Phenotypic Study of Lactation Curve in Iranian Holsteins

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ABSTRACT

A total of 136,250 monthly test day milk records collected from 13,625 Iranian Holstein heifers (three times a day milking) calved between 1991 and 2001 and distributed over 264 herds were used to study the effects of some environmental factors influencing lactation curve parameters as well as production characteristics. Wilmink's function ($Y_t = W_0 + W_1 t + W_2 e^{-0.05t}$) was fitted to individual lactations. Least squares analysis of variance indicated that the herd, year and month of calving had a significant effect on all traits under consideration. Correlation analysis showed that the parameter W_0 had a negative and significant ($p < 0.05$) relationship with parameters W_1 and W_2 while it was positively significantly correlated with milk at peak time and 305-day milk yield. Simple linear regression analysis of adjusted means of a 305-day milk yield, days to reach peak yield as well as peak milk yield in the first year of calving also revealed that there was a phenotypic increase of 137.152 Kg, 0.535 day and 0.434 Kg per year, respectively.

Keywords: Iranian Holsteins, Lactation curve, Wilmink's function.

INTRODUCTION

The production of milk and its components varies during different months of milking. Moreover, milk production traits follow a curvilinear pattern over the course of lactation. Knowledge of the lactation curve can provide a worthwhile information source about the pattern of milk production traits which, in turn, could be used for herd management decisions (Perochon *et al.*, 1996). To model the lactation curve of dairy cows, mechanistic and empirical approaches can be used (Perochon *et al.*, 1996). In most practical situations, the empirical method is preferred over the mechanistic method due to the fact that the former is based on the shape of the lactation curve while the latter is based upon the metabolism of udder tissues. On this basis, many studies have been undertaken over the past three decades to apply different mathematical models to obtain more accurate prediction of the shape of the lactation curve.

Recently there, has been considerable interest in using test day models to analyse individual test day records for the genetic evaluation of dairy cows as a replacement for the traditional use of estimating accumulated 305-day lactation yields in a lactation model. Canada, for example, has officially adopted and implemented a random regression test day model in 1999 to replace the lactation model (Schaeffer *et al.*, 2000). In a practical situation, as genetic evaluation of dairy cattle is undertaken using monthly test day records in a test day model, parametric models like Wilmink's or polynomial regression functions (Jamrozik and Schaeffer, 1997; Jamrozik *et al.*, 1997; Kaya *et al.*, 2003) or Orthogonal Legendre Polynomials in covariance function (Meyer and Hill, 1997; Druet *et al.*, 2003) could be used in the model (as fixed and random regressions) to take account of the shape of the lactation curve for individual cows at the genetic level. However, particular attention should

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be given to the number of monthly test day records available for each cow. This is due to the fact that the accuracy of estimation of genetic parameters and prediction of breeding values is affected to a great extent by the number of test day records available for each cow during lactation.

It has been well documented that the lactation curve is influenced by environmental factors such as the herd, year of calving, parity, age of calving and season of calving (Wood, 1976; Congleton and Everett, 1980; Danell, 1982; Grossman *et al.*, 1986; Keown *et al.*, 1986, Tekerli *et al.*, 2000). Cows that are raised in higher yielding herds have higher peak production and more persistency when compared with low production herd cows (Keown *et al.*, 1986). The lactation curve is also influenced by seasonal variations. For instance, cows calving in late Spring or at the beginning of Summer have a lactation curve which reaches a lower peak level than winter calvers (Wood, 1969; Rao and Sundaresan, 1979; Poso *et al.*, 1996).

The main objective of the present research was to analyse some environmental factors influencing lactation curve parameters for Iranian Holstein heifers as well as their production characteristics by fitting Wilmink's function to monthly test day milk yields. Furthermore, adjusted phenotypic trends for all the traits under consideration will also be obtained.

MATERIALS AND METHODS

An initial data set consisting of 457,576 first lactation monthly test day milk records was obtained from the Animal Breeding Centre of Iran. The data was subsequently edited on the basis of the number of monthly test days (during the lactation period) and interval between consecutive test days for individual cows (three times a day milking). The interval between consecutive test days was set up to be a maximum of 60 days. Furthermore, from a computational point of view, only cows with a complete first lactation which had 10 monthly test day records were utilized to obtain a better estimation of the lactation curve parameters for individual cows. The final data set consisted of 136,250 monthly test day milk yields belonging to 13,625 first lactations of Iranian Holstein heifers from 264 herds that calved from 1991 to 2001. Some descriptive statistics of data are presented in Table 1.

To describe the lactation curve and associated production characteristics, Wilmink's function (Wilmink, 1987) was applied in this study. The function is as follows:

$$y_t = W_0 + W_1 t + W_2 (Exp)^{-0.05t} \qquad (1$$

where:

t is days in milk, y_t is milk yield in Kg at day t, W_0 is associated with the level of production, W_1 is associated with production decrease after peak yield, and W_2 is associated with production increase towards peak yield.

The parameters of Wilmink's function (W_0, W_1 and W_2) were estimated for individual lactations by applying the REG procedure of

Table 1. Descriptive statistics of the data set.

Month of lactation	Days in milk (d)			Daily milk yield (Kg)		
	Mean	SD	CV %	Mean	SD	CV %
1	13.68	6.64	48.53	23.53	5.50	23.37
2	44.15	6.53	14.79	26.38	5.02	19.02
3	74.41	6.77	9.09	29.28	5.27	17.99
4	104.87	6.55	6.24	28.87	5.40	18.70
5	135.18	6.78	5.01	27.88	5.46	19.58
6	165.66	6.58	3.97	26.75	5.52	20.63
7	195.95	6.79	3.46	25.57	5.52	21.58
8	226.43	6.60	2.91	24.41	5.43	22.24
9	256.72	6.84	2.66	23.14	5.28	22.81
10	287.14	6.67	2.32	21.69	5.29	24.38

the SAS software (SAS, 1989). Based on the estimated lactation curve parameters, some production characteristics including peak time (PT), peak milk yield (PM), milk yields at days 60 (M60) and 280 (M280) and total 305-day milk yield (TM305) were also calculated for individual cows as follows:

$$PT = -20(ln\frac{20\hat{W}_1}{\hat{W}_2}) \qquad (2$$

$$PM = \hat{W}_0 + \hat{W}_1(-20(ln\frac{20\hat{W}_1}{\hat{W}_2})) + \hat{W}_2e^{-0.05(-20(ln\frac{20\hat{W}_1}{\hat{W}_2}))} \quad (3$$

$$M60 = \hat{W}_0 + \hat{W}_1(60) + \hat{W}_2e^{-0.05(60)} \qquad (4$$

$$M280 = \hat{W}_0 + \hat{W}_1(280) + \hat{W}_2e^{-0.05(280)} \qquad (5$$

$$TM305 = 305\hat{W}_0 + 46665\hat{W}_1 + 19.50416\hat{W}_2 \qquad (6$$

In order to analyse the effects of environmental factors including the herd, year of calving, month of calving and age at first calving a fixed linear model was fitted on estimated lactation curve parameters and production characteristics. Due to the highly unbalanced data, no attempt was made to fit all two- and three-way interactions in to the model. Least squares analyses of variance were undertaken by the use of the GLM procedure (General Linear Model) of the SAS software (SAS, 1989). The linear model was as follows:

$$y_{ijk} = \mu + (herd)_i + (year)_j + (month)_k + \\ \sum_{R=1}^{2} \beta_R *[(age_{ijk})^R - (\overline{a^R})] + e_{ijk} \qquad (7$$

where:

y_{ijk} is the value of the considered trait (W_0, W_1, W_2, PT, PM, M60, M280 and TM305) affected by the ith herd, j^{th} year of calving, k^{th} month of calving and covariable of age at calving

μ is the overall mean for each trait, $herd_i$ is the fixed effect of the ith herd (i =1 to 264), $year_j$ is the fixed effect of the jth year of calving (j =1 to 11), $month_k$ is the fixed effect of the kth month of calving (k =1 to 12), β_R is linear and quadratic regression coefficients of age_{ijk}, e_{ijk} is the random effect of residual with expectation and variance equal to 0 and σ_e^2 respectively.

Least squares means of year and month of calving for individual traits were obtained along with analysis of variance using LSMEANS option. Pearson correlation coefficients (r) among eight traits were calculated using SAS software (SAS, 1989). Tests of significance were also performed under $H_0 : \rho = 0$.

RESULTS AND DISCUSSION

Overall means of W_0, W_1, W_2, PM, M60, M280, TM305 and PT were 31.67, -0.032, -15.880, 29.13, 28.93, 22.60, 7839 Kg and 64.94 days, respectively. The results of least

Table 2. Sum of squares values resulting from least squares analysis of variance of lactation curve parameters as well as production characteristics for the environmental factors fitted in the GLM.

Trait	Source of variation				
	Herd	Year	Month	Age (Linear)	Age (Quadratic)
W_0[a]	86670***	11549***	6098***	718***	399***
W_1[a]	0.3168***	0.0077*	0.0883***	0.0037**	0.0020*
W_2[a]	98164***	3965***	18715***	186Ns	77Ns
PT[b]	265250***	20913***	41052***	2779**	2406*
PMc[c]	73928***	11623***	3984***	513***	286***
M60d[d]	73129***	11464***	3998***	505***	284***
M280[e]	71566***	14463***	5596***	94**	55Ns
TM305[f]	6085289482***	1133076573***	311008426***	25662663***	14709182***

[a] parameters of Wilmink's function; [b] Peak time; [c] Peak milk; [d] Milk yield at day 60; [e] Milk yield at day 280 and [f] Milk yield for 305 days.
Ns: Non significant.

squares analysis of variance for all eight traits are presented in Table 2. As can be seen, all analysed traits were significantly affected by the herd, year and month of calving. However, the year of calving affected parameter W_1 only on a probability level of $P<0.05$. The linear effect of age at first calving significantly influenced all traits except parameter W_2 which is associated with increased production towards peak yield. The quadratic order of first calving age in the model had no significant effect on parameter W_2 and M280 while it was significant for the other traits.

The results also revealed that the herd effect had the greatest contribution from the total sum of squares. In contrast, the age at first calving when fitted as a quadratic effect had the lowest proportion of total variation in all traits. Hence, the herd and age at first calving are considered to be the most and the least important factors, respectively, influencing lactation curve parameters and production characteristics.

Least squares means of month of calving for individual traits are presented in Table 3. For month of calving, the lowest W_0 (level of production) occurred for cows calved between April to October. The highest levels of production were found for cows calved between November to March. These results revealed that cows calved from August to November had the lowest rate of production

decrease after peak yield (W_1). In contrast, cows calved between February to March had the highest rate of production decrease after peak yield and are considered to be more persistent. Parameter W_2, which is associated with production increase towards peak yield, was found to be lower for cows calved during May to September than that of cows calved during October to April.

The results showed that cows calved from January to August reached earlier peak yield during lactation. On the other hand, the highest number of days needed to attain peak production was found for cows calved in October where by cows had a lower rate of decrease of production after peak yield towards the end of the lactation course. Peak milk yield (PM) at each month of calving was generally greater than milk yield at 60 days of lactation (M60) and both the same changes during different months of calving such that cows calved during May to September were found to have lower PM and M60 than that of cows calved during October to April. The results also indicated that cows calved in Spring and Summer (from April to September) produced lower total lactation milk yield (TM305) than that of cows calving during Autumn and Winter seasons.

Pearson product moment correlation coefficients among the lactation curve parameters and production characteristics are given

Table 3. Least squares means for month of calving.

Month of calving	Trait							
	W_0 [a]	W_1 [a]	W_2 [a]	PT [b]	PM [c]	M60 [d]	M280 [e]	TM305 [f]
Jan	30.45	-0.0324	-14.616	62.20	27.94	27.78	21.37	7490
Feb	30.47	-0.0342	-15.086	61.41	27.84	27.67	20.90	7404
Mar	30.67	-0.0354	-14.463	61.02	28.00	27.83	20.77	7423
Apr	29.87	-0.0349	-13.585	59.36	27.25	27.10	20.10	7217
May	29.30	-0.0329	-12.895	59.99	26.84	26.68	20.09	7150
Jun	29.23	-0.0324	-11.881	58.99	26.85	26.70	20.17	7175
Jul	29.13	-0.0317	-12.025	60.02	26.82	26.63	20.25	7171
Aug	28.49	-0.0281	-11.475	61.97	26.41	26.23	20.62	7155
Sep	28.93	-0.0271	-11.826	63.27	26.90	26.72	21.36	7333
Oct	29.58	-0.0279	-13.060	64.53	27.43	27.25	21.76	7465
Nov	30.27	-0.0298	-13.527	63.61	27.99	27.81	21.93	7581
Dec	30.49	-0.0314	-14.636	63.98	28.04	27.87	21.70	7549

[a] parameters of Wilmink's function; [b] Peak time; [c] Peak milk; [d] Milk yield at day 60; [e] Milk yield at day 280 and [f] Milk yield for 305 days.

Table 4. Pearson product moment correlations (r) between lactation curve parameters and production characteristics.

Trait	$W_0{}^a$	$W_1{}^a$	$W_2{}^a$	PT^b	PM^c	$M60^d$	$M280^e$	$TM305^f$
$W_0{}^a$	1.000	-0.556***	-0.465***	-0.070***	0.975***	0.976***	0.519***	0.830***
$W_1{}^a$		1.000	0.318***	0.525***	-0.371***	-0.376***	0.422***	-0.008ns
$W_2{}^a$			1.000	-0.430***	-0.375***	-0.365***	-0.179***	-0.242***
PT^b				1.000	0.011ns	0.001ns	0.464***	0.194***
PM^c					1.000	0.999***	0.682***	0.930***
$M60^d$			Symmetric			1.000	0.678***	0.929***
$M280^e$							1.000	0.897***
$TM305^f$								1.000

[a] parameters of Wilmink's function; [b] Peak time; [c] Peak milk; [d] Milk yield at day 60; [e] Milk yield at day 280 and [f] Milk yield for 305 days.

in Table 4. The results showed that parameter W_0, which is associated with the level of production, was negatively correlated with W_1, W_2 and peak time while it was positively correlated with peak yield, milk yields at days 60 and 280 as well as total lactation milk yield. Negative correlations were found between the parameter related to the production increase before peak yield and PT, PM, M60, M280 and TM305. The parameter W_1 had negative correlations with peak yield and milk yield at day 60 while it was positively correlated with W_2, peak time and milk yield at day 280. No significant (P>0.05) correlation was obtained between the lactation parameter W_1 and total lactation milk yield. Peak time had positive and significant (P<0.001) correlations with milk

yield at day 280 and total lactation milk yield. The correlation analysis revealed that milk yield at peak time had a positive correlation with M280 and very high positive correlations with M60 and TM305. Milk yields at days 60 and 280 were also strongly positively correlated with total lactation milk yield.

On the basis of adjusted means for the year of calving, phenotypic trends for each trait were calculated using simple linear regression analysis. The results obtained from the regression analysis showed that total lactation milk yield had an annual increase of 137.152 Kg (P<0.001) during 1991-2001. At the same time, the number of days needed to reach peak yield also showed a significant (P<0.001) annual increase of 0.535 days
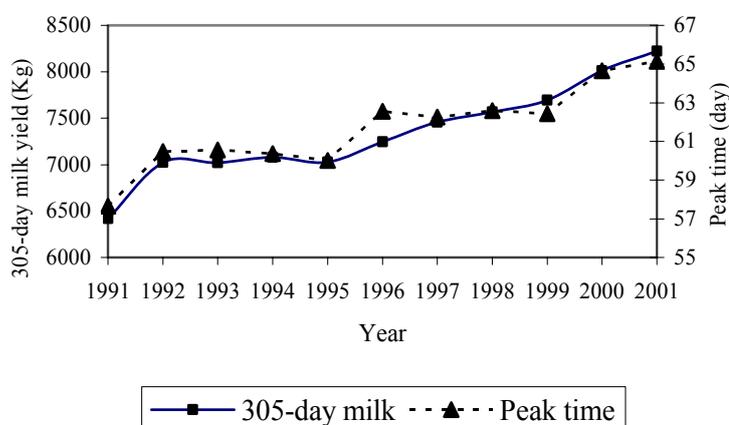

Figure 1. Phenotypic trends for 305-day milk yield (+137.152 Kg/year) and peak time (+0.535 day/year) in Iranian Holstein heifers over 11 years of calving.

(Figure 1). Phenotypic trends calculated for W_0, W_1, W_2, PM, M60, M280 were 0.428 Kg (P<0.001), 0.0002 (P<0.05), -0.157 (P<0.01), 0.434 Kg (P<0.001), 0.433 Kg (P<0.001) and 0.486 Kg (P<0.001) respectively.

CONCLUSION

Wilmink's function was used to evaluate the effects of some environmental factors affecting lactation curve parameters as well as some production characteristics of Iranian Holstein cows at first lactation. Thus far, some research has been carried out to analyse phenotypic and genetic aspects of the lactation curve using Wilmink's function. In accordance with the findings of Dedkova and Nemkova (2003), the year and month of calving had significant effects on most of the traits under consideration; the herd also affected all traits significantly. With regard to the continuous distribution of the calving, age of this environmental factor was also fitted in the GLM as a covariate (as applied by Visscher *et al.*, 1991; Visscher and Thompson, 1992; Baffour-Awuah *et al.*, 1996; Strabel and Szwaczkowski, 1999; Ojango and Pollott, 2001) and had a significant effect on all traits except the parameter W_2.

The results obtained from a correlation analysis of the traits in the present study indicated that milk yield at the peak time is strongly correlated at the phenotypic level with total lactation milk yield. However, a genetic study will have to be undertaken to see how closely these traits are genetically correlated as well as the magnitude of their heritabilities. A large positive genetic correlation between 305-day and peak milk yield was also found in most studies (Ferris *et al.*, 1985; Rekaya *et al.*, 2000). Peak time was also correlated with 305-day milk yield. Therefore, direct selection for total lactation yield would be expected to result in lactations with a higher peak production and later peak time in Iranian Holstein heifers.

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مطالعه فنوتیپی منحنی شیردهی در گاوهای هلشتاین ایران

ه. فرهنگ فر و ح. نعیمی پور

چکیده

در این تحقیق بمنظور بررسی آثار برخی از عوامل محیطی مؤثر بر فراسنجه‌های منحنی شیردهی و خصوصیات تولیدی شیر، از ۱۳۶۲۵۰ رکورد آزمون ماهیانه متعلق به ۱۳۶۲۵ راس گاو شیری نژاد هلشتاین (۳ بار دوشش در روز) ایران توزیع شده در ۲۶۴ گله که در فاصله سالهای ۱۳۷۰ تا ۱۳۸۰ زایش داشتند استفاده شد. تابع خطی ویلمینک (Wilmink) برای دوره شیردهی هر گاو برازش شد. نتایج بهدست آمده از تجزیه و تحلیل حداقل مربعات واریانس نشان داد که عوامل محیطی گله، سال و ماه زایش دارای آثار معنادار بالایی بر تمام صفات مورد توجه می‌باشند. تجزیه و تحلیل همبستگی بین صفات نشان داد که فراسنجه مرتبط با سطح تولید دارای همبستگی منفی معناداری با فراسنجه‌های مرتبط با کاهش و افزایش تولید در بعد و قبل از زمان اوج شیردهی بوده ولی همبستگی آن با زمان رسیدن به اوج شیردهی و مقدار شیر ۳۰۵ روز مثبت و معنادار است. تجزیه و تحلیل وایازی ساده خطی میانگینهای تصحیح شده برای صفات شیر ۳۰۵ روز، تعداد روزهای مورد نیاز برای رسیدن به اوج شیردهی و مقدار شیر در اوج تولید بر حسب سال اولین زایش نیز نشان داد که برای صفات فوق به ترتیب افزایش سالیانه فنوتیپی ۱۳۷/۱۵۲ کیلوگرم، ۰/۵۳۵ روز و ۰/۴۳۴ کیلوگرم وجود داشته است.