THE INFLUENCE OF MATERNAL EFFECTS ON THE EFFICIENCY OF SELECTION INDEX FOR GROWTH TRAITS OF FRIESIAN CALVES FROM BIRTH TO WEANING

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ABSTRACT

Estimates of (co)variance component and genetic parameters were obtained for growth traits from birth to weaning for 1713 Friesian calves (813 males and 900 females) daughters of 703 dams and 93 sires during the period from 1982 to 2001 at Sakha and El-Karada farms. Data were analysed using MTDFREML program. Three different animal models were fitted. Model 1 considered only the animal as a random effect. Model 2 included the maternal effect in addition to the additive direct genetic effect of the animal. In model 3 the maternal genetic effects were added to the content of the model 2 which allowed for the estimation of the genetic covariance between the direct and maternal effects. In all models fitted, the fixed effects were month and year of birth, sex, farm and parity. Weight of dam at calving was included as a covariate. (Co)variance components for birth weight (BW), weaning weight (WW) and daily gain (DG) from birth to weaning were used to construct all possible combinations of selection indices.

Overall means and standard deviations for BW, WW and DG were 30.77 ± 5.09 kg, 96.47 ± 10.25 kg and 546.69 ± 89.44 g/day, respectively. Heritability estimates from model 1 were 0.28, 0.24 and 0.32 for BW, WW and DG, respectively, 0.28, 0.42 and 0.20 from model 2 for the same traits, respectively and were 0.32, 0.34 and 0.37 from model 3 for the mentioned traits, respectively. The heritability of maternal effects from model 3 was 0.17 for BW, 0.14 for WW and 0.09 for DG. The genetic and phenotypic correlations between BW and DG were negative, being -0.42 and -0.31, respectively from model 1 and -0.30 and -0.24, from model 2. The genetic and phenotypic correlations between WW and DG were slightly high and positive, being 0.57 and 0.58, respectively from model 1 and were high, being 0.81 and 0.69 from model 2. Estimates of direct-maternal genetic correlations in all traits studied were negative, ranging from -0.59 to -0.02. The expected genetic change per generation from model 1 ranged from -0.115 to 2.07 kg for BW, 2.95 to 4.33 kg for WW and from 20.28 to 22.12 g/d for DG. From model 2 the values ranged between 0.17 and 1.91 kg, between 3.34 and 4.30 kg and 14.72 and 15.3 g for the same traits. Expected genetic progress from model 3 ranged from 0.76 to 2.44 kg for BW, 1.85 to 4.86 kg for WW and 25.89 to 36.32 g for DG. The accuracy of selection index realized 9 to 12% increase for all indices constructed from model 3. The present negative correlations between direct and maternal genetic effects and the increased accuracies for the indices in the model 3, suggest that the inclusion of the maternal effects in the selection criteria is unavoidable.

Key words: Selection index, Accuracy, Expected genetic change Growth traits, Friesian calves, Direct and Maternal effect, Direct heritability and Direct-maternal genetic correlations.

INTRODUCTION

Published researches on maternal effects in cattle in Egypt are few. El-Awady (2003) concluded that the maternal effects need to be considered in the analysis model. Also, selection for postnatal growth based on direct genetic components only may not give an optimal response because of the negative correlation between the direct genetic components and the maternal effects (Van Vleck et al. (1977)). Maternal effects have been defined as any influence results from the dam on its offspring, excluding the direct effects of the transmitted genes (Legates, 1972). Maternal effect is expressed through the pre- and post-natal environment that a dam avails to her progeny. There are also the genes that pass onto the dam's progeny and influence their response to the environment.

Maternal effects must be taken in to account in selection in beef cattle especially if there is an antagonistic relationship between direct and maternal genetic effects (Robison, 1981 and Diop and Van Vleck, 1998). Analla et al. (1999) concluded that when the association between direct and maternal effects to final performance is not negligible i.e, when the additive correlation between them is strong, inclusion of the maternal breeding values in the selection criteria is unavoidable. The aim of this study was to determine the influence of the maternal effects on the efficiency of the selection indices for birth weight (BW), weaning weight (WW) and daily gain from birth to weaning (DG) in Friesian calves in Egypt through application of different animal models.

MATIRIAL AND METHODS

Data and managements

Data on growth traits from birth to weaning were taken from the records of the Friesian calves kept in Sakha and El-Karada farms, located in the Northern Part of Middle Delta, during the period 1982 to 2001. These herds belong to the Animal Production Research Institute, Ministry of Agriculture, Egypt. A total of 1713 Friesian calves (813 males and 900 females) born for 703 cows mated by 93 sires were used in analysis. The same sires were used in the two farms. El-Awady (2003) gave a detail of the material and management of those farms.

Statistical Analysis

Data were analyzed with the MTDFREML program according Boldman et al. (1995) using multiple trait analysis animal model. Three different animal models were used to estimate variance and covariance components. Model 1 included the fixed effects of year and month of birth, sex of calf, farm and parity and the random effects of animal and residual. Weight of dam at calving was included as a covariate. In matrix notation the model 1 used was:

$$Y = Xb + Za + e$$

Where:

Y = Vector of observations, b = Vector of fixed effects, a = Vector of direct genetic effects, and e = Vector of residual effects. X, and Z are incidence matrices relating records to fixed and direct genetic effects, respectively.

Model 2 included the additive direct genetic effect of the animal and the maternal effect due to the dam (permanent environmental).

$$Y = Xb + Za + Wp_e + e$$

Where:

p_e = Vector of environmental effects contributed by dams to the records of their progeny (permanent environmental), W is the incidence matrix relating records to permanent environmental effect.

Model 3 included the maternal genetic effect which allowed for estimation of the genetic covariance between the direct and maternal genetic effects as follow:

$$Y = Xb + Za + Mm + Wp_e + e$$

Where:

m = Vector of maternal genetic effects, M is the incidence matrix relating records to maternal genetic effect. The variance and covariance structure for model 3 was as follows:

$$E(y) = Xb \quad \text{and}$$

$$V \begin{bmatrix} a \\ m \\ p_e \\ e \end{bmatrix} = \begin{bmatrix} A\sigma^2_a & A\sigma_{am} & 0 & 0 \\ A\sigma_{am} & A\sigma^2_m & 0 & 0 \\ 0 & 0 & I_d\sigma^2_{pe} & 0 \\ 0 & 0 & 0 & I_N\sigma^2_e \end{bmatrix}$$

Where:

d, is the number of dams and N is the number of records, A is the numerator relationship matrix among animals, σ^2_a is the additive direct genetic variance, σ^2_m is the maternal genetic variance, σ_{am} is the additive direct and maternal genetic covariance, σ^2_{pe} is the maternal permanent environmental variance, and I_d, I_N are identity matrices of appropriate order, the number of dam and number of animals with records respectively.

To estimate heritability (h^2) from model 1, the following equations were used:

$h^2_a = \sigma^2_a / (\sigma^2_a + \sigma^2_e)$, while ($h^2$) from model 2, estimated as:

$h^2_a = \sigma^2_a / (\sigma^2_a + \sigma^2_{pe} + \sigma^2_e)$

Where:

σ^2_a = additive genetic variance; σ^2_{pe} = permanent environmental variance and σ^2_e = the random residual effect associated with each observation.

From model 3 estimates of additive direct (h^2_a) and maternal (h^2_m) heritabilities were calculated as ratios of estimates of additive direct (σ^2_a) and maternal genetic (σ^2_m) variances, respectively to the phenotypic variance (σ^2_{ph}). The direct maternal correlation (r_{am}) was computed as the ratio of the estimates of direct maternal covariances (σ_{am}) to the product of the square roots of estimates of σ^2_a and σ^2_m. σ^2_{pe} is the ratio of estimates of maternal environmental variance (σ^2_{pe}) to the total phenotypic variance (σ^2_{ph})

Selection indices construction

a- Economic values

The basic index which included the three traits of interest was calculated using the matrix technique (Cunningham, 1972). Prior to computing the complete index, three reduced indices were computed using all combinations of the traits under investigation. According to September 2003 prices in animal husbandry section in Sakha and El-Karda farms, the economic weight for each trait was approximated based on the final actual net profit. (I) Calf value at birth = L.E 550. (II) Total expenses of calf rearing up till weaning = L.E 600, average selling price of calf at weaning = L.E 1650, giving a profit of L.E 500 [(1650-(550+600)]. (III) Selling price of one kg live weight at weaning = L.E 10.50, the cost of one kg growth = L.E 7.25. The average daily gain for calf is 0.7 kg/d, the cost of this gain = L.E 6.08, selling price of this gain = L.E 7.35, then the profit = L.E 2.27. Thus, the relative economic values for BW, WW and DG are 1: 0.833 : 0.425.

b- Selection index parameters

The index value was calculated as:

$$I= b_1P_1+b_2P_2+.........+b_nP_n = \sum_{i=1}^{n} bipi$$

Where:

bi = partial regression coefficient and

Pi= phenotypic value of traits

Regression coefficients (b) of all selection indices were estimated as:

$$Pb = Ga \text{ or } b = P^{-1}Ga$$

Where:

P = is the phenotypic variance-covariance matrix,

G = is the genetic variance-covariance matrix,

b = vector of partial regression coefficients to be used in the index,

a = vector and constants represent the economic values of yield traits, and

P^{-1} = is the inverse of phenotypic variance-covariance matrix.

Values of partial regression coefficients and phenotypic variance-covariance matrix (P) were used to calculate values of index variance as $\sigma^2 I = \underline{b}' \, \underline{P} \, \underline{b} = \underline{b}' \, \underline{G} \, \underline{a}$, where $\underline{b}'$ is the transpose of (b) vector of partial regression coefficients.

Variance of the total aggregate genotypic value was estimated as $\sigma^2 H = a'Ga$, where $\sigma^2 H$, is the aggregate genotypic variance, and a' is the transpose of economic value column vector. Accuracy of the index (defined as correlation between variance of aggregate genotypic value and variance of the index value), was calculated as $R_{IH} = \sigma I / \sigma H$. The expected genetic gain (ΔG) for any one of the traits was calculated as $\Delta G = i \, R_{IH} \, \sigma I$, where i is the selection intensity, and for a given trait was set to be 1.00 for only the purpose of comparisons, or calculated as according to Tabler and Touchberry (1959), $\Delta G = \sigma I * i * B_{YI}$ where i is the selection intensity (assuming that the selection differential as one standard deviation).

To determine which trait and how many traits combine best into an index, relative efficiencies of the different selection indices were evaluated on the basis of the correlation of index with aggregate genotype (R_{IH}) and the efficiency (RE) of different indices relative to the original index (I_1). Estimates of genetic and phenotypic variance and covariance of BW, WW and DG were used for construction of various selection indices using Henderson's modifications of Hazel's (1943) method.

RESULTS AND DISCUSSION

Overall means

Phenotypic means and their standard errors (SE) and coefficients of variability (CV) for birth weight (BW), weaning weight (WW) and daily gain (DG) from birth to weaning are presented in (Table 1).

Table (1) Phenotypic means for birth weight (BW), weaning weight (WW) and daily gain (DG) from birth to weaning.

Estimate	Traits		
	BW, kg	**WW, kg**	**DG, g**
Mean	30.77	96.47	546.69
SD	5.09	10.25	89.44
CV%	16.56	10.62	16.36
No. of records	1713		

(Co)variances and genetic parameters

Estimates of variance and covariance components and genetic parameters for BW, WW and DG (Table 2) indicated that Model 3 in all traits gave the phenotypic variance decrease than other models because it accounted for the maternal effects. The maternal permanent environmental effect for BW, WW and DG due to the dams accounted, 12%, 8% and 4%, respectively from the phenotypic variance in Model 3, while accounted for 12%, 0.69 and 9% in Model 2 for the same traits, respectively.

In addition, additive genetic effects from model 3 decreased for BW and WW but increased for DG than those estimated by model 1 and/or model 2. It is important that the appropriate (co)variances are used to insure optimal accuracy in genetic evaluations because prediction error variances for predicted genetic values increase as the difference between true and estimated (co)variance components (Lee et al. 1997).

Model 1 which ignored permanent environmental and maternal genetic effects resulted in a moderate estimated for h^2_a compared with that obtained from model 3 (Table 2). Maternal heritability estimates for BW, WW and DG were 0.17, 0.14 and 0.09, respectively. Diop and Van Vleck (1998) estimated heritabilities of direct genetic effects for birth and weaning weight in Gobra cattle were, 0.13 and 0.33 using a model including only animals as random effect, 0.08 and 0.15 using another model after adding the permanent environmental effect, 0.07 and 0.20 using a model including the maternal effect in addition to animals as

Table (2) Estimates of (co)variance components and parameters for birth and weaning weight and daily gain from birth to weaning using different animal models.

Item	Traits								
	BW, kg			WW, kg			DG, g		
	Model1	Model2	Model3	Model1	Model2	Model3	Model1	Model2	Model3
σ^2_a	22.13	17.53	12.96	88.91	58.65	41.61	1606.8	947.16	1749.1
σ_{a1a2}	25.45	26.10	11.36	25.45	26.10	11.36	25.45	26.10	11.36
σ_{a1a3}	-79.65	-38.90	-20.37	-79.65	-38.90	-20.37	-79.65	-38.90	-20.37
σ_{a2a3}	78.25	72.68	227.42	78.25	72.68	227.42	78.25	72.68	227.42
σ^2_m	------	------	6.85	------	------	17.55	------	------	421.94
σ_{am}	------	------	-1.93	------	------	-4.94	------	------	-38.94
σ^2_e	56.74	38.28	16.16	278.50	80.57	53.15	3375.8	3465.9	2311.8
σ^2_{pe}	------	7.37	5.11	------	0.97	9.39	------	422.4	182.63
σ^2_p	78.80	63.17	41.07	366.44	140.19	121.70	4964.5	4835.5	4665.4
r_{am}	------	------	-0.20	------	------	-0.33	------	------	-0.53
h^2	0.28	0.28	------	0.24	0.42	------	0.32	0.20	------
h^2_a	------	------	0.32	------	------	0.34	------	------	0.37
h^2_m	------	------	0.17	------	------	0.14	------	------	0.09

σ^2_a = direct additive genetic variance, σ_{a1a2} = additive genetic covariance between trait 1 and trait 2, etc., σ^2_m = maternal genetic variance, σ_{am} = direct maternal genetic covariance, σ^2_e = residual (temporary environmental variance), σ^2_{pe} = maternal permanent environmental variance, σ^2_p = phenotypic variance, r_{am} = direct-maternal genetic correlation, h^2 = heritability from model 1 and model 2, h^2_a = direct heritability and h^2_m = maternal heritability.

random effects and 0.07 and 0.20 using a model including both maternal genetic and permanent environmental effects and allowed for the genetic covariance between direct and maternal effects. Their heritability estimates for maternal effects were, 0.06 and 0.41 and 0.04 and 0.21 for the BW and WW for birth and weaning weight from the latter two models, respectively.

In addition, Bennett and Gregory (1996) estimated heritability of direct genetic effects for birth weight and 200d weight, as 0.50 and 0.32 and heritability for maternal effects as 0.09 and 0.10 for the same traits, respectively. This suggests that maternal effects showed be considered where planning selection for growth traits in Friesian calves.

The estimates of correlations between direct and maternal genetic effects were negative for all traits studied (Table 2). The same results were obtained by El-Awady (2003). Maternal effects must be taken in to account in selection for beef cattle especially if there is an antagonistic relationship between direct and maternal genetic effect (Robison, 1981; Mohiuddin, 1993; Koots et al, 1994 and Diop and Van Vleck, 1998).

The negative correlations between direct and maternal genetic effects suggested that many of the genes which favour the milking and mothering ability of a cow are partly detrimental for growth of the young calf (Mohiuddin, 1993). Negative genetic correlations between direct and maternal effects for birth weight and/or weaning weight have been reported by Tawah et al. (1993); Varona et al. (1999) and Lee et al. (2000) and ranged from -0.30 to -0.91. Lee et al. (2000) reported negative estimates (-0.91) of direct-maternal genetic correlation for weaning weight which was inflated when the effects of sire x year interaction was not included in the model. In addition, Koch et al. (1972) suggested that the negative correlations between direct and maternal genetic effects could be due to a negative direct influence of the dams on the maternal ability of their female offspring through overfeeding. In addition, Tawah et al. 1993 concluded that, these negative correlations may be attributed to the adaptation of the animals to the dry tropical environment where food resources are scare.

Estimates of genetic and phenotypic correlations between different traits from model 1 and model 2 were positive except the genetic and phenotypic correlation between BW and DG (Table 3).

Table (3) Genetic (above diagonal), phenotypic (below diagonal) correlations and accuracy of correlations estimated by model 1 and model 2 between different growth traits investigated.

Traits	Model 1			Model 2		
	BW	WW	DG	BW	WW	DG
BW, kg		0.57(0.82)	-0.42(0.79)		0.81(0.79)	-0.30(0.49)
WW, kg	0.58		0.21(0.69)	0.69		0.31(0.77)
DG, g	-0.31	0.06		0.24	0.38	

** P-value (accuracy of correlation) between parentheses.

The present positive genetic and phenotypic correlations between BW and WW and between WW and DG indicated that selection for birth weight would be associated with genetic and phenotypic improvement in the growth traits from birth to weaning. Abdel-Glil and El-Banna (2001) arrived at the same conclusion. Similarly, Peterson and Willis (1974), Abdel-Moez (1996) and El-Awady (2003), they reported that there were positive genetic and phenotypic correlations between BW and WW. The present genetic correlation estimates between BW and WW indicated a positive relationship between pre-and postnatal genetic effects. Similar results were reported by Koots et al (1994b).

Selection index

Four selection indices were constructed from each model (Table 4). The original index in any model (I_1) incorporated BW, WW and DG.

The inclusion of maternal genetic effect in the model resulted in a large expected genetic gain in all traits studied and increased the accuracy of the selection index. Model 3 which included the random direct and maternal genetic effects and allowed for the genetic covariance between them, improved the accuracy of the index 9 to 12% above other models and increase genetic improvement 85, 36.47, and 27.66% for BW, WW and DG, respectively compared with (I_1) of model 1. Including the permanent environmental effect in addition to the animal effect in model 2 did not improve the accuracy of the index.

Table (4): Selection indices (I's), expected genetic response per generation (ΔG), accuracy of the index (R_{IH}) and the efficiency of the different indices to the original index (I_1) (RE%) using different animal models for traits under investigation.

Index selection	Model 1					
	Expected genetic change (ΔG)			R_{IH}	Percentage reduction in R_{IH} over index I_1	Relative efficiency RE (%)
	BW,kg	WW,kg	DG,g			
I_1= 0.0386BW+0.3234WW+0.1306DG	-0.115	3.50	20.28	0.57	-----	100
I_2= 0.3177BW + 0.1866WW	2.07	4.34	------	0.51	-10.53	89.47
I_3= 0.1645BW + 0.1276DG	-0.75	------	22.13	0.55	-3.51	96.49
I_4= 0.2609WW + 0.1461DG	------	2.96	21.75	0.58	1.75	101.75
Model 2						
I_1= -1.4088BW+1.303WW+0.0125DG	0.836	3.85	15.30	0.62	------	100
I_2= -0.0064BW + 0.4054WW	1.91	4.30	------	0.54	-12.90	87.10
I_3= 0.3133BW + 0.1127DG	0.172	------	14.72	0.52	-16.13	83.87
I_4= 0.3782WW +0.1150DG	------	3.34	14.93	0.56	-9.68	90.32
Model 3						
I_1= -0.2889BW+1.0925WW+0.0657DG	0.761	4.78	25.89	0.63	-----	100
I_2= 0.4453BW + 0.4023WW	2.44	4.86	------	0.68	7.94	107.94
I_3= 0.7564BW + 0.2089DG	0.76	------	31.22	0.71	12.70	112.70
I_4= -1.0742WW + 0.4012DG	------	1.85	36.32	0.69	9.52	109.52

Obvious positive relationship was found between birth and weaning weights, therefore, when it is necessary to select against the increase birth weight due to it is positive relationship with dystocia (MacNeil et al. 1998 and Dzama et al. 2001). It is recommended to use I_1 in model 1. Brinks et al. 1964; Smith et al. 1976 and Amer et al. 1998 obtained positive correlations between birth weight and weight at subsequent ages, and concluded that selection for reduced birth weight may decrease production efficiency through the prolonged feeding in order to reach market weight. A selection strategy with negative emphasis on birth weight and positive emphasis on subsequent growth might be effective in reducing the incidence and severity of dystocia, and minimally reduce the rate of genetic progress in subsequently growth.

The maximum predicted genetic progress in BW and WW were 2.44 kg and 4.84 kg per generation and were achieved by I_2 from model 3, while for DG, the highest genetic gain was achieved when using index I_4 from model 3 (Table 4).

Analla et al. (1999) concluded that when correlation between them is strong, inclusion of the maternal breeding values in the selection criteria is unavoidable. They also added, the maternal effects model should be used in order to get a correct ranking of a candidate to selection and higher increase in final performance values. Van Vleck et al. (1977) showed the selection at weaning ages based only on direct breeding values may not yield optimal response because of the negative genetic correlation between direct and maternal effects.

From this work, it is concluded that the negative genetic correlation between direct and maternal genetic effects for all traits studied, suggest that postnatal growth can be increased without increasing birth weight. Consequently, inclusion of both types of maternal effects (genetic and permanent environmental) provide a better chance for genetic improvement and higher accuracy of the index for growth traits from birth to weaning than models with animal or permanent environmental or maternal effect only.

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تأثير التأثيرات الوراثية الأمية على كفاءة الدليل الإنتخابى لصفات النمو فى عجول الفريزيان من الميلاد حتى الفطام

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قدرت مكونات التباين والمعايير الوراثية باستخدام ١٧١٣ ســجلا لصفات النمو من الولادة حتى الفطام لعجــول الفريزيــان (٨١٣ ذكــر و ٩٠٠ أنثى) نسل ٧٠٣ بقرة و ٩٣ أب خلال الفترة مــن ١٩٨٢ حتــى ٢٠٠١ بمزرعة سخا والقرضا. حللت البيانات باســتخدام برنــامج الـــ MTDFREML. أخذت ثلاثة موديلات مختلفــة لنمــوذج الحيــوان. موديل ١ أشتمل على التأثير العشوائى للحيوان فقط. موديــل ٢ أشــتمل بالإضافة الى التأثير الوراثى المضيف للحيوان، التأثير الأمــى (البيئــى الدائم). موديل ٣ أضاف التأثير الوراثى الأمى الى موديل ٢ وأخذ أيضا الارتباطات بين التأثير الوراثى المباشر والتأثير الوراثى الأمى. فى جميع الموديلات كانت التأثيرات الثابتة سنة وشهر الميلاد والجنس والمزرعــة والموسم. أخذ وزن الأم عند الولادة كانحدار. استخدمت مكونات التبــاين للوزن عند الميلاد، الوزن عند الفطام ومعدل النمو اليومى مــن المــيلاد حتى الفطام فى عمل جميع التوليفات الممكنة من الأدلة الانتخابية.

كانت المتوسطات العامة والانحرافات القياسية للوزن عند الميلاد، الوزن عند الفطام ومعدل النمــو اليــومى مــن المــيلاد حتــى الفطــام ٣٠,٧٧±٥,٠٩ كجم ، ٩٦,٤٧±١٠,٢٥ كجــم و٥٤٦,٦٩±٨٩,٤٤ جــم على التوالى.

قدرت المكافئات الوراثية للتأثير الوراثى المباشر من موديل ١ بـــ ٠,٢٨، ٠,٢٤ و ٠,٣٢ للوزن عند الميلاد، الوزن عند الفطــام ومعــدل النمو اليومى من الميلاد حتى الفطام على التوالى. بينما قدرت من موديل ٢ بـــ ٠,٢٨، ٠,٤٢ و ٠,٢٠ لنفس الصفات السابقة على التوالى و كانت ٠,٣٢، ٠,٣٤ و ٠,٣٧ من موديل ٣ لنفس الصفات السابقة على التوالى. قدرت المكافئات الوراثية للتأثير الوراثى المباشر من موديل ٣ للوزن عند الميلاد، الوزن عند الفطام ومعدل النمو اليومى من الميلاد حتى الفطام بـــ ٠,٣٢، ٠,٣٤ و ٠,٣٧ على التوالى. بينما كانــت تقــديرات المكافئــات

الوراثية للتأثير الوراثى الأمى من نفس الموديل ٠,١٧ ، ٠,١٤ و ٠,٠٩ لنفس الصفات السابقة على التوالى.

الارتباط الوراثى والمظهرى بين الوزن عند الميلاد ومعدل النمو اليومى كان سالبا.، -٠,٤٢ و-٠,٣١ على التوالى من موديل ١ و -٠,٣٠ و -٠,٢٤ على التوالى من موديل ٢. بينما كان الارتباط الوراثى والمظهرى بين الوزن عند الفطام ومعدل النمو اليومى عاليا نوعا ما وموجبا ٠,٥٧ و ٠,٥٨من موديل ١ على التوالى بينما كان مرتفعا وموجبا بين نفس الصفتين ٠,٨١ و ٠,٦٩ على التوالى من موديل ٢.

كانت جميع الارتباطات بين التأثيرات الوراثية المباشرة والأمية سالبة بين الصفات المدروسة وتراوحت من -٠,٥٩ الى -٠,٠٢.

تراوحت قيم التحسين الوراثى المتوقع فى الجيل من موديل ١ من -٠,١١٥ الى ٢,٠٧ كجم للوزن عند الميلاد، ٢,٩٥ الى ٤,٣٣ كجم للوزن عند الفطام و ٢٠,٢٨ الى ٢٢,١٢ جم/يوم لمعدل النمو اليومى من الميلاد حتى الفطام. بينما تراوحت قيم التحسين الوراثى المتوقع فى الجيل من موديل ٢ من ٠,١٧ الى ١,٩١ كجم، ٣,٢٤ الى ٤,٣٠ كجم و ١٤,٧٢ الى ١٥,٣٠ جم/يوم للصفات السابقة على التوالى. بينما تراوحت قيم التحسين الوراثى المتوقع فى الجيل من موديل ٣ من ٠,٧٦ الى ٢,٤٤ كجم، ١,٨٥ الى ٤,٨٦ كجم و ٢٥,٨٩ الى ٣٦,٣٢ جم/يوم الصفات السابقة على التوالى.

زادت دقة الدليل الإنتخابى لجميع الأدلة المؤلفة من الموديل الثالث عن الموديلات الأخرى بـ ٩ الى ١٢%.

معامل الارتباط السالب بين التأثيرات الوراثية المباشرة والأمية بين الصفات المدروسة وزيادة دقة أدلة الانتخاب الناتجة من موديل ٣ يوضح أن اشتمال خطط الانتخاب على التأثيرات الأمية أمر لابد منة.