Estimation of genetic parameters and genetic trend for test day records of milk protein percentage trait in Holstein cows at first three lactations

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Abstract: This study estimated variance-covariance components, heritability of milk protein percentage test day records as well as genetic correlation among them using Animal Model methodology. Data were from a farm Holstein cows of Esfahan State having their three first calving from years 1991-2009. During the first three lactations these test day records were 46125, 35480 and 23825 respectively. Genetic analysis carried out using WOMBAT 1(© Karin Meyer 2006–2010). Years-calving season (YS) factor was defied as fixed effect while effects of age at calving as covariate and direct additive genetic effect as random were used. Results show that the lowest and the highest amount of additive genetic variance were at the first and the second half of lactation, respectively and the lowest amount of residual variance were at the second half of lactation. Also, Heritability at the second half of first lactation was higher than the first part. Estimated heritability at the third lactation in the repeatability model was lower than other models. Estimated genetic trend for first, second and third lactation were -0.139, -0.147 and -0.160 respectively.

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1. Introduction

In carrying out genetic evaluations and solving problems of data analysis, there are many situations for which it would be desirable to define a large number of highly correlated traits. For instance, yields of milk, fat, and protein measured on each day of lactation should be considered as different traits. In fact, evaluation of test day yields has become increasingly popular because it accounts for environmental effects more accurately (Veerkamp and Goddard, 1998).

Test day models (TDM) have been receiving considerable attention from research studies on the genetic improvement of dairy cattle (Gengler et al., 1999; Kettunen et al., 2000; Misztal et al., 2000; Schaeffer et al., 2000; Swalve, 2000; Jensen, 2002; Lopez-Romero and Carabano, 2003; Mrode and Swanson, 2004; Fischer et al., 2004; Schaeffer, 2004; Albuquerque and Meyer, 2005).

Strabel and Szwaczkowski (1997) reported that heritability of milk yield, fat yield, fat percentage, protein yield and protein percentage traits are 0.27, 0.22, 0.25, 0.18 and 0.20 respectively, based on test-day records of black and white Holstein cows. Permanent environmental effects of these traits were 0.45, 0.47, 0.25, 0.20 and 0.11 respectively.

Estimated breeding values (EBV) for production traits of Finnish dairy cattle have been calculated using a single trait repeatability animal model since 1990 (Strandén and Mantysaari, 1992).

Strabel and Jamrozik (2006) used a random regression test day model to estimate genetic parameters for milk, fat, and protein yield in the first three lactations of Polish Black and White cattle. They had three data sets with slightly different edits on minimal number of days in milk and on the size of herd-year subclasses. Each data subset included more than 0.5 million test-day records of more than 58 000 cows. The authors reported higher heritability of 305-days milk yield (0.18, 0.16, 0.17 in lactations 1, 2 and 3, respectively) than those for fat yield (0.12, 0.11, 0.12) and protein yield (0.13, 0.14, 0.15).

Abdullahpour et al.(2010) estimated heritability were ranged 0.13-0.21, 0.07-0.11 and 0.11-0.18 for milk, fat and protein percentages of Iranian first lactation Holstein cattle, respectively.

In order to estimation of genetic yield traits parameters, heritability of milk, fat and protein yield traits were reported 0.24, 0.16 and 0.16, respectively, using a teat-day model (Swalve, 1995). Weller and Ezra (2004) estimated Genetic and environmental correlations and heritability's protein yield from the multi-trait animal model. (Table 3).

Aims of this study are as follows: estimation of covariance components, coefficients of heritability in various lactation states and various lactations, estimation of genetic and phenotype correlations among various lactation states and various lactations.

2. Material and Methods

The pedigree structure is listed in Table 1.

The statistical summary test day records are listed in Table 2.

Table 1: Pedigree structure

	Test day									
	1	2	3	4	5	6	7	8	9	10
No. of sires	484	479	478	480	479	475	470	464	460	430
... with progeny in the data	403	402	406	404	408	404	396	397	386	356
No. of dams	4362	4380	4470	4481	4499	4473	4431	4359	4132	3370
... with progeny in the data	3466	3513	3626	3627	3675	3628	3578	3532	3252	2277
No. of animals with known/unpruned grand-parents										
... with maternal grand sire	6168	6216	6336	6368	6430	6371	6292	6116	5730	4321
... with maternal grand dam	5572	5613	5744	5783	5832	5770	5695	5533	5151	3790

Table 2: Number of records, average days in milk (DIM) and protein percentage records in each test day (TD) and standard errors in the first three lactations.

		Lactation 1			**Lactation 2**			**Lactation 3**		
N0.	**DIM**	**Number**	**Ave.**	**S.E**	**Number**	**Ave.**	**S.E**	**Number**	**Ave.**	**S.E**
1	17	4637	2.97	0.406	3587	3.08	0.438	2527	3.03	0.434
2	47	4638	2.78	0.329	3707	2.80	0.297	2568	2.77	0.281
3	78	4916	2.82	0.312	3807	2.85	0.315	2590	2.83	0.311
4	109	4963	2.89	0.271	3898	2.93	0.316	2587	2.92	0.331
5	139	5068	2.96	0.290	3922	3.00	0.314	2619	3.03	0.330
6	170	4983	3.01	0.312	3777	3.06	0.317	2518	3.03	0.309
7	200	4912	3.06	0.316	3723	3.11	0.325	2439	3.08	0.312
8	229	4812	3.11	0.327	3595	3.19	0.332	2391	3.15	0.316
9	260	4345	3.17	0.334	3289	3.25	0.339	2196	3.23	0.360
10	290	2715	3.21	0.346	2175	3.31	0.358	1390	3.28	0.356
Total		46125	2.99	0.350	35480	3.04	0.367	23825	3.01	0.366

2.1 Test-day model

A monthly record of production traits in dairy cattle is called test-day record. Variance components were estimated by animal model procedure using WOMBAT 1.in order to measure genetic Parameters of milk protein percentage trait, related to test-day records, the following model is used:

$$\mathrm{Y_{ijk}} = \mathrm{ys_i} + \sum_{\mathrm{m=1}}^{2} \mathrm{b_m\, x_{m_{ijk}}} + \mathrm{a_j} + \mathrm{e_{ijk}}$$

Where Y_{ijk}= The Test-day record of the *k*th trait of the *j*th animal in *i*th year-calving season effect. ys_i= Fixed effect of year-calving season, x_1= Random effect of the calving age, x_2= Random effect of the Days in milk, b_1= Coefficient of calving age effect, b_2= Coefficient of days in milk effect, a_j= Random effect additive genetic, e_{ijk}= Random error effect.

2.2 Repeatability Model

These records analyzed based on repeatability method using test-day model and the applied matrix model is as below (Mrode, 2005).

$$Y = Xb + Za + WPe + e$$

Where Y= Vector of observations, b = Vector of fixed effects, a = Vector of random animal effects, Pe = Vector of random permanent environmental effects and non-additive genetic effects, e = Vector of random residual effect and X, Z and W are incidence matrices relating records to fixed, animal and permanent environmental effects, respectively.

2.3 Multi-trait Animal Model

Multi-trait analysis is done using several bivariate and trivariate analysis (Mrode, 2005).

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \end{bmatrix} \begin{bmatrix} x_1 & 0 \\ 0 & x_2 \end{bmatrix} + \begin{bmatrix} a_1 \\ a_2 \end{bmatrix} \begin{bmatrix} z_1 & 0 \\ 0 & z_2 \end{bmatrix} + \begin{bmatrix} e_1 \\ e_2 \end{bmatrix}$$

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix} \begin{bmatrix} x_1 & 0 & 0 \\ 0 & x_2 & 0 \\ 0 & 0 & x_3 \end{bmatrix} + \begin{bmatrix} a_1 \\ a_2 \\ a_3 \end{bmatrix} \begin{bmatrix} z_1 & 0 & 0 \\ 0 & z_2 & 0 \\ 0 & 0 & z_3 \end{bmatrix} + \begin{bmatrix} e_1 \\ e_2 \\ e_3 \end{bmatrix}$$

Where y_i = vector of observations for the *i*th trait, b_i = vector of fixed effects for the *i*th trait, a_i = vector of random animal effects for the *i*th trait, e_i = vector of random residual effects for the *i*th trait, and X_i and Z_i are incidence matrices relating records of the *i*th trait to fixed and random animal effects, respectively.

$$\mathrm{Y_{ijkl}} = \mathrm{TD_i} + \mathrm{Age_k} + \sum_{\mathrm{n=1}}^{5} \mathrm{b_{ln}\, x_{jln}} + \sum_{\mathrm{n=1}}^{5} \mathrm{a_{jln}\, x_{jln}} + \mathrm{Pe_j} + \mathrm{e_{ijkl}}$$

Where Y_{ijkl} = *l*th test day record of *j*th animal in the *i*th test date and *k*th calving age, TD_i = , Age_k =

random effect of the *k*th calving age , b_{ln} = *n*th fixed dependency coefficient trait of DIM functions *j*th animal, a_{jln} = *n*th genetic dependency coefficient trait of *j*th animal in *l*th test day record, x_{jln} = , Pe_j = random permanent environmental effect for *j*th animal , e_{ijkl} = random residual effects for *l*th test day record of *j*th animal in the *i*th test date and *k*th calving age.

$X_1 = DIM/305$

$X_2 = (DIM/305)^2$

$X_3 = \ln(305/DIM)$

$X_4 = \ln(305/DIM)^2$

$X_5 = 305/DIM$

3. Results

By bivariate genetic correlation analysis of milk protein percentage between first and second, first and third and second and third lactation, were 0.986, 0.969 and 0.980, respectively. Also, phenotypic correlation of milk protein percentage between first and second, first and third and second and third lactation, were 0.685, 0.568 and 0.546, respectively and heritability of milk protein percentage trait at first three lactations were 0.515, 0.454 and 0.433, respectively (Table 4).

By trivariate genetic correlation analysis of milk protein percentage between first and second, first and third and second and third lactation, were 0.911, 0.962 and 0.982, respectively. Also, phenotypic correlation of milk protein percentage between first and second, first and third and second and third lactation, were 0.566, 0.518 and 0.486, respectively. Heritability of milk protein percentage trait at first three lactations were 0.520, 0.474 and 0.435, respectively (Table 5).

Table 3: Genetic correlations are above the diagonal, environmental correlations are below the diagonal, and heritability are on the diagonal (Weller and Ezra, 2004).

Lactation	**Lac. 1**	**Lac. 2**	**Lac. 3**
Lac. 1	**0.34**	0.89	0.85
Lac. 2	0.54	**0.29**	0.98
Lac. 3	0.48	0.59	**0.27**

Table 4: Estimates of heritability (on the diagonal), genetic correlations (above diagonal) and phenotypic correlations (below diagonal) of milk protein percentage trait test-day records at 1st, 2ed and 3ed lactations using bivariate analysis

Lactation	**Lac. 1**	**Lac. 2**	**Lac. 3**
Lac. 1	**0.515**	0.986	0.969
Lac. 2	0.685	**0.454**	0.980
Lac. 3	0.568	0.546	**0.433**

Table 5: Estimates of heritability (on the diagonal), genetic correlations (above diagonal) and phenotypic correlations (below diagonal) on test day records for milk protein percentage trait at first three lactations using trivariate analysis

Lactation	**Lac. 1**	**Lac. 2**	**Lac. 3**
Lac. 1	**0.520**	0.911	0.962
Lac. 2	0.566	**0.474**	0.982
Lac. 3	0.518	0.486	**0.435**

Heritability, genetic correlations, phenotypic correlations and standard errors test day records in Holstein cows at first three lactations are given in tables 6, 7 and 8, respectively.

Table 6: Estimates of heritability (on the diagonal), genetic correlations (above diagonal) phenotypic correlations (below diagonal) and standard errors (in the parentheses) on test day records for milk protein percentage in first lactation using multivariate analysis

	TD1	**TD2**	**TD3**	**TD4**	**TD5**	**TD6**	**TD7**	**TD8**	**TD9**	**TD10**
TD1	**0.107 (0.024)**	0.623	0.871	0.707	0.643	0.588	0.624	0.335	0.587	0.596
TD2	0.206	**0.149 (0.023)**	0.670	0.883	0.848	0.770	0.777	0.669	0.765	0.692
TD3	0.091	0.211	**0.206 (0.030)**	0.902	0.910	0.895	0.879	0.734	0.794	0.680
TD4	0.155	0.273	0.382	**0.321 (0.031)**	0.949	0.892	0.892	0.842	0.853	0.805
TD5	0.126	0.253	0.318	0.432	**0.276 (0.029)**	0.977	0.943	0.907	0.946	0.922
TD6	0.112	0.206	0.270	0.310	0.394	**0.244 (0.025)**	0.975	0.879	0.842	0.743
TD7	0.099	0.209	0.338	0.351	0.356	0.402	**0.284 (0.031)**	0.789	0.801	0.791
TD8	0.077	0.199	0.227	0.306	0.334	0.354	0.286	**0.361 (0.032)**	0.971	0.847
TD9	0.096	0.206	0.193	0.305	0.305	0.326	0.321	0.373	**0.325 (0.031)**	0.989
TD10	0.093	0.189	0.196	0.275	0.335	0.107	0.333	0.353	0.198	**0.377 (0.043)**

Table 7: Estimates of heritability (on the diagonal), genetic correlations (above diagonal) phenotypic correlations (below diagonal) and standard errors (in the parentheses) on test day records for milk protein percentage in second lactation using multivariate analysis

	TD1	**TD2**	**TD3**	**TD4**	**TD5**	**TD6**	**TD7**	**TD8**	**TD9**	**TD10**
TD1	**0.153 (0.029)**	0.930	0.900	0.622	0.660	0.615	0.376	0.427	0.547	0.361
TD2	0.342	**0.181 (0.031)**	0.995	0.962	0.998	0.890	0.723	0.821	0.846	0.551
TD3	0.130	0.306	**0.166 (0.029)**	0.990	1.000	1.000	0.879	0.953	0.981	0.795
TD4	0.154	0.382	0.435	**0.267 (0.033)**	0.967	0.999	0.945	0.929	0.911	0.680
TD5	0.117	0.337	0.382	0.427	**0.256 (0.032)**	0.984	0.979	0.908	0.906	0.790
TD6	0.115	0.302	0.511	0.407	0.435	**0.241 (0.033)**	0.942	0.948	0.878	0.849
TD7	0.090	0.300	0.327	0.344	0.414	0.479	**0.251 (0.033)**	0.954	0.991	0.933
TD8	0.071	0.249	0.286	0.310	0.366	0.445	0.252	**0.260 (0.037)**	1.000	1.000
TD9	0.093	0.253	0.288	0.288	0.330	0.510	0.394	0.329	**0.255 (0.037)**	0.941
TD10	0.080	0.213	0.266	0.254	0.296	0.333	0.313	0.407	0.546	**0.274 (0.043)**

Table 8: Estimates of heritability (on the diagonal), genetic correlations (above diagonal) phenotypic correlations (below diagonal) and standard errors (in the parentheses) on test day records for milk protein percentage in third lactation using multivariate analysis

	TD1	**TD2**	**TD3**	**TD4**	**TD5**	**TD6**	**TD7**	**TD8**	**TD9**	**TD10**
TD1	**0.101 (0.031)**	0.980	0.998	0.982	0.864	0.844	0.997	0.799	0.684	0.729
TD2	0.324	**0.196 (0.039)**	0.800	0.999	0.863	0.915	0.866	0.835	0.638	0.716
TD3	0.240	0.217	**0.170 (0.037)**	0.997	0.898	0.950	0.870	0.782	0.747	0.799
TD4	0.222	0.448	0.394	**0.183 (0.038)**	0.999	0.935	0.934	0.836	0.909	0.911
TD5	0.156	0.259	0.372	0.370	**0.179 (0.038)**	0.921	1.000	0.999	0.961	0.891
TD6	0.195	0.319	0.301	0.369	0.433	**0.233 (0.043)**	1.000	0.954	0.998	0.988
TD7	0.112	0.308	0.322	0.355	0.446	0.486	**0.261 (0.044)**	1.000	0.918	0.989
TD8	0.231	0.296	0.313	0.296	0.352	0.400	0.424	**0.305 (0.039)**	0.997	0.988
TD9	0.184	0.288	0.210	0.205	0.254	0.291	0.244	0.569	**0.242 (0.048)**	1.000
TD10	0.153	0.212	0.250	0.206	0.218	0.319	0.331	0.458	0.449	**0.261 (0.062)**

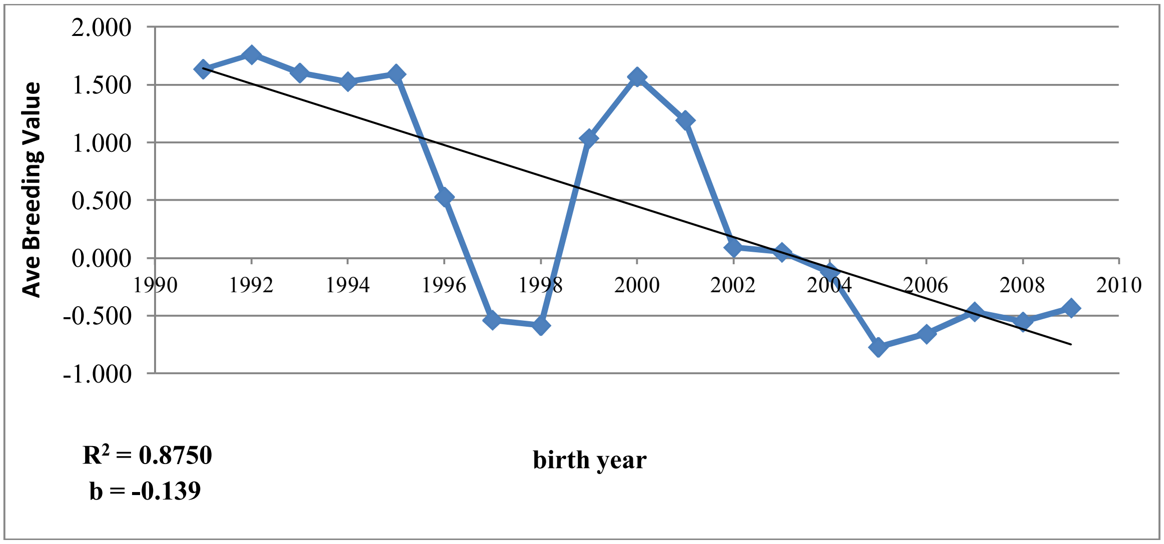

Figure 1: Genetic trend of milk protein percentage for test day records in first lactation (multivariate analyses).

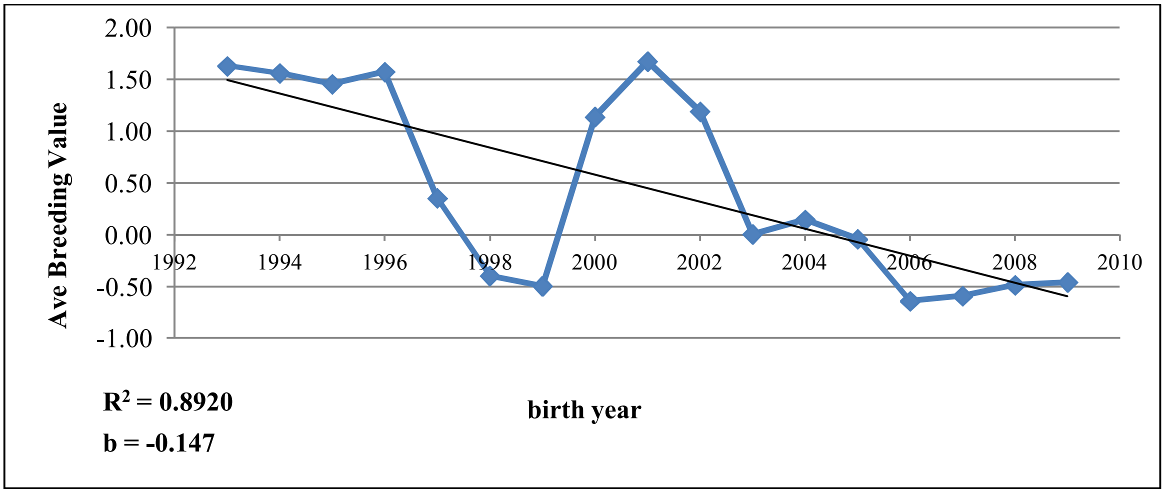

Figure 2: Genetic trend of milk protein percentage for test day records in second lactation (multivariate analyses).

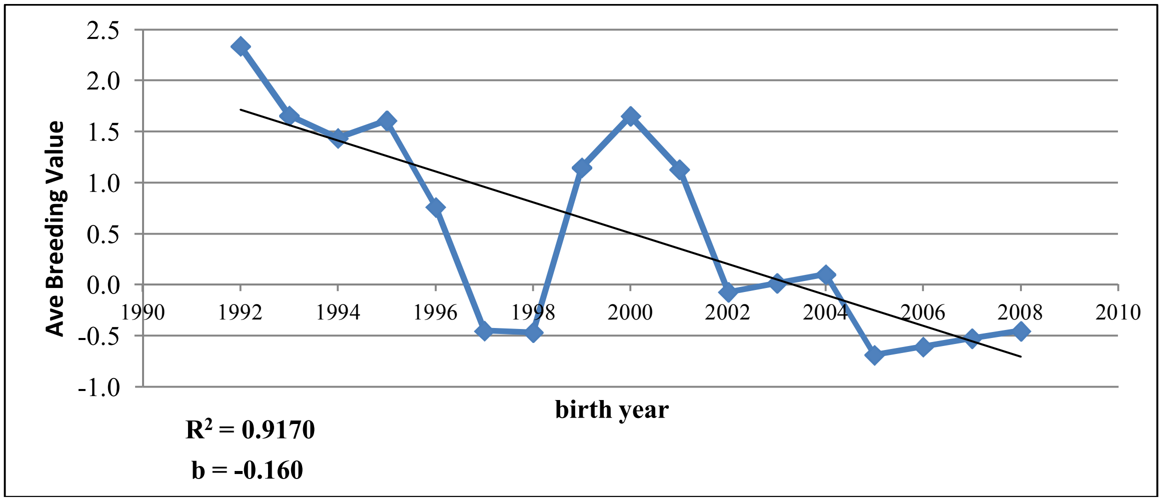

Figure 3: Genetic trend of milk protein percentage for test day records in third lactation (multivariate analyses).

4. Discussion

In this study, in most cases, genetic correlation between each two sequential records was high. At the first lactation, except for correlation between the first and second two sequential records, this parameter was higher than 0.90. At the second and third lactation, genetic correlation between each two sequential records was higher than 0.930 and 0.80, respectively. Heritability of protein percentage trait at first, second and third lactations were 0.515, 0.446 and 0.382 respectively. Also, repeatability of protein percentage trait at first, second and third lactations were 0.797, 0.696 and 0.969 respectively (Table 9). Heritability in this herd was higher of the other studies. Because of the increased amount of additive genetic variance and reduce the amount of environmental variance in a herd.

Table 9: Variance components and genetic parameters of milk protein percentage in test-day records (Repeatability Model)

	Lactation 1	**Lactation 2**	**Lactation 3**
σ_a^2	0.007163	0.0193465	0.0162793
σ_{pe}^2	0.0105042	0.0108592	0.0250470
σ_e^2	0.0187838	0.0132198	0.0013249
σ_p^2	0.036451	0.0434265	0.0426512
h^2	0.515	0.446	0.382
S.E	0.027	0.032	0.041
r	0.797	0.696	0.969

Genetic trend of milk protein percentage for test day records at 1st, 2ed and 3ed lactations using multivariate analyses are given in Figure 1, 2 and 3, respectively. Genetic trend of trait were negative that may be due to selection is based on other production traits like milk production.

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