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GENETIC PARAMETER ESTIMATES OF LIFETIME PERFORMANCE TRAITS FOR HOLSTEIN-FRIESIAN CATTLE RAISED IN EGYPT

H. O. Alhammad[1], U. M. El-Saied[2], M. A. M. Ibrahim[1] and A. A. Nigm[1]

1- Department of Animal Production, Faculty of Agriculture, Cairo University, Giza, Egypt, 2- Animal Production Research Institute, Ministry of Agriculture and Land Reclamation, Dokki, Giza, Egypt

SUMMARY

A total of 5662 lactation records for 1029 Holstein-Friesian cows sired by 139 bulls raised in three commercial herds was used in the present study to estimate genetic parameters of total and partial lifetime traits with a multiple trait animal model. The study took into account four lifespan traits (lifetime, productive life, lifetime days in milk and lifetime score), lifetime milk yield and two reproductive traits (age at first calving and calving interval). Milk yield was calculated per day of lifetime, productive life and lifetime days in milk. Partial lifetime traits were considered for the first three parities.

The model of analysis included herd, season of birth and year of birth as fixed effects and animal as a random effect. Milk/d of lifetime days in milk was added to the model as a covariate for lifespan traits only. Year of birth contributed significantly to variation in all traits. Herd showed significant effect on all the traits except for milk per-day of productive life and milk per-day of lifetime days in milk. Season of birth showed a significant effect on all lifespan traits. Heritability estimates for lifespan traits were low (0.05 to 0.12), indicating few possibilities for direct genetic selection. All estimates of genetic correlations (0.97 – 0.98) between lifespan traits were high and very proximate to their corresponding phenotypic correlations. Heritability estimates for partial lifetime performance traits increased notably when more parities were included. Genetic and phenotypic correlations between partial lifetime traits and their corresponding total lifetime traits also increased gradually when more information was considered. These results may indicate that early indirect selection to improve total lifetime could be achieved.

Keywords: Genetic parameters, lifetime traits, Holstein-Friesian, Egypt

INTRODUCTION

A concern of many dairy producers is that continued selection for milk yield may reduce the overall fitness of dairy cattle, thereby decreasing herd life and profitability (Short and Lawlor, 1992). In the countries with developed cattle breeding, the productive life of cows is shortened due to the increase in their producing capacity (Powell, 1985). Culling based on low milk production is often referred to as voluntary culling, and culling based on health or reproductive problems is normally termed as involuntary culling (Vollema and Groen, 1996; Boettcher *et al*., 1999b; and

Cruickshank, 2002). The early culling will shorten the average lifetime of cows and decrease the profitability of milk production (Orgmets, 2003). A long lifetime is a desirable trait from several different perspectives. It means good health and fertility, allows the animal to achieve its maximum productive capacity, contributes to reducing replacement and treatment costs, and increases the scope of voluntary culling (Dekkers, 1993; Jairath *et al.,* 1994; Boettcher *et al.*, 1997 and Vukasinovic *et al.*, 2001). However, direct genetic improvement of herd life is very hard to be achieved because of its low heritability that ranged from 0.03 to 0.05 (Van Doormaal *et al.*, 1985; Jairath *et al.*, 1998). Moreover, one must wait for the animal or its relatives to leave the herd before obtaining a direct measurement (Sewalem *et al*., 2004). Weigel *et al*. (1995) stated that indirect selection for lifetime merit is usually the method of choice because evaluation can be based on traits measured earlier in life. The objective of this work was to estimate genetic parameters of several total and partial lifetime performance traits and investigate improvement possibilities in Holstein-Friesian cattle raised in Egypt.

MATERIALS AND METHODS

Animals and herd management

This study was carried out on three commercial herds of Holstein-Friesian cows belonging to El-Salhia Agricultural Company, Ismailia Governorate (East to the south of Nile Delta). All animals were imported from the USA as pregnant heifers since 1982.

All cows were kept under similar feeding and management systems. All year round, cows were fed concentrates and corn silage according to their body weight and milk production. During winter and spring months, animals were supplied with Egyptian clover (*Trifolium alexandrium*), while, beets, maize and green sorghum (*Sorghum vulgar*) were available during summer and autumn. In addition, rice straw was available all the year round. Free clean water and mineral mixture were always available.

Artificial insemination was practiced during the first heat period following the 45^{th} day post-partum using frozen semen imported from the USA. Pregnancy was detected by rectal palpation 60 days after the last service. Cows were machine milked twice daily until two months before their expected calving dates. Then if they did not go dry, they were dried off gradually by milking them once a day until completely dried off. Milk per lactation was estimated through a set of test-day records taken at monthly intervals.

Data and general edits

A total of 5662 complete lactation records for ١٠٢٩ cows, daughters of 139 sires were used. Of the total sires, only 2 sires had a single daughter in the file, while the rest of sires had between 2 and 58 daughters distributed in the 3 herds. Therefore, many genetic links existed between the 3 herds because of the use of AI. All cows were required to have consecutive lactations, starting with the first. Birth dates between 1981 and 1983 were required, calving dates were between 1982 and 1994 inclusive, and therefore the youngest cows had at least 11 years of opportunity for life. Age at first calving was between 18 and 40 months and calving interval was restricted to 300–600 days.

Traits

Four variables related to the life of the cow were considered in the present study including:

Total lifetime (LT): number of days between birth and death or disposal (voluntary or involuntary); **Productive Life (PL):** length of time between first calving and the last dry date: **Lifetime days in milk (LDIM):** total number of days in milk (DIM) during lifetime and **lifetime score:** number of lactations a cow survived.

Two intervals of time that are unprofitable from a milk production standpoint are the period from birth to first calving and dry periods (Lormore and Galligan, 2001). These periods represent nonproductive days that dilute the profit of production per day of life. Therefore, other measures for lifespan were added that considered both productivity and lifespan. These measures included, milk /d for each of LT, PL, and LDIM.

Partial lifetime traits were also calculated for the first three calving. Traits included age at each calving; PL, LDIM, LMY and milk yield per day of LT, PL, and LDIM.

Statistical Analysis

Genetic parameters of lifetime traits were estimated using REML and the VCE 4.0 software (Geroneveld and Garcia Cortes, 1998) with the following multiple-trait animal model:

$$\mathbf{Y_{ijklm} = H_i + YB_j + S_k + A_l + e_{ijklm}}$$

where:

Y_{ijklm} = productive and reproductive total or partial lifetime traits;

H_i = fixed effect of the i^{th} herd, (i= 1, 2, 3);

YB_j = fixed effect of the j^{th} year of birth, (j= 1, 2);

S_k = fixed effect of the k^{th} season of birth, (k= 1, 2, 3, 4), where 1= December, January and February, 2= March through May, 3= Jun through August and 4= September through November ; and

e_{ijklm} = error term.

Milk/d of lifetime days in milk was added to the above mentioned model as a covariate for lifespan traits only (LT, PL, LDIM and lifetime score). A comparison in heritability estimates for lifespan traits was made when milk/d of lifetime days in milk was not in the model. Means and phenotypic correlations were calculated using the SAS program (SAS, 1999).

The model described above was a linear model. In theory, survival analysis is a more appropriate statistical method for analysis of lifetime traits because it deals properly with the typically skewed distributions of the data and can account for censored records. However, Banks *et al*. (1985) and Jairath *et al*. (1994) indicated that estimates from a linear model can be of practical use even when normality does not hold. Moreover, only uncensored records were used in this work. Hence, the use of the linear model was justifiable in this case.

RESULTS AND DISCUSSION

Descriptive statistics for total and partial lifetime performance traits

Phenotypic means, standard deviations (SD), minimums (Min.), maximums (Max.), and coefficients of variation (CV) for total and partial lifetime performance traits are given in tables 1 and 2. The coefficients of variation for lifespan traits (LT, PL, LDIM, and lifetime score) were high (23.6–31.6). While, the per-day milk yield traits (M/dLT, M/dPL and M/dLDIM) had lower CV, ranging from 16.1 to 22.1. The standardization effect on per day traits by days of life may explain this difference in CV.

Table 1. Phenotypic means, standard deviations (SD), minimums (Min.), maximums (Max.) and coefficients of variation (CV) for total lifetime performance traits

Trait	Mean	SD	Min.	Max.	CV%
LT, d	3200	754	1422	5144	23.6
PL, d	2399	759	604	4397	31.6
LDIM, d	2042	644	549	3622	31.6
LT score	5.5	1.5	2	9	26.8
LMY, l	35741	14396	6894	77689	40.3
M/dLT, l	10.76	2.38	4.7	16.7	22.1
M/dPL, l	14.60	2.35	9.6	20.7	16.1
M/dLDIM, l	17.13	2.76	11.8	24.6	16.1
Age1C, d	711	50.6	570	960	7.1
CI	439	35	343	547	8

Number of analyzed records = 1029 for all variables.
LT = Lifetime, PL = productive life, LDIM = lifetime days in milk, LT score = lifetime score; number of given parities during lifetime, LMY = lifetime milk yield, M/dLT = milk per day of lifetime, M/dPL = milk per day of productive life, M/dLDIM = milk per day of lifetime days in milk, Age1C = age at first calving, CI= Calving interval ; average interval between successive lactations.

Total LT mean obtained in this study was 3200 d. (105.3 months). The reviewed estimates ranged between 59.9 month for Holstein cattle in the USA (Dentine *et al*., 1987) and 76.4 month for Friesian cattle in Egypt (Halawa, 2007). PL represented 75% of total LT of the cow while LDIM represented 64% and 85% of LT and PL, respectively. Longer productive life leads to a higher proportion of cows reaching high producing lactations (Vukasinovic *et al*., 1997). The highest effect of longer productive life decreases the costs of replacement.

Analysis of variance of total lifetime performance traits

Table 3 presents analysis of variance of total lifetime performance traits. Year of birth contributed significantly to variation in all traits. Except for milk per day of productive life and milk per day of lifetime days in milk, herd showed significant effect on all traits in table 3. Season of birth showed a significant effect on all lifespan traits.

Milk per day of lifetime days in milk was included in the model as a covariate to adjust lifespan traits (lifetime, productive, lifetime days in milk, and lifetime score) for milk production level. As in Table 3, milk production level contributed significantly (P< 0.001) to variation in all lifespan traits.

Table 2. Phenotypic means, standard deviations (SD), minimums (Min.), maximums (Max.), and coefficients of variation (CV) for partial lifetime performance traits

Trait	Mean	SD	Min.	Max.	CV%
Age1C, d	711	50.6	570	960	7.1
Age2C, d	1106	73.7	962	1428	6.7
Age3C, d	1522	91.2	1303	1957	6
PL2, d	734	67.8	572	1023	9.2
PL3, d	1174	85.7	961	1525	7.3
LDIM1, d	323	48.4	230	489	15
LDIM2, d	662	70	499	969	10.6
LDIM3, d	1025	87	790	1386	8.5
MY1, l	4746	1122	3036	9841	23.7
MY2, l	10524	2170	6480	18932	20.6
MY3, l	17395	3457	10140	29358	19.9
M/dLT1, l	4.3	0.93	2.6	7.7	21.8
M/dLT2, l	6.9	1.35	4.4	11.1	19.6
M/dLT3, l	8.9	1.69	5.4	13.7	19.1
M/dPL2,l	14.3	2.60	9.8	24.7	18.1
M/dPL3,l	14.8	2.73	9.6	22.4	18.4
M/dLDIM1,l	14.7	2.64	10.6	30.8	17.9
M/dLDIM2,l	15.9	2.78	11.5	26.5	17.5
M/dLDIM3,l	17	3	11.7	25.9	17.8

Age1C = Age at first calving, Age2C = age at second calving, Age3C = age at third calving, PL2 = 2-parity productive life, PL3 = 3-parity productive life, LDIM1 = first parity lifetime days in milk, LDIM2 = 2-parity lifetime days in milk, LDIM3 = 3-parity lifetime days in milk, MY1 = milk yield of first parity, MY2 = cumulative milk yield of first 2 parities, MY3 = cumulative milk yield of first 3 parities, M/dLT1 = milk per day of lifetime at end of first parity, M/dLT2= milk per day of lifetime at end of second parity, M/dLT3 = milk per day of lifetime at end of third parity, M/dPL2 = milk per day of productive life at end of second parity, M/dPL3 = milk per day of productive life at end of third parity, M/dLDIM1 = milk per day of lifetime days in milk at end of first parity, M/dLDIM2 = milk per day of lifetime days in milk at end of second parity, M/dLDIM3 = milk per day of lifetime days in milk at end of third parity.

Table 3. Analysis of variance of total lifetime performance traits

Trait	***F*-Value and significance level**			
	Herd	**Year**	**Season**	**MPL**
LT, d	14.05***	17.19***	3.70*	125.79***
PL, d	18.47***	12.57***	3.75*	124.73***
LDIM, d	17.20***	15.29***	3.72*	127.95***
LT score	24.24***	7.55**	4.05**	117.24***
LMY, l	9.74***	74.31***	1.93^{NS}	—
M/dLT, l	11.28***	209.58***	1.85^{NS}	—
M/dPL, l	1.01^{NS}	298.60***	1.89^{NS}	—
M/dLDIM, l	2.06^{NS}	341.49***	2.14^{NS}	—
Age1C, d	98.32***	100.55***	2.11^{NS}	—
CI	15.69***	8.88**	2.53^{NS}	—

LT= Lifetime, PL= productive life, LDIM= lifetime days in milk, LT score= lifetime score; number of given parities during lifetime, LMY = lifetime milk yield, M/dLT = milk per day of lifetime, M/dPL = milk per day of productive life, M/dLDIM = milk per day of lifetime days in milk, Age1C = age at first calving, CI= Calving interval ; average interval between successive lactations. Year = year of birth of the cow, Season= season of birth of the cow, MPL= milk production level.

*P< 0.05, **P<0.01, ***P<0.001; NS= Not significant.

Heritability estimates for lifetime performance traits

Heritability estimates (h^2) for lifetime performance traits are shown in table 4. Heritability estimates were low for lifespan traits (lifetime, productive life, lifetime days in milk, and lifetime score) and lifetime milk yield, ranging from 0.05 to 0.12 which, in general, lies within the range of estimates published for the same traits worldwide. Most estimates of heritability in the literature were obtained using multivariate sire model. Vollema and Groen (1996) explained that differences between sire and animal models are expected to be small for lowly heritable traits, such as longevity, because most information comes from the sire component.

Table 4. Estimates of heritability (h^2) and standard errors (SE) for total lifetime performance traits

Trait	h^2	SE
LT	0.05	0.05
PL	0.08	0.07
LDIM	0.12	0.06
Score	0.09	0.04
LMY	0.12	0.05
Age1C	0.27	0.08
M/dLT	0.23	0.03
M/dPL	0.14	0.01
M/dLDIM	0.17	0.01

LT = Lifetime, PL = productive life, LDIM = lifetime days in milk, Score = lifetime score; number of given parities during lifetime, LMY= lifetime milk yield, Age1C = age at first calving, M/dLT = milk per day of lifetime, M/dPL = milk per day of productive life, M/dLDIM = milk per day of lifetime days in milk

The heritability estimate for length of lifetime was 0.05. The present estimate is comparable to that 0.04 reported by Vollema and Groen (1996) on Dutch black and white cows. While, the productive life had a heritability estimate of 0.08 which is exactly the same as that obtained by Jairath *et al*. (1994) on Holstein cows in Canada. The heritability estimated (0.12) for lifetime days in milk was slightly higher than that (0.09) recorded for Holstein cows by VanRaden and Klaaskate (1993) and Jairath *et al*. (1994) in the USA and Canada, respectively. With regard to lifetime score; heritability estimate was 0.09. Hoque and Hodges (1980) and VanRaden and Klaaskate (1993) found the same estimate for Holstein cows in Canada and USA, respectively. Heritability estimate of lifetime milk yield in the present study was 0.12 which falls between the estimates of the same trait reported by Hoque and Hodges (1980) and Jairath *et al*. (1994) on Holstein cows in Canada.

These low heritability estimates suggest that direct selection to improve such traits would not be efficient. Therefore, genetic improvements for such traits should be made indirectly through correlated response when selection is applied to other correlated traits. Some passive selection for these traits takes place because individuals that live longer usually have more progeny. When milk/d of lifetime days in milk was excluded from the model, heritability estimates were decreased for all lifespan traits. This decrease averaged 15.54% and ranged from 14.29% for lifetime score to 17.88% for lifetime days in milk.

The heritability for the per day milk traits for lifetime (0.23), productive life (0.14), and lifetime days in milk (0.17) had higher heritability estimates than lifespan traits and LMY. Jairath *et al.* (1994) explained that higher heritability estimates for per day traits are due to the standardization effect on per day traits by days of lifetime.

Genetic and phenotypic correlations among lifetime performance traits

Table (5) presents estimates of genetic correlations (r_g above the diagonal) and phenotypic correlations (r_p below the diagonal) among the studied total lifetime performance traits. Most estimates of correlation coefficients among total lifetime performance traits were high. Both types of correlations among total lifetime, productive life, lifetime days in milk, lifetime score, and lifetime milk yield were very high. Genetic correlations among these traits were >0.96 and the corresponding phenotypic correlations were >0.92. Genetic correlations between milk per day of lifetime and other total lifetime performance traits ranged from 0.90 to 0.98, while phenotypic correlations were lower ranging from 0.72 to 0.91. The high correlations among lifetime traits are attributed to the fact that many of the same factors are involved in controlling these traits (Klassen *et al.*, 1992 and Jairath *et al.,* 1994).

Table 5. Genetic correlations (r_g above the diagonal), and phenotypic correlations (r_p below diagonal) among total lifetime performance traits

Trait	LT	PL	LDIM	Score	LMY	Age1C	M/dLT	M/dPL	M/dLDIM
LT		0.99	0.99	0.98	0.99	-0.82	0.98	0.59	0.59
PL	0.99		0.99	0.98	0.99	-0.85	0.97	0.58	0.58
LDIM	0.99	0.99		0.97	0.98	-0.84	0.96	0.55	0.55
Score	0.97	0.98	0.97		0.96	-0.85	0.98	0.57	0.58
LMY	0.93	0.93	0.93	0.92		-0.86	0.98	0.64	0.63
Age1C	-0.11	-0.18	-0.17	-0.22	-0.16		-0.89	-0.43	-0.49
M/dLT	0.73	0.75	0.75	0.76	0.91	-.024		0.72	0.74
M/dPL	0.40	0.40	0.41	0.41	0.69	-0.11	0.90		0.97
M/dLDIM	0.42	0.43	0.43	0.45	0.70	-0.14	0.90	0.98	

LT = Lifetime, PL = productive life, LDIM = lifetime days in milk, Score= lifetime score; number of given parities during lifetime, LMY = lifetime milk yield, Age1C = age at first calving, M/dLT = milk per day of lifetime, M/dPL = milk per day of productive life, M/dLDIM= milk per day of LDIM .

With regard to the correlation coefficients between age at first calving and lifetime performance traits, all estimates of correlations were negative with phenotypic correlations of -0.11 to -0.22 and genetic correlations of -0.43 to -0.89. These results suggested that selection for extending lifespan traits and increase lifetime milk yield would cause a correlated decrease in the age at first calving. Ashmawy (1986) and Atil and Khattab (2005) stated that a reduction in age at first calving will minimize the cost of raising the heifers, shorten the generation interval and maximize the number of lactations per cow. Age at first calving is expected to contribute positively towards the producing capacity of an animal during her lifetime and consequently needs an important consideration in selecting cows.

Indirect selection for lifetime performance traits

Total lifetime performance traits with the highest heritability in this study (Lifetime days in milk, total milk yield, milk per day of lifetime, milk per day of productive life, and milk per day of lifetime days in milk) were chosen to estimate their performance early in life during the first three parities. Heritabilities of partial lifetime performance traits and their genetic and phenotypic correlations with total lifetime performance are given in table 6. Heritability estimates for partial lifetime performance traits were higher than estimates of their corresponding total lifetime performance traits. Jairath *et al.* (1994) interpreted these results by the residual variation accumulates as the length of herd life increases. The heritability estimates for partial lifetime performance traits, increased notably when more information (i.e., more parities) were included. In addition, both genetic and phenotypic correlations between total and partial lifetime traits increased gradually when more information was included in partial lifetime traits. These results coincide with those reported by Jairath *et al*. (1994) who stated that high genetic correlations can arise from pleiotropy (same gene(s) involved in controlling same characteristics) and also because early life yield is a part of lifetime yield (i.e., a part- whole relationship).

Table 6. Heritability estimates (±SE) for selected partial lifetime performance traits and their phenotypic and genetic correlations with total lifetime performance traits

Total lifetime trait	Partial lifetime trait	h^2 (± SE) of partial lifetime trait	Correlation	
			Phenotypic	Genetic
LDIM	DIM1	0.18 ± 0.06	0.11	0.25
	DIM2	0.16 ± 0.06	0.19	0.44
	DIM3	0.23 ± 0.07	0.29	0.61
LMY	MY1	0.32 ± 0.03	0.28	0.17
	MY2	0.35 ± 0.02	0.45	0.38
	MY3	0.37 ± 0.02	0.56	0.54
MdLT	MdLT1	0.33 ± 0.03	0.51	0.33
	MdLT2	0.32 ± 0.01	0.71	0.65
	MdLT3	0.35 ± 0.01	0.82	0.80
MdPL	MdPL2	0.28 ± 0.01	0.82	0.41
	MdPL3	0.39 ± 0.01	0.91	0.88
MdLDIM	MdLDIM1	0.29 ± 0.03	0.60	0.35
	MdLDIM2	0.31 ± 0.03	0.82	0.65
	MdLDIM3	0.40 ± 0.04	0.92	0.85

LDIM= lifetime days in milk, DIM1= first-parity days in milk, DIM2= two-parity days in milk, DIM3= three-parity days in milk, LMY = lifetime milk yield, MY1 = milk yield of first parity, MY2 = cumulative milk yield of first 2 parities, MY3 = cumulative milk yield of first 3 parities, MdLT = milk per day of lifetime, M/dLT1 = milk per day of lifetime at end of first parity, M/dLT2= milk per day of lifetime at end of second parity, M/dLT3 = milk per day of lifetime at end of third parity, M/dPL2 = milk per day of productive life at end of second parity, M/dPL3 = milk per day of productive life at end of third parity, M/dLDIM1 = milk per day of lifetime days in milk at end of first parity, M/dLDIM2 = milk per day of lifetime days in milk at end of second parity, M/dLDIM3 = milk per day of lifetime days in milk at end of third parity.

Most estimates of genetic correlations between total and partial lifetime traits were lower than their corresponding phenotypic correlations. This means that, with exception of the correlation between lifetime days in milk and their corresponding partial lifetime performance traits, there are positive environmental correlations between total lifetime performance traits and their corresponding partial lifetime performance traits. Therefore, a favorable correlated response is expected in total milk yield, milk per day of lifetime, milk per day of productive life, and milk per day of lifetime days in milk when early selection is carried out for their corresponding partial lifetime traits.

As shown in table (4) the highest heritability estimate for lifetime traits in the present study was that for milk per day of lifetime (0.23 ± 0.03). This trait is of a practical use, as it can be easily calculated at any time through the lifetime of the cow. Heritability estimates for partial milk per day of lifetime (Table 6) were 0.33, 0.32, and 0.35 for first, first and second, and first three parities, respectively. These estimates are greater than those for milk per day of lifetime. Phenotypic correlations of these three traits with milk per day of lifetime were moderate to high (0.33, 0.65, and 0.80, respectively), and the corresponding genetic correlations were 0.51, 0.71, and 0.82, respectively. Based on its reasonable estimates of heritability, and the high phenotypic and genetic correlations with milk per day of lifetime, partial milk per day for three parities is seem to be suitable as early indirect selection trait for milk per day of lifetime.

CONCLUSIONS

The estimates of heritability for lifespan traits suggest that direct selection holds little promise for enhancing lifetime of cows because response to selection will be slow. In view of the reasonable heritability estimates for partial lifetime traits and their high genetic correlations with total lifetime traits, early, indirect selection to improve total lifetime could be achieved.

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تقدير المقاييس الوراثية لصفات أداء مدى الحياة لماشية الهولشتين فريزيان المرباة في مصر

حارث عمر الحماد[1]، أسامة محمد السعيد[2]، محمد عبد العزيز محمد إبراهيم[1]، على عطية نجم[1]

١ – قسم الإنتاج الحيواني، كلية الزراعة، جامعة القاهرة، الجيزة، مصر، ٢– معهد بحوث الإنتاج الحيواني، وزارة الزراعة واستصلاح الأراضي، الدقى ، الجيزة، مصر

أستخدم في الدراسة ٥٦٦٢ سجلاً ل ١٠٢٩ بقرة هولشتين فريزيان بنات ١٣٩ طلوفة مرباه في ثلاثة قطعان تجارية وذلك لتقدير المقاييس الوراثية للصفات المعبرة عن الأداء الكلي والجزئي مدى الحياة باستخدم نموذج الحيوان المتعدد. حيث أخذ بعين الإعتبار كل من صفات فترة الحياة (طول الحياة، طول الحياة الإنتاجية، أيام الحلب خلال الحياة، عدد المواسم المكتملة)، إنتاج اللبن الكلي خلال الحياة، الصفات التناسلية (العمر عند أول ولادة، متوسط الفترة بين كل ولادتين متعاقبتين)، كما تم حساب إنتاج اللبن لكل يوم من طول الحياة ولكل يوم من طول الحياة الإنتاجية ولكل يوم من أيام الحلب خلال الحياة، كذلك أخذ في الحسبان الصفات المعبرة عن جزء من الأداء مدى الحياة خلال الموسم الأول، و أول موسمين و المواسم الثلاثة الأولى.

تضمن النموذج الرياضي كل من القطيع وسنة الميلاد وفصل الميلاد كعومل ثابتة وتأثير الحيوان كعامل عشوائي. أثرت سنة الميلاد بشكل معنوي على جميع صفات الأداء مدى الحياة فيما عدا صفتي إنتاج اللبن لكل يوم من الحياة الإنتاجية وإنتاج اللبن لكل يوم من أيام الحلب خلال الحياة، بينما كان تأثير فصل الميلاد معنوياً على جميع صقات فترة الحياة. تم إضافة مستوى إنتاج اللبن إلى النموذج الرياضي كمتغير مشترك لتعديل صفات فترة الحياة.

كانت تقديرات العمق الوراثي لصفات فترة الحياة منخفضة تراوحت مابين (٠.٠٥ إلى ٠.١٢) مما يشير إلى صعوبة إجراء التحسين الوراثي المباشر لهذه الصفات. كانت جميع معاملات الإرتباط الوراثي بين صفات فترة الحياة مرتفعة (٠.٩٧ – ٠.٩٨) ومتقاربة جداً لما يقابلها من معاملات الإرتباط المظهري.

بالنسبة للصفات المعبرة عن جزء من الأداء مدى الحياة؛ كانت تقديرات العمق الوراثي تزداد بشكل ملحوظ بازدياد عدد المواسم التراكمي، كذلك ازدادت وبشكل تدريجي معاملات الإرتباط الوراثي والمظهري لها مع صفات الأداء الكلي مدى الحياة مع ازدياد عدد المواسم التراكمي مما يدل على امكانية تطبيق الإنتخاب المبكر لتحسين الأداء مدى الحياة اعتماداً على الصفات المعبرة عن جزء من الأداء مدى الحياة.