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Genetic Analyses for Milk Yield, Lactation Period and Fat Percentage in Brown Swiss Cattle

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Abstract: In this study, a total of 733 milk yield records of Brown Swiss cows raised at Konuklar State Farm in Konya Province in Turkey were used for estimation of phenotypic and genetic parameters for milk yield, lactation period and fat percentage. The Phenotypic and genetic parameters were estimated by the MTDFREML program using Multiple Trait Animal Model. The model included individual, permanent environment and errors as random effects, year and season of calving, parity, year and age as fixed effects and days in milk as a covariate for milk yield; milk yield as a covariate for lactation period and milk yield and lactation period as covariate for fat percentage. Genetic parameters and breeding value of cow, sire and dam for milk yield in kg, for lactation period in days and for fat percentage in percent were estimated. Cow breeding values ranged from -3006-1724 kg for milk yield, from 10.81-14.22 days for lactation period and from -1.48-0.97% for fat percentage. Likewise, dam breeding values ranged from -1628-862 kg, from -5.69-7.74 days and from -0.76-0.48% for the same traits, respectively. Sire breeding value ranged between -1129 and 862 kg, -8.63 and 5.73 days and -0.68 and 0.83% for the above mentioned traits, respectively. Estimates of heritability were 0.33, 0.11 and 0.39 for milk yield, lactation period and fat percentage, respectively. The genetic correlation between milk yield and fat percentage was positive and high (0.95), whereas the genetic correlation between lactation period and milk yield and between lactation period and fat percentage was negative, -0.49 and -0.73, respectively. Repeatability estimates were 0.34, 0.47 and 0.54 for the same traits, respectively.

Key words: Breeding values, brown swiss, milk traits, multiple traits

INTRODUCTION

Accurate knowledge of genetic parameters is required in a selection effort, especially one using selection index with multiple traits (Falconer and Mackay, 1996). Heritabilities are used to estimate genetic change in between generations and genetic correlations are used to estimate how traits change in the next generation in relation to each other. Selection schemes as an alternative to progeny testing depends on the heritability of the trait considered (Santus *et al*., 1993). Estimates of repeatability help culling decisions; animals with an inferior performance in high-repeatability traits may be culled early.

Brown Swiss cattle are quite common in Turkey and they are in need of genetic improvement, which requires selection for various traits. Though Holsteins have been replacing these cattle, they do not have the high capacity for fat percentage and do not have the adaptability of Brown Swiss to environmental conditions in Turkey. Brown Swiss cattle are relatively low maintenance and are thus, preferred by the common farmer in Turkey.

Estimating genetic parameters in these cattle can help calculate more accurate estimates of genetic improvement and increase accuracy of breeding value calculations (Falconer and Mackay, 1996). The estimations give an idea to breeders and farmers what to expect in a selection program and what kind of a genetic improvement scheme should be used.

Milk traits are influenced by maternal effects and permanent environmental effects in addition to direct genetic effects. Including maternal effects in the model decreases the variance of direct genetic effects (Meyer, 1992; Hoque *et al*., 2007). These effects should be taken into consideration in a selection program, increasing the accuracy of the estimates (Meyer *et al*., 1994).

Major aim of this study, was to estimate heritabilities, repeatabilities and genetic correlations for milk yield, fat percentage and lactation period in Brown Swiss cattle raised in Konya, Turkey.

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MATERIALS AND METHODS

The data used in this study were collected from Brown Swiss cattle reared at Konuklar state farm in Turkey. The 203 cows, 182 dams and 41 sires constituted pedigree data. Cows were artificially inseminated by using frozen semen. Parity of cows varied from 1-9, year-season of calving from January-December, year 1984-1996 and age 2 from 14. Records arranged with integer fixed fields to left (parity, year-season of calving, year and age) and real fields to right (Lactation Period (LP) as a covariate for Milk Yield (MY), MY as a covariate for LP and MY and LP as covariate for Fat Percentage (FP)). Data were analyzed by Multiple Trait Derivative Free Restricted Maximum Likelihood (MTDFREML) according to Boldman *et al.* (1995), using repeatability animal model multiple trait analysis. Table 1 shows the data structure considered in the analysis, mean of Milk Yield (MY) in kg, Days in Milk (DIM) and Fat Percentage (FP) in days, number of mixed model equations and number of iterations.

To ensure global convergence, the algorithm by (Boldman *et al.*, 1995) was restarted with estimates until the log likelihood did not change at the fourth decimal (Robison *et al.*, 2002). The solutions given are from the final round of iteration. Fixed effects for the model included year and season of calving, parity, year and age and lactation period was included as a covariate for MY. Milk Yield was included as a covariate for lactation period and MY and LP were included as covariate for FP.

Permanent environmental effects for each cow were used to calculate the permanent covariance between each two traits, while the genetic and residual covariances were obtained using the Mixed Model Least Squares and Maximum Likelihood (LSMLMW) in the computer program of (Harvey, 1990) for all traits. Duncan multiple comparison test (Duzgunes, 1993) was used to test the differences between factors. Experiment was carried out according to Selcuk University, Faculty of Agriculture guidelines.

Table 1 shows the data structure considered in the analysis, means of Milk Yield (MY) in kg, Lactation Period (LP) in day, Fat Percentage (FP) in percent, number of mixed model equations and number of iterations.

Table 1: Data structure, unadjusted mean, Standard Deviation (SD) and Coefficient of Variation (CV%) for Milk Yield (MY), Lactation Period (LP) and Fat Percentage (FP)

Traits	Mean	SD	CV (%)
Milk Yield (kg)	4713.12	1412.13	29.96
Lactation Period (day)	308.16	29.92	9.71
Fat Percentage (%)	3.67	0.06	1.64
Observations			
No. of records	733	-	-
No. of cows	203	-	-
No. of sires	41	-	-
No. of dams	182	-	-
Animals in relationship matrix (A-1)	426	-	-
Mixed Model Equations (MME)	2003	-	-
No. of iterations	2571	-	-

Variance components were estimated using the following animal model:

$$Y = X\beta + Za + Wp + e$$

where:

- Y = A vector of the observations
- β = A vector of fixed effects (year = 1 (1984), 2 (1985) ….. 13 (1996); parity = 1-9; season of calving = 1 (winter), 2 (spring), 3 (summer) and 4 (autumn); age = 2, ….14)
- a = A vector of direct genetic animal effects
- p = A vector of permanent environmental effects
- e = A vector of residual effect

Variance-covariance structure of the model described by El-Arian *et al.* (2003) was used:

$$\begin{pmatrix} a1 \\ a2 \\ a3 \\ P1 \\ P2 \\ P3 \\ e1 \\ e2 \\ e3 \end{pmatrix} = \begin{pmatrix} A\sigma^2_{a_1} & \sigma_{a_1a_2} & \sigma_{a_1a_3} & 0 & 0 & 0 & 0 & 0 & 0 \\ \sigma_{a_2a_1} & A\sigma^2_{a_2} & \sigma_{a_2a_3} & 0 & 0 & 0 & 0 & 0 & 0 \\ \sigma_{a_3a_1} & \sigma_{a_3a_2} & A\sigma^2_{a_3} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & I\sigma^2_{p_1} & \sigma_{p_1p_2} & \sigma_{p_1p_3} & 0 & 0 & 0 \\ 0 & 0 & 0 & \sigma_{p_2p_1} & I\sigma^2_{p_2} & \sigma_{p_2p_3} & 0 & 0 & 0 \\ 0 & 0 & 0 & \sigma_{p_3p_1} & \sigma_{p_3p_2} & I\sigma^2_{p_3} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & In_1\sigma^2_{e_1} & \sigma_{e_1e_2} & \sigma_{e_2e_3} \\ 0 & 0 & 0 & 0 & 0 & 0 & \sigma_{e_3e_1} & In_2\sigma^2_{e_2} & \sigma_{e_2e_3} \\ 0 & 0 & 0 & 0 & 0 & 0 & \sigma_{e_3e_1} & \sigma_{e_3e_2} & In_3\sigma^2_{e_3} \end{pmatrix}$$

where:

- A = The numerator relationship matrix
- σ^2_{a1}, σ^2_{a2} and σ^2_{a3} = Direct genetic variance for a trait
- σ^2_{p1}, σ^2_{p2} and σ^2_{p3} = Variance due to permanent environmental effects, each of In_1, In_2 and In_3 is an identity matrix of order equal to the records of traits 1, 2 and 3
- σ^2_{e1}, σ^2_{e2} and σ^2_{e3} = Residual variance effects
- $\sigma_{ai\,aj}$ = Direct genetic covariance items between any pair of 3 traits studied
- $\sigma_{pi\,pj}$ = Permanent environmental covariance items between any pair of the three traits
- $\sigma_{ei\,ej}$ = All the residual covariance items between any pair of the three traits.

To estimate heritability (h^2) and repeatability (r) the following equation was used:

$$h^2 = \sigma^2_a / (\sigma^2_a + \sigma^2_p + \sigma^2_e)$$

$$r = \sigma^2_a + \sigma^2_p / (\sigma^2_a + \sigma^2_p + \sigma^2_e)$$

where:

σ^2_a = Additive genetic variance

σ^2_p = Permanent environmental variance

σ^2_e = The random residual effect associated with each observation

The Mixed Model Equations (MME) for the Best Linear Unbiased Estimator (BLUE) of estimable functions of b and for the Best Linear Unbiased Prediction (BLUP) of a and p in matrix notation were as follows:

$$\begin{vmatrix} X'X & X'Z & X'W \\ Z'X & Z'Z + A^{-1}\alpha_1 & Z'W \\ W'Z & W'Z & W'W + I\alpha_2 \end{vmatrix} \begin{vmatrix} \hat{b} \\ \hat{a} \\ p \end{vmatrix} = \begin{vmatrix} X'y \\ Z'y \\ W'y \end{vmatrix}$$

where, $\alpha_1 = \sigma^2_e/\sigma^2_\alpha$ and $\alpha_2 = \sigma^2_e/\sigma^2_p$.

RESULTS AND DISCUSSION

Unadjusted Mean and Standard Deviation (SD) for MY in kg, LP in days and FP in percent were 4713.12±1412.13 kg, 308.16±29.92 day and 3.67±0.06%, respectively (Table 1). Estimates of Coefficient of Variations (CV%) are given in Table 1. The highest CV% value for MY (29.96) reflects a medium variation between individuals. The lowest CV% value for FP (1.64) reflects a small variation between individuals. The Least Squares Means (LSM) and Standard Deviations (SD) of milk yield, lactation period and fat percentage according to year and season of calving, parity, year and age is given Table 2.

The effect of year and year-season of calving on milk yield was statistically significant ($p<0.01$). The highest milk yield was obtained from 1996 year and the lowest milk

Table 2: The Least Squares Means (LSM) and Standard Deviations (SD) of milk yield, lactation period and fat percentage according to year and season of calving, parity, year and age

	Milk yield (kg)			Lactation period			Fat percentage	
	n	LSM (SD)		n	LSM (SD)		n	LSM (SD)
Year								
1	27	4016±255^{d}	1	27	298±6.9	-	-	-
2	34	5029±232^{bc}	2	34	298±6.2	-	-	-
3	58	5192±193^{bc}	3	58	304±5.2	-	-	-
4	71	5591±181^{b}	4	71	303±4.9	4	4	3.68±0.29^{ab}
5	68	5090±183^{bc}	5	68	312±4.9	5	15	3.63±0.16^{cd}
6	84	4369±173^{d}	6	84	307±4.7	6	78	3.63±0.08^{d}
7	105	4035±161^{d}	7	105	312±4.4	7	99	3.66±0.07^{bc}
8	98	4152±165^{d}	8	98	312±4.5	8	96	3.69±0.07^{ab}
9	69	4354±172^{d}	9	69	309±4.6	9	65	3.69±0.08^{ab}
10	49	5023±192^{bc}	10	49	314±5.2	10	47	3.70±0.09^{a}
11	25	5014±254^{bc}	11	25	314±6.8	11	24	3.68±0.12^{ab}
12	14	4935±323^{c}	12	14	307±8.7	12	4	3.62±0.22^{d}
13	31	7245±256^{a}	13	31	316±7.3	13	19	3.66±0.18^{bc}
Season								
1	184	5190±134^{a}	1	184	310±3.6	1	117	3.67±0.07
2	232	4979±127^{ab}	2	232	307±3.4	2	143	3.66±0.07
3	151	4758±138^{b}	3	151	306±3.7	3	97	3.65±0.08
4	166	4779±133^{b}	4	166	309±3.6	4	97	3.67±0.08
Parity								
1	191	4850±307	1	191	290±8.2	1	92	3.65±0.19
2	136	5216±283	2	136	298±7.6	2	60	3.65±0.16
3	109	5233±263	3	109	300±7.1	3	67	3.65±0.14
4	93	5067±249	4	93	302±6.7	4	67	3.65±0.13
5	73	5241±250	5	73	307±6.7	5	60	3.66±0.13
6	63	4939±251	6	63	311±6.8	6	57	3.66±0.13
7	35	5088±288	7	35	322±7.7	7	29	3.67±0.15
8	17	4749±386	8	17	324±10.4	8	13	3.66±0.12
9	16	3957±485	9	16	318±13.1	9	9	3.70±0.31
Age								
2	21	3744±394^{E}	2	21	335±10.6			
3	110	3885±300^{EF}	3	110	326±8.1	3	45	3.66±0.20
4	150	4313±270^{E}	4	150	325±7.2	4	76	3.67±0.17
5	106	4797±244^{D}	5	106	319±6.6	5	57	3.67±0.14
6	86	5030±224^{CD}	6	86	314±6.0	6	59	3.68±0.13
7	66	5132±219^{BCD}	7	66	306±5.9	7	51	3.66±0.13
8	65	5277±211^{ABC}	8	65	305±5.7	8	58	3.66±0.12
9	51	5509±229^{AB}	9	51	300±6.2	9	46	3.67±0.13
10	42	5521±259^{AB}	10	42	289±7.0	10	38	3.68±0.14
11	19	5693±389^{A}	11	19	291±10.5	11	15	3.66±0.22
12	11	5332±525^{ABC}	12	11	295±14.1	12	6	3.65±0.32
13	4	5535±787^{AB}	13	4	292±21.2	13	3	3.61±0.46
14	2	4279±1014^{E}	14	2	307±27.3			

a, b: Means in a column with different superscripts differ ($p<0.01$), A, B: Means in a column with different superscripts differ ($p<0.05$)

Table 3: Estimates of variance and covariance components, heritability (h^2), repeatability (t) and genetic correlation (r_G), for Milk Yield (MY), Lactation Period (LP) and Fat Percentage (FP)

	Traits		
Estimate	MY (kg)	LP (day)	FP (%)
Additive (co) variances			
σ^2_a	40.57046	73.54086	4.96641
σ_a MY with LP or FP	-	-26.67271	13.50665
σ^2_a LP with FP	-	-	-14.00926
Permanent variances and covariances			
σ^2_p	0.473045	241.083	1.94058
σ_p MY with LP or FP	-	-0.939350	-0.194709
σ_p LP with FP	-	-	-20.7095
Environmental variances and covariances			
σ^2_e	78.70277	349.81585	5.81169
σ_e MY with LP or FP	-	-34.98774	17.99957
σ_e LP with FP	-	-	-31.78706
Heritability and repeatability estimates			
h^2	0.33	0.11	0.39
t	0.34	0.47	0.54
Genetic correlations			
r_G MY with LP or FP	-	-0.49	0.95
r_G LP with FP	-	-	-0.73
R^2	0.406	0.042	0.221
-2 log L = 7939	-	-	-

σ^2_a = Additive genetic variance; σ_a = Additive genetic variance, σ^2_p = Permanent environmental variance, σ_p = Permanent environmental covariance, σ^2_e = Temporary environmental variance, σ_e = Temporary environmental covariance, -2 log L = log likelihood, h^2 = heritability, t = repeatability, r_G = genetic correlation, R^2 = determination coeefficient

Table 4: Range of predicted Cows' Breeding Values (CBV's), Sires (SBV's) and Dams (DBV's) their accuracy for MY, LP and FP

	Traits		
	MY (kg)	LP (day)	FP (%)
CBV's			
Min.	-3006	-10.80	-1.48
Max.	1724	14.20	0.96
Range	4730	25	2.44
Accuracy	0.76-0.80	0.45-0.61	0.59-0.79
SBV's			
Min.	-1129	-8.60	-0.68
Max.	862	5.70	0.82
Range	1991	14.3	1.50
Accuracy	0.38-0.90	0.47-0.59	0.66-0.88
DBV's			
Min.	-1628	-5.69	-0.76
Max.	862	7.70	0.47
Range	2490	13.39	1.23
Accuracy	0.38-0.43	0.22-0.30	0.42-0.60

yield was obtained from 1984 year. On account of milk yield was occurred considerable differences until from 1984-1996. This might have resulted from effect of improvement level performed along the years in herd. The highest milk yield was obtained from winter season and the differences between winter and spring season was not statistically significant. Likewise, the lowest milk yield was determined to summer season and the differences between summer and spring season was not statistically significant. The differences between summer, spring and autumn, winter seasons were statistically significant ($p<0.01$). Increase in the milk yield of animals giving birth to the winter and spring seasons can be due to excessive green feed crops in the spring season and an applying of feed diet by concentrated feed in the winter season. The effect of age and parity on milk yield was statistically significant ($p<0.05$, $p<0.01$). The effect of investigated traits on lactation period was not statistically significant. The effect of year on fat percentage was statistically significant ($p<0.01$) and other traits not significant.

The heritability estimates in this study for MY, LP and FP were 0.33, 0.11 and 0.39, respectively (Table 3). The present estimate was higher than Espinoza *et al.* (2007) findings for MY as 0.14-0.17, Wiggans *et al.* (2002) findings for MY for Brown Swiss as 0.29, for FP as 0.26, Rosati and Van Vleck (2002) findings for Buffalo as 0.23 for MY and as 0.14 for FP, Ilatsia *et al.* (2007) findings for MY as 0.16 and for LP as 0.07, Ojango and Pollott (2001) findings for MY as 0.29 and for LP as 0.087, similar to Atil *et al.* (2001) finding for LP as 0.13, lower than Costa *et al.* (2008) finding as 0.32 for 305 day LP and Atil *et al.* (2001) finding for MY as 0.38.

Low h^2 estimates for LP (0.11) indicate that this trait is affected by environmental factors. Improvement of herd management, feeding, service period, arrangement of heat, proper milking, inseminated at proper time of animals by good quality semen would help in improving of LP. Medium h^2 estimates for MY and FP indicates that these traits can be improved by mass selection in addition to increased level of environmental conditions.

The repeatability estimates in this study for MY, LP and FP were 0.34, 0.47 and 0.54, respectively (Table 3). Repeatability estimates were higher than Ojango and Pollott (2001) for FP as 0.11, (Meyer *et al.*, 1994) for MY as 0.228 for Hereford, Sawalha *et al.* (2005) as 0.36 for fat, as

0.52 for MY, lower than Paura *et al.* (2002) finding for MY and higher than for FP; Wiggans *et al.* (2002) for Brown Swiss as 0.47 for MY, as 0.42 for fat, Ilatsia *et al.* (2007) finding for MY as 0.49 and lower than for LP as 0.40, similar to Ojango and Pollott (2001) for MY as 0.34. The highest repeatability was obtained by FP. According to this, It is possible that to say sufficiently reliable of using to fat percentage at first lactation for early selection of animal.

The results in Table 3 show that the genetic correlation between MY and FP was positive and high (0.95), MY and LP was negative and medium (-0.49) and LP and FP was negative and high (-0.73). This result similar to Ozcelik and Dogan (1999) findings for MY and LP Genetic correlation as -0.16, Atil *et al.* (2001) findings for MY and FP as 0.43, different from Farhangfar *et al.* (2003) findings for MY and FP as -0.69, Rosati and Van Vleck (2002) findings for MY and FP as -0.08.

This result indicates that high yielding cows may have the capacity for high FP. The genetic correlation between MY and LP was negative, indicating cows with increased genetic capacity for LP may have lower capacity for MY. Similarly, cows with longer lactation periods may have lower capacity for FP. Based on these results, selecting animals based on longer lactation periods and higher milk yield can be difficult. However, selection using both milk yield and fat percentage should be simple and effective. Although, these are contrary to the expectations based on phenotypic observations, many times genetic correlations can be different than phenotypic correlations, even in the sign.

Estimates of minimum and maximum Predicted Breeding Values (PBV) and their accuracies for MY, LP and FP estimated from Cow Breeding Values (CBV'S), Sire Breeding Values (SBV'S) and dam breeding values (DBV'S) are given in Table 4.

Breeding values were calculated from 203 cows, fathered by 40 sires and mothered by 182 dams. Estimates of minimum and maximum predicted Breeding value and their accuracies for milk yield ranged from -3006 and 1724, 0.76-0.80 for cows; -1129 and 862, 0.38-0.90 for sires; -1628 and 862, 0.38-0.43 for dams, for lactation period ranged from -10.80 and 14.20, 0.45-0.61 for cows; - 8.60 and 5.70, 0.47-0.59 for sires; - 5.69 and 7.70, 0.22-0.30 for cows; for fat percentage ranged from -1.48 and 0.96, 0.59-0.79 for cows; - 0.68 and 0.82, 0.66-0.88 for sires; - 0.76 and 0.47, 0.42-0.60, respectively (Table 4). Obtained BV in this study for MY was higher than Espinoza *et al.* (2007) and Peixoto *et al.* (2006) findings.

Results in Table 4 show the importance of cow, since it gave the higher range of breeding value for MY, LP and FP. Thus, selection of cows for the next generation would lead to higher genetic improvement in the herd for these traits. Moderate improvement can be obtained with mass selection for milk yield and fat percentage because of the heritability value as 0.33 and 0.39, respectively. Also, the accuracy of the estimates of cow breeding value was higher than the accuracy of dam and sire breeding values, which may be due to the higher number of cows than dam and sire number.

CONCLUSION

This model caused the greatest differences between genetic and residual correlations, the highest heritability values for the milk yield and fat percentage, the highest values of EBV's difference for the best and worst cows, as well as the greatest correlation among estimated genetic values. The present estimates showed large genetic differences between cows for different traits for milk yield and fat percentage, which indicate the high potential for rapid genetic improvement in milk traits of Brown Swiss cattle in Turkey through selection. So, the results presented here show that the multiple trait animal models could be used appropriately for genetic evaluation of milk yield, lactation period and fat percentage for Brown Swiss cattle in Turkey.

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