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Variance components due to direct and maternal effects for birth weight of Brown Swiss cattle

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ABSTRACT

This study was conducted to estimate variance components and genetic parameters for birth weights of Brown Swiss calves. Experimental data were gathered from the records of a State Farm of Turkey (Konuklar) covering the years between 1995 and 2005. Random effects considered in this study included direct and maternal additive genetic effects, maternal permanent environmental effects with direct-maternal genetic covariance and random residual effects. AI-REML algorithm of WOMBAT software was used to estimate variance and covariance components, genetic parameters and breeding values. The general mean for birth weights of all calves was calculated as 38.12±0.006 kg. The least square for mean birth weights was calculated as 38.99±0.007 kg for male calves and as 37.26±0.008 for female calves. Direct heritability (h_D^2), maternal heritability (h_M^2), total heritability (h_T^2), r_{AM} and c_{AM} estimates were respectively calculated as 0.15, 0.10, 0.39, 0.96 and 0.13.

Key words: Calves, Direct heritability, Maternal heritability, Swiss Cattle, Total heritability.

INTRODUCTION

Brown Swiss cattle was brought to Turkey toward to end of 1940s. The cattle is raised for both milk and meat production. Meat production and profitability of beef cattle operations largely depend on calf weights at birth. Beef cattle selection studies therefore mostly include birth weight of the calves. Breeding works and genetic assessments require comprehensive knowledge on genetic characteristics of breeds (Baker, 1980). Several previous studies investigated various genetic and phenotypic traits effective on calf birth weights. Birth weights of the calves mostly depend not only on animal genetics, but also environmental conditions to which animals are exposed. Therefore, direct and maternal genetic factors should definitely be taken into consideration for an optimum genetic progress in cattle breeding programs since there is an antagonistic correlation between these two groups of genetic factors (Meyer, 1992).

Calf birth weight is a significant performance indicator of cattle raising operations and thus several researchers studies on birth weights of the calves were conducted (Yin and Konig 2004). Birth weight is therefore commonly used as a performance indicator of livestock animals. Birth weight is also used as a reliable measure of growth for prenatal period. Such weights also greatly influence animal growth in postpartum period. Birth weight of dairy calves thus is usually taken into consideration in majority of breeding programs since it is easily measured and correlated with various growth parameters. Despite easy measurement, birth weight is still a complex parameter influenced by several genetic parameters and environmental factors. The genetic factors are composed of direct genetic effects and maternal effects with great influences on calves and dams. Number of studies and available information about the effects of maternal factors on calf birth weights are quite limited.

Animal model methodology was used in this study to estimate variance and covariance components of direct genetic effects, maternal effects and environmental effects influencing birth weights of Brown Swiss calves. The methodology allows researchers to separately assess direct genetic effects, maternal effects and environmental effects.

MATERIALS AND METHODS

Experimental data were collected between the years 1995-2005. Data about 2,490 Brown Swiss calves coming from 48 sires and 429 dams were gathered. Data included information about pedigree of the calves (parents-sire and dam) and information about birth parameters (gender, date and type of birth, birth weight). Abnormal data induced by diseases and abortion were omitted and not considered in analyses. Type of birth included single or twin births. Calving months included all months of a year. In statistical model for least squares analyses, effect of birth year (11 levels), birth month (12 levels), calf gender (2 levels) and type of birth (2 levels) were considered as fixed effects and age of dam was considered as covariate. All these effects on birth weights were found to be significant (P≤0.05).

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Generalized Linear Model (GLM) of SAS statistical software (SAS, 2009) was used to identify the fixed effects to be included in the models. Means were compared with Duncan's multiple range test (Duncan 1995).

Analyses revealed that birth year, gender, birth type and dam age had significant effects on birth weights of the calves. Therefore, they were included into the model.

The following model was used to analyze calf birth weights;

$Y_{ijklmn} = \mu + A_i + B_j + C_k + D_l + F_m + b\,(Y_{ijklm} - \bar{Y}) + e_{ijklmn}$

where Y_{ijklmn} represents the vector for birth weights, μ represents the population mean, A_i represents the effect of birth month, B_j represents birth year with j corresponding to 1995-2005, C_k represents the effect of parity with corresponding to a value between 1-8, D_l represents the effect of birth type with l corresponding to single or twin births, F_m represents the effect of gender with m corresponding to male or female, b represents the fixed regression coefficient for calving age, Y_{ijklm} represents *ijklm* calving age sub-group; $\bar{Y}$ represent the average calving age of the herd, finally e_{ijklm} represents the random error.

To estimate genetic parameters, variance components and breeding values, the following model was used;

$Y = Xb + Z_a a + Z_m m + e$

where:

Y is the vector of observations; *b* is the vector of fixed effects including birth year, gender, type and dam age; *a*, *m*, *c*, *e* are respectively the vectors of direct additive genetic effects, maternal genetic effects, permanent environmental effects and the residual; *X*, *Za*, *Zm* are the incidence matrices related respectively to *b*, *a* and *m*; *A* is the numerator relationship matrix; *σam* is covariance between direct and maternal genetic effects.

The (co) variance structure of the random effects can be described as:

$V(a) = A\sigma^2_A$; $V(m) = A\sigma^2_M$; $V(c) = Id\sigma^2 c$; $V(e) = I_n\sigma^2_E$; $Cov(a,m) = A\sigma_{AM}$

The covariance and variance matrix of the model is presented below;

$$v\begin{vmatrix} a \\ m \\ c \\ e \end{vmatrix} = \begin{vmatrix} A\sigma^2_A & A\sigma_{AM} & 0 & 0 \\ A\sigma_{AM} & A\sigma^2_M & 0 & 0 \\ 0 & 0 & I_c\sigma^2_C & 0 \\ 0 & 0 & 0 & I_n\sigma^2_E \end{vmatrix}$$

Where;

I : Identity matrix (I_c : Identity matrix with order number of calves, I_n : Identity matrix with order number of records),

σ^2_A : Direct additive genetic variance,

σ^2_M : Maternal genetic variance,

σ^2_C: Variance of the permanent environmental effect of the dam,

σ^2_E : Residual variance.

Total heritability was calculated by using the following equation (Willham, 1972);

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

AI-REML algorithm of WOMBAT software was used to estimate (co) variance components and genetic para meters of birth weight (Meyer, 2009). Convergence was assumed in case the vari-ance of likelihood values in the simplex is < 10^{-8}. Additionally, each analysis was restarted with different starting values to prevent convergence to local maxima.

RESULTS DISCUSSION

Basic statistics including means, standard errors, coefficient of variations and multiple comparison test results for birth weights are provided in Table 1. With regard to birth weights, birth month, year, lactation number, calf gender, type of birth and age of dam were found to be significant (P<0.05).

The greatest calf weight (38.78±0.026 kg) was observed in calves born in October and the lowest calf weight (37.76±0.018 kg) was observed in calves born in June. The differences in calf weights of the months were found to be significant (P<0.05). Single-born calves had 4.05 kg higher birth weights than twin-born calves and male calves had 1.73 kg higher birth weights than female calves. While the least birth weight (37.22±0.018 kg) was obtained from the first parity, the greatest birth weight (38.67±0.057 kg) was obtained from the 7th parity. With regard to birth years, the greatest value (38.79±0.028 kg) was obtained in 2005 and the lowest value (37.51±0.023 kg) was obtained in 1997 and 1998. Direct heritability (h^2_D), maternal heritability (h^2_M), total heritability (h^2_T), direct maternal genetic correlation (r_{AM}) and genetic covariance between direct and maternal effects of proportion (c_{AM}) were respectively calculated as 0.15, 0.10, 0.39, 0.96 and 0.13. Present findings revealed that direct heritability was greater than maternal heritability. The genetic parameters and (co) variance components of the present model are provided in Table 2.

Available performance and pedigree data were used to estimate breeding values of the animals for birth weights. Estimated breeding values were then subjected to regression analysis to calculate the genetic trend for birth weight. Expected Breeding Values (EBV) were estimated and year-based trends in direct breeding values are presented in Fig 1. In general, an irregular fluctuation was observed for genetic trend in birth weight (-0.01 kg/year).

The general average for birth weight of Brown Swiss calves was calculated as 38.12±0.006 kg (Table 2). Previous researchers reported the birth weight of Brown

Table 1: Means, standard errors (s_x) and multiple comparison test results (^{a,b,c}) for birth weights (kg).

Factors	N	Mean	S_x	Min	Max
Year of birth		**			
1995	151	38.32^{b}	0.03	25	52
1996	175	37.64^{a}	0.027	25	55
1997	214	37.51^{a}	0.023	30	60
1998	215	37.53^{a}	0.029	20	60
1999	229	38.15^{ab}	0.022	30	50
2000	251	38.36^{b}	0.021	20	50
2001	261	38.19^{ab}	0.02	21	50
2002	302	38.46^{b}	0.019	30	49
2003	282	38.26^{ab}	0.02	30	48
2004	244	38.20^{ab}	0.021	30	46
2005	166	38.79^{c}	0.028	30	46
Month of birth		**			
January	167	38.13^{ab}	0.028	30	46
February	154	37.83^{a}	0.03	25	50
March	171	38.11^{ab}	0.027	20	60
April	200	38.16^{ab}	0.024	20	47
May	272	37.86^{a}	0.019	30	60
June	318	37.76^{a}	0.018	30	56
July	256	37.80^{a}	0.02	25	47
August	238	37.94^{a}	0.021	25	50
September	223	38.22^{ab}	0.022	21	52
October	183	38.78^{b}	0.026	25	50
November	153	38.67^{b}	0.03	32	50
December	155	38.26^{ab}	0.029	30	46
Type of birth		**			
Single	2442	40.15	0,003	20	60
Twin	48	36.1	0.069	30	45
Calf gender		**			
Female	1213	37.26	0.008	20	52
Male	1277	38.99	0.008	20	60
Parity		**			
1	459	37.22^{a}	0.018	30	50
2	494	38.09^{b}	0.014	30	50
3	515	38.57^{bc}	0.011	25	60
4	394	38.15^{b}	0.014	21	55
5	266	38.55^{bc}	0.022	30	56
6	181	38.39^{b}	0.033	20	50
7	101	38.67^{bc}	0.057	30	50
8	80	37.39^{ab}	0.083	25	45
General mean	2490	38.12	0.006		

$^{a-c}$: means in the same column indicated with different letters are significantly different (P<<0.05) ** : (P<<0.05)

Table 2: Estimates of (co)variance components for direct and maternal effects on birth weight of Brown Swiss calves.

Parameters and (co) variance components	
σ^2_A	1.833
σ^2_M	1.255
σ^2_{AM}	1.517
σ^2_E	7.455
σ^2_p	12.060
h^2_D	0.15
S.E	0.028
h^2_M	0.10
S.E	0.048
c_{AM}	0.13
r_{AM}	0.96
h^2_T	0.39
-2 Log L	83312

σ^2_A: Direct additive genetic variance, σ^2_M : Maternal genetic variance, σ^2_{AM} :direct-maternal additive genetic covariance, σ^2_E : residual variance, σ^2_p : phenotypic variance, h^2_D : direct heritability (σ^2_A/σ^2_p), S.E: standard error, h^2M: maternal heritability (σ^2_M/σ^2_p), C_{AM} : ratio of direct-maternal covariance to phenotypic variance (σ^2_{AM}/σ^2_p), r_{AM} : direct maternal genetic correlation, h^2_T : total heritability (σ^2_A+0.5σ^2_M+1.5σ^2_{AM})/(σ^2_p), -2 Log L: Log likelihood.

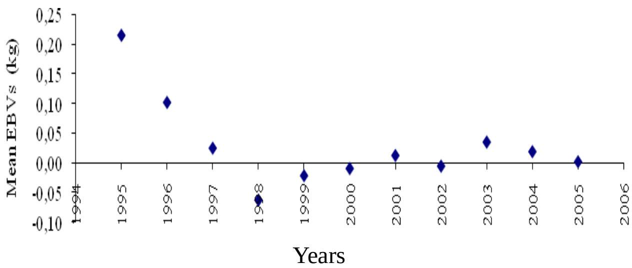

Fig 1: Mean FBVs of birth weight according to years.

Swiss calves as 35.6 - 43.6 kg for males and as between 32.4 - 39.2 kg for females with a general average as between 35.5 - 40.1 kg (Akbulut *et al.* 2001; Tilki *et al.* 2003; Bayram *et al.* 2007; Diler, 2007; Tilki *et al.* 2008).

The least squares mean for birth weights of female calves was calculated as 37.26±0.018 (Table 2). Such a value was greater than the values of Bayram *et al.* (2007), Diler (2007), and Tilki *et al.* (2008), but smaller than the value of Balcı (1996). Such differences in mean birth weights mostly resulted from the differences in genotypes, herd management practices and analysis methods.

For birth weight of the calves, calving year was identified as a significant source of variation (P>0.05) (Table 1). Present findinds well comply with the results of Kaygısız (1996) and Aksakal and Bayram (2009) indicating quite similar findings for Turkish and Iraqi (Balcı, 1996; Kaygısız, 1996).

The least square mean for birth weights of male calves was calculated as 38.99±0.058 kg (Table 2). Such a value was smaller than the values of Kaygısız (1998) (41.25

kg) and Diler (2007) (41.90 kg), but greater than the values of Tilki *et al.* (2003).

Average birth weight of male calves was 1.73 kg greater than the average birth weight of female calves and such a difference in average birth weights was found to be significant (P<0.05). Kaygısız (1998), Akbulut *et al.* (2001), Tilki *et al.* (2003), and Tilki *et al.* (2008) carried out studies with Brown Swiss calves of Turkey and reported significant effects of calf gender on birth weights. Such greater birth weights of male calves probably resulted from anabolic effects of male gender hormones during the prenatal growth stages of the calves. Male calves also have longer gestation periods. On the other hand, Bakır *et al.* (2004) and Kaygısız and Tümer (2007) indicated insignificant effects of calf gender on birth weights (P>0.05).

Present findings indicated that type of birth had significant effects on birth weights (P<0.05). The twin-born calves had 4.05 kg greater mean birth weight than single-born ones. Current results comply with the findings of Bakır *et al.* (2004) and Tilki *et al.* (2008).

It was observed in this study that parity had also significant effects on calf birth weights (P<0.05).

Present findings revealed that calving month had significant effects on birth weights (P<0.05) (Table 2). The greatest birth weights were observed in calves born in November (38.67±0.030 kg) and the differences in calf weights of November and the other months were found to be significant (P<0.05). Present findings comply with the results of Kaygısız *et al.* (1995). Effects of calving month largely depend on environmental factors and can vary from one place to another.

It was observed in this study that the age of dam was a significant source of variation for birth weights. Present findings well comply with the results of Akbulut *et al.* (2001) and Tilki *et al.* (2008). Such differences in findings mostly come from the differences in methodologies of the studies. The maternal heritability (h_M^2) for birth weights was estimated to be 0.10. Direct and maternal heritability estimates were also low and were able to explain respectively 0.15% and 0.10% of the total phenotypic variance. The direct heritability (h^2_D) estimate for birth weights was 0.15 which was greater than maternal heritability. Present direct heritability (h^2_D) estimate (0.15) was greater than the values reported by Kaygısız (1998) and Tilki *et al.* (2003) (0.084 and 0.10), similar with the value of Bakır *et al.* (2004) and Tilki *et al.* (2008) (0.11-0.15). Singh *et al.* (1989) and Aksakal and Bayram (2009) carried out a study with Holstein calves and reported the direct heritability respectively as 0.23.

The estimates of Akbulut *et al.* (2002) for direct heritability in Brown Swiss calves (0.76 and 0.29) were greater than the estimates of Bilgiç and Alıç (2004) a for Holstein cattle. Akbulut *et al.* (2001) reported greater estimate (0.36) for direct heritability in Brown Swiss calves of another farm in Turkey.

The present maternal heritability (h^2M) value (0.10) was similar with the one reported by Meyer (1993) for Hereford (0.10), the one reported by Robinson (1996) for Angus (0.08) and the one reported by Tilki *et al.* (2008) for Brown Swiss (0.09). The present value was greater than the ones reported by Hetzel *et al.*(1990) for Africander Cross and Hereford-Shorthorn Cross (0.05, 0.03), but smaller than the estimate of Atil *et al.* (2005).

Intaratham *et al* (2008) reported direct heritability, maternal heritability and maternal permanent environment effect respectively as 0.40, 0.14 and 0.04 for Thai indigenous; Robinson (1996) respectively as 0.35, 0.08, and 0.05 for Angus and Meyer (1993) respectively as 0.43, 0.10 and 0.09 for Hereford.

In present study, direct maternal genetic correlation (r_{AM}) and genetic covariance between direct and maternal effects (c_{AM}) were respectively calculated as 0.96 and 0.13. There was a highly positive correlation between direct and maternal genetic effects. Tilki *et al.* (2008) also reported a positive correlation Brown Swiss calves. However, Dezfuli and Mashayekhi (2009) were not able to report any positive correlations.

Genetic trend was calculated with the regression of breeding values by the years. There was an irregular trend in expected breeding values. The value was negative in some years and positive in the others. Genetic trend for birth weight was calculated as -0.01 kg/year. Tilki *et al.* (2008) also calculated expected breeding values for birth weights, but was not able to observe any positive or negative changes between the years.

Present calf birth weights were quite close to earlier reports of the researchers for Brown Swiss calves. Calf gender, parity, calving year and month and type of birth were identified as the significant environmental factors influencing calf birth weights. Estimated heritability values were also well complying with the earlier reports for birth weights of Brown Swiss calves.

It was concluded based on present findings that maternal effects significantly influenced birth weights of Brown Swiss calves and present findings could reliably be used in further breeding programs for Brown Swiss cattle.

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