LACTATION CURVES OF MILK, FAT AND PROTEIN IN EGYPTIAN BUFFALO USING TEST-DAY MODEL

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ABSTRACT

Data on 4971 test-day milk yield traits [milk (TDMY), fat (TDFY) and protein (TDPY)] for 691 Egyptian buffalo cows, daughters of 120 sires and 532 dams were used for fitting the lactation curve parameters of milk, fat and protein yields using multiple-trait animal model. The random effects included in the model were direct additive genetic, permanent environment and error, while the fixed effects were herd test-day, year and season of calving and parity as well as days in milk as a covariable.

The means for TDMY, TDFY, TDPY and lactation curve parameters [initial (a), ascending slope (b), descending slope (c), persistency (P), and maximum milk production during lactation (Ymax) and the peak test-day (PY)] were estimated. Heritabilities of TDMY, a, b, c, P, PY and Ymax were 0.22, 0.37, 0.38, 0.39, 0.37, 0.37 and 0.38, respectively. The corresponding heritabilities for TDFY and fat curve parameters were 0.21, 0.41, 0.40, 0.39, 0.38, 0.36 and 0.42, while the estimates for TDPY and protein curve parameters were 0.22, 0.38, 0.40, 0.40, 0.38, 0.40 and 0.43, respectively. Genetic correlations among TDMY and curve parameters of a, b, c, P, PY and Ymax were 0.31, -0.23, -0.34, 0.52, 0.48 and 0.87, respectively. Genetic and phenotypic correlations between milk yield traits were high (mostly of 0.83 and 0.99), like the correlations between curve parameter in milk, fat and protein (from 0.71 to 0.96). In practice, genetic selection for lactation curve parameters (a, P and Ymax) in the Egyptian buffalo would improve total milk yield traits.

Keywords: *Bubalus bubalis*, buffaloed, Egyptian buffalo, lactation curve parameters, genetic parameters

INTRODUCTION

The total number of buffalo in Egypt is estimated to be 3.9 million. It is a very well adapted animal to the small-holder conditions and is raised under the extensive production system. Therefore, it plays as important role in Egyptian agriculture. It is the main dairy animal in Egypt; its contribution to the country's milk production is nearly 45.5% (FAOSTAT, 2013). In general, lactation curves in dairy animals reach the peak yield after calving and then decrease steadily after peak yield to the drying off (Swalve and Guo, 1999). Based on the information obtained from the curve (e.g. days in milk to peak, maximum milk production during lactation and lactation persistency), it can be used as a tool for evaluating and selecting the lactating

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herds (Swalve, 1995). Persistency of lactation has direct economic value as it is the ability of a buffalo cow to continue producing milk at a high level after the peak of her lactation.

Some researchers derived the lactation curve parameters of milk, fat and protein traits. Aziz et al. (2006) tried to fit the linear logarithmic transformed form of the Incomplete Gamma function Wood (1967) to weekly milk yield records to describe the shape of the lactation curve for the first four lactations of the Egyptian buffaloes. The author mentioned that Wood's function seemed to be suitable for Egyptian lactation data and might be used for predicting the whole lactation yield from part lactation data. This result agrees with other work presented by Fooda *et al.* (2010). Abdel-Salam *et al*. (2011) for Egyptian buffalo found that, in comparison between Wood, Wilmink and Guo and Swalve, the goodness-of-fit statistics of the expected curves for daily milk, fat and protein yield, for the best-fit models, appear that Wood model gave the best fit for the studied criteria. The objective of this study was investigating the genetic improvement possibilities for test-day milk yield traits and their lactation curve parameters in the Egyptian buffalo.

MATERIALS AND METHODS

Dataset

A total of 4971 test-day milk, fat and protein yield records was used in this study and they were collected at monthly intervals over the period from 1999 through 2009 from four buffalo experimental herds (El-Nattafe El-Gadid, El-Nattafe El-Kadim, Mahalet Mousa and El-Gemmiza) belonging to the Animal Production Research Institute (APRI), Ministry of Agriculture, Egypt. Test day milk yield (TDMY) records were measured following an alternative am-pm monthly recording scheme. Milking was practiced twice a day at 7 am and 4 pm throughout the lactation period. In general, using TD models could have advantages over a 305-day model (Swalve, 1995). All the known relationships among the individuals were considered in the animal model employed in analysis. The structure of the data analyzed is shown in Table 1.

Measuring the fat and protein percentages in milk

Fat and protein quantities were measured by the automated method of infrared absorption spectrophotometry (Milk-o-Scan; Foss Electric, Hillerφd, Denmark) at the Dairy Services Unit,

Table 1. Structure of test day data analyzed for Egyptian buffaloes.

Item	Data
No. of sires	120
No. of dams	532
No. of cows with records	691
No. of base animals	469
No of non-base animals	684
Total number of animals	1153
Total number of lactation records	4971

Animal Production Research Institute, Sakha, Kafr El-Sheikh Governorate. The device needs a set of solutions: The first solution is used to wash the device after the analysis of the samples and before turning it off the name of this solution non foaming stella 0.5% (Foss company electric Denmark). The second solution is used to reset the device which gives the readings 0.000 so it is ready to read the new samples and its name is Triton x-100 and we use only 1 cm/liter of distilled water, and finally we have to give the device the order Prog 2 then Prog 3 then Prog 4, and then the device is programmed to read the buffalo milk samples. After that has been converted the percentages of fat and protein to yields in grams.

Estimating the curve parameters of milk, fat and protein yields

In this work, the shape of the milk, fat and protein curves of Egyptian buffaloes were studied using the gamma type function (Wood, 1967) which was described as sufficiently good for modeling extended lactations (Abdel-Salam *et al*., 2011). The following gamma-type function was used for describing the lactation curve of all parameters:

$$Y_n = an^b e^{-cn}$$

The constants a, b and c were calculated by using a general linear model (GLM) procedure of SAS software (SAS, 2002); where Y_n is the test-day milk (kg), fat (g) and protein yields (g), in the n^{th} month of lactation, a is the initial yield, b describing the rate of production increase up to the peak during the ascending phase, c describes the rate of yield decrease during the descending phase and e is base of natural logarithms. The NLIN procedure of SAS software was used for fitting the gamma type function. After fitting the function, the following components were estimated from the primary components of the equation. Persistency of lactation (P = -(b+1)Ln(c)) was also estimated. Days in milk (DIM) at peak yield (PY) was defined as b/c and the maximum production during lactation (Ymax) was calculated as $a(b/c)^b e^{-b}$ according to Wood (1967).

Genetic analysis for lactation curve parameters

Variance and covariance components (direct additive genetic, permanent environmental, error and phenotypic) and heritabilities were estimated using the following linear multi-trait repeatability animal model of the VCE6 program (Groeneveld *et al*., 2010):

$$Y_{ijklmno} = \mu + A_i + Pe_j + HTD_k + Ye_l + Pa_m + S_n + b(A) + e_{ijklmno}$$

Where: Y_{ijklmn} = The recorded trait of test-day yields (milk, fat and protein), initial yield, ascending phase, descending phase, persistency, DIM at peak yield and maximum production during lactation; μ = The overall mean; A_i = The additive genetic random effect of buffalo, assumed to be NID (0, σ^2_a); P_{ej} = The permanent environmental random effect, assumed to be NID (0, σ^2_{pe}); HTD_k = The fixed effect of the k^{th} herd-test-day (k = 40 levels for all paritie); Ye_l = The fixed effect of l^{th} year of calving (l = 10 levels for all paritie); Pa_m = The fixed effect of m^{th} parity (m = 5 levels for all paritie); S_n = The fixed effect of n^{th} season of calving (n = 2 level); b(A) = The covariable for days in milk; $e_{ijklmno}$ = The random residual term associated with each observation. The previous repeatability animal model could be written in the following matrix structure:

$$y = Xb + Za\,a + Zc\,c + e$$

Where: y = The vector of lactation observations, X = The incidence matrix relating the fixed effects to y, b = The vector of an overall mean and the fixed effects of herd test day, parity, year and season of calving and days in milk (as a covariable), Za = The incidence matrix relating the direct additive genetic effects to y, a = The vector of the random direct additive genetic effect associated with the incidence matrix Za, Zc = The incidence matrix relating the permanent environmental effect, c = The vector of permanent environmental effect associated with the incidence matrix Zc and e = The vector of random residual effects N (0, Is^2e) where I is an identity matrix. The variance-covariance components of the random effects were as follows:

$$Var\begin{pmatrix} a \\ c \\ e \end{pmatrix} = \begin{pmatrix} A\sigma_a^2 & 0 & 0 \\ 0 & I_c\sigma_c^2 & 0 \\ 0 & 0 & I_n\sigma_e^2 \end{pmatrix}$$

Where: a = Numerator relationship matrix, Ic, In = identity matrix with order equal to number of animals and number of records, respectively, σ^2_a, σ^2_c, σ^2_e, and are the variances due to effects of diract additive genetic, permanent environmental and random error, respectively. Occurrence of local maxima was checked by repeatedly restarting the analyses until the log-likelihood did not change beyond the first decimal. The heritability (h^2) was computed as:

$$h^2 = \frac{\sigma^2 g_i}{\sigma^2 g_i + \sigma^2 p_i + \sigma^2 e_i}$$

Where σ^2_{gi} is the additive genetic variance of the i^{th} TD milk traits, σ^2_{pi} is the permanent environmental variance and σ^2_{ei} is the residual variance. Similarly, the genetic correlation coefficients (r_{gij}) between any two TDMY traits were calculated by dividing the additive genetic covariances (σ_{gij}) between any two TD's milk yield traits (i^{th} and j^{th}) by the square root of the product of their additive genetic variances of (σ^2_{gi} and σ^2_{gj}). Then, the genetic correlation between the i^{th} and j^{th} TDMY traits is calculated as:

$$r_{gij} = \frac{\sigma g_{ij}}{\sqrt{(\sigma^2 g_i)}\sqrt{(\sigma^2 g_j)}}$$

The estimates of phenotypic correlation coefficients (r_{pij}) between any two TDMY traits were calculated as:

$$r_{pij} = \frac{\sigma p_{ij}}{\sqrt{(\sigma^2 p_i)}\sqrt{(\sigma^2 p_j)}}$$

The estimates of permanent environmental coefficients (rpe_{ij}) between pairs of TDMY traits were calculated as:

$$r_{pe_{ij}} = \frac{\sigma pe_{ij}}{\sqrt{(\sigma^2 pe_i)}\sqrt{(\sigma^2 pe_j)}}$$

Predicted breeding values

The predicted breeding values (PBVs) were estimated by REML using the computer PEST package (Groeneveld *et al*., 2001) for test-day milk, fat and protein yields according to the repeatability animal model matrix structure. The solutions for the equations of animals were computed from the pedigree file, one animal at a time for animals with records and animals without records (sires and dams). The diagonal element (d_t) and the adjusted right-hand side (y^*_t) were accumulated with each pedigree file record for the t^{th} animal. For the animals with and without records, the formula used to estimate the PBV was (Kennedy, 1989):

$$PBV = [^{y}_{t}/d_{t}]$$

The lactation yield traits curves were measured as the regression of least squares means and breeding values on test day.

Plotting the lactation curve from the phenotypic values and the breeding values for test-day milk, fat and protein yields

The lactation curves from the phenotypic values were measured as the regression of least squares means on test-day. As stated before, the breeding values of the animals with records and without records were estimated using the PEST program (Groeneveld *et al*., 2002). Accordingly, the breeding values were measured by regressing the breeding values on test-day.

RESULTS AND DISCUSSION

Means and variations of lactation curve parameters

The test-day lactation curve parameters were calculated using the gamma-type function according to Wood (1967) for initial milk yield (a), the rate of yield increase up to peak (ascending phase, b), the rate of yield decrease during the descending phase (c), persistency (P), the days in milk to peak or the time required to attain this peak (PY) and the maximum peak milk yield during lactation (Ymax).

The estimates of means, standard deviations, coefficients of variation (CV), minimum and maximum are shown in Table 2 for TDMY, TDFY and TDPY, a, b, c, P, PY and Ymax for the whole data that were calculated by the logarithmic gamma-type function (Table 2).

The means for TDMY (7.00 kg), showed a lactation curve initializing with 5.59 kg, followed by an increase in milk yield until the peak of the lactation, occurred in the third and fourth test-day (0.99 kg), and a decrease until the end of lactation for 0.19 kg for parameter c. Means of persistency of lactation was also estimated to be 6.09 kg.

The result of parameter a in TDMY was the same for those reported by Kianzad *et al.* (2013); Shokrollahi and Hasanpur (2014), higher than those reported by Atashi *et al.* (2009), but lower than those reported by Bouallegue *et al.* (2013); Sahoo *et al.* (2014); Sahoo *et al.* (2015).

The rate of increase to reach the peak during the ascending phase (b) and the rate of decrease (c) were the same trend by Fooda *et al.* (2010) for the Egyptian buffalo. The ascending phase (b) was faster and bigger as reported by Fooda *et al.* (2010); Bouallegue *et al.* (2013); Kianzad *et al.* (2013); Shokrollahi and Hasanpur (2014), differ those reported by Sahoo *et al.* (2014); Sahoo *et al.* (2015) in buffalo. This trend was attributable to the improvement of nutrition for post-partum, and since 2005, a correct methodology of elimination and replacement activities was performed (Fooda *et al.*, 2010). Therefore, the breeders had a trend to increase the nutrition, vitamins and minerals at the pre, post-partum and the whole lactation period which lead to an increase in the milk yield and the income.

The average persistency in milk yield was 6.09 kg, indicating the deteriorating status of the herd's persistency of the Animal Production Research Institute, which required more work based on a selection index including persistency trait. This estimate of persistency is lower than that of Fooda *et al*. (2010); Bouallegue *et al*. (2013) on the same population of Egyptian buffalo, lower than reported by Atashi *et al*. (2009); Kianzad *et al*. (2013); Shokrollahi and Hasanpur (2014), but greater than Sahoo *et al*. (2015); Şahin *et al*. (2015) in buffalo.

The peak milk yield averaged 10.77 kg and the peak test day (the time required to attain this peak) was 54.97 days. The peak time estimate is the same as that reported by Atashi *et al*. (2009); Shokrollahi and Hasanpur (2014), but lower than that of Bouallegue *et al*. (2013); Kianzad *et al*. (2013); Şahin *et al*. (2015), and higher than that Aziz *et al*. (2006). The maximum peak milk yield is the same as that of Kianzad *et al*. (2013); Shokrollahi and Hasanpur (2014), increased more as reported by Aziz *et al*. (2006), but decreased as cited by Atashi *et al*. (2009); Bouallegue *et al*. (2013).

The means for fat and protein yields and parameters curves were estimated and illustrated in Table 2. The means for fat and protein yields were 45.59 and 26.87 g, respectively, and these results were the same of those obtained by Silvestre *et al*. (2009), but less than that Bouallegue *et al*. (2013) in cattle. The initialized by estimates were 3.79 and 3.31 g, followed by an increase of 1.06 and 1.01 g in yields until the peak of the lactation occurred in the third and fourth test-day, and decreased for the parameter c again at the end of lactation with a production of 0.33 and 0.32 g, respectively. Means of persistency were also estimated to be 2.38 and 2.33 g for fat and protein, respectively. The peak of fat and protein yield (Ymax) being 4.68 and 3.92 g and the peak test day (PY) was 3.47 and 3.31 days, respectively.

The largest coefficient of variations (CV) among the lactation curve traits were for parameter c and the smallest for parameter a in all traits. These results differ from described by Boujenane and Hilal (2012) that the largest for parameter b but the smallest for parameter P of milk.

The phenotypic and genetic estimates for the lactation curve

For the phenotypic values, it could be observed that the initial yield was 5.59 kg for milk and 32.8 and 20.3 g for fat and protein for the first test day (Figure 1, 2 and 3), then it gradually increased as the lactation period advanced (parameter b) till reached 7.7 kg for the animals in the third and fourth test day in milk and 49.7 and 29.4 g in fat and protein (peak yield or persistency), and reached 4.06 kg (parameter c) in milk and 27.81 and 16.03 g in fat and protein for the animals dried off at the tenth test day. The curve parameters of a and c in milk yield showed lower estimates than that reported by Silvestre *et al*. (2009) and unlike to b parameter, but a, b, c estimates in fat and protein showed higher than Silvestre *et al*. (2009). The Ymax showed a higher estimate than that of Silvestre *et al*. (2009) but unlike PY. However, the curve parameters for fat and protein traits were lower than Bouallegue *et al*. (2013).

For the lactation curve plotted from the breeding values, it could be observed that the initial breeding value was 0.109 kg for milk and 1.125 and 0.280 g for fat and protein for the first test day (Figure 4, 5 and 6), then it gradually increased as the lactation period advanced (parameter b) till reached 5.3 kg for the animals in the third and fourth test day in milk and 3.5 and 0.81 g in fat and protein (peak yield or persistency), and reached 0.026 kg (parameter c) in milk and 0.9 and 0.17 g in fat and protein for the animals dried off at the tenth test day.

Table 2. Means, standard deviations (SD), standard error (SE), coefficients of variation (CV), minimum (min.) and maximum (max.) for test-day milk, fat and protein curve parameters.

Variables	Mean	SD	SE	CV	Min.	Max.
Milk yield						
TDMY, kg	7.00	2.37	0.03	33.91	3.00	13.50
a, kg	5.59	1.60	0.02	28.55	2.50	7.50
b, kg	0.99	0.37	0.005	36.60	0.01	1.50
c, kg	0.19	0.16	0.002	83.09	0.03	0.50
P, kg	6.09	2.64	0.04	43.36	4.30	11.63
PY, day	54.97	20.06	0.28	36.49	45.00	97.00
Ymax, kg	10.77	4.69	0.07	43.53	6.50	17.00
Fat yield						
TDFY, g	45.59	16.66	0.24	36.53	13.86	113.88
a, g	3.79	0.31	0.004	8.15	2.88	5.05
b, g	1.06	0.46	0.01	43.71	0.10	3.26
c, g	0.33	0.18	0.002	53.03	0.10	1.51
P, g	2.38	0.66	0.01	27.84	0.05	5.48
PY, day	3.47	1.33	0.02	38.31	1.07	19.54
Ymax, g	4.68	0.87	0.01	18.64	2.18	8.04
Protein yield						
TDPY, g	26.87	9.16	0.13	34.08	7.89	59.80
a, g	3.31	0.28	0.004	8.41	2.30	4.28
b, g	1.01	0.43	0.01	42.37	0.05	2.81
c, g	0.32	0.17	0.002	50.98	0.01	1.38
P, g	2.33	0.61	0.01	26.16	0.01	5.43
PY, day	3.31	1.02	0.01	30.99	0.92	18.99
Ymax, g	3.92	0.73	0.01	18.62	1.76	7.38

Variables are defined before.

Heritabilities Parameters

The heritability estimates of test-day (TD) milk traits (milk, fat and protein) and the lactation curve parameters are presented in Table 3.

Estimates of heritability (h^2) of the Wood's function for yields milk, fat and protein were 0.22, 0.21 and 0.22, respectively. These results are in the ranges as reported by Flores and van der Werf (2015). But, these estimates were greater than that cited by El-Bramony *et al*. (2010). The h^2 estimates for lactation curve parameters of a, b, c, P, PY and Ymax were 0.37, 0.38, 0.39, 0.37, 0.37 and 0.38, respectively (Table 3). These estimates were greater than those obtained by Gebreyohannes and Koonawootrittriron (2013). The h^2 estimates for fat curve parameters of a, b, c, P, PY and Ymax were 0.41, 0.40, 0.39, 0.38, 0.36 and 0.42, respectively, while the estimates for protein curve parameters were 0.38, 0.40, 0.40, 0.38, 0.40 and 0.43, , respectively. Linde *et al*. (2000) estimated the heritability of milk curve parameter (b) to be 0.13, 0.20, and 0.18, in the first three lactations, respectively. These estimates are much lower than the estimates found here, but are similar in pattern, where the second lactation heritability having the highest magnitude.

Genetic and phenotypic correlations

Genetic correlations in Table 4 for milk yield between initial (a) and increasing phases (b) (-0.8) is comparable with that of Macciotta *et al*. (2005), but differ with Boujenane and Hilal (2012), however, the decreasing phase slope (c = -0.43) estimate with a was similar to those from Tekerli *et al*. (2000); Boujenane and Hilal (2012), but unlike with that of Macciotta *et al*. (2005). The negative genetic correlation between the parameters a and b implies that a higher initial yield is associated with a slower rate of increase until peak yield. Tekerli *et al*. (2000), based on a moderate to large positive correlation estimates of the lactation yield with peak yield and persistency, suggested that one of these traits should be used as a criterion to improve all the three traits. Similarly, considering the large negative correlation among initial yield with increasing and decreasing slopes, Moradi Shahrbabak (2001) recommended the selection based on initial milk yield in order to decrease the increasing slope and the decreasing slope of the lactation curve and to produce steadier lactation and reach peak yield early. Although Ymax had a favorable high genetic correlation with TDMYs (0.87) as Boujenane and Hilal (2012). PY presented a relatively high genetic correlation

Table 3. The estimates of heritability (h^2) and their standard errors (SE) for test-day milk traits and lactation curve parameters.

Trait	**h^2±SE**	**Trait**	**h^2±SE**	**Trait**	**h^2±SE**
TDMY	0.22±0.002	TDFY	0.21±0.00011	TDPY	0.22±0.00002
a	0.37±0.006	a	0.41±0.00014	a	0.38±0.00003
b	0.38±0.007	b	0.40±0.00014	b	0.40±0.00003
c	0.39±0.006	c	0.39±0.00014	c	0.40±0.00003
P	0.37±0.006	P	0.38±0.00014	P	0.38±0.00003
PY	0.37±0.006	PY	0.36±0.00014	PY	0.40±0.00003
Ymax	0.38±0.007	Ymax	0.42±0.00015	Ymax	0.43±0.00003

with TDMY (0.48), but Boujenane and Hilal (2012) showed this correlation equal one. TDMY was positively correlated with initial milk yield (parameter a) similar to the results of Boujenane and Hilal (2012). The moderate genetic correlation coefficient between TDMY and initial milk yield was (0.31). This means that initial milk yield seems to be the best predicator of total milk yield (Table 4).

Genetic and phenotypic correlations in Table 4 between b and c curve parameters in the milk yield (0.5 and 0.88, respectively), differ with Boujenane and Hilal (2012); Macciotta *et al*. (2005) indicate that buffalo cows that peaked more rapidly also had a quicker decline after peak. Similar results have been reported by Tekerli *et al*. (2000). The rate of milk yield increase was negatively correlated with persistency of lactation (-0.71), except Boujenane and Hilal (2012), this means that selection for persistency of lactation decreases the rate of increasing milk production till the peak (parameter b).

Genetic correlation in Table 4 between PY and P of milk yield (0.87) is comparable to results obtained by Boujenane and Hilal (2012), suggesting that buffalo cows that reached their peak yield early during their lactation had higher persistency.

Genetic correlations between parameter c with each PY and P of milk yield were -0.48 and -0.26, respectively (Table 4), indicating that selecting for Ymax early in lactation would improve persistency by lowering the rate of decrease after peak yield. Genetic correlation between TDMY and P (0.52) unlike Boujenane and Hilal (2012), suggested that buffalo cows with higher estimated breeding value (EBV) for persistency would be expected to have higher EBV for TDMY. These findings are supported by previous research by Ferris *et al*. (1985).

Phenotypic correlation in Table 4 between initial milk yield (a) with parameters b, c and PY were negative. This result is supported by those of Boujenane and Hilal (2012); Bouallegue *et al*. (2013). On the other hand, positive phenotypic correlations were found between initial milk yield and TDMY, persistency and Ymax as also reported by Mansour *et al*. (1993) on Egyptian buffaloes.

The rate of milk production increase till peak (b) was highly phenotypically correlated (0.88) with the rate of milk yield decrease (c) similar to results of Atashi *et al*. (2009); Boujenane and Hilal (2012). Positive and moderate phenotypic correlation (0.47) was found between b and PY similar to the results of Atashi *et al*. (2009), opposite with Bouallegue *et al*. (2013), however, a low estimate (0.10) was found between b and Ymax unlike Boujenane and Hilal, 2012. The phenotypic correlation between b and persistency was negative (-0.78) similar to those found by Atashi *et al*. (2009); Boujenane and Hilal (2012).

Positive phenotypic correlation in Table 4 was detected between persistency of lactation and TDMY (0.49) as reported by Atashi *et al*. (2009); Bouallegue *et al*. (2013) but differ with Boujenane and Hilal (2012).

The estimates of genetic and phenotypic correlations (Table 4) between all curve parameters in fat and protein were close to a large degree with lactation curve parameters. These results are in line with those reported by Bouallegue *et al*. (2013).

Genetic and phenotypic correlation between milk, fat and protein traits and every curve parameter and its match in each trait

Genetic and phenotypic correlations among test-day lactation traits (milk, fat and protein yields) and curve parameters are presented

Table 4. The estimates of additive genetic correlations and their standard errors (SE) (above the diagonals), and phenotypic correlations (below the diagonals) for yields of milk, fat and protein, and the lactation curve parameters for each trait of milk, fat and protein separately.

Milk yield	**TDMY**	**a**	**b**	**c**	**P**	**PY**	**Ymax**
TDMY	-	0.31±0.002	-0.23±0.009	-0.34±0.009	0.52±0.002	0.48±0.001	0.87±0.009
A	0.50	-	-0.80±0.009	-0.43±0.003	0.49±0.001	-0.30±0.009	0.50±0.001
B	-0.34	-0.75	-	0.50±0.001	-0.71±0.002	0.45±0.002	0.15±0.003
C	-0.38	-0.68	0.88	-	-0.26±0.004	-0.48±0.003	-0.33±0.001
P	0.49	0.54	-0.78	-0.46	-	0.87±0.005	0.35±0.005
PY	0.45	-0.61	0.47	-0.15	0.70	-	0.37±0.009
Ymax	0.83	0.18	0.10	-0.08	0.45	0.42	-
Fat yield	TDFY	a	b	c	P	PY	Ymax
TDFY		0.33±0.0003	-0.28±0.0003	-0.38±0.0002	0.52±0.0002	0.48±0.0003	0.79±0.0003
A	0.55	-	-0.65±0.0003	-0.43±0.0002	0.48±0.0002	-0.30±0.0003	0.46±0.0003
B	-0.38	-0.80	-	0.49±0.0002	-0.63±0.0002	0.45±0.0003	0.16±0.0003
C	-0.41	-0.72	0.89	-	-0.28±0.0002	-0.48±0.0003	-0.38±0.0003
P	0.50	0.49	-0.82	-0.48	-	0.88±0.0003	0.32±0.0003
PY	0.52	-0.58	0.49	-0.18	0.81	-	0.41±0.0003
Ymax	0.93	0.22	0.13	-0.16	0.54	0.46	-
Protein yield	TDPY	a	b	c	P	PY	Ymax
TDPY		0.38±0.00005	-0.28±0.00005	-0.37±0.00005	0.55±0.0005	0.47±0.00005	0.85±0.00005
A	0.52	-	-0.85±0.00005	-0.45±0.00005	0.51±0.00005	-0.34±0.00005	0.41±0.00005
B	-0.40	-0.82	-	0.49±0.00005	-0.60±0.00005	0.39±0.00005	0.17±0.00005
C	-0.32	-0.64	0.79	-	-0.20±0.00005	-0.47±0.00005	-0.41±0.00005
P	0.50	0.60	-0.80	-0.48	-	0.84±0.00005	0.37±0.00005
PY	0.47	-0.59	0.48	-0.18	0.79	-	0.36±0.00005
Ymax	0.84	0.26	0.15	-0.11	0.51	0.47	-

Traits are defined before.

Table 5. Estimates of genetic correlations (r_G±SE), and phenotypic correlations (r_p) among test-day lactation traits (milk, fat and protein yields) and lactation curve parameters.

Traits correlated	**r_G±SE**	**r_P**
TDMY and TDFY	0.98±0.02	0.86
TDMY and TDPY	0.99±0.01	0.92
TDFY and TDPY	0.99±0.03	0.83
Lactation curve parameter (a):		
a-milk and a-fat	0.71±0.007	0.86
a-milk and a-protein	0.86±0.007	0.88
a-fat and a-protein	0.85±0.007	0.87
Lactation curve parameter (b):		
b-milk and b-fat	0.82±0.13	0.86
b-milk and b-protein	0.87±0.12	0.92
b-fat and b-protein	0.88±0.15	0.95
Lactation curve parameter (c):		
c-milk and c-fat	0.85±0.005	0.86
c-milk and c-protein	0.82±0.005	0.87
c-fat and c-protein	0.84±0.005	0.87
Lactation curve parameter (P):		
P-milk and P-fat	0.85±0.005	0.90
P-milk and P-protein	0.87±0.005	0.92
P-fat and P-protein	0.86±0.005	0.91
Lactation curve parameter (PY):		
PY-milk and PY-fat	0.74±0.006	0.75
PY-milk and PY-protein	0.73±0.006	0.88
PY-fat and PY-protein	0.72±0.006	0.83
Lactation curve parameter (Ymax):		
Ymax-milk and Ymax-fat	0.94±0.007	0.95
Ymax-milk and Ymax-protein	0.91±0.007	0.96
Ymax-fat and Ymax-protein	0.92±0.007	0.95

in Table 5.

These results showed the high genetic and phenotypic correlation between all traits (milk, fat and protein) as reported by El-Bramony *et al.* (2010) on Egyptian buffalo. The results showed a high genetic and phenotypic correlation between the same curve parameters of milk, fat and protein. The results of lactation curve parameters fully apply to fat and protein curve parameters (Cismaş *et al.*, 2012). Genetic and phenotypic correlations of favorite milk, fat and protein curve parameters (a, P and Ymax) are presented in Table 6.

Moderate genetic and phenotypic correlation were found between the favorable curve parameters (a, P and Ymax) with their corresponding traits for all traits. These results may indicate that the use of any of these parameters (a, P, Ymax) can be used to improve the curve of these traits and therefore total yields of these traits.

CONCLUSIONS

Selection for persistency of traits decreases the rate of parameter b (increasing production till peak), the rate of decreasing production, increasing the maximum milk production during lactation and finally total yields. High genetic correlation between TDMY and P suggested that buffalo cows with higher estimating breeding value (EBV) for persistency is expected to have higher EBV for TDMY. High and moderate genetic and phenotypic correlation between all traits (milk, fat and protein yields), between every curve parameter and its match in each trait (e.g. a-milk, a-fat and a-protein, b-milk, b-fat, etc) and the favorable curve parameters (a, P and Ymax) in each trait with the same curves in the other traits, indicate that fat and protein moving in the same direction of genetic parameters of lactation curve parameters. Genetic selection for curve parameters (a, P and Ymax) especially P would improve total milk yield traits.

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Table 6. Estimates of genetic (r_G), and phenotypic correlations (r_P) among favorable lactation curve parameters (a, P and Ymax).

Traits correlated	r_G±SE	r_P
a-milk and P-fat	0.45±0.006	0.56
a-milk and Ymax-fat	0.46±0.007	0.55
a-milk and P-protein	0.44±0.006	0.55
a-milk and Ymax-protein	0.44±0.007	0.54
P-milk and Ymax-fat	0.44±0.007	0.55
P-milk and Ymax-protein	0.42±0.007	0.53
a-fat and P-protein	0.43±0.005	0.49
a-fat and Ymax-protein	0.44±0.007	0.48
P-fat and Ymax-protein	0.39±0.007	0.49

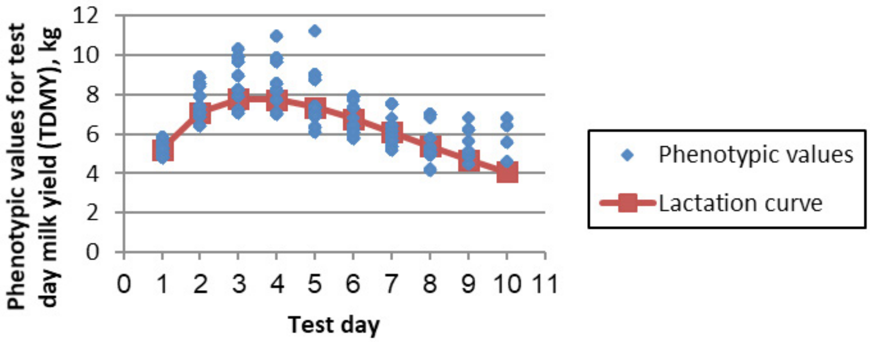

Figure 1. Lactation curve plotted from the phenotypic values for test-day milk yield (TDMY) in the Egyptian buffalo.

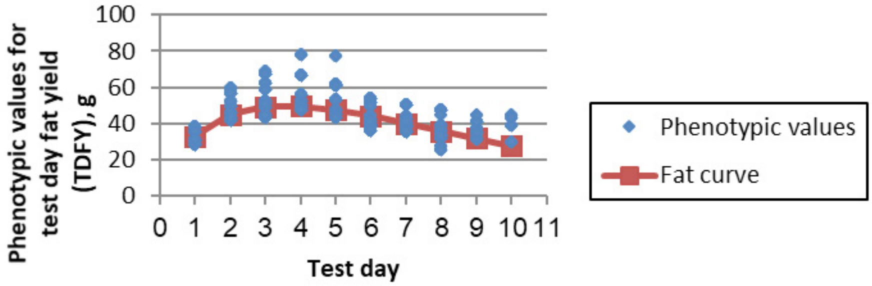

Figure 2. Fat curve plotted from the phenotypic values for test-day fat yield (TDFY) in the Egyptian buffalo.

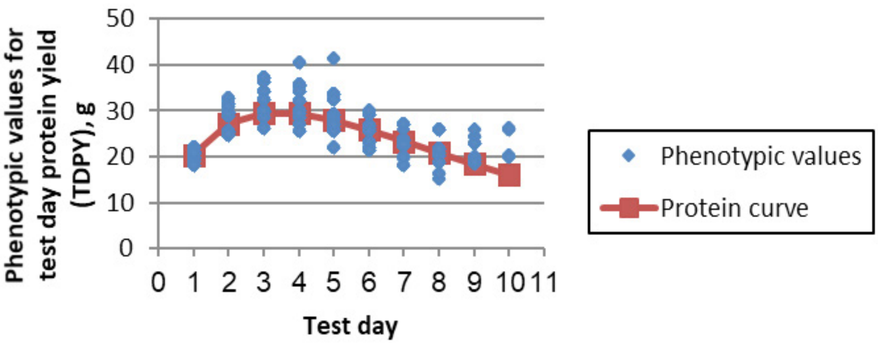

Figure 3. Protein curve plotted from the phenotypic values for test-day protein yield (TDPY) in the Egyptian buffalo.

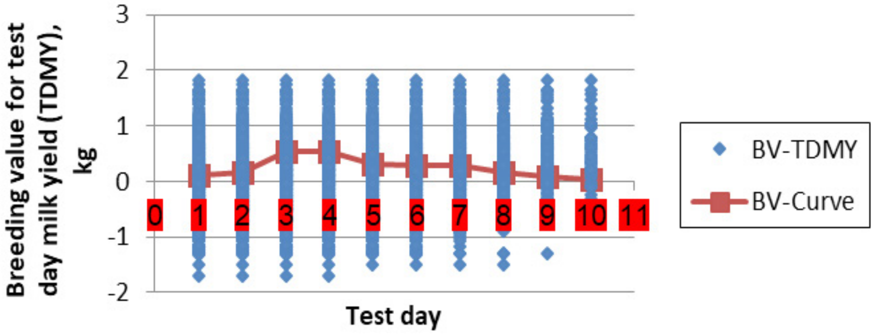

Figure 4. Lactation curve plotted from the breeding values for test day milk yield (TDMY) in the Egyptian buffalo.

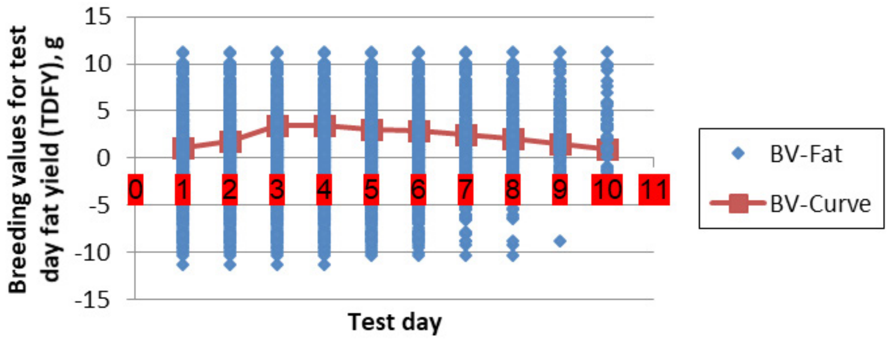

Figure 5. Fat curve plotted from the breeding values for test-day fat yield (TDFY) in the Egyptian buffalo.

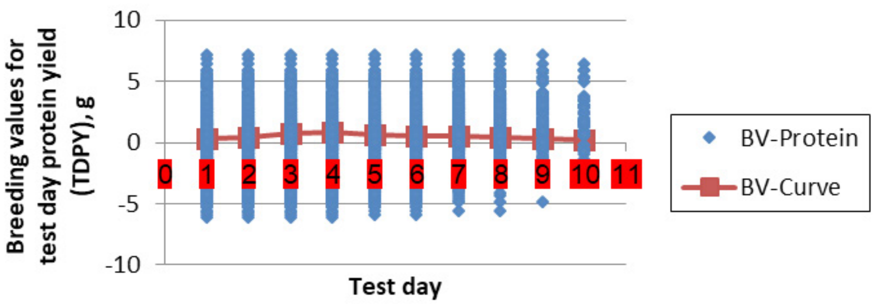

Figure 6. Protein curve plotted from the breeding values for test-day protein yield (TDPY) in the Egyptian buffalo.

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