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GENETIC AND NON-GENETIC ESTIMATES OF LACTATION CURVE IN FRIESIAN COWS

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SUMMARY

Under modern dairy production systems, the accurate description of lactation curve is critical for developing management and breeding programs. The purpose of this study was to determine the non-genetic and genetic effects, estimate heritability (h^2), genetic and phenotypic correlations (co) for lactation curve traits in Friesian cows. Over six years, data were gathered from Alkarda experimental station Kafr El-Sheikh, which is part of the Animal Production Research Institute, Agricultural Research Center, Egypt. Total of 5386 lactation 423 cows' daughters of 134 sires, and 232 dams were analyzed of non-genetic (year, season, and parity) and genetic parameters have been using SAS program to estimate the Malty-Trait animal mode (MTAM). The studied traits were daily milk yield (DMY), initial slope yield (a), ascending slope yield (b), descending slope yield (c), persistency (Ps), day of peak daily milk yield (PY), and peak daily milk yield (Y_{max}/kg). The overall means of DMY, a, b, c, Ps, PY, and Y max were 13.69 Kg, 12.34 Kg, 0.99 kg, 0.03 kg , 7.57 kg , 52.56 day and 26.75 kg respectively. The analysis of variance showed that the influences of sire and parity were significant (P<0.01-0.001) for all studied traits, likewise, year of calving (P<0.001) was expecting for DMY. However, the influence season of calving was non-significant for all studied traits. The analysis of MTAM except revealed that the values of heritability and repeatability were 0.29±0.007, 0.31±0.007, 0.38±0.036, 0.27±0.043, 0.31±0.07, 0.38±0.036 and 0.27±0.043, 0.31, 0.34, 0.41, 0.31, 0.37, 0.36, for DMY, a, b, c, Ps, PY and Y_{max}, respectively. Genetic correlation (GC) between DMY and lactation curve a, b, c, Ps, PY and Y max were 0.32, -0.49, -0.44, 0.28, -0.34 and 0.31, respectively. Notably, these genetic estimates described Y_{max} as a good measure of persistency, also PS and PY traits were positively correlated with high milk yield under the herd environmental conditions. Overall, the tested traits of lactation curve can effectively promote breeding strategies for dairy production of Friesian cows and accelerate the gain of correlated low heritable traits. Therefore, further research is needed to evaluate the feasibility of including lactation curve traits in a selection index for Friesian populations.

Keywords: Friesian cows, genetic estimates, lactation curve, persistency

INTRODUCTION

Friesian cattle in Egypt are reared in the governmental or privately owned large dairy herds which began to increase in number. Under modern dairy production systems, the accurate description of lactation curve is critical for developing management and breeding programs. The lactation curve provides useful information about the pattern of milk production during the day in milk. It also displays a summary of the milk yield pattern, which is governed by the biological efficiency of the cow (Scott *et al*., 1996). The lactation curve is defined as a graphical depiction of the connection between milk output and milking days (Fadlelmoula *et al*., 2007), and its shape has been used to suggest poor performance because of environmental stresses (Nassuna-Mosoke *et al.*, 2007). It is also beneficial for dairy cow health monitoring, genetic evaluation, feeding methods, and economic considerations (Bouallegue *et al.,* 2013). The cost of milk production is heavily influenced by lactation persistency or the rate of fall in output after peak milk supply. Low persistency is related with a quick rate of reduction in daily milk supply, whereas high persistency is associated with a gradual rate of decline in milk production. After the peak output, milk production generally declines at a rate of around 7% per month. (Val-Arreola *et al*., 2004). Lactation curve models have been used to estimate milk supply at any time throughout the lactation (Macciotta *et al*., 2005). In the case of insufficient lactation records, the characteristics lactation model may be useful. Different researchers have tried various models to match the lactation curve in both exotic and indigenous cattle. (Rashia, 2010). Further use of lactation models is getting the test-day milk yield information to compare with data under field conditions

Lactation curves in dairy animals have extensively been used for early prediction of milk yield and thus culling the low producers, forward planning for feed and farm resources and unbiased ranking of sires by using incomplete records of their daughters, and future milk output from half lactations can result in early culling or retaining of cows (Bermejo *et al*., 2020, Lee *et al*., 2020 and Mohamed *et al*., 2021). Effect of environmental factors on lactation curve coefficients have been studied for most of the temperate breeds. The lactation curve parameters a, b, and c reflect milk output at the start of lactation, slope before peak milk production, and slope after peak milk production. A lactation pattern for an individual cow begins after calving (initial yield; IY), milk production usually increases from the start to the peak of lactation (peak yield; PY) in 60 to

90 days (days to peak; DTP), and subsequently declines (persistency; PS) until the cow is dried off (Wood, 1967). In terms of fitting lactation, the incomplete gamma function may be depended on. (Darfour-Oduro *et al.,* 2015). Dairy cows that have higher IY, higher PY and more ability to continue to produce milk at near peak levels throughout the lactation are expected to have higher milk yields per lactation. Lactation patterns could be different among groups of cows or individuals, and cows that produce similar amounts of milk may not necessarily have similar lactation patterns (Skorn and Mauricio, 2009). The lactation pattern (IY, PY, DTP, and PST) and milk yield could be influenced by genetic effects (Rekaya *et al*., 2000; Skorn and Mauricio, 2009) and non-genetic effects (environmental conditions, management, parity, age and health status (Rekik *et al*., 2003). Thus, accurate knowledge of lactation patterns of individual or groups of animals is necessary to improve the efficiency of management and selection in dairy cattle operations. These factors are impacted by the year of calving, the season of calving, and the cow's parity (Kopec *et al*., 2013). Complete understanding of lactation patterns (a, b, c, Ps, PY and Y_{max}/kg) and their association with milk production (DMY) is needed. Thus, the goals of this study were to use the incomplete gamma function to describe lactation curve of cows and to investigate the impact of environmental variables on the curve's parameters. In addition to estimating heritability, repeatability, and genetic and phenotypic correlations.

MATERIALS AND METHODS

Data and economic traits:

Data were obtained from experimental farm Alkarda located in Kafr El-Sheikh, and belong to the Animal Production Research Institute, Agricultural Research Center, Egypt. Total 5386 lactations of 423 cows' daughters of 134 sires, and 232 dams representing the period from 1999 to 2004 were used in this study.

The studied traits were the daily milk yield (DMY), initial slope yield (a), ascending slope yield (b), descending slope yield (c), persistency (Ps), day of peak daily milk yield (PY), and peak daily milk yield (Y_{max}/kg).

Herd management:

Animals were fed concentrate mixture along with wheat or rice straw in addition to Egyptian clover in winter or clover hay summer. Friesian heifers were artificially inseminated around 305kg of weight using semen of Friesian proven sires, and pregnancy was detected at day 60 after service. The animals were machine milked 2 times/days.

Statistical analysis:

Parameters estimated and characteristics of lactation curve:

The shape of the lactation, curve of Friesian cows was described using the gamma type function (Wood, 1967): $Y_n = an^b e^{-cn}$

Where constants a, b and c were calculated using the general linear model (GLM) procedure of (SAS, 2003); where Y_n is the test-day milk (kg) in the n^{th} month of lactation, a = the initial yield, b = the rate of milk increase up to the peak during the ascending phase, c = the rate of yield decrease during the descending phase and e= base of natural logarithms.

Persistency of lactation, from the primary components of the equation Days in milk (DIM) at peak. P = - (b+1) Ln (c) was estimated. *Peak* yield (PY) was defined as b/c and the maximum production during lactation (Y_{max}) was calculated as a $(b/c)^{b} e^{-b}$ according to Wood (1967).

Fixed effect: The following model was used to describe the dependent variable

$$\mathbf{Y_{ijklm} = \mu + S_i + P_j + SE_k + R_l + b\ (A) + e_{ijklm}}$$

Where: Y_{ijklm} = is the dependent variable (DMY, a, b, c, Ps, PY, and $_{Ymax}$);μ = overall mean; S_i= random effect of i^{th} sire; P_j= fixed effect of j^{th} parity of calving; SE_k= the fixed effect of k^{th} season of calving; R_l= the fixed effect of l^{th} year of calving; b (A) = The co-variable for days in milk and e_{ijklm} = random residual assumed to be independent normally distributed with mean zero and variance σ^2e.

Genetic parameters:

The animal model MTDFREML program of Boldman *et al*., (1995) could be written in the following matrix format:

$$\mathbf{y = X_b + Z_{1a} + Z_{2Pe} + e}$$

Where: y = The vector of lactation observations, X = The incidence matrix relating the fixed effects to y, b = The vector of the overall mean and the fixed effects of parity, year and season of calving and days in milk (as a co-variable), Z_1 = 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 Z_1, Z_2 = The incidence matrix relating the permanent environmental effect; Pe = The vector of the permanent environmental effect associated with the incidence matrix Z_2 and e = The vector of random residual effects N (0, Is²e).

RESULTS AND DISCUSSION

The average and standard errors of the lactation curve parameters for Friesian cows are shown below in Table1.

The overall means of DMY, a, b, c, Ps, PY, and Y_{max} were 13.7 Kg, 12.3 Kg, 0.99 kg, 0.033 kg, 7.6 kg, 52.5 day and 26.8 kg, respectively. These estimates were higher than those reported by Yilmaz *et al*., (2011), and were less than those of Ameena *et al*., (2009) which found to be of 14.90 Kg, 6.62 Kg, 40.75 day and 18.58 kg respectively

Table1. Means, standard deviations (SD) and coefficients of variation (CV %) of lactation curve traits for Friesian cows

Traits	Means	SD	CV %
DMY (kg)	13.7	5.3	38.8
a (kg)	12.3	3.45	28.7
b (kg)	0.99	0.40	38.2
C (kg)	0.033	0.03	83.9
PS(kg)	7.6	1.89	24.9
PY(day)	52.5	19.8	37.8
Y_{max}(kg)	26.8	10.9	40.8

Environmental factors affecting parameters and characteristics of lactation curve:

Least square means and standard errors of non genetic factors affecting lactation curve traits are shown in (table 2). All lactation curve traits were affected (P<0.001) by parity, season of calving and year of calving except DMY and parameters a. The first had a tendency increase to 14.9±0.25 in the 3thparity and decreased there after. There was a decrease in parameters a and c in the 3rd and 6thparities.

Table 2. Least square means and standard error (LSM±SE) for factors affecting lactation curve traits in Friesian cows

Independent Variable	NO	DMY (kg)	a (kg)	b (kg)	C (kg)	PS(kg)	PY(day)	Y_{max}(kg)
PARITY								
1	1712	13.3±0.28	11.5±0.17	1.13±0.02	0.05±0.001	6.3±0.06	41.5±0.81	26.0±0.53
2	1278	14.3±0.27	11.9±0.17	1.08±0.02	0.05±0.001	6.2±0.05	39.6±0.79	26.0±0.52
3	936	14.9±0.25	11.7±0.16	1.03±0.02	0.05±0.009	6.3±0.05	40.1±0.74	25.9±0.48
4	495	14.6±0.29	12.3±0.18	1.03±0.02	0.05±0.001	6.3±0.06	41.03±0.87	26.1±0.57
5	374	13.3±0.34	11.9±0.21	1.16±0.02	0.06±0.001	6.21±0.09	35.9±0.99	23.6±0.65
6	591	13.7±0.38	11.1±0.23	1.12±0.03	0.06±0.001	0.14±0.11	37.5±1.11	27.8±0.73
Significance				***	***	***	***	***
Season								
Autumn	1327	14.5±0.19	11.8±0.12	1.11±0.01	0.05±0.0007	6.3±0.06	39.6±0.58	25.9±0.38
Winter	1581	14.3±0.19	11.8±0.12	1.11±0.01	0.05±0.0007	6.2±0.05	39.6±0.55	26.0±0.36
Spring	1550	13.9±0.19	11.7±0.12	1.12±0.01	0.05±0.0007	6.3±0.05	39.2±0.56	25.9±0.37
Summer	928	13.4±0.22	11.7±0.14	1.12±0.02	0.05±0.0008	6.3±0.06	39.4±0.64	25.7±0.42
Significance				***	***	***	***	***
Year								
1	1189	14.4±0.19	11.7±0.12	1.03±0.01	0.04±0.0007	7.06±0.06	47.9±0.57	26.9±0.37
2	1208	13.9±0.19	11.9±0.12	1.12±0.01	0.04±0.0007	7.3±0.05	47.7±0.56	24.2±0.37
3	1163	13.8±0.76	11.8±0.12	1.05±0.01	0.04±0.0007	6.9±0.06	46.6±0.57	26.9±0.38
4	858	14.2±.22	11.9±0.14	0.94±0.02	0.04±0.0008	6.8±0.06	49.5±0.65	28.9±0.43
5	561	13.9±.51	11.6±0.31	1.28±0.03	0.08±0.002	4.8±0.14	21.6±1.48	24.6±0.97
6	407	13.9±0.37	11.6±0.23	1.26±0.03	0.08±0.001	4.8±0.11	22.3±1.09	23.9±0.72
Significance				***	***	***	***	***

***highly significant (P< 0.001)

The parity effect was high for parameter a but lower parameter for b while parameters c was least affected by parity. The value of parameter a has reached its maximum at third parity while parameter c showed the highest value in parities 5 and 6 parity. Similar results were found that Mohamed *et al.*, (2021).

The seasonal effects differed from are season to another Parameter a for cows calving in the autumn and winter differed (P<0.001) from those calving in the spring and summer probably due to extreme heat of cold stressed. Similar results were obtained by Darfour-Oduro *et al.,* (2015) and Mohamed *et al.*, (2021). Season of calving affected (P<0.001) all lactation parameters with a major hot season calvers (Table 2). (Tekerli *et al*., 2000) reported that calving seasons were significant (*P*<0.05) for y/y max and highly significant (*P*<0.001) for the other lactation curve traits except a, b, and b/c.

The effect of year of calving on all traits under study was highly significant (P<0.001) (Table 2). Parameters a and b were found different for different years of calving. In general, trends of increased parameter a and parameter b were observed with advancement years starting from year 2000. While for year 2003 parameters a was estimated to be

11.6 kg. This could be due to variation in number of cows and different management and nutritional of the herd from year to year**.** Similar results were obtained by Abd-Elhamid (2018), Darfour-Oduro *et al.*, (2015) and Mohamed *et al*., (2021). Who obtained variation in parameter a with increasing parities and years for Friesian cows Bouallegue *et al.,* (2013) revealed that aged cows have higher beginning milk output in general. Possible explanations for this observation include the fact that cows in the first parity did not reach maturity and thus needed to meet their growth requirements before producing milk (Osorio-Alce and Segura 2005), creating a tendency for older cows to consume more feed than younger cows (Darfour-Oduro *et al.,* 2015). Furthermore, because the body and mammary gland of young cows are still developing, the first milk production of first parity cows is poor. The comparatively low beginning milk output and pace of decline after peak production displayed by cows in the fourth parity corroborated with the fact that cattle in the tropics reach peak production in their third or fourth lactation. (Safaa Sanad and Hassanane 2019). While their performance decline thereafter. Third parity cows may not have had enough chances to elicit substantial changes in parameters a, b, and c.

The relatively large variation in milk production to wards the end of the lactation curves. The incomplete gamma function may cause issues in the prediction process. (Kawonga *et al.*, 2012).

Genetic parameters for lactation curve traits:

Heritability estimates and genetic variance:

Variance components, heritability and repeatability estimates for lactation curve traits are presented in Table 3 Heritability estimates of DMY and lactation curve parameters (a, b, c, Ps, PY and Y $_{max}$/kg) were 0.29±0.007, 0.31±0.007, 0.38±0.036, 0.27±0.043, 0.31±0.07, 0.38±0.٠36 and 0.27±0.043. Heritability estimates for parameter "a" was lower than that reported by Bakir *et al.,* (2004), while higher

The variation in heritability estimates obtained in the present study and other studies could be due the differences between models used, breeds and also environmental and genetic variation affecting different measurements. The high estimates of h^2_a of Ps, PY and Y_{max} indicated that the genetic improvement for these traits can be brought about quickly by appropriate individual selection and this is in agreement with results of Yilmaz *et al.,* (2011).

Table 3. Estimates of variance components and genetic parameters for lactation curve traits in Friesian cows

Parameter	Traits						
	DMY	**a**	**b**	**c**	**PS**	**PY**	**Y_{max}**
V_a	0.3673	0.3263	0.3641	0.2315	0.32631	0.36406	0.23151
Vp_e	0.2594	0.3599	0.343	0.4361	0.236	0.343	0.436
V_e	0.8584	0.7047	0.5621	0.5863	0.705	0.562	0.586
V_p	1.2516	1.0669	0.96039	0.86146	1.067	0.960	0.862
h^2_a	0.29±0.007	0.31±0.007	0.38±0.036	0.27±0.043	0.31±0.07	0.38±0.036	0.27±0.043
pe^2	0.21±0.001	0.034±0.002	0.36±0.009	0.05±0.016	0.43±0.002	0.36±0.009	0.51±0.016
e^2	0.69±0.007	0.66±0.008	0.59±0.037	0.68±0.046	0.66±0.008	0.59±0.037	0.68±0.046
R	0.31	0.34	0.41	0.31	0.37	0.36	0.32

Va = direct additive genetic variance, Vpe = permanent environmental variance, Ve = residual (temporary environmental variance), Vp = phenotypic variance, h^2a = direct heritability, pe^2 = fraction of phenotypic variance due to permanent environmental effects and e^2 = fraction of phenotypic variance due to residual effects, r = repeatability.

Repeatability estimates (r) of DMY and lactation curve parameters (a, b, c, Ps, PY and Y_{max}/kg) were 0.31, 0.34, 0.41, 0.31, 0.37, 0.36, and 0.32, respectively. Repeatability estimates for parameters "a" and "b" were higher than those reported by El-Barabary *et al.,* (1999) and Tekerli *et al.,* (2000), In general, estimates of repeatability of the lactation curve parameters are higher than the range of such estimates in the literature due to the high permanent environmental and high genetic variances for these traits.

Genetic correlation:

Estimates of genetic and phenotypic correlations are listed in table (4). Genetic correlations between DMY and lactation curve a, b, c, Ps, PY and Y max were 0.32, -0.49, -0.44, 0.28, -0.34 and 0.31; respectively.

Estimates of genetic correlations between each of "a" and "b", "a" and "c" was negative. While was positive between a and PY (0.32). Similar results were reported by Yilmaz *et al.,* (2011). Peak yield was positively correlated with persistency (0.66). Cows which had longer lactations tend to give higher yields which indicated a possible synergistic genetic control for these traits. This may facilitate the preliminary selection of cows based on their initial a peak milk yield and bulls may be progeny tested much earlier before completing the lactation of their daughters. These results agree with those of Yilmaz *et al.,* (2011). Furthermore, Muir *et al.,* (2004) suggested that cows with moderate PY and high PS throughout lactation usually have less stress, also high genetic correlations between traits under study (DMY, PS, and Y_{max}) suggested that selection on the basis of these parameters will bring improvement in other traits due to correlated response. Among the different measures of persistency, the ratio of lactation to peak yield (PY /Y_{max}) may be preferred by breeders, especially for cow evaluation, because of its higher correlation with lactation yield and computational ease.

Table 4. Genetic and phenotypic correlations among different lactation curve traits in Friesian cows

	DMY	a	b	C	Ps	PY	y_{max}
DMY		0.32±0.015	-0.49±0.031	-0.44±0.052	0.28±0.017	-0.34±0.0006	0.31±0.007
a	0.038±0.005		-0.31±0.032	-0.41±0.046	0.45±0.017	0.32±0.007	-0.30±0.017
b	-0.05±0.0002	-0.31±0.0001		0.37±0.113	-0.33±0.063	0.28±0.019	0.33±0.023
c	0.013±0.359	-0.247±0.0001	0.567±0.0001		-0.46±0.053	-0.42±0.035	-0.52±0.025
Ps	-0.058±0.0001	0.0159±0.242	0.3189±0.0001	-0.59±0.0001		0.31±0.007	0.42±0.05
PY	0.007±0.61	0.198±0.0001	-0.43±0.0001	-0.924±0.0001	0.66±0.0001		0.35±0.035
y_{max}	0.05±0.0002	-0.045±0.001	-0.707±0.0001	0.363±0.0001	-0.263±0.0001	0.31±0.007	

The above the diagonal represent genetic correlation while these blow diagonals, represent phenotypic correlation

Phenotypic correlation:

Phenotypic correlations are presented in table (4). DMY had small correlation approaching zero with all lactation curve parameters. Thus, high initial milk yield is associated with high rate of ascend to peak and high rate of descend after peak yields weak positive phenotypic correlation was found between parameter "a" and peak milk yield (0.19). The parameter "b" was Positive correlated with persistency (0.32). The parameter "c" had also negative phenotypic correlation with persistency (-0.59). These results reflect the fact that low rate of declining after peak is associated with higher persistent cows. These results agree with those of Darfour-Oduro *et al.,* (2015) and Mohamed *et al.,* (2021). The moderate to large positive phenotypic correlations of lactation yield with peak yield and persistency suggest that one of those traits could be used as a selection criterion to improve all traits (Tekerli, 2000). On the other hand Ameena *et al.,* (2009) reported that, higher estimates of phenotypic correlations suggested that changes in PY or PS would affect milk yield.

CONCLUSION

Results of this study indicated that the incomplete gamma function succeeded to describe the lactation curve. Estimating the genetic and environmental parameters of the lactation curve characteristics, showed a highly significant effect of the environmental factors of the year of birth, the season of the year, and parity on most of the studied traits.

Genetic selection for curve parameters (DMY, a, b, c, Ps, PY, and Y max) was found feasible since genetic parameters were moderately high. Also, high genetic correlations were found among traits under study (DMY, persistency, and Ymax) suggesting that selection on the basis of these parameters will bring improvement in other traits due to the correlated response; especially between Ps, PY, and Y max which would improve total milk yield. Also, selection for high peak milk yield and persistency will result in higher daily milk yield. The moderate to the large positive phenotypic correlation of lactation yield with peak yield and persistency suggested that one of those traits could be used as a selection criterion to improve all traits for mutation highly producing kernel herd of Friesian cows in Egypt including the influencing factors. The genetic evaluation should improve the accuracy of genetic predictions especially if parameters of lactation curves for high producing cows are adopted. Determining breeding and selection strategies in addition to developing an optimal feeding program related to the amount of milk produced should achieve a greater lactation yield.

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التقديرات الوراثية والغير وراثية لمنحنى الحليب في أبقار الفريزيان

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في أنظمة أنتاج الألبان، يعد الوصف الدقيق لمنحنى الحليب أمرًا بالغ الأهمية للإدارة والتربية الناجحة. الغرض من هذه الدراسة هو تقدير التأثيرات غير الوراثية والوراثية وتقدير المكافئ الوراثي والارتباط الوراثي والظاهري لصفات منحنى الحليب في أبقار الفريزيان. على مدى ٦ سنوات، تم جمع البيانات من محطة القرضا وهي محطة حكومية بكفر الشيخ تابعة لمعهد بحوث الإنتاج الحيواني، مركز البحوث الزراعية، مصر. اشتملت الدراسة على ٥٣٨٦ سجل تخص ٤٢٣ بقرة، بنات ١٣٤ أب، و٢٣٢ أم. تم استخدام التحليلات الإحصائية للمعلمات الوراثية باستخدام برنامج SAS لتقدير العوامل غير الوراثية تأثير (ترتيب موسم الولادة، فصل سنة الولادة و سنة الولادة وكذلك أيام الحليب كتغاير) بالإضافة إلى استخدام برنامج النموذج الحيواني .Malty-Trait Animal Model (MTAM) وتضمنت الصفات المدروسة متوسط انتاج اللبن اليومي، متوسط إنتاج اللبن في البداية، معدل الصعود، معدل الهبوط ، المثابرة، أقصى يوم انتاجا (الوقت اللازم للوصول إلى أقصى إنتاج) وأقصى انتاج خلال مرحلة الحليب.

أظهرت النتائج ان متوسط انتاج اللبن اليومي، متوسط إنتاج اللبن في البداية، معدل الصعود، معدل الهبوط ، المثابرة، أقصى يوم انتاجا و أقصى انتاج خلال مرحلة الحليب كانت ١٣.٧ كجم ،١٢.٣ كجم ،٠.٩٩ كجم ،٠.٠٣٣ كجم ،٧.٦ كجم ،٥٢.٥ يوم و٢٦.٨ كجم على التوالي. أظهر تحليل التباين أن تأثير الاب كان معنوياً لجميع الصفات المدروسة، وبالمثل بالنسبة لسنة الولادة (P<0.001) المتوقعة لمتوسط انتاج اللبن اليومي و لصفات منحني الحليب. كما اظهرت النتائج عن طريق تحليل MTAM أن قيم المكافئ الوراثى و المعامل التكراري كانت (٠.٢٩ ± ٠.٠٠٧، ٠.٣١ ± ٠.٠٠٧، ٠.٣٨ ± ٠.٠٣٦، ٠.٢٧ ± ٠.٠٤٣، ٠.٣١ ± ٠.٠٧، ٠.٣٨ ± ٠.٠٣٦ و ٠.٢٧ ± ٠.٠٤٣) و (٠.٣١، ٠.٣٤، ٠.٤١، ٠.٣١ ، ٠.٣٧ ، ٠.٣٦ ، ٠.٣٢.) و(٠.٣٢ و-٠.٤٩ و0.44- و٠.٢٨ و -٠.٣٤ و٠.٣١) لصفات متوسط انتاج اللبن اليومي، متوسط إنتاج اللبن في البداية، معدل الصعود، معدل الهبوط ، المثابرة، أقصى يوم انتاجا و أقصى انتاج خلال مرحلة الحليب على التوالى. كانت قيم الارتباط الوراثى بين متوسط انتاج اللبن اليومي و صفات منحني الحليب (٠.٣٢ ، 0.49- ، 0.44- ٠.٢٨ ،٠ -٠٣٤ و 0.31على التوالى.

وتجدر الإشارة إلى أن التقدير الوراثي لقيم أقصى يوم انتاجا كمقياس جيد للاستمرارية، وكذلك لصفتي المثابرة و أقصى انتاج خلال مرحلة الحليب مرتبطة بشكل إيجابي مع إنتاج الحليب اليومي العالي. اوضحت الدراسة انه بتقدير صفات منحنى الحليب يمكن ان يعزز بشكل فعال استراتيجيات التربية والوراثة لزيادة انتاجية الألبان من لأبقار الفريزيان، مما يساهم في سرعة استجابة الصفات المنخفضة للارتباط الوراثي والتحسين، لذلك توصي الدراسة بانه هناك حاجة إلى مزيد من الابحاث لتقييم جدوى تضمين صفات منحنى الحليب في دليل الانتخاب لقطعان الفريزيان.