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Estimates of Repeatability and Heritability of Productive Trait in Holstein Dairy Cattle

Research Article

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ABSTRACT

Dairy cattle breeding programs have been based in the selection for traits related to milk production. In this research a data set of 63 herds of East Azerbaijan province Holstein cattle, collected during 2002-2013 by the Iranian Animal Breeding Center was used to estimate the repeatability and heritability of three traits of economic importance. Genetic parameters for first three lactations of Holstein cows were estimated using repeatability models. Single-trait repeatability models were fitted for milk, fat and protein yields. The model contained milk frequency and herd-year-months of test-days (HTD) as fixed effects; effect of animals were the random effects. The estimated heritabilities in first three lactations for milk yield were 0.154, 0.263 and 0.334, for protein yield 0.134, 0.166 and 0.274 and for fat yield 0.059, 0.083 and 0.052. The estimated repeatability in first three lactations for milk yield were 0.475, 0.847 and 0.898, for protein yield 0.398, 0.479 and 0.678 and for fat yield 0.198, 0.281and 0.279. The results imply that milk traits for Holstein dairy cattle in east Azerbaijan, Iran are more heritable. Therefore, these traits can be employed by breeders as selection criteria in developing effective genetic improvement programs.

KEY WORDS genetic parameters, heritability, Holstein cow, repeatability, yield traits.

INTRODUCTION

Dairy cattle breeding programs have been based on the selection for traits related to milk production, composition and other traits such as conformation, udder health and longevity. Planning efficient breeding programs in animal husbandry requires knowledge of genetic and phenotypic parameters. Two of these parameters are heritability and repeatability. Heritability explains the extent to which observed differences between individuals are associated with additive genetic variance (Adnan *et al*. 2010). This parameter enables animal geneticists to determine whether a particular trait can be improved by selection, or by better management practices, or both. Heritability is defined as the correlation between measurements made on the same animal or plant over time or space (Lush, 1937). Repeatability explains how a production trait or parameter measured, keeps a constant value in following measurements in the future (Cilek and Sahin, 2009). Unequal numbers of observations per subclass are frequently seen in animal breeding data. In general, heritability estimates are higher for composition traits than for yields. Differences in the estimates are expected as a result of difference in population, in estimation method, in mathematical method employed and because of sampling errors (Roman *et al.* 2000). Various authors have suggested that models with herd-year-months of test-days (HTD) classes are superior to herd-year-season (HYS) based on residual variance (Meyer *et al.* 1989; Ptak *et al.* 1993; Stanton *et al.* 1992; Strabel *et al.* 1995; Swalve *et al.* 1995).

For dairy cattle improvement, however, prediction of breeding values using an animal model rather than going through computation of separate genetic evaluations for cows and bulls is becoming common. Evaluation is done using a repeatability model, which includes the first five lactation records of cows. The objective of this study was to estimate heritabilities and repeatabilities for milk, fat, protein yields in East Azerbaijan Holstein-Fresian cattle by the restricted maximum likelihood (REML) algorithm using the animal model with repeated records, in Iran.

MATERIALS AND METHODS

Yield records of the first three lactations were extracted from the file of the Iranian East-Azerbaijan Holstein. The cows were part of 63 herds. The data set comprised of information on lactations between years 2002 and 2013. Table 1 shows data and pedigree characteristics for cows. Information included herd, animal identification, month of recording, year of recording, days in milk (DIM), milking frequency and yields (milk, fat, and protein). Lactation was truncated at 305 days and monthly DIM records were obtained between 5 and 305 days after calving, for a total of ten monthly classes of milk yield (Test-day), (TD 1 to 10). Lactation records were required to have only 2 or 3 milking per day and at least 5 test days between 5 and 305 days in milk (DIM).

To determined range for milk, the animals with yield more than 75 liters or less than 1.5 liters per 24 hour were excluded from the study. Also animals reported between 1.5-9% percent fat and 1-7% percent protein were used for analysis. The number of TD records for each trait (milk production, fat yield and protein yield) based on different classes of DIM for lactation 1, lactation 2 and lactation 3 is shown in Figure 1. The basic single trait repeatability model in matrix notation was:

$$Y_{ijkl} = \mu + MF_i + HTD_j + a_k + pe_l + e_{ijkl}$$

Where:

Y_{ijkl}: observed value for all traits (milk yield; fat and protein yields).

μ: overall mean common to all observations.

MF_i: fixed effect of i^{th} milking frequency.

HTD_j: fixed effect of j^{th} herd- year- season;

a_k: random effect of k^{th} animals.

Pe_m: m^{th} permanent environmental effect of cow and e is the random effect of residual.

The following (co)variance structure was assumed for random effects of model:

$$\text{Var}\begin{bmatrix}\beta\\ \gamma\\ e\end{bmatrix} = \begin{bmatrix} A\otimes G & 0 & 0\\ 0 & I_l\otimes P & 0\\ 0 & 0 & I_m\otimes R\end{bmatrix}$$

Where:

G, P and R: variance components for direct genetic, permanent environmental and residual effects, respectively.

A: additive genetic relationship matrix.

I_l: identity matrix of size l × l for the permanent environmental effect (l is the number of cows with records).

I_m: identity matrix of size m × m for the residual (m is the number of test-day records).

⊗ : direct product operator.

The ration of the between-individual component to the total phenotypic variance measures the repeatability (r^2) of the character:

$$r^2 = \frac{\delta^2_a + \delta^2_{pe}}{\delta^2_a + \delta^2_{pe} + \delta^2_e}$$

The ration of the additive genetic variance to the total phenotypic variance is called the co-efficient of heritability:

$$H^2 = \frac{\delta^2_a}{\delta^2_a + \delta^2_{pe} + \delta^2_e}$$

Where:

δ^2_α, δ^2_{Pe} and δ^2_e: additive genetic variance, permanent environment variances and residual variance respectively.

Consistency of the data was performed by EXCEL, VISUAL FOXPRO and WOMBAT software. Repeatability model were used for the analysis of milk, fat and protein yield.

RESULTS AND DISCUSSION

In this study, genetic parameters were estimated for milk yield, protein yield and fat yield trait for first three lactations using data from East Azerbaijan Holstein Friesian cows, Iran. Overall means, numbers and standard deviation of test day (TD1-10) for milk, fat and protein production related to the first three lactations are given in Table 2. According to Table 2, the maximum milk production was measured in lactation 3 (28.79 kg average). In all three lactations, the peak and minimum milk production occurred at TD2 and TD10, respectively. Several reasons may account for maximum milk production at TD2. For fat yield, TD2 and TD10 in lactation 1 had the maximum and minimum amounts, respectively.

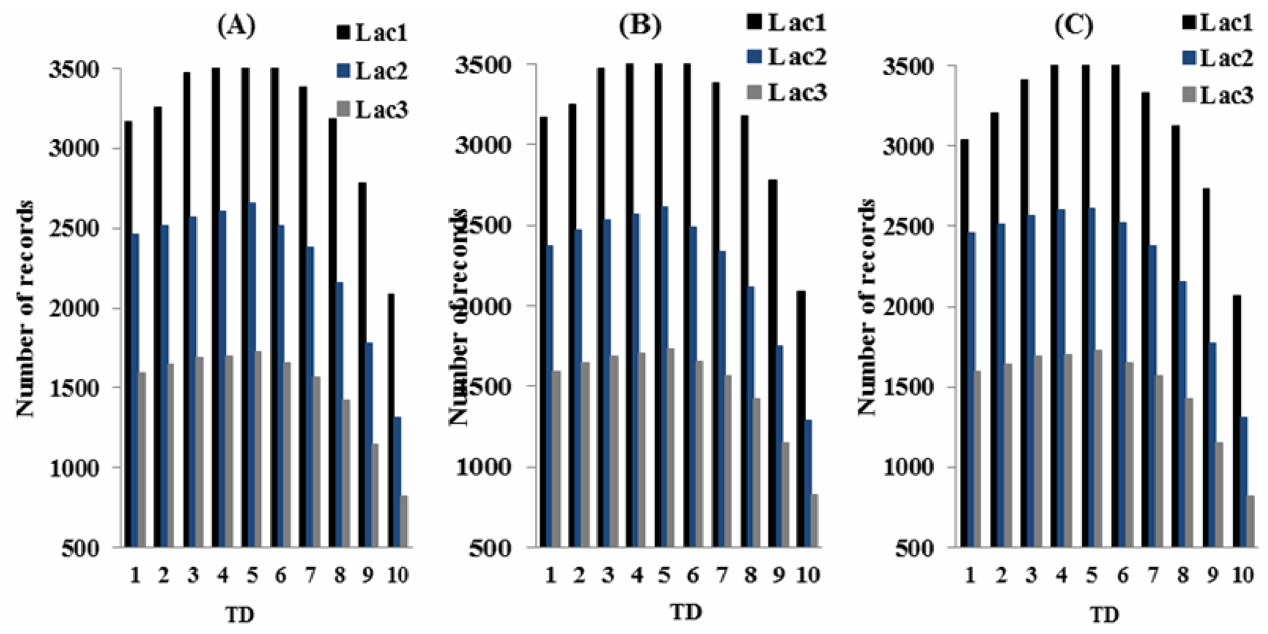

Figure 1 Number of records for milk (A), fat (B) and protein (C) yields among different test days (TD) of the first three lactations

In lactation 2, TD1 and TD10 had the maximum and minimum amounts, respectively. In lactation 3, TD7 and TD5 yielded maximum and minimum amounts, respectively.

Table 1 Data and pedigree characteristic

Number of herds	63
Number of records	6719
No. of animals with records	3884
No. of animals with 5 records	334
No. of animals with 6 records	359
No. of animals with 7-10 records	3179
No. of animals with11-20 records	12
No. of sires	753
No. of dams	3036
No. of animals with records and progeny in data	801

Estimates of variance components, heritability (h^2), ratio of variance due to permanent environmental effects on total phenotypic variance (σ_{pe}^2) and repeatability (r^2) for the traits in first three lactations are presented in Table 3. According to Table 3, estimates for phenotypic variance, permanent environmental variances and residual variances for milk yield, protein yield and fat yield in all three lactations have an increasing trend. Likewise, additive genetic variances estimated by repeatability model for milk yield and protein yield in all three lactations show an increasing trend. But additive genetic variances estimated for fat yield followed a different pattern, with lactation 1 and lactation 2 showing the minimum and maximum amounts. According to the Table 3, analysis of traits using repeatability model showed low estimates of heritability for fat yield, with lowest amount of 0.052 in lactation 3 and highest amount 0.083 in lactation 2. The highest estimates for milk and protein yield were in third lactation. Estimates of repeatability for fat production yielded the lowest amount (0.19) in lactation 1 and the highest (0.28) in lactation 2. Finally, the repeatability estimates (r^2) for milk and protein gives the maximum and minimum estimates in third and first lactations, respectively.

Estimates of heritability from univariate analysis for milk and fat yield traits in Iranian Holstein cattle in lactations 1, 2 and 3 were 0.27, 0.23 and 0.14 for milk yield and 0.23, 0.21 and 0.14 for fat yield, respectively. The heritability and repeatability estimates from repeated-record analysis were 0.22 and 0.47 for milk yield, and 0.22 and 0.43 for fat yield, respectively.

Pooled estimates of genetic parameters from bivariate analysis for the first and second lactations were similar to the corresponding univariate estimates (Safijahanshahi *et al.* 2003).

Average heritabilities for Holstein cows in Japan by the DFREML algorithm using the animal model with repeated records were 0.30, 0.30 and 0.26 for milk, fat and protein yields respectively. Also average repeatability was 0.54 for milk yield and was 0.52 for fat and protein yields (Suzuki *et al.* 1994).

The h^2 estimate for milk and fat yield in the Khorasan Razavi province Holstein cows using repeatability model was 0.21 and 0.15. The repeatability (r^2) estimates for milk and fat yield were 0.46 and 0.35, respectively (Amini *et al.* 2011). Estimated values for heritability in the Markazi province Holstein cattle for milk production, fat yield and fat percentage were 0.20, 0.23 and 0.32, respectively.

Table 2 Summary of the data structure, number of animals (N), mean and standard deviation (SD) for first three lactations from TD1 to TD10 for milk, fat and protein yield

Lac 1	Milk			Fat			Protein		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
TD1	3172	28.02	7.05	3170	0.89	0.28	3041	0.89	0.24
TD2	3261	29.29	7.08	3255	0.90	0.29	3211	0.92	0.25
TD3	3477	28.62	7.07	3474	0.88	0.28	3412	0.90	0.25
TD4	3572	27.95	7.02	3570	0.86	0.28	3508	0.89	0.25
TD5	3656	27.24	7.14	3653	0.84	0.28	3591	0.88	0.25
TD6	3584	26.39	7.09	3584	0.83	0.28	3529	0.86	0.24
TD7	3388	25.81	7.15	3383	0.82	0.27	3336	0.84	0.25
TD8	3183	25.11	6.91	3178	0.80	0.26	3125	0.82	0.23
TD9	2780	24.21	9.94	2779	0.78	0.26	2735	0.79	0.23
TD10	2088	23.84	6.96	2086	0.77	0.27	2065	0.78	0.23
Total	32163	26.64	7.34	32104	0.83	0.27	32163	0.85	0.24
Lac 2									
TD1	2459	33.53	8.43	2373	1.05	0.33	2459	1.07	0.29
TD2	2515	34.04	8.80	2475	1.04	0.35	2515	1.07	0.30
TD3	2570	32.56	8.71	2531	1.00	0.35	2570	1.03	0.30
TD4	2604	31.05	8.55	2567	0.97	0.33	2604	0.99	0.29
TD5	2662	29.52	8.84	2610	0.93	0.33	2610	0.93	0.28
TD6	2518	27.99	8.32	2485	0.88	0.31	2518	0.92	0.28
TD7	2378	26.76	8.12	2338	0.85	0.30	2378	0.87	0.27
TD8	2156	24.78	7.93	2114	0.80	0.29	2156	0.81	0.27
TD9	1777	23.68	7.75	1753	0.77	0.27	1777	0.77	0.26
TD10	1311	22.81	7.82	1294	0.75	0.28	1311	0.74	0.26
Total	22950	28.67	8.32	22950	0.90	0.31	22950	0.92	0.28
Lac 3									
TD1	1592	34.27	8.99	1592	1.03	0.34	1592	1.09	0.30
TD2	1642	34.81	9.16	1642	0.97	0.34	1642	1.09	0.31
TD3	1691	32.85	9.06	1691	0.89	0.30	1691	1.04	0.31
TD4	1704	31.11	8.79	1704	0.82	0.28	1704	1.00	0.29
TD5	1730	29.28	8.44	1730	0.75	0.26	1730	0.94	0.29
TD6	1652	28.14	8.59	1652	1.01	0.38	1652	0.91	0.29
TD7	1569	26.33	8.06	1569	1.06	0.35	1569	0.85	0.27
TD8	1425	24.88	8.10	1425	0.97	0.33	1425	0.81	0.27
TD9	1149	23.51	7.85	1149	0.89	0.32	1149	0.77	0.26
TD10	824	22.73	8.03	824	0.80	0.32	824	0.75	0.27
Total	14978	28.79	8.50	14978	0.91	0.32	14978	0.92	0.28

Lac 1: lactation 1; Lac 2: lactation 2 and Lac 3: lactation 3.

Table 3 Estimates of variance components and genetic parameters for first three lactations for milk, fat and protein yield

Estimate trait	δ^2_P	δ^2_α	δ^2_{Pe}	δ^2_e	h^2	r^2
Lactation 1						
Milk yield	32.460	5.024	10.421	17.015	0.154	0.4758
Protein yield	0.033	0.004	0.008	0.0207	0.134	0.398
Fat yield	0.046	0.002	0.006	0.037	0.059	0.198
Lactation 2						
Milk yield	151.77	39.939	88.634	23.201	0.263	0.847
Protein yield	0.0747	0.0124	0.0234	0.032	0.166	0.479
Fat yield	0.0734	0.006	0.0145	0.052	0.083	0.281
Lactation 3						
Milk yield	249.52	83.381	140.76	25.383	0.334	0.898
Protein yield	0.109	0.031	0.044	0.035	0.274	0.678
Fat yield	0.082	0.004	0.018	0.058	0.052	0.279

Also estimates of repeatability for milk production, fat yield and fat percentage were 0.46, 0.39 and 0.40 respectively (Razavi *et al*. 2007).

Abdallah *et al*. (2000) reported repeatability of 0.25 and 0.28 for milk production and fat yield and heritability of 0.25 and 0.28, respectively, for milk production and fat yield in six experimental dairy herds of north Carolina. According to the results of Dematawewa and Berger (1998), the heritabilities for milk, fat, and protein were 0.2, 0.18 and 0.18, respectively. The corresponding repeatabilities were 0.42, 0.41 and 0.41, respectively.

In a study, Teimurian *et al.* (2011) reported that the heritability of milk and fat yield were 0.21 and 0.17, and the repeatability estimates for these traits were 0.47 and 0.36, respectively. Heritabilities for milk yield, fat yield and fat percentage were 0.29, 0.27 and 0.39 respectively and their repeatabilities were 0.33, 0.32 and 0.39 respectively in Holstein-Friesian cows enrolled in the Moroccan official milk-recording program (Boujenane, 2002). Visscher and Thompson, (1992) through the analysis of animal repeatability model reported the estimates of repeatability for milk and fat yield at 0.56 and 0.53 respectively. Heritability estimated for first lactation in Holstein cows with the repeatability model was 0.27 and the coefficient of repeatability for first lactation was 0.66 for milk yield (Laureano *et al.* 2011). In our study, Estimate of heritability for milk production overall in first three lactations is in general agreement with those reported by others (Safijahanshahi *et al.* 2003; Suzuki *et al.* 1994; Amini *et al.* 2011; Razavi *et al.* 2007; Abdallah *et al.* 2000; Dematawewa and Berger 1998; Teimurian *et al.* 2011; Boujenane, 2002; Visscher and Thompson, 1992; Laureano *et al.* 2011). Estimate of heritability for fat yield overall in first three lactations is in general agreement with those reported by others (Safijahanshahi *et al.* 2003; Amini *et al.* 2011; Razavi *et al.* 2007; Abdallah *et al.* 2000; Dematawewa and Berger 1998; Teimurian *et al.* 2011; Boujenane, 2002; Visscher and Thompson, 1992; Laureano *et al.* 2011), though higher estimates have been reported by some authors (Suzuki *et al.* 1994).

In this study, Low heritability estimates for protein yield in first three lactations (0.059, 0.083 and 0.05) were not in the range of 0.18-0.26 published in other works (Suzuki *et al.* 1994; Dematawewa and Berger 1998). Here, higher heritability estimate in third lactation both for milk and fat production than in first and second lactations indicates that selection for milk and fat production in third lactation would be more effective than first and second lactations. Repeatability estimates for milk production in first lactation (0.47) were consistent with the values reported in literatures (Safijahanshahi *et al.* 2003; Suzuki *et al.* 1994; Amini *et al.* 2011; Razavi *et al.* 2007; Dematawewa and Berger 1998; Teimurian *et al.* 2011; Boujenane, 2002; Laureano *et al.* 2011) with a repeatability of 0.66 for milk production in Holstein cows in Sa˜ o Paulo, Brazil which was higher than the value estimated in our study and also Abdallah *et al.* (2000) and Boujenane (2002) reporting a repeatability of 0.25 and 0.32 respectively for milk production which was lower than the value estimated in our study. Repeatability estimates for milk production in second and third lactation were higher than the values estimated in the literature (Safijahanshahi *et al.* 2003; Suzuki *et al.* 1994; Amini *et al.* 2011; Razavi *et al.* 2007; Abdallah *et al.* 2000; Dematawewa and Berger, 1998; Teimurian *et al.* 2011; Boujenane, 2002; Visscher and Thompson, 1992; Laureano *et al.* 2011). In our study, the repeatability estimates for fat yield in the first three lactations (0.39, 0.47 and 0.67) are in general agreement with those reported by others (Safijahanshahi *et al.* 2003; Suzuki *et al.* 1994; Amini *et al.* 2011; Razavi *et al.* 2007; Dematawewa and Berger, 1998; Teimurian *et al.* 2011; Visscher and Thompson, 1992; Laureano *et al.* 2011) though lower estimates have been reported by some authors (Abdallah *et al.* 2000; Boujenane, 2002). Low heritability estimates for protein yield in the first three lactations (0.19, 0.28, 0.28) in our study were not in the range of 0.40-0.41, published in literature (Suzuki *et al.* 1994; Dematawewa and Berger, 1998). Not many researches have been performed on the estimation of protein, so few comparisons can be done. Repeatability estimates for the studied traits were close to higher than previously published heritability estimates. Therefore, the accuracy of selection for these traits especially milk and fat on the first lactation should be medium, as repeatability measures correlation between performance records in different calving of the cow. This parameter indicates the existence of a high degree of association between the milk productions measures obtained during the different period of first lactation of a cow; higher heritability estimates for fat and milk in our study indicates that selection for milk would be more effective than fat. The repeatability model considers genetic variances to be constant through the lactation. The coefficient of repeatability for milk production and fat yield was high, and this parameter indicates the existence of a high degree of association between the milk production and fat yield obtained during the different period of first three lactations. Heritability estimates for yields using repeatability animal models in first lactation are lower than in second and third lactation in the three traits. Heritability estimates of milk production and fat yield using an animal model were in the range of those previously reported in the literature. Visscher and Thompson (1992) suggested that some differences in estimates of genetic variances may be due to types of relatives contributing to parameter estimates (Zishiri *et al.* 2013). Dong *et al.* (1988) recognized that ignoring existing relationships resulted in reduced REML estimates of genetic variance. Thus, higher estimates of heritability might result more precise pedigree data could be used. The low estimates for heritabilities and repeatabilities of protein yield in all three lactation in this research imply that selection based on this trait may result in slow genetic improvement in production efficiency in east Azarbaijan Holstein cows. Therefore, improvement of non-genetic factors in the flocks such as cow nutrition before mating and late pregnancy can lead to the improvement of these characteristics. Milk production had higher heritability and repeatability than fat yield, thus this trait should be considered as a useful criterion in a selection program to improve production efficiency. In general, the higher heritability of a trait, the higher the accuracy of selection and the greater possibility to make genetic GAIN THROUGH SELECTION.

CONCLUSION

According to the results of this study the high estimates for heritabilities and repeatabilities of milk production, fat and protein yield obtained in this research imply that selection based on these traits may result in speed genetic improvement in production efficiency in Holstein cow. Differences in the estimates are expected as a result of differences in populations, in estimation methods, in the mathematical models employed.

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