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Analysis of Test Day Milk Yield by Random Regression Models and Evaluation of Persistency in Iranian Dairy Cows

Research Article

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ABSTRACT

Variace / covariance components of 227118 first lactaiom test-day milk yield records belonged to 31258 Iranian Holstein cows were estimated using nine random regression models. Afterwards, different measures of persistency based on estimation breeding value were evaluated. Three functions were used to adjust fixed lactation curve: Ali and Schaeffer (AS), quadratic (LE3) and cubic (LE4) order of Legendre polynomial but for random effects, unequal order of Legendre polynomials (LE3, LE4, LE5 and Ali and Schaffer) functions were evaluated. Heterogeneous residual variance considered during days in milk and evaluation of models was based on eigenvalues and associated eigenvectors and residual variance. Model with Ali and Schaeffer function for fixed part and LE3 and LE4 for additive and permanent environmental effects was selected as the best model for random regression analysis in first parity dairy cows. The highest and lowest heritability were observed in the middle (0.29) and beginning (0.08) of lactation, respectively. Persistency measurement proposed by Cobuci (PSY_1) (difference between estimation breeding value between 290 and 90 days) was preferential for using in further genetic evaluations for persistency in milk yield of Iranian Holstein cows.

KEY WORDS estimation breeding value, Legendre polynomial, persistency, random regression.

INTRODUCTION

Nowadays, genetic evaluation of dairy cows using day milk yield test and random regression method has been officially adopted in several countries (Jensen, 2001). The use of test day records in random regression method has several benefits including flexibility to account for the environmental and genetic components of the shape of lactation curve (Costa *et al.* 2008), reducing generation interval and cost of recording by making fewer measurements, increasing the accuracy of genetic evaluation, direct correction for fixed effects (especially of fixed effects whose impact change along lactation trajectory) (Swalve, 2000) and allowing curve to be estimated for each lactation of every cow. Kirkpatric *et al.* (1994) demonstrated the use of Legendre polynomial (LE) in modeling the covariance structure of test day records for additive genetics and permanent environmental effects. The order of the Legendre polynomial in the random regression model is important in that estimates of genetic parameters can differ. Moreover, the order of Legendre polynomial does not need to be equal for additive genetics and permanent environmental effects (Liu *et al.*

2006). Based on the shape of the lactation curve after peak, it is possible to describe the potential of maintaining the level of milk production or persistency. Nowadays calculation of persistency is based on by-products of random regression test day model.

Persistency of lactation is ability of animal to continue producing milk at a high level after the peak of lactation (Jamrozik and Schaeffer, 1997). In other words, high persistency is associated with a slow rate of decline in production and in this situation the lactation curve would be flatter. Cows with higher persistency use better and cheaper roughage around peak yield (Sölkner and Fuchs, 1987), improvement of health (less metabolic stress) and fertility (Zimmermann and Sommer, 1973). It's better to calculate persistency in primiparous cows because first parity cows showed an initial and peak milk yield lower than second and third parity cows, however together with greater persistency (Togashi *et al.* 2008).

There is no clear consensus on the best way of measuring persistency but generally it refers to the rate of decline in production after peak milk yield (Dzomba *et al.* 2010). Grossman *et al.* (1999) and Gengler (1996) classified persistency measures into three groups: 1) measures based on ratios of yield 2) measures based on variation of test day yields and 3) measures developed by mathematical lactation curve function.

According to Jakobsen *et al.* (2002) a good persistence measure should have high heritability and it must be uncorrelated with 305 d yield because there is antagonist relationship between persistency and 305 d yield. Biassus *et al.* (2010) evaluated some measures of persistency using higher order of Legendre polynomials and reported that persistence measurement proposed by Jakobsen *et al.* (2002) [it was based on partial estimation breeding value from 106 to 205 d subtracted by partial estimation breeding value from 6 to 105 d] is useful for further genetic evaluation for milk yield persistency.

The lower the genetic correlation between persistence measures and EBV_{305} d milk yield, the better the evaluation of persistency. This means that animals with higher estimation breeding value (EBV) for persistency are not necessarily the same as those with larger EBV for this trait (Cobuci *et al.* 2007). Togashi and Lin (2006) showed that the first three eigenvector of additive covariance matrix are enough to maximize milk yield and genetic response for persistency together.

The object of this study was the evaluation of different unequal order of LE and parametric function of Ali and Schaeffer for fixed and random effects in random regression analysis, finding the optimal model for genetic evaluation and comparison of different measures based on EBV for describing persistency of lactation in Iranian primiparous Holsteins.

MATERIALS AND METHODS

The originally used data included 298990 records of test day milk yield of primiparous Holstein in Iran. The number of records per cow was from 3 to 10, three milking per day, both parents were known and age at calving was between 18 and 29 month. The contemporary groups (CG) were defined by grouping the variables herd, year and season of milk production. After editing, data were 227118 test day records for milk yield of 31258 first cows calved from 1999 to 2008. The structure of data set and pedigree after editing is summarized in Table 1.

Table 1 Description of the dataset

No. of cows	31258	No. of records	227118
No. of sire	2064	No. of CG	8597
No. of dam	28887	Average No. (progeny/sire)	15.14
Year of calving	1999-2008	Average No. (progeny/dam)	1.08
Age at calving:		**Milk yield:**	
Average (day)	742.68	Average (kg)	28.88
SD (day)	43.52	SD (kg)	7.05
Maximum (day)	931	Maximum (kg)	64.60
Minimum (day)	542	Minimum (kg)	2.10

CG: contemporary group and SD: standard deviation.

Models

Several different functions have been applied for fixed regression model as well as additive and permanent environmental effects including Ali and Schaeffer (AS) and different unequal orders of Legendre polynomial. Table 2 shows the characteristics of the models used for different random regression analysis.

Table 2 Characteristics of the order of Legendre or functions used for fixed and random regression effects

Model	Fixed regression	AD	PE
LE334	3	3	4
LE434	4	3	4
AS34	AS	3	4
LE345	3	4	5
LE445	4	4	5
AS45	AS	4	5
LE356	3	5	6
LE456	4	5	6
AS56	AS	5	6
AS	AS	AS	AS

AD and PE: order of Legendre for additive genetic and permanent environmental effects, respectively.

Ali and Schaeffer (1987), a function with five parameters, which is a regression model of yields on day in lactation (linear and quadratic) and log of 305-day yield divided by day in lactation (linear and quadratic) fitted:

$$Y_t = a + b\,(t/305) + c\,(t/305)^2 + d \ln(305/t) + f \ln^2(305/t)$$

1. In this function 'a' is an intercept, parameters d and f are connected with the increasing slope, parameters b and c with the decreasing slope of lactation curve and t is time of milking.
2. Legendre Polynomial (LE). In calculation of Legendre polynomials it is assumed that $P_0(\chi)= 1$ and $P_1(\chi)= \chi$. Then in general, n+1 polynomial is described by the following function:

$$P_{n+1}(\chi)= (1/n+1)((2n+1)\chi\, P_n(\chi)-nP_{n+1}(\chi))$$

These quantities are normalized using

$$\Phi_n(\chi)= (2n+1/2)^{0.5}\, P_n(\chi)$$

Where:
n: the order of the polynomials.

Test day records in the interval 5 to 305 days were standardized to the interval -1 to +1. In other words, ages or time periods have to be standardized (converted) to the interval between -1 to +1 with the following formula:

$$\alpha_i= -1 + 2\,(t_i\text{-}t_{min}/t_{max}\text{-}t_{min})$$

Where:
t_{min} and t_{max}: the earliest and latest age represented in data (Schaeffer, 2004).

Based on power of Legendre, Random regression analysis provides different coefficients (b) for each animal. For example for animal 'i' in days in milk 't' it can be written as below:

$$\lambda= b_{0i} + b_{1i} + b_{2i} + b_{3i} + \ldots$$

Models for different power of Legendre (k=2, 3 and 4) with three, four and five coefficients can be written as below:

$$\Gamma= (b_0\times plg_0) + (b_1\times plg_1) + (b_2\times plg_2)$$
$$\Gamma= (b_0\times plg_0) + (b_1\times plg_1) + (b_2\times plg_2) + (b_3\times plg_3)$$
$$\Gamma= (b_0\times plg_0) + (b_1\times plg_1) + (b_2\times plg_2) + (b_3\times plg_3) + (b_4\times plg_4)$$

In these functions Γ is estimation breeding value, plg_0, $plg_1 \ldots plg_4$ are Legendre polynomial coefficients, which standardized based on unite of time and b_0, $b_1 \ldots b_4$ are coefficients of Legendre estimated by VCE6 for each animal in different models.

The model in matrix notation can be represented as:

$$Y= Xb + Za + Wp + e$$

Where:
Y: the vector of observations measured in animals.
b: vector of fixed effect.
a and ***p***: vectors of additive genetic and permanent environmental effects.
X, Z and W: incidence matrixes of fixed, additive genetics and permanent environmental effects.
e: the vector of residual.

The assumptions of this model are:

$$\text{var}\begin{bmatrix} A \\ p \\ e \end{bmatrix} = \begin{bmatrix} G\otimes A & 0 & 0 \\ 0 & P\otimes I & 0 \\ 0 & 0 & R \end{bmatrix} \qquad \begin{bmatrix} Y \\ a \\ P \\ e \end{bmatrix} = \begin{bmatrix} Xb \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

G and P are (co)variances of additive genetic and permanent environmental effects, R= I δ^2_e is diagonal matrix (residual) with elements related to days in milk and ⊗ is Kronecker product between matrices.

In this study residual variance is assumed to be heterogeneous thorough the lactation (10 residual classes) to evaluate the parameters and variance components over DIM more accurately. The following model shows the parts of the models were used in random regression analysis:

$$Y_{ijlnp} = HYS_i + CS_p + \sum_{k=1}^{2} b_j + \sum_{m}^{k} \beta_m X_m + \sum_{k=0}^{q} a_{ln}\Phi_m(t_{ml}) + \sum_{k=0}^{q} p_{ln}\Phi_m(t_{ml}) + e_{ijlnp}$$

Where:
Y_{ijlnp}: observation of test day n of cow l obtained in herd-year-season 'i' of a cow calved in season' p'.
HYS_i: fixed effect of herd-year season of production (i= 1,…., 8597).
CS_p: fixed effect of season of calving (p=1 to 4 for spring, summer, autumn and winter, respectively).
b_j: regression coefficient of age at calving as covariate (Linear and Quadratic form).
β_m: the coefficient of fixed regression for an average population curve (Legendre polynomial or Ali and Schaeffer functions).
$\Phi_m(t_{mL})$: the m^{th} standardized lactation age of the 1^{th} animal in DIM (t= 5,… , 305).

q: the order of orthogonal Legendre polynomial.
$a_{\ln}$: additive genetic random regression coefficient.
$p_{\ln}$: permanent environmental random regression coefficient.
$e_{ij\ln p}$: random residual effect.

Persistency

Different measures of persistency based on EBV were used in literature. In this study four different measures of persistency (PSY_1, PSY_2, PSY_3, and PSY_4) were used:

1. The difference between estimation breeding value between day 290 and 90:

$PSY_1 = (EBV_{290} - EBV_{90})$ (Cobuci *et al.* 2007)

2. The difference between estimation breeding value between day 280 and 60:

$PSY_2 = (EBV_{280} - EBV_{60})$ (Jamrozik and Schaeffer, 1997)

3. Selection based on partial EBV during lactation: (cumulative EBV from DIM 106-205 subtracted from cumulative EBV from DIM 6-105).

$$PSY_3 = (\sum_{t=106}^{205} EBV - \sum_{6}^{105} EBV)$$ (Jakobsen *et al.* 2002)

4. Selection based on partial EBV during lactation: (cumulative EBV from DIM 206-305 subtracted from cumulative EBV from DIM 6-105).

$$PSY_4 = (\sum_{t=206}^{305} EBV - \sum_{6}^{105} EBV)$$ (Cobuci *et al.* 2007)

In PSY_1 and PSY_2 measures, persistency was defined as difference in yield between days in milk 280 or 290 and peak DIM. Moreover, Estimation breeding value for a complete 305 DIM for all animals obtained by the sum of EBV of each time of days in milk, and the other criteria ($EBV_{5\text{-}100}$, $EBV_{101\text{-}200}$ and $EBV_{201\text{-}305}$) are calculated with the following formulas:

$$EBV_{305} = \sum_{6}^{305} EBV \qquad EBV_{5-100} = \sum_{i=5}^{100} EBV$$

$$EBV_{101-200} = \sum_{101}^{200} EBV \qquad EBV_{201-305} = \sum_{201}^{305} EBV$$

According to different measures of persistency, lower values of PSY_1, PSY_2, PSY_3 and PSY_4 indicate higher persistency because it is associated to slow rate of decline in production. Comparisons of the models were done by eigenvalues and associated eigenvectors and residual variance across days in milk. For evaluation of fixed effects and fitting of lactation curve, proc GLM in SAS package (SAS, 2005) was used. The PEST software (Groeneveld *et al.* 2002) was used for coding the original data and then the VCE6 software package (Kovac and Groeneveld, 2008) was applied for estimation of covariance components and obtaining solutions (random regression coefficients of additive genetic and permanent environmental effects of each animal) based on restricted maximum likelihood (REML). Using IML procedure in SAS package (SAS, 2005) the eigenvalues, corresponding eigenfunction and the other parameters were calculated for covariance matrices of random regression coefficients. Finally, calculations of different persistency criteria for each animal using mentioned models were evaluated with SAS programming.

RESULTS AND DISCUSSION

For choosing the best model in this study, eigenvalues, associated eigenvectors and mean square error were used. The eigenvalues and their proportion for additive genetic and permanent environment coefficient matrices are presented in Table3. The first genetic eigenvalue in LE334, LE434, AS34 and LE445 models accounted for about 93% of sum of all eigenvalues, although these percentages for the other models were less than 90%. Eigenvalues represent the amount of variation explained by the corresponding eigenfunction (Kirkpatrick *et al.* 1990). For each eigenfunction, a specific eigenvalue is associated. The size of the first eigenvalue indicated that selection would produce rapid change if this kind of alternation in the mean trajectory was favored (Kirkpatrick *et al.* 19904; Olori *et al.* 1999). According to the result (Table 3) three eigenvalues for additive genetic effect in LE334, LE434 and AS34 models accounted around 99.9% of genetic variation of milk yield. Moreover, the intercept and the linear coefficient accounted for the most of variance in these models, while the remaining eigenvalues accounted for less variation and were less important. Fourth and fifth eigenvectors play a minimal role for genetic improvement of milk production and persistency. Togashi and Lin (2006) also reported that when the goal was to maximize milk yield and persistency, the first three eigenvectors were needed for modeling additive genetic effects.

For permanent environmental effect, the first three eigenvalues accounted for less than 97% of total variation, so consequently four eigenvalues and associated eigenvectors needed to account for more than 99.9% of variation. Using equal order of Legendre polynomial for additive genetics and permanent environmental effects in this study showed that the results were not optimal, especially the error variance (data was not shown). Considering these results, it seems that LE334, LE434 and AS34 were optimal models for random regression analysis and the results were the same in this study. Moreover, mean square error variances over DIM in these models were smaller than the other mod-

Table 3 Eigenvalues and their proportions (%) (in parenthesis) for additive genetic and permanent environmental covariance functions

Model	Additive genetic effect					
	λ1	λ2	λ3	λ4	λ5	λ6
LE334	14.2 (93.79)	0.57 (3.81)	0.36 (2.38)			
LE434	14.10 (93.86)	0.58 (3.88)	0.34 (2.24)			
AS34	14.17 (93.85)	0.59 (3.90)	0.34 (2.23)			
LE345	15.14 (84.56)	1.94 (10.81)	0.53 (2.93)	0.30 (1.68)		
LE445	14.44 (93.71)	0.56 (3.60)	0.32 (2.06)	0.09 (0.61)		
AS45	14.41 (92.96)	0.58 (3.76)	0.34 (2.20)	0.16 (1.06)		
LE356	15.09 (85.18)	1.65 (9.29)	0.55 (3.12)	0.34 (1.89)	0.09 (0.50)	
LE456	14.51 (81.89)	2.44 (13.77)	0.46 (2.58)	0.23 (1.30)	0.08 (0.43)	
AS56	14.43 (88.61)	1.18 (7.26)	0.42 (2.60)	0.20 (1.25)	0.04 (0.26)	
AS	68.60 (89.50)	6.47 (8.44)	1.57 (2.04)	0.00 (0.00)	0.00 (0.00)	
	Permanent environmental effect					
LE334	26.87 (74.53)	4.98 (13.81)	2.77 (7.68)	1.43 (3.96)		
LE434	26.12 (78.93)	4.36 (13.17)	1.98 (5.99)	0.63 (1.89)		
AS34	26.43 (76.98)	4.65 (13.53)	2.15 (6.26)	1.10 (3.21)		
LE345	25.4 (74.42)	5 (14.63)	2.27 (6.65)	1.48 (4.28)	0.00 (0.00)	
LE445	25.34 (71.71)	4.95 (14.01)	2.64 (7.47)	1.45 (4.09)	0.95 (2.69)	
AS45	25.54 (75.20)	4.81 (14.15)	1.83 (5.39)	1.20 (3.53)	0.58 (1.71)	
LE356	26.28 (75.13)	4.93 (14.10)	1.96 (5.60)	1.25 (3.55)	0.56 (1.59)	0.00 (0.00)
LE456	26.37 (75.87)	4.73 (13.60)	1.87 (5.39)	1.08 (3.10)	0.70 (2.20)	0.00 (0.00)
AS56	26.20 (76.87)	4.59 (13.46)	1.73 (5.08)	0.76 (2.24)	0.51 (1.50)	0.28 (0.82)
AS	281.69 (77.24)	74.98 (20.56)	7.97 (2.18)	0.03 (0.008)	0.00 (0.00)	

els. In optimal models the only difference was related to the fixed regression part and the results were similar together. It means that the effect of fixed regression function on the best RRM models is negligible. Jamrozik and Schaeffer (1997) reported that functions used for random regression analysis had more impact than the functions used for the fixed regression. Comparison of the residual variance in these models showed that the AS34 model had the lowest residual variance along DIM and this model was more parsimonious compared to other models. The average of residual variance during DIM in LE334, LE434 and AS34 models were 10.393, 10.594 and 9.903, respectively. Difference in these models was related to fixed part of the model. It seems that Ali and schaeffer function was better than Legendre polynomial with order of three and four in fitting of average lactation curve. Eigenvectors for additive genetic effect estimated by additive genetic random regression coefficient matrix of AS34 model was shown in Figure 1. The eigenvalues associated to these eigenvectors for additive genetic effects in AS34 model explained 93.85, 3.90 and 2.23% of the variation of the random regression coefficients, respectively. The first eigenvector was the largest and positive and selection based on this eigenvector increased average of milk production during days in milk (DIM). The second eigenvector was negative at the first of lactation up to 180 d and positve during the later days. In this case, a selection before 180 d of days in milk for increasing milk yield, led to a negative effect on this trait from 185 to 305 d of lactation. For increasing the maximum average milk yield and persistency, the first three eigenvectors are needed (Togashi and Lin 2006).

The first and second eigenvectors are more important, although the third eigenvector increases when economic weight on persistency is desirable. In this study, selection of animal between 180 and 210 days will improve both milk yield and persistency.

Variance components and heritability of milk yield during lactation by AS34 model are presented in Figure 2. According to the results, residual variance was high at the beginning of lactation and slightly constant till the end of lactation. Also, the additive genetic variance was the highest at the middle of lactation (between 180 and 210 days) and estimates were especially lower at the beginning of lactation.

Permanent environmental variance showed different trend, with peak value at the end of lactation. The range of heritability changed from 0.08 to 0.29 in this model. The highest heritability was observed in the middle of lactation and the lowest at the beginning of lactation. Our findings confirmed the results of other authors with the highest heritability in the middle of lactation (Jakobsen *et al.* 2002; Druet *et al.* 2003). Biassus *et al.* (2010) reported the same range and trend of heritability for milk yield in primiparous holstein cows in Brazil, however heritability estimates were lower in this study than those reported by Jamrozik and Schaeffer (1997) and Costa *et al.* (2008), because they assumed constant permanent environmental and residual variance during DIM respectively.

Genetic correlation (ranged from 0.47 to 0.98) between test days were higher value (close to unity) in adjacent period but decreased with increasing period among test day yield.

Jakobsen *et al.* (2002) reported that the genetic correlation between test days were higher than 0.4. Indeed, permanent environmental correlations were lower than genetic correlations as permanent environmental correlation between two ends of lactation was 0.26.

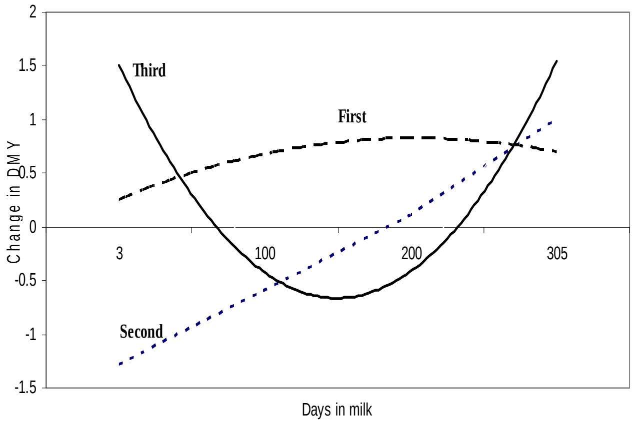

Figure 1 Eigenvectors of additive genetic effect in AS34 model

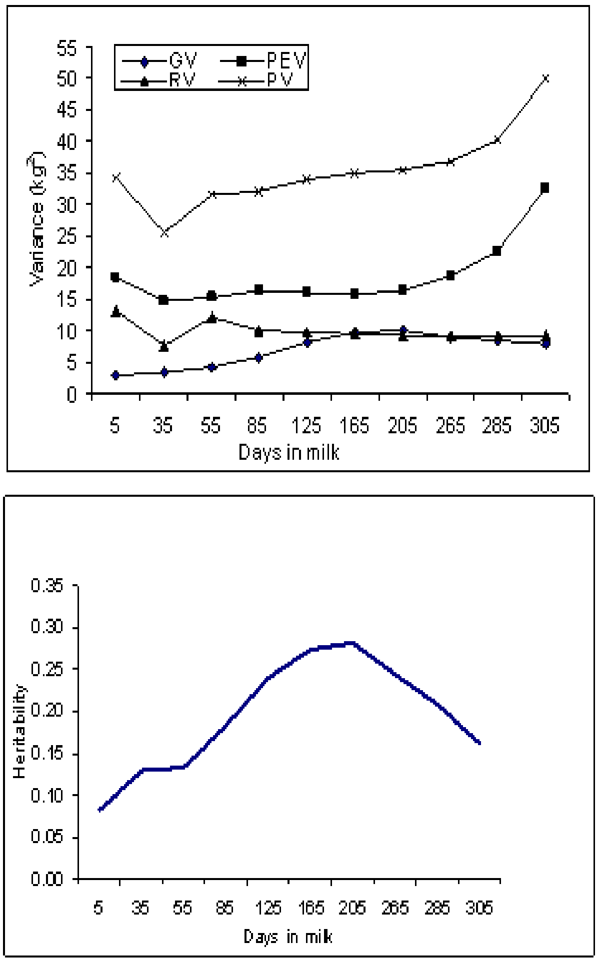

Figure 2 Variance components (GV: additive genetic; PEV: permanent environment; RV: residual and PV: phenotypic) (above) and heritability (below) across DIM in model AS34 for first parity

In other words, increasing the time between test days, the rate of decrease in permanent environmental correlation was higher than additive genetic effect (Figure 3).

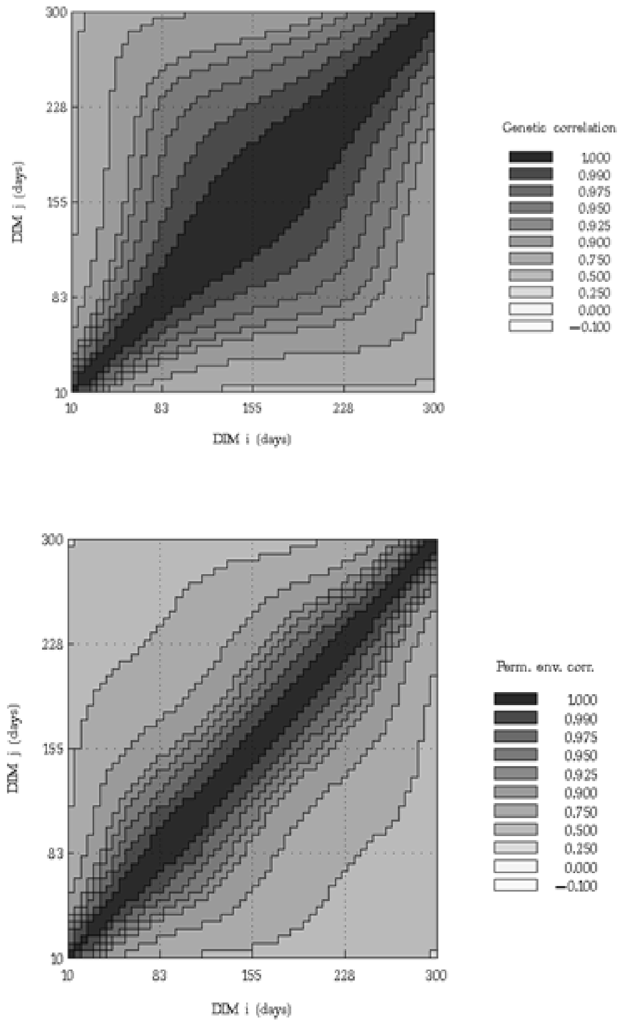

Figure 3 Additive genetic and permanent environmental correlations in AS34 model

Persistency is an economic trait with an important impact on milk production. The daily estimated breeding values changed across the whole lactation period, which showed differences among animals for persistency. The average, standard deviation, minimum and maximum of different measures of persistency with estimation breeding values from 5 - 100, 101 - 200, 201 - 305 and total 305 days for sires of dairy cows are presented in Table 4. PSY_1 measure had lower standard deviation and variation. The average amount EBV for PSY_3 and PSY_4 were higher than PSY_1 and PSY_2 because they were calculated based on EBV from different lactation period but PSY1 and PSY_2 were based on subtraction of two EBV values during days in milk. The difference between PSY_1 and PSY_2 is related to peak time of milk production. In PSY_1 it was assumed that peak of milk production was after 90 days as observed in some tropical conditions but in PSY_2 the peak time of milk production it was assumed to be on 60 days. The difference between average of PSY_1 and PSY_2 was negligible (-0.050 vs -0.080), however standard deviation of these means was completely different (Table 4).

Table 4 Means, standard deviation (SD), minimum and maximum of EBV for milk yield using different persistency criteria for the sires of Holstein cows

Variable	Mean	SD	Min	Max
PSY_1	-0.050	0.102	-0.309	0.298
PSY_2	-0.080	0.267	-0.950	0.668
PSY_3	-12.183	38.368	-132.571	113.972
PSY_4	-11.177	35.879	-126.592	98.332
EBV_{5-100}	-18.241	59.182	-181.048	201.400
$EBV_{101-200}$	-31.415	99.197	-316.178	326.141
$EBV_{201-305}$	-32.377	101.816	-330.522	330.267
EBV_{305} d	-82.033	259.585	-820.729	857.809

Correlation between estimated breeding values for persistency measures and parts of lactation in sires and cows are given in Table 5. Correlations among different persistency measures were positive and larger than 0.557 for both sires and cows. This indicated that differences between the performances of persistency measures were high. Moreover, ranking of animals based on these measures ddid not provide similar ranking.

The range of correlation in sires and cows were similar. Correlation between persistency measures and EBV_{305} d in both sires and cows was ranges from 0.340 to 0.971. Both the highest and lowest correlation between persistency measures and EBV_{305} d in sires attributed to PSY_3 and PSY_1. Higher correlation between EBV_{305} d and persistency measures (PSY_1, PSY_2, PSY_3 and PSY_4) suggests that ranking of animals based on these criteria provides similar results.

Estimation breeding value for 305 days milk yield divided into three parts of nearly equal length in top five sires and cows (the first, second and third 100 DIM). Correlation between EBV_{305} d and different parts of lactation showed the highest correlation for $EBV_{101-200}$ and $EBV_{201-305}$ respectively (Table 5). In agreement with previous results, the middle part of lactation had a higher correlation with EBV_{305} d milk yield.

The higher correlation between these parts of lactation and 305 - d milk yield indicated that these parts of lactation could be more affected by genetic variation differences between animals than the other parts of lactation. The lowest correlation was obtained between PSY_1 and EBV_{305} d compare to other persistency measures in cows and sires (0.523 and 0.340). The correlation between PSY_3 and PSY_4 in sires and cows was bigger than correlation between PSY_1 and PSY_2.

Higher proportion of EBV_{305} d was associated to $EBV_{101-200}$ and $EBV_{201-305}$ in sires and cows (Table 5). Thus, based on EBV the correlation of persistency with the second and third parts of lactation could be used as a criterion to evaluate the persistency criteria regarding improving both persistency and 305 d milk yield using random regression method. High correlations are caused by selection of animals based on the first three eigenvalues and associated eigenvectors which increase milk yield and persistency together. This means that EBV_{305} d is less affected by difference between estimation breeding value 290 and 90 days. Jamrozik and Schaeffer (1997) proposed difference between day 60 and 280 lactation for measure persistency which used in Canada. Herd Management and climate might influence the wide variability in length and time of peak yield and persistency. Production peak is not 60 days in all cases especially tropical countries. The real peak time in dataset and prediction of peak time using Ali and Schaeffer function were 90 and 86 days, respectively. This shows that peak time of milk production is different with 60 DIM in Iranian first parity cows. Cobuci *et al.* (2007) and Gengler, (1996) reported that the best persistency criteria should be independent from 305d milk production and also it should have lower genetic correlation with EBV_{305} d. Dekkers *et al.* (1996) recommended the use of differential yield between days in milk 60 and 280 for genetic evaluation for persistency because it was less correlated with 305 d yield. Strabel *et al.* (2001) also reported that low correlation between persistency and milk yield meant it was possible to select quite independently for both traits. In our study PSY_1 was much less correlated with EBV_{305} d in sires and cows, meant that PSY_1 less affected by peak yield than the other measures. Moreover, PSY_1 was more independent from EBV_{305} d. Respect to the results of Table 4 and Table 5, PSY_1 shows the best result for the persistency in animals because sires or cows were assumed to be more persistent when the EBV_{290} - EBV_{90} was smaller than on average. This indicated that in Iranian Holsteins, lactation curves for milk yields tended to peak after 60 DIM. Ranking of top 5 cows and top 5 sires based on estimated breeding values for 305 d of their daughters is shown in Table 6. Ranking of top five sires based on PSY_1 and EBV_{305} d was completely different because of lower genetic correlation. This indicated that the best animals for EBV_{305} d are not necessarily the same that the best animals based on PSY_1 measure and these two traits are independent. Estimated breeding value of five top cows during 305 d milk yield was shown in Figure 4. The range of breeding values in these cows was between 0.90 and 5.14. This figure demonstrates that the cows producing highest milk yield and consequently highest EBV_{305} d, did not have the same curve of breeding value during lactation.

Table 5 Correlation between estimated breeding values for different persistency criteria in sires (lower diagonal) and cows (upper diagonal)

Trait	PSY_1	PSY_2	PSY_3	PSY_4	$EBV_{5\text{-}100}$	$EBV_{101\text{-}200}$	$EBV_{201\text{-}305}$	EBV_{305} d
PSY_1	-	0.754	0.557	0.663	0.232	0.355	0.390	0.340
PSY_2	0.851	-	0.965	0.991	0.814	0.881	0.898	0.874
PSY_3	0.710	0.974	-	0.991	0.937	0.974	0.981	0.970
PSY_4	0.789	0.994	0.992	-	0.882	0.935	0.947	0.929
$EBV_{5\text{-}100}$	0.415	0.831	0.935	0.886	-	0.991	0.986	0.993
$EBV_{101\text{-}200}$	0.537	0.900	0.975	0.942	0.990	-	0.999	0.999
$EBV_{201\text{-}305}$	0.570	0.916	0.983	0.954	0.984	0.999	-	0.998
EBV_{305} d	0.523	0.892	0.971	0.936	0.992	0.999	0.998	-

Table 6 Estimated breeding values for different measures of persistency for five top sires (upper) and five top cows (lower) based on EBV_{305} d

Sire	PSY_1	PSY_2	PSY_3	PSY_4	$EBV_{5\text{-}100}$	$EBV_{101\text{-}200}$	$EBV_{201\text{-}305}$	EBV_{305} d
S1	0.089	0.668	113.972	98.332	201.400	326.141	330.267	857.809
S2	0.019	0.434	80.201	66.652	154.223	242.615	243.527	640.366
S3	-0.159	0.026	30.875	15.772	108.132	144.548	137.170	389.852
S4	0.117	0.384	54.926	51.773	75.4339	134.492	139.906	349.832
S5	0.129	0.397	55.464	52.933	72.9577	132.437	138.414	343.809
Cow	PSY_1	PSY_2	PSY_3	PSY_4	$EBV_{5\text{-}100}$	$EBV_{101\text{-}200}$	$EBV_{201\text{-}305}$	EBV_{305}
C1	0.419	1.374	196.232	185.083	268.919	479.885	499.319	1248.1245
C2	0.402	1.320	188.783	177.943	259.227	462.209	480.814	1202.252
C3	0.426	1.263	173.893	167.242	222.337	408.504	428.248	1059.091
C4	0.330	1.084	155.020	146.130	212.868	379.548	394.838	987.255
C5	-0.003	0.576	111.309	90.667	223.125	346.247	346.077	915.449

This means that the lactation curves of these animals are different. Cow number 5 (C5) had the highest breeding value for 305 d milk yield but ranking of top cows based on PSY_1 showed that this cow had the highest persistency. So ranking of animals based on these criteria were completely different. The same result was shown for sires (Figure 5). Sire one (S1) was the best animal based of EBV_{305} d but ranking of these animals for PSY_1 showed that the lactation curve of daughters of sire three (S3) was steeper than the other sires. Overall, these results indicated that an increase in EBV_{305} d ddid not mean the higher level of persistency of lactation. In other words, higher EBV_{305} d might not lead to improvement in level of persistency in sires and cows. Our findings confirmed the weak association between EBV_{305} d and the best persistency measures in Iranian primiparous Holstein.

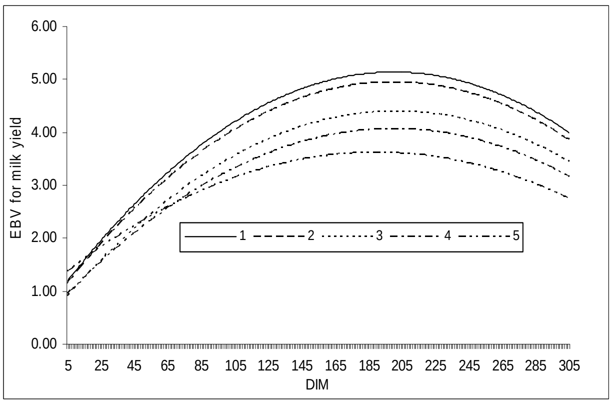

Figure 4 Estimation breeding values of five top cows across 305 days milk yield

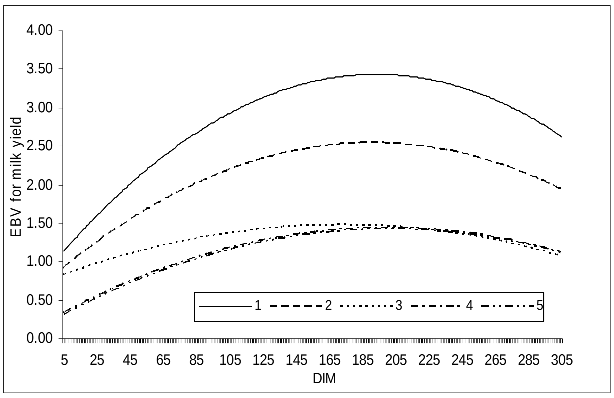

Figure 5 Estimation breeding values of five top sires based on estimation breeding value of their daughters for PSY_1 measures

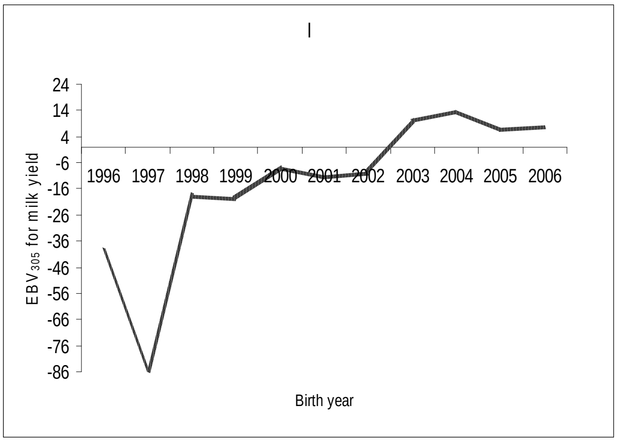

Figure 6 The trend of Estimation breeding values of cows for 305 d milk yield in different birth years

Figure 6 shows genetic trend of the cows for milk yield in birth year of 1996-2006, which interprets that breeding value for milk yield improved gradually from 1996 to 2006; however this trend is lower comparing to the other countries (Canada and Netherland). The mean of milk yield from birth year 1996 to 2006 increased gradually from 22.30 to 31.17 kg (data not shown) but the rate of increasing EBV was low. This means that improvement in environmental effects like changes in management; feeding regime and other environmental factors are responsible for increasing milk yield in different birth years.

CONCLUSION

In this study, modeling of test day records using different random regression models was conducted for evaluation of milk yield in Iranian first parity cows. Different functions including unequal orders of Legendre polynomial (quadratic, cubic and quartic) for random effects and parametric function of Ali and Schaeffer were used in this study. Using the coefficients of Legendre polynomials produced by VCE software, estimation breeding values of animals in 305 DIM, partial lactation (EBV_{5-100}, $EBV_{101-200}$ and $EBV_{201-305}$ days) and different persistency measures (PSY_1, PSY_2, PSY_3 and PSY_4) were calculated by SAS programming. Comparison of the RRM models was done by eigenvalues and associated eigenvectors as well as residual variance along lactation. Based on these criteria, model with quadratic and cubic orders of Legendre polynomials for additive genetic and permanent environmental effects with fixed function of Ali and Schaffer (AS34) showed the best quality of adjustment of this productive trait. The highest and lowest heritability was observed in the middle (0.29) and beginning (0.08) of lactation respectively. Evaluation of lactation curve of the cows with Ali and Schaeffer function showed that the peak time of milk production in Iranian first parity cows is in around 85 days and not at 60 days. Hence, the persistency measure PSY_1 (EBV_{290}-EBV_{90}) is a good option for persistency evaluation because of lower correlation with EBV_{305} d in Iranian primiparous Holsteins.

REFERENCES

Ali T.E. and Schaeffer L.R. (1987). Accounting for covarainces among test day milk yields in dairy cows. *Can. J. Anim. Sci.* **67,** 637-644.

Biassus I.D.O., Cobuci J.A., Costa J.A., Rorato P.R.N., Neto J.B. and Cardoso L.L. (2010). Persistence in milk, fat and protein production of primiparous Holstein cows by random regression models. *Brazilian J. Zootec*. **39(12),** 2617-2624.

Cobuci J.A., Euclydes R.F., Costa C.N., Torres R.A. and Carmenn S.P. (2007). Genetic evaluation for persistency of lactation in Holstein cows using a random regression model. *Gene. Mol. Biol*. **30,** 349-355.

Costa C.N., De Melo C., Packer I.U., Freitas A., Teixeira N. and Cobuci J.A. (2008). Genetic parameters for test day milk yield of first lactation Holstein cows estimated by random regression using Legendre polynomials. *R. Bras. Zootec*. **4**, 602-608.

Dekkers I.C.M., Jamrozik J., Hag J.H., Schaeffer L.R. and Weersink A. (1996). Genetic and economic evaluation of persistency in dairy cattle. Workshop on genetic improvement of functional traits in cattle. Gembloux, Belgium, *Interbull Bulletin*. **12,** 97-102.

Druet T., Jaffrézic F. and Ducrocq V. (2003). Modeling of lactation curves and estimation of genetic parameters for first lactation test–day records of French Holstein cows. *J. Dairy Sci*. **86,** 2480-2490.

Dzomba E.F., Nephawe K.A., Maiwashe A.N., Cote S.W.P., Chimonyo M., Banga C.B. Muller C. and Dzama K. (2010). Random regression test day model for analysis of dairy cattle production data in South Africa: creating the frameworek. *South African J. Anim. Sci.* **40(4),** 273-284.

Gengler N. (1996). Persistency of lactation yields: A review. *Interbull Bulletin*. **12,** 97-102.

Groeneveld E., Kovac M. and Wang T. (2002). PEST User's Guide and Reference Manual. Version 4.2.3. Department of Animal Science, University of Illinois.

Grossman M., Hartz S.M. and Koops W.J. (1999). Persistency of lactation yield: A novel approach. *J. Dairy Sci.* **82,** 2192-2197.

Jakobsen J.H., Madsen P., Jensen J., Pedersen J., Christensen L.G. and Sorensen D.A. (2002). Genetic parameters for milk production and persistency for Danish Holstein estimated in random regression models using REML. *J. Dairy Sci*. **85,** 1607-1616.

Jamrozik J. and Schaeffer L. (1997). Estimates of genetic parameters for a test day model with random regression for yield traits of first lactation Holsteins. *J. Dairy Sci*. **80,** 762-770.

Jensen J. (2001). Genetic evaluation of dairy cattle using test day models. *J. Dairy. Sci*. **84,** 2803-2812.

Kirkpatrick M., Lofsvold D. and Bulmer M. (1990). Analysis of the inheritance, selection and evolution of growth trajectories. *Genetics*. **124,** 979-993.

Kirkpatrick M., Thompson R. and Hill W.G. (1994). Estimation of covariance structure of traits during growth and aging, illustrated with lactation in dairy cattle. *Genet. Res.* **64,** 57-69.

Kovac M. and Groeneveld E. (2008). VCE-6 User's Guide and Reference Manual. Version 6. Biotechnical Faculty, Department of Animal Science, University of Ljubljana, Slovenia.

Liu Y.X., Zhang J., Schaeffer L.R., Ynag R.Q. and Zhang W.L. (2006). Short communication: optimal random regression models for milk production in dairy cattle. *J. Dairy Sci*. **89,** 2233-2235.

Olori V.E., Hill W.G., Mcguirk B.J. and Brotherstone S. (1999). Estimating variance components for test day milk records by restricted maximum likelihood with a random regression animal model. *Livest. Prod. Sci.* **61,** 53-63.

SAS. (2005). Statistics Analysis System User's Guide, (Release 9.1). SAS Institute Inc., Cary, North Carolina, USA.

Schaeffer L.R. (2004). Application of random regression models in animal breeding. *Livest. Prod. Sci*. **86,** 35-45.

Sölkner J. and Fuchs W. (1987). A comparison of different measures of persistency with special respect to variation of test-day milk yields. *Livest. Prod. Sci.* **16,** 305-319.

Strabel T., Kopacki W. and Szwaczkowski T. (2001). Genetic evaluation of persistency in random regression test day models. *Interbull Bulletin*. **27,** 189-192.

Swalve H.H. (2000). Theoretical basis and computational methods for different test-day genetic evaluation methods. *J. Dairy Sci*. **83,** 1115-1124.

Togashi K. and Lin C.Y. (2006). Selection for milk production and persistency using eigenvectors of the random regression coefficient matrix. *J. Dairy Sci.* **89,** 4866-4873.

Togashi K., Lin C.Y., Atagi Y., Hagiya K. and Nakanishi T. (2008). Genetic characteristics of Japanese Holstein cows based on multiple lactation random regression test day animal model. *J. Dairy Sci*. **114,** 194-201.

Zimmermann E. and Sommer H. (1973). Zum laktationsverlauf von kuhen in hocheistung-sherden und dessen beeinflussung durch nichterbliche faktoren. *Zuchtungskunde*. **45,** 75-88.