All genetic and phenotypic correlations among lactations in this study were also moderate and positive. Positive genetic correlations among lactations showed that the first lactation milk yield of cattle would provide useful information for subsequent lactations.

Genetic, environmental and phenotypic trends

Genetic, environmental, and phenotypic trends for first lactation 305-day milk yield and lactation length are shown in Figures 3, 4, 5, and 6. Over all linear estimates of phenotypic trends were 122 kg/year and 0.475 d/year for 305-day milk yield and lactation length. Phenotypic 305-day milk yields are shown in Figure 3. Although a small overall positive trend was observed, the change in phenotypic values of 305-day milk yield are inconsistent (Figure 3). Similar results for milk production have been reported (Powell and Wiggans, 1990; Ulutas, 2002; Tilki et al., 2009; Ulutas et al., 2010). Phenotypic values for lactation length fluctuated over the years studied with a short consistent increase during the last five years. Similar phenotypic results were reported by Bakir and Kaygisiz (2009) for Turkish Holsteins.

Overall genetic trends for 305-day milk yield and lactation length were -2.46 kg/year and -
Improvements in productive and environmental trends across the 20-year period studied indicated the need for improved environmental conditions. No consistent trends were observed for lactation length (Figures 5 and 6).

Conclusions

Estimates of genetic parameters for Turkish Holsteins were consistent with those reported throughout the literature. Analysis of genetic and environmental trends across the 20-year period studied indicated the need for improved breeding programs. Improvements in production over the most recent five-year period appeared to be environmental and may indicate improved management and husbandry. Selection and mating based upon reliable estimates of breeding value offer great opportunity for improved productivity in Turkish Holsteins.

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