Journal of Agriculture and Rural Development in the Tropics and Subtropics
Vol. 115 No. 2 (2014) 125–133

urn:nbn:de:hebis:34-2014121946912 ISSN: 1612-9830 – journal online: www.jarts.info

Study of individual lactation patterns of Iranian dairy buffaloes

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Abstract

The aims of the current study were 1) to investigate the effects of some environmental factors on lactation curve traits (LCTs) including initial milk yield (A), peak yield (PY), days to attain peak yield (PD), inclining- and declining slope of lactation (B and C, respectively), persistency (Per), and 240-d milk yield, and 2) to estimate pairwise phenotypic correlations between these traits in two Iranian buffalo ecotypes (Khuzestani and Azeri buffaloes). The dataset consisted of 15396 and 9283 lactations from 6632 Khuzestani and 3558 Azeri buffaloes, respectively (collected during 1992–2009). The results revealed that almost all of the factors had significant effects on the majority of the LCTs, whereby age group, parity and season of calving had greater influence on 240-d milk yield and PY than the other LCTs in both of the ecotypes. These effects were more apparent in Khuzestani buffaloes than in Azeri buffaloes. In the Khuzestani ecotype, the LCTs were significantly correlated with each other. However, in the Azeri ecotype the 240-d milk yield showed no significant relationship with parameters B, PD and Per. In conclusion, the studied factors play an important role in determining both the shape of the lactation curve and the overal performance of Iranian dairy buffaloes.

Keywords: buffalo, lactation curve, persistency, Wood's incomplete gamma function

1 Introduction

The lactation curve is influenced by two linked physiological mechanisms including cell growth and activity before the peak and death of mammary gland cells after the peak (Dijkstra *et al.*, 1997; Penchev *et al.*, 2011; Stelwagen, 2001; Van-Arreola *et al.*, 2004). The increment of milk yield from the beginning of the lactation to the peak can be attributed to the increase in the number and activity of secretive cells which is particularly related to the increment of milk flow all over the mammary gland; decline of milk yield after the peak can be attributed to the death of secretive cells together with hormonal changes in the animal's body (Stelwagen, 2001). The lactation curve shows the biological efficiency of an animal and is an appropriate tool for selection as well as for nutritional and reproductive management (Adediran *et al.*, 2007; Cziszter *et al.*, 2013; Dongre *et al.*, 2011). An appropriate milk yield curve has a relatively high peak and a moderate persistency (Dongre *et al.*, 2011; Penchev *et al.*, 2011). Animals which steadily produce milk at a moderate level throughout the lactation are preferred to those with higher milk production at peak but little thereafter (Dongre *et al.*, 2011). Modifying the shape of the lactation curve by breeding is somewhat difficult (Toghashi & Lin, 2003). On the one hand, it is under the control of complicated interactions of hormones involved in milk secretion (Hart *et al.*, 1979) and, on the other hand, it is under the influence of some identified and unidentified non-genetic

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factors (Dongre *et al.*, 2011). Both of these factors add to the complexity of addressing the issue of lactation curve shape improvement through selective breeding. To deal with this problem, an identification of the effective genetic and non-genetic factors is necessary (Angeles-Hernandez *et al.*, 2013). So far, researchers in Iran have only studied the lactation curve of Khuzestani buffaloes but the other Iranian buffalo ecotypes remain to be comprehensively studied. The main objectives of the current study were, therefore, to determine the relevant components of individual lactation curves using the Incomplete Gamma Function proposed by Wood (Wood, 1976) and to investigate the effects of some environmental factors on the variability of these components in two Iranian dairy buffalo ecotypes, namely Khuzestani and Azeri.

2 Materials and methods

In the current study, data from 15396 and 9283 lactations of Khuzestani and Azeri ecotypes, respectively, were used. These data originated from 6632 Khuzestani and 3558 Azeri buffaloes which were recorded by the buffalo breeding stations of at least eight provinces located in southeast, north and northeast of Iran during 1992–2009. The Animal Breeding Center of Iran supervised the data collection and pre-processed them for analyses.

At first, the Incomplete Gamma Function was fitted for lactation records of animals with at least four test-day records during 240 days after parturition. The equation of this function is as below:

$$y_t = At^B e^{-Ct}$$

Where: y_t is the milk yield at time t, A is the initial milk yield, B is the inclining slope of lactation, C is the declining slope of lactation, and e is the natural exponential or base of the natural logarithm.

The NLIN procedure of SAS 9.2 software (SAS Institute, 2002) was used for fitting the function to the lactation records using Gauss-Newton algorithm.

After fitting, the following components were estimated from the primary components of the equation:

$PY = A(B/C)Be^{-B}$ is the peak yield (kg),

$PD = B/C$ is the number of days to attain peak yield (day),

$Per = -(B+1)\ln(C)$ is the persistency of lactation, and

$Milk_{240} = A\int_1^{240} t^B exp^{-Ct} dt$ is the total 240-d milk yield (kg).

After estimating these components, lactations with abnormal curves (curves with a negative sign for B or C parameters) were eliminated. Subsequently 8233 and 4697 normal lactation curves were obtained for the Khuzestani and Azeri ecotypes, respectively. Also, lactations with PD before 5 days in milk and after 125 days in milk were excluded from further analyses. This resulted in 6484 and 3835 normal, filtered lactation curves for the Khuzestani and Azeri ecotypes, respectively, to be analysed further. A general linear model (GLM procedure of SAS software) was used to analyse the effects of some known environmental factors on the LCTs as detailed below:

$$y_{ijklmn} = \mu + by_i + cy_j + age_k + c_l + cs_m + v_n + e_{ijklmn}$$

Where y is dependent variable (LCTs), μ is the overall mean, by is year of birth, cy is year of calving, age is age group at calving, c is parity, cs is season of calving, v is village, and e is the residual with an expected value of 0 and a variance of σ_e^2. All factors except the random residual were assumed to be fixed.

Ranges of years of birth of the cows and their years of calving were 1980 to 2008 and 1992 to 2009, respectively. Age at calving was categorised into five groups; age <60 months, 60 to 84 months, 84 to 108 months, 108 to 132 months, and age >132 months. Data belonging to parities higher than ten were set into the tenth parity. The season of calving was categorised into two six-months periods namely in-season (summer and autumn), and out-of-season (winter and spring).

Because of the higher number of data at each level of a given factor, as compared to experiments in which only a few numbers of replicates are usually used for each level of a given factor or treatment, small differences between the means of different levels of a factor already become statistically significant at 0.05 significance level. Therefore we decided to reduce the first type error to 0.01 instead of 0.05.

In the last stage of the current study, pairwise phenotypic (Pearson) correlations between the LCTs were estimated using the CORR procedure of SAS software.

3 Results and discussion

Sometimes, abnormality of lactation curve data prevents a used algorithm to converge properly to a desired solution, and even if it converged the fitted curve would not have a normal shape. In this study 44.9 % and 44.4 % of the fitted lactation curves of Khuzestani and Azeri ecotypes, respectively, were atypical.

These frequencies of atypical lactation curves (ALCs) were considerably higher than those reported by Khan & Chaudhry (2001) for Nili-Ravi buffaloes (9.4 %) and by Macciotta *et al.* (2006) and Dimauro *et al.* (2005) for Italian buffaloes (around 30 %). Also, the frequency of ALCs was considerably higher than those reported in dairy cattle which range from 20–30 % (Macciotta *et al.*, 2006; Rekik & Ben Gara, 2004). Milk recording of Iranian buffaloes takes place in rural areas and, in many cases, is based on farmers' reports; therefore it is absolutely not as accurate as records of dairy cattle in industrial operations. Because of the shorter lactation length of dairy buffaloes in traditional rearing systems, as compared to the industrial ones, more frequent recording of the milk yield seems to be beneficial. Macciotta *et al.* (2006) reported that beside environmental factors, the structure of the data also had a significant effect on the shape of the lactation curve of Italian buffaloes. Jeretina *et al.* (2013) mentioned that one of the most probable reasons for the occurrence of ALCs is the non-efficiency of the milk recording scheme. As expected, most of the normal curves that were successfully fitted in this study were from lactations with several test-day records (results not shown). This also means that incomplete lactation test-day records are detrimental for estimating the standard lactation records. Although there are numerous methods to extend partial lactation records to a standard one, standard data generated by such methods are, in most cases, not accurate enough to be used in genetic selection of candidates (Wiggans & Van Vleck, 1979).

Means (S.D.) of LCTs are presented in Table 1, followed in Table 2 and Table 3 by the test on the influence of age group, parity, and other environmental factors on LCTs in Khuzestani and Azeri ecotypes. Least square means of LCTs for calving age group, parity, and season of calving in Khuzestani and Azeri ecotypes are reported in Table 4 and Table 5, respectively.

In both ecotypes, almost all factors had significant effects on 240-d milk yield, C and PY traits. Effect of year of birth on PD and Per parameters was not significant in either ecotype, however, it affected the remaining traits significantly ($P<0.01$). Year of calving significantly affected all of the traits in both ecotypes. Chhikara *et al.* (1998) reported that year of calving had significant effects ($P<0.01$) on both PY and PD in Murrah buffaloes. The effects of the year of calving and the year of birth as sources of variation on the traits are relatively difficult to explain. However, their effects are probably due to management and environmental variations such as change in nutrition and climate conditions in different years. The factor village, which was considered as the management unit in this study, significantly influenced all LCTs.

The factor age group at calving affected the PY and 240-d milk yield more than the other traits, especially in the Khuzestani ecotype. Since the effect of age group at calving on the remaining LCTs was not significant, it appears that aging of the buffaloes increases total milk yield via increasing PY. The highest PY and 240-d milk yield was obtained for Khuzestani buffaloes aged between 60 and 84 months, whereas the lowest of these two traits were obtained for the oldest cows. This shows that the increment of milk production until the middle age in this ecotype and its subsequent reduction are related to aging. In the Azeri ecotype, however, there were no significant differences ($P>0.01$) among the least square means of the LCTs of different age groups. Catillo *et al.* (2002) showed that the milk production of Italian dairy buffaloes increased with aging in almost all phases of lactation, especially at peak time, so that the lowest and highest daily milk production were found in the youngest and oldest buffaloes, respectively.

The parity factor affected the PY and 240-d milk yield differently within different age groups. As mentioned above, milk production increased until the middle age and decreased afterward. However, the production of milk increased continuously with parity number in both ecotypes. Such that parameters A, PY and 240-d milk yield were lower in early parities, increased with the number of parity and reached their highest values in parity ten. These increments were significant for both PY and 240-d milk yield but not significant for the other LCTs. Similar results have been reported by Amin (2003) who observed that LCTs of Egyptian dairy buffaloes improved with parity number from first to fifth parity. Also, Coletta & Caso (2008), by studying the lactation curves of the first, second, and third parities of Italian dairy buffaloes, reported that the lactation potential of the buffaloes increased from the first to the third parity throughout the lactation, but especially at peak time. Anwar *et al.* (2009) reported that the parity effect was significant on A and B parameters but not significant on the C parameter. They reported the highest value of parameter A and the lowest values of parameters B and C for the third parity. Their results are not in line with the findings of the current study. The discrepancy between the effects of age group and parity factor on PY and 240-d milk yield is probably due to the presence of buffaloes with different parities in a given age group, especially in older ages. The buffalo is usually blamed for higher age at first calving and prolonged calving interval as well as for poor reproductive performance (Aziz *et al.*, 2001). This may explain why some buffaloes were in early parities but of older ages.

Table 1: *Number and means (standard deviation) of lactation curve traits in Khuzestani and Azeri buffaloes*

Ecotype	*Lactation curve traits*							
	n	*A*	*B*	*C*	*PY* (kg)	*PD* (day)	*Per*	$Milk_{240}$ (kg)
Khuzestani	6484	4.00 (3.46)	0.521 (0.544)	0.0068 (0.0063)	11.1 (3.0)	72.3 (28.2)	9.52 (3.41)	2184 (612)
Azeri	3835	3.41 (2.71)	0.463 (0.520)	0.0071 (0.0062)	8.2 (2.8)	60.5 (30.5)	9.16 (3.25)	1540 (472)

A, *B*, *C*, *PY*, *PD*, *Per*, and $Milk_{240}$ are initial milk yield, inclining slope of the curve, declining slope of the curve, peak milk yield, days to attain peak milk yield, persistency of lactation, and total milk yield (240-day), respectively.

Table 2: *Significance of the sources of variation of lactation curve traits in Khuzestani buffaloes*

Variable	*Lactation curve traits*							
	df	*A*	*B*	*C*	*PY* (kg)	*PD* (day)	*Per*	$Milk_{240}$ (kg)
Year of birth	27	n.s.	n.s.	*	*	n.s.	n.s.	**
Year of calving	17	**	**	**	**	**	**	**
Age group at calving	4	n.s.	n.s.	n.s.	*	n.s.	n.s.	**
Village	47	**	**	**	**	**	**	**
Parity	9	n.s.	n.s.	n.s.	**	n.s.	n.s.	**
Calving season	1	n.s.	n.s.	*	**	**	*	**

A, *B*, *C*, *PY*, *PD*, *Per*, and $Milk_{240}$ and *df* are initial milk yield, inclining slope of curve, declining slope of curve, peak milk yield, days to attain peak milk yield, persistency of lactation, total milk yield (240-day), and degree of freedom, respectively.
* Significant at P<0.01; ** Significant at P<0.001; n.s. not significant (P>0.01)

Table 3: *Significance of the sources of variation of lactation curve traits in Azeri buffaloes*

Variable	*Lactation curve traits*							
	df	*A*	*B*	*C*	*PY* (kg)	*PD* (day)	*Per*	$Milk_{240}$ (kg)
Year of birth	22	n.s.	n.s.	*	**	n.s.	n.s.	**
Year of calving	14	**	**	**	**	**	**	**
Age group at calving	4	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Village	40	**	**	**	**	**	**	**
Parity	9	n.s.	n.s.	n.s.	**	n.s.	n.s.	**
Calving season	1	n.s.	***	***	**	n.s.	n.s.	n.s.

A, *B*, *C*, *PY*, *PD*, *Per*, and $Milk_{240}$ and *df* are initial milk yield, inclining slope of curve, declining slope of curve, peak milk yield, days to attain peak milk yield, persistency of lactation, total milk yield (240-day), and degree of freedom, respectively.
* Significant at P<0.01; ** Significant at P<0.001; n.s. not significant (P>0.01)

Table 4: *Least square means of lactation curve traits for different age groups at calving (month), parities and seasons of calving in Khuzestani buffaloes*

Variable	*Lactation curve traits*							
	n	*A*	*B*	*C*	*PY* (kg)	*PD* (day)	*Per*	$Milk_{240}$ (kg)
Age < 60	1142	4.07	0.47	0.00660	10.3 ^{b}	69.5	7.62	2021 ^{bc}
60 ≤ Age < 84	1210	3.99	0.521	0.00718	10.4 ^{b}	69.0	7.71	2026 ^{c}
84 ≤ Age < 108	1175	4.14	0.474	0.00693	10.2 ^{ab}	66.5	7.57	1992 ^{bc}
108 ≤ Age < 132	1009	4.18	0.462	0.00699	10.1 ^{ab}	65.4	7.50	1945 ^{b}
Age ≥ 132	1948	3.74	0.526	0.00786	9.8 ^{a}	67.6	7.62	1867 ^{a}
1st parity	743	3.61	0.534	0.00754	9.6 ^{a}	68.6	7.69	1834 ^{a}
2nd parity	837	3.82	0.497	0.00731	9.9 ^{ab}	67.2	7.59	1891 ^{ab}
3rd parity	742	3.89	0.517	0.00737	9.9 ^{ab}	68.3	7.69	1896 ^{ab}
4th parity	732	4.01	0.506	0.00714	9.9 ^{ab}	68.2	7.67	1928 ^{ab}
5th parity	779	4.16	0.505	0.00743	10.0 ^{abc}	65.8	7.62	1925 ^{ab}
6th parity	704	4.06	0.485	0.00720	10.2 ^{bcd}	67.2	7.56	1974 ^{bc}
7th parity	556	3.99	0.49	0.00690	10.3 ^{bcd}	70.7	7.66	2032 ^{cd}
8th parity	435	4.17	0.482	0.00686	10.5 ^{cd}	68.1	7.59	2052 ^{cd}
9th parity	312	4.08	0.458	0.00675	10.6 ^{d}	66.2	7.52	2069 ^{cd}
10th parity	644	4.46	0.433	0.00658	10.6 ^{d}	65.5	7.46	2099 ^{d}
Out-of-season	528	4.05	0.477	0.00753 ^{b}	9.9 ^{a}	63.6 ^{a}	7.50 ^{a}	1890 ^{a}
In-season	5956	4.00	0.505	0.00669 ^{a}	10.4 ^{b}	71.5 ^{b}	7.71 ^{b}	2050 ^{b}

A, *B*, *C*, *PY*, *PD*, *Per*, and $Milk_{240}$ are initial milk yield, inclining slope of lactation curve, declining slope of lactation curve, peak milk yield, days to attain peak milk yield, persistency of lactation, and total milk yield (240-day), respectively. Different supperscripts within a column indicate significant differences between different levels of a given factor (P<0.01). Tukey post-hoc test was used for least square means comparison of different levels of a factor.

Table 5: *Least square means of lactation curve traits for different age groups at calving (month), parities and seasons of calving in Azeri buffaloes*

Variable	*Lactation curve traits*							
	n	*A*	*B*	*C*	*PY* (kg)	*PD* (day)	*Per*	$Milk_{240}$ (kg)
Age < 60	797	3.52	0.447	0.00720	8.6	64.1	7.34	1646
60 ≤ Age < 84	954	3.29	0.48	0.00753	8.4	65.3	7.43	1611
84 ≤ Age < 108	903	3.48	0.478	0.00758	8.5	62.9	7.39	1611
108 ≤ Age < 132	682	3.32	0.514	0.00826	8.6	61.6	7.43	1578
Age ≥ 132	499	3.19	0.572	0.00882	9.0	61.7	7.58	1634
1st parity	543	2.88	0.49	0.00808	7.8 ^{a}	64.0	7.40	1442 ^{a}
2nd parity	631	3.26	0.485	0.00774	8.2 ^{b}	61.3	7.38	1533 ^{b}
3rd parity	614	3.05	0.513	0.00808	8.5 ^{bc}	64.2	7.48	1581 ^{bc}
4th parity	613	3.27	0.505	0.00774	8.5 ^{bc}	63.9	7.48	1597 ^{bc}
5th parity	525	3.30	0.460	0.00725	8.5 ^{bc}	62.9	7.39	1623 ^{c}
6th parity	397	3.19	0.536	0.00809	8.7 ^{bc}	66.3	7.59	1641 ^{c}
7th parity	242	3.49	0.489	0.00781	8.8 ^{bc}	61.9	7.41	1659 ^{c}
8th parity	139	3.83	0.505	0.00783	8.9 ^{bc}	62.1	7.45	1663 ^{c}
9th parity	77	3.46	0.502	0.00771	8.8 ^{bc}	65.6	7.49	1666 ^{c}
10th parity	54	3.87	0.497	0.00845	9.4 ^{c}	59.0	7.29	1754 ^{c}
Out-of-season	2116	3.30	0.531b	0.00841 ^{b}	8.8 ^{a}	62.4	7.46	1621
In-season	1719	3.41	0.465a	0.00734 ^{a}	8.4 ^{b}	63.9	7.41	1610

A, *B*, *C*, *PY*, *PD*, *Per*, and $Milk_{240}$ are initial milk yield, inclining slope of lactation curve, declining slope of lactation curve, peak milk yield, days to attain peak milk yield, persistency of lactation, and total milk yield (240-day), respectively. Different supperscripts within a column indicate significant differences between different levels of a given factor (P<0.01). Tukey post-hoc test was used for least square means comparison of different levels of a factor.

In the Khuzestani ecotype, A and B parameters of buffaloes that calved in out-of-season period did not differ significantly from those that calved in-season (P>0.01). However, due to a higher peak, flatter curve progression and more persistent production, buffaloes of the in-season class had a significantly higher total lactation performance (240-d milk yield) than those in the out-of-season group (P<0.01). Total milk yield in the Azeri ecotype, however, was not affected significantly by the season of calving. Nevertheless, by comparing the average lactation curve components for the two calving seasons, it appeared that even in this ecotype the buffaloes that calved in-season had more desirable lactation patterns than those that calved out-of-season.

Since in Iran buffaloes are mostly reared in rural conditions and under extensive management, it seems that the season of calving affects the production pattern of buffaloes more than the production pattern of animals which are reared in intensive production systems such as dairy cattle. However, some researchers have observed a substantial effect of season of calving on the shape of the lactation curve of Holstein Friesian cattle (Atashi & Moradi, 2009; Tekerli *et al.*, 2000).

The lactation curves of both the Khuzestani and the Azeri ecotypes, fitted by Wood's Incomplete Gamma Function, are shown in Figure 1. The curves show that, as compared to the Azeri ecotype, the initial milk yield and inclining slope of lactation were higher in Khuzestani buffaloes and resulted in a higher peak milk yield. For the declining slope of lactation, however, the two ecotypes showed a similar trend. This superiority in the primary parameters as well as a more persistent production resulted in considerably higher 240-d milk yield (area under the lactation curve) in the Khuzestani than in the Azeri ecotype.

Phenotypic correlations between LCTs are presented in Table 6. The direction and strength of correlations between the traits are nearly identical in the two ecotypes, ranging from −0.67 to 0.92 (Khuzestani) and from −0.72 to 0.91 (Azeri). These results are in accordance with the reports of Anwar *et al.* (2009) who studied Nili-Ravi buffaloes. The A parameter was positively correlated with both PY and 240-d milk yield, but negatively related to the remaining parameters. In consequence, a higher initial milk yield resulted in a gentle slope during the inclining phase of lactation, a higher peak yield, a steeper slope in the declining phase of lactation, a lower persistency and a higher 240-d milk yield.

The high correlation between parameters B and C indicates that a steeper slope in the inclining phase of the lactation is accompanied by a steeper slope in the declining phase as well.

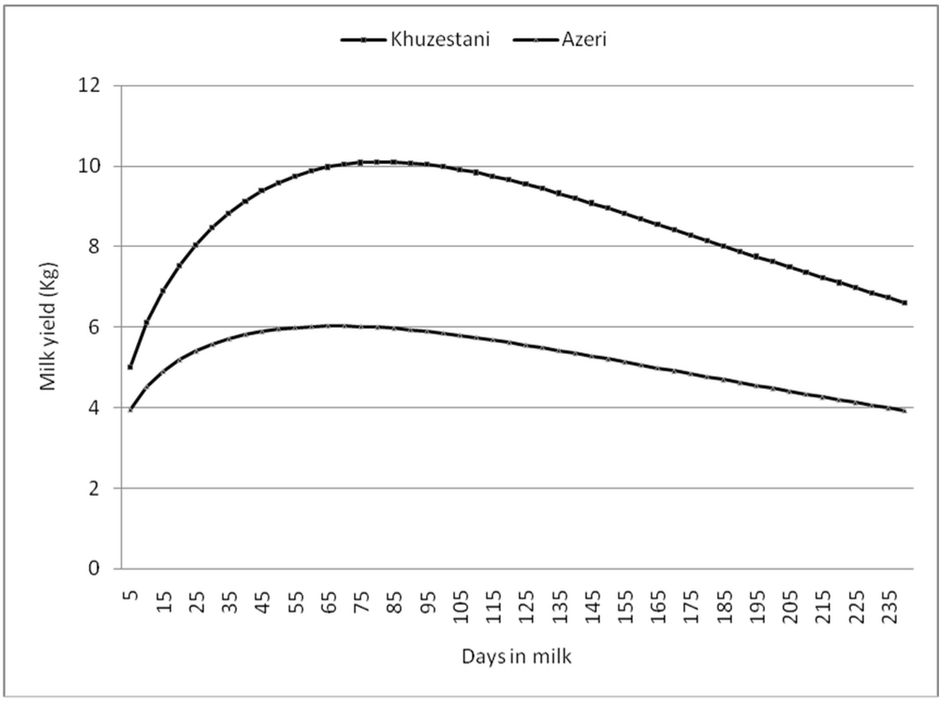

Fig. 1: *Average lactation curves of first-parity Khuzestani and Azeri buffaloes which calved in out-of-season class*

Table 6: *Correlation coefficients between lactation curve traits in Khuzestani (above diagonal) and in Azeri buffaloes (below diagonal).*

	Khuzestani buffaloes						
Azeri buffaloes	*A*	*B*	*C*	*PY* (kg)	*PD* (day)	*Per*	$Milk_{240}$ (kg)
A	–	−0.67 **	−0.58 **	0.22 **	−0.63 **	−0.60 **	0.43 **
B	−0.66 **	–	0.90 **	0.10 **	0.44 **	0.92 **	−0.23 **
C	−0.49 **	0.86 **	–	0.11 **	0.14 **	0.68 **	−0.31 **
PY	0.22 **	0.22 **	0.32 **	–	−0.04 **	0.05 **	0.87 **
PD	−0.72 **	0.53 **	0.18 **	−0.09 **	–	0.64 **	0.03 n.s.
Per	−0.67 **	0.91 **	0.60 **	0.07 **	0.74 **	–	−0.13 **
$Milk_{240}$	0.31 **	−0.02 n.s.	−0.07 **	0.88 **	0.02 n.s.	0.00 n.s.	–

A, *B*, *C*, *PY*, *PD*, *Per*, and $Milk_{240}$ are initial milk yield, inclining slope of lactation curve, declining slope of lactation curve, peak milk yield, days to attain peak milk yield, persistency of lactation, and total milk yield (240-day), respectively.
* Significant at P<0.01; ** Significant at P<0.001; n.s. not significant (P>0.01)

PY had the highest correlation with total milk yield (0.87–0.88) and the lowest correlation with persistency (0.05–0.07), which indicates that buffaloes with a high potential for milk production at peak will also have a higher potential for 240-d milk yield. Therefore, PY can be used as an indicator trait for early selection of dairy buffaloes, provided that the selection criteria are the phenotypic values. Moreover, the low but positive correlation between PY and Per parameters indicates that buffaloes with a higher PY may or may not have a high persistency. There is apparently high phenotypic variation in persistency between individual buffaloes, which provides the opportunity to phenotypically select buffaloes for proper lactation curves; that is high peak, moderate lactation persistency and high total milk yield. The negative correlation between PY and PD indicates that buffaloes with higher milk yield at peak reach this peak earlier in their lactation than those with a lower peak yield. Furthermore, since the correlation between PD and 240-d milk yield is weak and non-significant, it can be concluded that PY, but not PD, is the most important factor influencing the lactation curve shape of Iranian buffaloes. The highest correlation (0.93) between 305-day milk yield and LCTs in Iranian Holstein cattle has also been obtained for PY (Farhangfar & Naeemipour, 2007). In spite of the stronger effect of PY on the shape of the lactation curve, Borghese *et al.* (2013) stated that the persistency of the lactation was the most important criterion determining the amount and profitability of milk production in Italian dairy buffaloes. By definition, persistency is the ability of an animal to maintain its milk production at higher level after peak yield, and the more persistent the animal is the more milk will be produced during the whole lactation period. Dairy buffaloes with a flater lactation curve are more profitable as compared to those with the same total milk yield but with a rapidly declining lactation curve (Anwar *et al.*, 2009). Adediran *et al.* (2007) stated that PY, Per and lactation length are the main components determining the lactation curve of dairy cattle and also declared that emphasis of selection on PY may increase cow's metabolic stress at insemination time and may increase metabolic disorders. However, if genetic correlations between PY and both total milk yield and Per parameters are similar to the phenotypic correlations obtained in this study, we will be able to define a suitable set of lactation parameters from which selection indices for dairy buffaloes can be derived.

In conclusion, the non-genetic factors play an important role in determining the shape and components of the lactation curve as well as the total milk production of Iranian dairy buffaloes and should, therefore, be considered in selecting them for proper and desirable lactation curve shapes in breeding programs. The PY is the most important factor determining the shape and total milk production of a buffalo. Because of the strong positive phenotypic correlation between PY and 240-d milk yield, it seems that basing selection decisions on PY can deliver the majority (if not all) of selection response for total milk yield. Of course, the possible side-effects of selecting buffaloes based on PY on other economically and physiologically important traits should be evaluated in these breeds.

Acknowledgement

This study was supported by Sanandaj branch, Islamic Azad University. We thank the staff of the Animal Breeding Center for providing the data.

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