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# GENETIC PARAMETERS FOR DIRECT AND MATERNAL EFFECTS AND AN ESTIMATION OF BREEDING VALUES FOR BIRTH WEIGHT OF HOLSTEIN FRIESIAN CALVES

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## Abstract

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In this study, genetic and phenotypic parameters for birth weight in Holstein calves raised at Tahirova and Polatli State Farms were estimated. Analysis of the results showed that the least squares means of birth weight were 38.71 ± 3.56 and 37.53 ± 2.09 kg for the calves raised at state farms at Tahirova and Polatli, respectively. The effects of birth year, season and sex on birth weight were significant ($P < 0.05$) or highly significant ($P < 0.01$). The effect of calving parity on birth weight was highly significant ($P < 0.01$) for state farm at Tahirova, but insignificant for state farm at Polatli. Direct heritability ($h^2_d$), maternal heritability ($h^2_m$), total heritability ($h^2_T$) and the fraction of variance due to maternal permanent environmental effects ($c^2$) were 0.15, 0.56, 0.12 and 0.0004, respectively for calves raised at state farm at Tahirova. Direct heritability ($h^2_d$), maternal heritability ($h^2_m$), total heritability ($h^2_T$) and the fraction of variance due to maternal permanent environmental effects ($c^2$) were 0.04, 0.002, 0.039 and 0.002, respectively for calves raised at state farm at Polatli. It was concluded that the effects of environmental factors should be eliminated for the implementation of effective selection program to be conducted on birth weight in Holstein calves.

*Key words*: Holstein calf, birth weight, heritability, repeatability

## Introduction

Holstein cattle have been reared commonly for the milk production in Turkey at dairy cattle farms. The main breeding aim of this breed is to obtain milk production; however, male calves are to rear for beef production (Unalan, 2009). In cattle breeding, calf birth weight that is of great importance is used as an early selection criterion. Knowledge on body weight at early ages (until pre-weaning) in farm animals plays a vital role for genetically improving meat production (Kucuk and Eyduran, 2009; Eyduran et al., 2009; Karakus et al., 2010). Birth weight in farm animals is the characteristic that influences lifetime yields (Karakus et al., 2010). Additionally, this trait is an indicator of determination of calving difficulty. Some authors reported that the trait is highly correlated with first calving age (Kaygisiz, 1998; Akbulut et al., 1998).

Genetic and environmental factors (dam age, calving weight of dam, mothering ability, nutritional conditions of dam, litter size, gestation length, calving year, season, geographical region and altitude) may influence birth weight (Holland and Odge, 1998; Sakhare and Ingle, 1983; Sang et al., 1986). Information on these environmental factors affecting birth weight plays an important role for estimating accurate and reliable genetic parameters on the trait.

Information about genetic parameters for a genetic improvement program of farm animals is considerably important. Effects of environmental factors affecting characteristics should be investigated in prediction of genetic parameters (Javed et al., 2007; Kuthu et al., 2007). Many authors have reported heritability estimates with moderate level for birth weight, one of the most important characteristics.

The present paper aims to estimate genetic parameters belonging to direct and maternal effects influencing birth weight and to determine the effects of various environmental factors on birth weight of Holstein Friesian calves born at State Farms of Tahirova and Polatli in Turkey.

## Material and Methods

Birth weight data of 3909 Holstein Friesian calves born in two different farms located at Polatli and Tahirova were evaluated.

Birth weights were taken within 24 h after calving. The effects of environmental factors on birth weight were investigated. Birth weight of calves were analyzed using the following linear model,

$$Y_{ijklm} = \mu + a_i + b_j + c_k + d_l + e_{ijklm}$$

where, $Y_{ijklm}$ = a vector connected to birth weight observations, $\mu$ = the population mean, $a_i$ = $i^{th}$ calving year effect, $b_j$ = $j^{th}$ calving season effect, $c_k$ = $k^{th}$ parity effect, $d_l$ = l. sex effect, $e_{ijklm}$ = the random error normally distributed with mean zero and variance $\sigma_e^2$.

Statistical analysis of the linear model was performed using GLM (General Linear Model) procedure of SAS package program. Significant differences were determined by Duncan's test.

The following model was used to estimate genetic parameters within the population (Mrode and Linear, 1996).

$$y = X_b + Z_a + W_m + S_{pe} + e,$$

Where **y** is a vector of birth weight observation, **b** is a vector of fixed effects, **a** is an unknown random vector of additive genetic effects, **m** is a vector of random maternal additive genetic effects, **pe** is a vector of random maternal permanent environmental effects, **S** is design matrix, **e** is an unknown random vector of residuals, **W** is design matrix, **X** and **Z** are known as incidence matrices relating observations to **b** and **a**, respectively.

The variance-covariance structure of the model is as follows:

$$V \begin{vmatrix} a \\ m \\ pe \\ e \end{vmatrix} = \begin{vmatrix} A\sigma^2_A & A\sigma_{AM} & 0 & 0 \\ A\sigma_{AM} & A\sigma^2_M & 0 & 0 \\ 0 & 0 & I_{pe}\sigma^2_{PE} & 0 \\ 0 & 0 & 0 & I_n\sigma_E^2 \end{vmatrix}$$

Where $\sigma^2_A$ is additive direct genetic variance, $\sigma_{AM}$ is the additive direct and maternal genetic covariance, $\sigma^2_M$ is the additive maternal genetic variance, $\sigma^2_{PE}$ is the permanent environmental variance, $\sigma^2_E$ is the residual variance, **A** is the numerator relationship matrix, $\mathbf{I_{pe}}$ an identity matrix with order number of calves, and $\mathbf{I_n}$ an identity matrix with order number of records.

The genetic correlations between direct and maternal genetic effects, direct heritability ($h^2_d$), maternal heritability ($h^2_m$), and total heritability ($h^2_T$) were calculated using the (co)variance components at convergence. Total heritability was calculated as defined by Willham, (1980) below:

$$h^2_T = [(\sigma^2_A + 0.5\sigma^2_M + 1.5\sigma_{AM})/(\sigma^2_P)]$$

Genetic parameters, (co)variance components and genetic parameters of birth weight were estimated with MTDFREML software (Boldman et al., 1993). Convergence of the REML solutions was considered to be reached when the variance of function values (-2logL) in the simplex was less than $10^{-6}$. To ascertain that a global maximum was reached, analyses were restarted for several other rounds of iterations using results from the previous round as starting values.

## Results

Table 1 presents the estimates of (co)variance components and genetic parameters for birth weight.

Direct heritability ($h^2_d$), maternal heritability ($h^2_m$), total heritability ($h^2_T$) and the fraction of variance due to maternal permanent environmental effects ($c^2$) were found as: 0.15, 0.56, 0.12 and 0.0004, for calves in Tahirova State Farm, respectively, and 0.04, 0.002, 0.039 and 0.002 for ones in Polatli State Farm, respectively.

The breeding values (EBV) were estimated and the trends in direct breeding values over years are illustrated in Figures 1 and 2. No positive or negative trends in direct additive EBVs were observed within the years.

Figures 1 and 2 show that breeding value at calf birth weight increased within years in State Farm Tahirova, while it declined at State Farm Polatli. Genetic trends for State Farms at Tahirova and Polatli were estimated as 0.01175 kg/year ($P < 0.01$) and -0.00285 kg/year ($P < 0.01$), respectively. The least squares means ± SE values of calf birth weight were 38.71±3.56 and 37.53±2.09 kg, respectively for State Farm at Tahirova and Polatli (Table 2).

Calving season ($P<0.05$), calving year, and sex ($P<0.01$) factors significantly affected birth weight at both farms. However, calving parity had a significant effect on birth weight at State Farm Tahirova ($P<0.01$), but an insignificant effect for State Farm Polatli.

## Discussion

The heritability ($h^2_d$) estimate of birth weight for Polatli state farm (0.04) was also compared with the heritability estimates of birth weight for different ($h^2$) Holstein herds in previous studies. This heritability estimate was lower than reported by many authors (Unalan (2009), Akbulut et al. (2001a), Kaygisiz (1998), Bilgic and Alic (2004), Choi et al. (1996), Kocak et al. (2007), Aksakal and Bayram (2009), Atil et al. (2005), Coffey et al. (2006), Stamer et al. (2004)). On the other hand, the heritability ($h^2_d$) estimate of birth weight for State Farm at Tahirova (0.15) was higher compared to estimates (0.07 to 0.115) of Bilgic and Alic (2004), Choi et al. (1996), Kocak et al. (2007), but in agreement with the estimates (0.13) of Bakir et al. (2004).

When heritability ($h^2$) estimates (0.04 and 0.015) of Holstein's calves for two farms were compared with the estimates in previous studies, it was observed that the heritability results obtained from this study were lower than those obtained by Unalan (2009), Aksakal and Bayram (2009), Atil et al. (2005), Coffey et al. (2006), Stamer et al.(2004), Akbulut et al. (2001b). Therefore, the heritability estimate may be changed by the genetic and environmental factors in all populations.

The low-modest heritability estimates for birth weight in the present study illustrate that the genetic improvement for this trait will be possible with a successful selection program. Maternal effects on birth weight of calves were significant. For this reason, both direct additive effects and maternal

**Table 1**
**Estimates of (co) variance components for direct and maternal effects on birth weight of Holstein calves**

| (Co) Variance Components and Parameters | | Tahirova Farm | Polatli Farm |
|---|---|---|---|
| Direct additive genetic variance | $\sigma^2_A$ | 1.49 | 0.11 |
| Maternal genetic variance | $\sigma^2_M$ | 5.7 | 0.006 |
| Direct-maternal additive genetic covariance | $\sigma_{AM}$ | -2.11 | -0.004 |
| Maternal permanent environmental variance | $\sigma^2_{PE}$ | 0.0042 | 0.006 |
| Residual variance | $\sigma^2_E$ | 5.1 | 2.6 |
| Phenotypic variance | $\sigma^2_P$ | 10.18 | 2.72 |
| Direct heritability ($\sigma^2_A/\sigma^2_P$) | $h^2_d$ | 0.15 | 0.04 |
| Maternal heritability ($\sigma^2_M/\sigma^2_P$) | $h^2_m$ | 0.56 | 0.002 |
| Maternal permanent enrironmental variance as a proportion of the Phenotypic variance ($\sigma^2_{PE}/\sigma^2_P$) | $c^2$ | 0.0004 | 0.002 |
| Covariance ratio ($\sigma_{AM}/\sigma^2_P$) | $C_{AM}$ | -0.21 | -0.0015 |
| Direct-maternal genetic correlation | $R_{AM}$ | -0.72 | -0.16 |
| Total heritability $[(\sigma^2_A + 0{,}5\sigma^2_M + 1{,}5\sigma_{AM})/(\sigma^2_P)]$ | $h^2_T$ | 0.12 | 0.039 |
| Repeatability | r | 0.147 | 0.0426 |
| Records | | 2025 | 1474 |
| Sires | | 83 | 47 |
| Dams | | 1923 | 723 |
| Animals in relationship matrix | ARM | 4031 | 2244 |
| Mixed Model Equations | MME | 8095 | 5238 |
| Means and SD | $\overline{X} \pm S_x$ | 38.71±3.56 | 37.53±2.09 |
| Coefficient of Variation | CV | 8.25 | 4.4 |
| -2logL | | 6710 | 3000 |

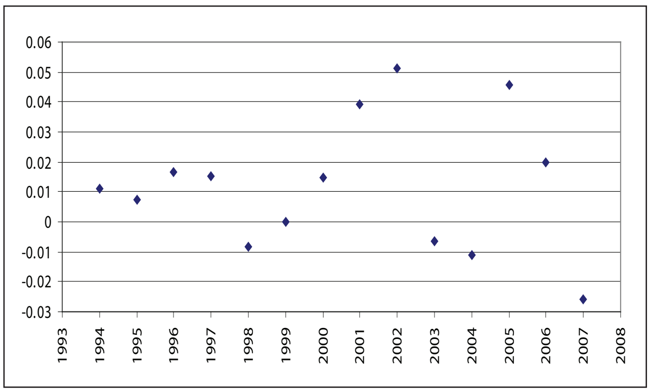


**Fig. 1. Means EBVs of birth weight over years for calves raised at State Farm Polatli**

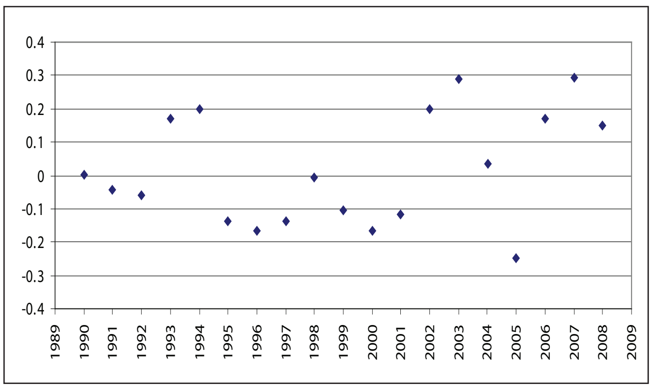


**Fig. 2. Means EBVs of birth weight over years for calves raised at State Farm Tahirova**

effects should be taken into consideration to improve the trait with selection.

Repeatability estimates of birth weight for Polatli and Tahirova farms were 0.04 and 0.15 respec-

**Table 2**
**Effects of parity, year, season and sex on birth weight, kg**

| Classing | N | Tahirova Farm | Polatli Farm | |
|---|---|---|---|---|
| | | $\bar{X} \pm S_x$ | N | $\bar{X} \pm S_x$ |
| Means | 2309 | 38.71 ± 3.56 | 1600 | 37.53 ± 2.09 |
| Calving Parity | | ** | | n.s |
| 1 | 598 | 38.04 ± 0.15c | 671 | 37.50 ± 0.08 |
| 2 | 585 | 38.64 ± 0.15bc | 452 | 37.69 ± 0.09 |
| 3 | 430 | 39.08 ± 0.17ab | 235 | 37.33 ± 0.12 |
| 4 | 301 | 38.90 ± 0.20ab | 126 | 37.57 ± 0.16 |
| 5 | 199 | 39.44 ± 0.24a | 67 | 37.77 ± 0.21 |
| 6 | 106 | 38.44 ± 0.33bc | 31 | 37.32 ± 0.31 |
| 7 | 90 | 39.38 ± 0.36a | 18 | 37.66 ± 0.40 |
| Calving Year | | ** | | ** |
| 1990 | 17 | 37.05 ± 0.31g | | |
| 1991 | 33 | 38.00 ± 0.81cdef | | |
| 1992 | 61 | 38.50 ± 0.58bcde | | |
| 1993 | 70 | 41.58 ± 0.43a | | |
| 1994 | 105 | 39.56 ± 0.40b | 15 | 37.40 ± 0.44d |
| 1995 | 113 | 39.26 ± 0.33bc | 19 | 38.42 ± 0.39abc |
| 1996 | 96 | 39.04 ± 0.31bcd | 23 | 38.82 ± 0.36a |
| 1997 | 79 | 37.55 ± 0.34ef | 41 | 38.75 ± 0.27ab |
| 1998 | 74 | 36.27 ± 0.38g | 49 | 38.48 ± 0.25ab |
| 1999 | 56 | 36.01 ± 0.44g | 46 | 37.93 ± 0.25cd |
| 2000 | 25 | 37.64 ± 0.66ef | 78 | 37.51 ± 0.21d |
| 2001 | 71 | 37.64 ± 0.40ef | 217 | 38.75 ± 0.14ab |
| 2002 | 138 | 37.93 ± 0.40def | 226 | 38.13 ± 0.14abcd |
| 2003 | 190 | 37.73 ± 0.30ef | 100 | 37.87 ± 0.18cd |
| 2004 | 178 | 37.63 ± 0.25ef | 162 | 38.04 ± 0.15bcd |
| 2005 | 292 | 38.11 ± 0.26cdef | 167 | 37.92 ± 0.14cd |
| 2006 | 314 | 40.81 ± 0.20a | 226 | 35.79 ± 0.13e |
| 2007 | 284 | 39.13 ± 0.19bcd | 231 | 36.13 ± 0.13e |
| 2008 | 113 | 39.10 ± 0.20bcd | | |
| Calving Season | | * | | * |
| Spring | 726 | 38.85 ± 0.15a | 463 | 37.85 ± 0.12a |
| Summer | 575 | 38.46 ± 0.17a | 389 | 37.20 ± 0.13b |
| Autumn | 493 | 38.73 ± 0.17a | 270 | 37.14 ± 0.11b |
| Winter | 515 | 38.68 ± 0.16a | 478 | 37.75 ± 0.12a |
| Sex | | ** | | ** |
| Male | 1180 | 39.07 ± 0.13a | 838 | 38.16 ± 0.10a |
| Female | 1129 | 38.30 ± 0.13b | 762 | 36.86 ± 0.10b |

n.s; non-significant, * $P<0.05$, ** $P<0.01$

a, b, c, d,e,f: Means with different superscripts for each factor within a column are significant ($P<0.05$).

tively. Repeatability estimate for Tahirova farm was lower than those reported by Unalan (2009), Bilgic and Alic (2004) and Atil et al. (2005), who found repeatability estimate of 0.206, 0.29 and 0.75, respectively.

The least squares means ± SE values of calf birth weights were found as 37.53±2.09 and 38.71±3.56 kg for Polatli and Tahirova farms, respectively (Table 4). However, the least squares means reported by Atil et al. (2005), Kabuga and Agyemang (1984), Ugur et al. (1999) were lower compared to the results reported in this study. On the other hand, Aksakal and Bayram (2009), Stamer et al. (2004), Kocak and Gunes (2004), Zhang et al. (2002), Johanson and Berger (2003) recorded higher means for birth weights.

The results showed significant effect (P<0.01) of years due to birth weight at both farms. The results of this study are in agreement with previous researchers (Akbulut et al., 2001a; Bakir et al., 2004; Bilgic and Alic, 2004; Kocak et al., 2007; Akbulut et al., 2001b; Akbulut et al., 2002). The highest birth weights (41.58 kg and 40.81 kg) at Tahirova Farm were obtained during 1993 and 2006 years, while the lowest birth weights of 37.05 kg, 36.27 kg and 36.01 kg were recorded during 1990, 1998 and 1999 respectively. The difference between maximum and minimum means within years was 5.57 kg., The highest birth weights of 38.82 kg was obtained during 1996 and the lowest birth weights of 35.79 kg, 36.13 kg were recorded during 2006 and 2007. The difference between maximum and minimum birth weight means within years was 3.03 kg. In the light of these results, it could be suggested that fluctuations occurring in birth weights during years may be due to changes in climatic conditions and availability of pasture.

The effect of parity on birth weight was significant (P<0.01) for Tahirova farm, but not significant for Polatli farm. The lowest birth weights (38.04 kg) were obtained in 1$^{st}$ parturitions and the highest birth weight (39.38 kg) was recorded in 7$^{th}$ parturitions for Tahirova farm. Calves born in late-parity dams were heavier in weight than those born in early parities were. However, similar results on the mean birth weights between 2$^{nd}$ and 7$^{th}$ parturitions were obtained (Figure 3).

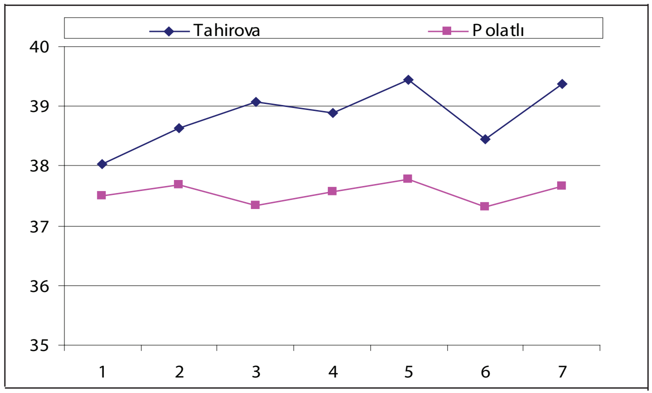


**Fig. 3. Changing of birth weight according to parity**

These findings were in agreement with Bakir et al. (2004), Kocak et al. (2007), Akbulut et al. (2001a, 2001b), Johanson and Berger (2003), Swali and Wathes (2006) who reported that the effect of parity on birth weight of calves was highly significant. One explanation of these results is that earlier-parity cows persist to grow up to reaching adult size.

Spearman rank correlation test was used to determine whether effects of birth parity in both state farms were in the same direction. However, birth weights in terms of sorting between two state farms ($r_s$ = 0.25) were statistically insignificant (P<0.59).

The effect of calving season on birth weight was significant (P<0.05) at both farm. The results of the present study were in agreement with previous studies by Akbulut et al. (2001a), Bakır et al. (2004), Bilgic and Alic (2004), Kocak et al. (1996), Aksakal and Bayram (2009); who emphasized significant effect of the season on birth weight. In both farms, the highest birth weights (38.85 kg and 37.85 kg) were obtained during spring season. These results were in agreement with previous studies by Akbulut et al. (2001a) and Kocak et al. (2007). The lowest birth weights (38.46 kg and 37.14 kg) were obtained during summer or autumn season at Tahirova and Polatli farms. This may have resulted from low temperatures and the availability of high quality fodder to spring calves during the last one-third of gestation.

The effect of calf sex on birth weight was highly significant (P<0.01). Birth weights of male calves ranged 0.37 -1.3 kg and were heavier compared to females at Tahirova and Polatli farms. These results were similar to the findings of Kabuga and Agyemang (1984), Akbulut et al. (2001a), Bilgic and Alic (2004), Kocak et al. (2007), Aksakal and Bayram (2009) and Holland and Odge (1992), who reported that birth weight of male calves were 5-8 % heavier than female calves.

Birth weight that is connected with growth, development and various yield traits at the early ages can be considered as an indirect selection criterion in farm animals. Birth weight means determined in the present study were similar to the findings in literature; which indicated that the cows in the farms were treated well during gestation when intrauterine growth of the fetus was rapid. In the present study, calving year, farm, birth parity and season were important factors affecting birth weight. In the next studies, the effects of environmental factors should be eliminated for the effective selection program based on birth weight.

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