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Genetic Analysis of Wood's Lactation Curve Parameters and its Derived Traits Using Single and Multi-Traits Animal Models in Zaraibi Goats in Egypt

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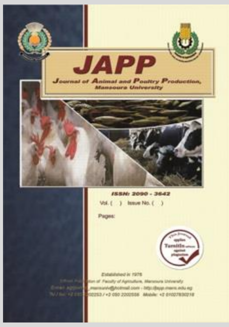

ABSTRACT

Single and multi-traits animal models were utilized to estimate variance and covariance components and genetic parameters of Wood's lactation curve parameters and associated traits in Zaraibi goats. A dataset comprising 1323 test day record collected from the Zaraibi herd at the El-Serw Experimental Station Damietta, Egypt between 2005 and 2014 were analyzed. Overall means of initial milk yield (a), ascending slope up to peak (b), descending slope after peak (c), persistency (S), weeks to peak (PW), and peak milk yield (PMY) were 1.504 kg, 0.421 kg, 0.098 kg, 1.433 kg, 4.295 weeks, and 1.823 kg, respectively. Heritability estimates for a, b, c, S, PW, and PMY were found to be 0.05 (0.06), 0.07 (0.07), 0.12 (0.14), 0.13 (0.13), 0.12 (0.14), and 0.11 (0.13), respectively, as indicated by single-trait (multi-trait) animal models, respectively. Strong positive genetic correlations were identified between various lactation curve traits varied between 0.72 and 0.91. Negative genetic correlation was observed between initial yield and both of ascending slope up to peak (-0.59) and time to peak (-0.38). Moreover, the ascending slope displayed a negative correlation with persistency (-0.32), while time to peak showed a positive correlation with ascending slope (0.37) and a negative correlation with descending slope (-0.58). In conclusion, the findings indicate slight discrepancies between single and multi-trait animal models in estimating variance components and genetic parameters. The moderate to high genetic correlations among lactation curve parameters and their related traits suggest that utilizing any of these parameters could effectively improve the traits' curves.

Keywords: Lactation curve, wood's function, Zaraibi goats, genetic parameters

INTRODUCTION

Zaraibi goats, a standout dairy breed among the indigenous Egyptian varieties, are distinguished by their remarkable genetic potential for milk production (Dowidar et al., 2018). Globally, goat milk holds significant economic importance, attributed to its health benefits and nutrient richness (Selvaggi et al., 2014; Chen et al., 2019). The absorbability, digestibility, and hypoallergenic properties of goat milk make it a preferred choice for individuals with cow's milk allergies (Clark and Mora Garcia, 2017). The lactation curve, a visual representation of milk production across the postpartum period, serves as a key indicator of the biological efficiency of lactating animals during different lactation phases (Lopez et al., 2019). The lactation curve provides crucial insights into milk production features, aiding in decision-making for breeding strategies and herd management. This information is essential for designing effective selection methods to evaluate the genetic potential of dairy animals (Cankaya et al., 2011; Chegini et al., 2015; Saghanezhad et al., 2017).While a simple three-parameter model can determine the biological aspects of the lactation curve (Pereira et al., 2016), the widely recognized incomplete gamma function or the Wood's model (Wood, 1967) is commonly used to evaluate the biological efficiency of dairy animals in different lactation phases (Radjabalizadeh et al., 2022). These models accurately interpret peak milk yield, milk yield persistency, and time of peak yield (Amin et al., 2019; Somida, 2024). Wood's model lactation curve parameters exhibit genetic variation, indicating that genetic information could potentially be leveraged to affect the shape of the lactation curve (Lopez-Ordaz et al., 2009). Given the distinct variations in lactation curve shapes across different species and breeds, it becomes imperative to explore the genetic aspects of these curve parameters, considering them as individual traits. In animal breeding, crucial genetic parameters depend on variance and covariance components. Precise estimation of these components is pivotal for the success of such breeding programs. Traditional statistical methods have been commonly utilized for parameter estimation and statistical inferences (Rahman et al., 2024). Previous studies have employed single-trait and multi-trait models to evaluate genetic parameters for economically important traits (Srivastava et al., 2019; Moawed, 2024). Extensive evaluations have been conducted on these models over many years, but additional confirmatory results are needed to endorse the most efficient methodology for selection programs. Former studies indicate that multivariate methods outperform single-trait models in genetically evaluating dairy animal traits. The superiority of multi-trait methods lies in their ability to estimate genetic parameters with enhanced precision (Moawed, 2024). Limited studies have investigated the genetic variation of Wood lactation curve parameters and related traits, specifically within the Zaraibi breed. Therefore, this study aims to employ the Wood function for constructing lactation curve using test day data from Zaraibi goats. Additionally, the study aims to genetically evaluate lactation curve parameters and milk production traits derived from this function by employing both single and multi-trait animal models.

MATERIAL AND METHODS

Data:

A dataset comprising 1323 test day records were amassed from the Zaraibi herd at the El-Serw Experimental

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Station in Damietta, Egypt during the period from 2005 to 2014 comprised 701 goats in their initial three parities. Animals with culling, unknown pedigrees or abnormal lactations were excluded from the datasets. Table 1 presents an overview of the structure of the analyzed data.

Management of the experimental herd:

At the experimental farm, a breeding system of one mating annually was implemented, dividing the herd into two groups for mating (one in spring and the other in autumn). A strict protocol was upheld, ensuring that does were not bred until they attained a minimum body weight of 30 kg and/or approximately 18 months of age. In the mating season, female goats were randomly grouped into sets of 30-35 does, with each set assigned randomly to a fertile buck. Precautions were taken to prevent inbreeding between full siblings, and the fertile bucks were rotated every three mating seasons. Following kidding, newly born kids remained with their mothers during the suckling period until weaning at 3 months old. The animals were fed a diet comprising a blend of green clover (*Trifolium Alexandrinum*) and concentrate feed mixture in the winter months. During the summer, their diet consisted of a mix of concentrate feed, rice straw, or crop stubbles, supplemented with green fodder whenever possible. Nutritionally balanced diets were prepared based on the farm's feeding protocol as advised by the Animal Production Research Institute according to NRC (1981). All animals were housed in semi-open barns and received feeding twice a day (before morning grazing and after evening grazing)

Access to water was ensured three times daily after meals, with mineral blocks consistently accessible to the animals. Approximately two weeks before the mating season began, a supplementary concentrate feed mixture was introduced at a rate of about 0.25 kg per doe per day. This additional feed was maintained during the last 2-4 weeks of pregnancy and the initial week of lactation whenever it was available. In the suckling period, the morning milk yield was recorded by separating kids from their mothers at 5:00 pm. The next morning at 8:00 am, the kids were weighed prior to suckling. They were then permitted to suckle until satisfied before being weighed once more. The rise in the kid's weight following suckling was utilized to gauge milk consumption. The does were manually milked to measure the stripped milk (remaining milk). The combined amount of stripped and suckled milk indicates the quantity of morning milk yield. A similar process was performed to estimate the evening milk yield. Following the weaning of the kids, milk yield was measured through two daily hand milking sessions (at 8:00 am and 5:00 pm). Does were classified as dry once their milk yield dropped to 100 g/day. The total milk yield was determined by aggregating the milk yields from test days throughout the entire lactation cycle. This calculation included the period from kidding to the first test day, from the last test day until the end of lactation, and the intervals between consecutive test days over the 248-day lactation span (≈ 35 weeks).

Estimating the curve parameters of milk yield:

The lactation curve parameters were described by the incomplete gamma function or Wood's function as outlined by Wood (1967) through the application of the following nonlinear model.

$$y_t = at^b\, e^{-ct}$$

where

y_t represents the daily milk yield on the t^{th} test day, and 'a' is the initial milk yield after kidding), 'b' is the ascending slope up to peak), and 'c' is the descending slope after peak. Animals with negative values of the descending slope after peak yield and/or ascending slope up to peak yield determined through Wood's function were excluded from further analysis as they did not exhibit typical lactation curve traits. Aforementioned lactation curve parameters of the Wood's function were determined for each goat individually using the SAS 9.3 (PROC NLIN; SAS Institute Inc., 2012). Corresponding lactation curve traits were derived using the following formulas:

$$\textbf{Persistency of lactation}: S = -(b+1)\ ln(c)$$

$$\textbf{Peak week}: PW = b/c$$

$$\textbf{Peak milk yield}: PMY = a(b/c)^b e^{-b}$$

Variance components and genetic parameters:

The variance and covariance components for random effects were estimated using the MTDFREML programs (Boldman, 1995). Both single and multi-trait animal models were employed in this study for the analysis of lactation curve parameters and related traits. The final model used for analyzing the examined traits included fixed effects, including parity order (first, second, and third), kidding year (2005-2014), kidding season (spring and autumn), litter size (single, twins, triplets, and quadruplets), and age of goat at first kidding as a covariate

The matrix notation of the utilized model was:

$$y = Xb + Z_1a + Z_2c + e$$

Where

y is the vector representing the phenotypic information; b denote the vector of aforementioned fixed effects; a represent the vector of random additive animal effects; c is the permanent environmental effect; e stand for the vector of residual effects related to the analyzed trait; X, Z_1, and Z_2 are the incidence matrices corresponding to both the fixed, additive genetic effects, and permanent environmental effects, respectively.

Direct heritability (h^2d), repeatability (r), genetic correlation (r_g), and phenotypic correlation (r_p) were calculated according to the following formulas

$$\mathbf{h^2d} = \frac{\boldsymbol{\sigma}^2\mathbf{d}}{\boldsymbol{\sigma}^2\mathbf{p}}$$

$$\mathbf{r} = \frac{\boldsymbol{\sigma}^2\mathbf{d} + \boldsymbol{\sigma}^2\mathbf{pe}}{\boldsymbol{\sigma}^2\mathbf{p}}$$

$$\mathbf{r_g} = \frac{\boldsymbol{\sigma}_{\mathbf{aij}}}{\sqrt{\boldsymbol{\sigma}^2\ \mathbf{ai}\quad \boldsymbol{\sigma}^2\ \mathbf{aj}}}$$

$$\mathbf{r_p} = \frac{\boldsymbol{\sigma}_{\mathbf{pij}}}{\sqrt{\boldsymbol{\sigma}^2\ \mathbf{pi}\quad \boldsymbol{\sigma}^2\ \mathbf{pj}}}$$

Where,

σ^2d, σ^2pe, and σ^2p are the variances for additive genetic effects, permanent environmental effects, and phenotypic variance, respectively. σ^2_{ai} and σ^2_{aj} are additive genetic variance for trait I and J, respectively; σ^2_{pi} and σ^2 pj are phenotypic variance for trait I and J, respectively; σ_{aij} and σ_{pij} are additive genetic and phenotypic covariance between two traits (I and J).

RESULTS AND DISCUSSION

Lactation curve parameters and its traits:

The overall means along with their standard deviations of studied traits based on the wood equation (Wood, 1967) are illustrated in Table 1 and Figure 1. Among 1323 test day records, the overall mean of parameter (a) was observed to be 1.504±0.483 kg. This result closely aligns with findings by Shaat (2014) within the same herd (1.22-1.78 kg) and exceeds the 0.9 kg noted by Mousa et al. (2016) for Aradi goats. Meanwhile, Abosaq et al. (2012) identified even higher values of 3.1 kg for Cyprus Damascus goats. In entire context, the overall average for parameter (b) was estimated to be 0.421±0.141 kg /week. This value closely resembles the value of 0.45 kg/week detected by Almasri et al. (2023) for Syrian Damascus goats. However, this estimation falls below that reported by El-Wakil and Fooda (2013) for Defray goats

(0.83 kg/week) and higher than the values of 0.13 and 0.20 noted by Mousa et al. (2016) and Siqueira et al. (2017) for Damascus goats and Saanen goats, respectively. The overall mean for parameter (c) was showed to be 0.098±0.041 kg/week, aligning closely with the estimation determined by Waheed and Khan (2013) for Beetal goats (0.12 kg/week).In contrast; this value surpasses the estimate from Siqueira et al. (2017) for dairy goats (0.005 kg/week).

Table 1. Descriptive statistics for lactation curve parameters as well as its derived traits in Zaraibi goat.

Items	a (kg)	B (kg/week)	C (kg/week)	PW (week)	PMY (kg)	S (kg)
Mean	1.504	0.421	0.098	4.295	1.823	1.433
SD	0.483	0.141	0.041	1.094	0.612	0.534
CV, %	32.11	33.49	41.84	25.47	33.57	37.26
No. of sires			79			
Numbers of dams			411			
Numbers of goats			701			
Numbers of lactation records			1323			
Lactation period		247.81day	≈	35 weeks		

a, initial milk yield; b, the rate of ascending in milk production before peak; c, the rate of descending in milk production after peak; PW, peak week; PMY, peak milk yield; S, persistency of lactation; SD, standard deviation.

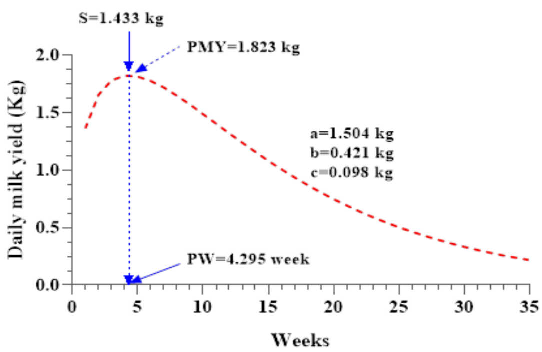

Figure 1. Predicted daily milk yield on lactation curve over time (after kidding) up to 35 weeks in dairy Zaraibi goats using the Wood function

The overall average of peak yield for Zaraibi goats was 1.823±0.612 kg. This finding mirrors the value (1.830 kg) showed by Shaat (2014). However, this value is higher than the estimates of 1.29 kg and 1.1 kg reported by Ayasrah et al. (2013), and Suranindyah et al. (2020) for Damascus goats and Etawah crossed goats, respectively. Conversely, this estimation is lower than the value of 4.08 kg for Damascus Cyprus goats in Libya as noted by Abosaq et al. (2012).

The time to peak was achieved at 4.295±1.094 weeks, which was closely aligned with those reported by Ayasrah et al. (2013) at 3.9 weeks. In contrast, Miranda-Alejo et al. (2019) reported a higher estimate of 7.14 weeks. The overall average for the persistency of milk lactation was calculated to be 1.433±0.534 kg. This result agrees with the estimates of Shaat (2014) within the same herd, varied between 1.01 and 1.79 kg. A comparison of the results from the current study with those from various literature sources underscores significant variability in the impact of different environmental factors on lactation curve parameters and its traits. Factors like feed quality, climate conditions, and overall management practices were among the key contributors to this variability.

The variance components estimates from the single-trait animal model up to the simultaneous analyses exhibited strong convergence and consistency. This agrees with the investigations of Meyer (2018) who noted that single-trait analysis serve as a validation mechanism for multi-trait analysis, facilitating the identification of any underlying concerns. However, as the number of traits analyzed concurrently increases, so does the computational burden significantly. The variance component highlights traits primarily affected by environmental factors, with genetic variance playing a minor role in total variance. It is crucial to emphasize that the environment does not directly alter an individual's genetic composition but it influences how these genetic traits are expressed, showcasing the animals' genetic potential and their interactions (Miranda et al., 2019).

Heritability estimates for lactation curve parameters and associated traits are important for the economic interests of animal breeders. In the current study, heritability estimates for lactation curve parameters (a, b, and c) were 0.05, 0.07, and 0.12, respectively in a single-trait model. Notably, there was no significant rise showed in the multi-trait model, with corresponding estimates remaining at 0.06, 0.07, and 0.14, respectively (Tables 2 and 3). The present results suggest that directly selecting for lactation curve parameters may not significantly change the shape of the lactation curve within the existing management system. The lack of substantial additive genetic variations among animals could be a key factor influencing this outcome Rahman et al., 2024). Additionally, the present low direct heritability estimates of studied traits indicate that these traits are largely affected by environmental conditions. The lower heritability estimates for lactation curve parameters in the current study corresponded with the findings of Shaat (2014), who observed lower estimates for these traits in Zaraibi goats, being 0.044, 0.023, and 0.024 for the a, b, and c parameters, respectively. Similarly, Radjabalizadeh et al. (2022) found lower estimates of 0.035, 0.043, and 0.058 for these parameters in Holstein dairy cattle. Conversely, Rekaya et al. (2000) noted higher heritabilities of 0.26, 0.32, and 0.19 for a, b, and c, respectively, in Holstein-Friesian cows. These observed differences between literatures could stem from variations in breed, sample size, location, or estimation methods.

Heritability estimates of lactation curve traits are illustrated in Tables 2 and 3. The importance of milk lactation persistency lies in sustaining a steady lactation curve without a decline in overall production, a highly sought-after trait. Its economic importance derived from its positive links to factors such as health (Jakobsen et al., 2002) and female fertility (Muir et al., 2004). This suggests a promising avenue for adjusting lactation curves through genetic selection (Chang et al., 2001). Therefore, this could assist milk producers in effectively managing reproduction and feeding strategies during early lactation. In this study, heritability estimates for persistency were modest, varied between 0.11 and 0.13 in both single and multi-trait models, indicating a greater effect of environmental conditions on this trait. The present findings align closely with those of González-Peña (2011) in Murciano-Granadina goats, where estimates varied from 0.06 to 0.13. Similarly, De Oliveira-Menezes et al. (2010) reported lower heritability values of 0.03 to 0.09 for persistency in Saanen goats. Regarding the heritability of peak milk yield, estimates ranged from 0.12 to 0.14, generally consistent with the value of 0.13 (Miranda et al., 2019). In this study, lower heritability estimates for time to peak were observed, being

0.13 in both two models. Miranda et al. (2019) and Rahman et al. (2024) also reported low heritability estimates for milk yield persistency and the time of peak yield. The consistently low heritability estimates for various lactation curve parameters and associated traits in this study underline the limited genetic diversity within the Zaraibi goat population. Consequently, slow genetic enhancements could be achievable through well-designed selection strategies.

Repeatability serves as a crucial indicator in defining the upper limit of heritability. Its calculation is essential because while it doesn't directly represent genetic diversity, it does set a cap on it. Additionally, repeatability helps establish how many consistent records of a particular trait across various times in an animal's lifespan are required before those records should be disregarded (Oldenbroek and van derWaaij, 2014). Herein, the repeatability assessments for the parameters a, b, and c were notably low, contrasting with the moderately estimated lactation curve traits (PW, PMY, and S). These current results align with the results of Shaat (2014), who also noted decreased repeatability in lactation curve parameters. Additionally, several studies across different dairy cattle breeds have reported moderate repeatability estimates for lactation curve traits (Saghanezhad et al., 2017; Miranda et al., 2019; Pangmao et al., 2022). The moderate repeatability estimates of lactation curve traits observed in Zaraibi goats in our study underscore the effect of both temporary and permanent environments on the phenotypic variation of these traits. Consequently, selecting based on early measurements of these traits during lactation could enhance lactation curve traits.

Table 2. The estimates of variance component and heritability for lactation curve parameters and its traits according to the single trait animal model

Items*	$\sigma^2 a$	$\sigma^2 e$	$\sigma^2 pe$	$\sigma^2 p$	h^2	r
a (kg)	0.0117	0.1959	0.0262	0.2338	0.05±0.02	0.162
b (kg/week)	0.0014	0.0175	0.0009	0.0198	0.07±0.03	0.116
c (kg/week)	0.0002	0.0014	0.0001	0.0017	0.12±0.03	0.176
PW (week)	0.1556	0.9790	0.0623	1.1969	0.13±0.08	0.182
PMY (kg)	0.0449	0.3006	0.0289	0.3744	0.12±0.06	0.197
S (kg)	0.0314	0.2018	0.0521	0.2853	0.11±0.04	0.293

***,See abbreviations in Table 1; σ^2 a, additive genetic variance; σ^2 e, residual variance; σ^2 p, phenotypic variance; h^2, heritability; r, repeatability.**

Table 3. Variance component and heritability for lactation curve parameters and its traits according to the multi-traits animal model

Items*	$\sigma^2 a$	$\sigma^2 e$	$\sigma^2 pe$	$\sigma^2 p$	h^2	r
a (kg)	0.0140	0.1916	0.0285	0.2341	0.06±0.01	0.182
b (kg/week)	0.0014	0.0171	0.0011	0.0196	0.07±0.02	0.128
c (kg/week)	0.0002	0.0011	0.0001	0.0014	0.14±0.04	0.214
PW (week)	0.1556	0.9684	0.0731	1.1971	0.13±0.06	0.191
PMY (kg)	0.0524	0.2928	0.0288	0.3740	0.14±0.03	0.217
S (kg)	0.0371	0.1912	0.0571	0.2854	0.13±0.05	0.330

***,See abbreviations in Table 1 and Table 2**

Table 4 displays the genetic and phenotypic correlations between lactation curve parameters and their derived traits in Zaraibi goats. Moderate to high coefficients were observed between the parameters (a, b, and c) and their associated traits. This suggests that utilizing any of these parameters has the potential to improve the traits' curves effectively. The negative correlation coefficient between parameter 'a' and both 'b' and 'c' implies that goats with higher initial milk yield typically undergo a gradual ascent to peak lactation and a slow decline post-peak. This trend was also noted by Sanad and Gharib (2022) in Friesian cows and by Almasri et al. (2023) in Damascus goats. The positive genetic correlation identified between the lactation curve traits, including time to peak, peak milk yield and lactation persistency suggests that breeding programs focusing on these traits could potentially enhance the others through related responses.

Table 4. Additive genetic correlation (above diagonal) and phenotypic correlation (below diagonal) for lactation curve parameters and its traits.

Items	a	b	c	PW	PMY	S
a (kg)	--	-0.59±0.002	-0.41±0.001	-0.38±0.003	0.23±0.006	0.21±0.008
b (kg/week)	-0.75	--	0.44±0.009	0.37±0.001	0.40±0.002	-0.32±0.002
c (kg/week)	-0.63	0.38	--	-0.58±0.005	-0.67±0.001	-0.59±0.004
PW (week)	-0.59	0.34	-0.61	--	0.72±0.001	0.91±0.001
PMY (kg)	0.17	0.45	-0.70	0.58	--	0.86±0.007
S (kg)	0.18	-0.47	-0.63	0.83	0.77	--

See abbreviations in Table 1.

This aligns with the results reported by Shaat (2014) in Zaraibi goats and Somida (2024) in dairy cattle. Meanwhile, the negative correlation between lactation persistency and parameter 'b' denotes that prioritizing consistent production could potentially delay the rise to peak yield. These findings are in line with former studies (Tekerli et al., 2000; Amin et al., 2019; Sanad and Gharib, 2022; Rahman et al., 2024). Moreover, the initial milk production demonstrates moderate positive genetic correlations with lactation persistency (r=0.21) and peak milk yield (r=0.23). However, it displays negative genetic correlations with the ascending slope (r=-0.59) and time to peak yield (r=-0.38). These trends are consistent with the findings of Shaat (2014) in Zaraibi goats and Rahman et al. (2024) in dairy cattle. This suggests that selecting for high initial yield may lead to increased peak yield and persistency, while potentially delaying time to peak (r = -0.38).

CONCLUSION

The present study investigated genetic variations in the lactation curve parameters and their associated traits modeled by Wood's incomplete gamma function. All studied traits displayed low heritability levels and were significantly affected by environmental factors. Consequently, direct genetic selection solely based on lactation curve parameters and linked traits are expected to result in slow genetic progress. Consequently, altering the shape of the lactation curve in Zaraibi goats is likely to be a prolonged process. Additionally, in this study, we observed moderate to high genetic and physiological correlations between lactation curve parameters and traits, underscoring the importance of incorporating these relationships into genetic improvement initiatives for the Zaraibi goats in Egypt.

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تحليل وراثي لمعلمات منحنى وود للحليب والصفات المنبثقة منه باستخدام نموذج حيوانى أحادي ومتعدد الصفات فى الماعز الزرايبي فى مصر

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الملخص

تم استخدام نموذج حيواني أحادي ومتعدد الصفات لتقدير مكونات التغاير والتغايير المشترك والمعايير الوراثية لمعلمات منحنى وود للحليب والصفات المنبثقة منه فى الماعز الزرايبي. تم تجميع 1323 سجل حليب يومي من قطيع للماعز الزرايبي بمحطة السرو البحثية خلال الفترة من 2005 وحتى 2014. كان المتوسط العام لإنتاج الحليب الأولى(a) ومعدل الصعود حتى ذروة الإنتاج(b) ومعدل الهبوط بعد ذروة الإنتاج (c) ومحصول المثابرة (S) والوقت حتى الوصول لذروة الإنتاج (PW) ومحصول الذروة (PMY) 1.504 كجم و 0.421 كجم و 0.098 كجم و 1.433 كجم 4.295 اسبوع و 1.823 كجم على التوالي . كانت تقديرات المكافيء الوراثي 0.05 (0.06) و 0.07 (0.07) و 0.12 (0.14) و 0.13 (0.13) و 0.12 (0.14) و 0.11 (0.13) للقياسات a و b و c و S و PW و PMY على التوالي باستخدام النموذج الاحادي (متعدد الصفات) على التوالي. كان هناك ارتباط وراثي موجب قوي بين الصفات المختلفة لمنحني الحليب فى المدي من 0.72 الى 0.91 بينما كان هناك ارتباط وراثي سالب بين محصول اللبن الأولى وكل من معدل الزيادة حتى ذروة الإنتاج (-0.59) والوقت حتى الوصول للذروة (-0.38) علاوة على ذلك كان هناك ارتباط سالب بين محصول المثابرة ومعدل الزيادة حتى الوصول للذروة (-0.32) بينما كان هناك ارتباط موجب للوقت حتى الوصول للذروة مع معدل النيادة حتى الذروة (0.37) وسالب مع معدل الهبوط بعد الذروة (-0.58). الخلاصة ، اظهرت الدراسة الحالية فروق طفيفة بين النموذج احادى الصفة والنموذج متعدد الصفات فى تقدير مكونات التباين والمعايير الوراثية كما أن المدي المتوسط والمرتفع للإرتباط الوراثي بين معلمات منحنى الحليب والصفات المرتبطه به يشير الى ان استخدام اى من هذه المعلمات يمكنه تحسين صفات الحليب.

الكلمات الدالة : منحني الحليب ، معادلة وود، الماعز الزرايبي، المعايير الوراثية.