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GENETIC EVALUATION FOR EGG COMPONENTS IN CROSSBREEDING EXPERIMENT OF SAUDI CHICKENS WITH WHITE LEGHORN

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SUMMARY

Two-year crossbreeding experiment involving Baladi Saudi (S) and White Leghorn (L) chickens was carried out in El-Qassim region in Saudi Arabia to evaluate the egg component traits of the resulting crossbreds. A random sample of 1989 eggs for egg weight (EW), albumen weight (AW), yolk weight (YW) and shell weight (SW) were used. Variance components, heritabilities and genetic and environmental correlations for the egg traits were estimated using DFREML procedure of multi-trait animal model. The genetic model of Dickerson under multi-trait animal model was used to estimate the crossbreeding components of this experiment in terms of direct (G^I) and maternal (G^M) additive effects and direct (H^I) heterosis. Hens of L breed showed higher qualities of eggs compared to the S hens. Estimates of heritability were moderate and ranged from 0.22 to 0.29. All estimates of genetic correlations among egg components were high and ranged from 0.53 to 0.93. The direct additive effects considerably affected all egg traits. L-sired hens had high direct additive effects (G^I) compared to the S-sired hens for all traits studied. Maternal additive effects (G^M) for all traits were considerable and in favour of the L breed. The percentages of G^I for egg components ranged from 8.2 to 11.7, while percentages of G^M ranged from 4.7 to 9.8%. Crossbred hens recorded negative estimates of H^I for most egg component traits since these percentages ranged from 7.0 to 1.2%.

Keywords: *Saudi chickens, egg components, heritability, correlations, crossbreeding components, Multi-trait Animal Model.*

INTRODUCTION

Crossbreeding between egg-type breeds and Saudi chickens raised under the hot conditions of Saudi Arabia is not widely carried out. To date, publications concerning crossbreeding of local chickens with egg-type breeds (e.g. White Leghorn) seem to be not available. Direct and maternal additive effects and direct heterotic effects from crossbreeding experiments including Saudi chickens were expected to be important especially for egg component traits. Therefore, this study was conducted to quantify direct and maternal additive effects and direct heterosis for some egg traits in a crossbreeding experiment involving local Saudi and egg-type breed of White Leghorn chickens.

MATERIALS AND METHODS

Two-year crossbreeding experiment for one generation was carried out in the poultry farm of the Research Center of the Agricultural Experiments (**RCAE**), College of Agriculture and Veterinary Medicine, King Saud University, Saudi Arabia. This experiment started in January 1997.

Breeding plan

Hens used in this study represent one local breed (Baladi Saudi, **S**) and one exotic breed (White Leghorn, **L**). Details and description of general features of the two breeds raised under conditions of Saudi Arabia are reported by Al-Sobayel (1985). Chicks of the parental stock were raised up to the age of five months in the rearing house. Breeding hens of each of the two breeds were randomly divided into two breeding groups. The first group of hens of each of the two breeds was artificially mated with cocks from their own breed, while the second group was artificially mated with cocks from the other breed. Accordingly, four genetic groups of **LXL**, **SXS**, **LXS** and **SXL** hens were obtained. Birds of this first generation hatched in 1/1/1997 and started their egg production in May 1997. Each cock was allowed to sire all his chicks from the same dams, i.e. separate cocks were used in each breed group. The distribution of breeding sires and dams and number of hens used in the genetic groups are presented in Table 1. Eggs were collected when the birds were approximately 24 weeks of age and continued for 12 months. Over the year, the eggs were collected as random samples of one week per month. Random samples of eggs in the four mating groups were broken and components of eggs were recorded.

Table 1. Number of sires, dams and hens used in the four genetic groups of the study

Genetic group[+]	Sires	Dams	Hens	Eggs broken
Birds used in the experiment:				
L x L	28	40	111	
S x S	32	50	143	
L x S	10	14	45	
S x L	9	16	37	
Total	79	120	336	
Pedigree of random sample of eggs broken:				
L x L	8	19	21	502
S x S	6	8	15	451
L x S	5	7	16	430
S x L	9	16	22	606
Total	28	50	74	1989

[+] L = White Leghorn; S = Saudi; Breed of cock listed first.

Management and feeding

All chicks of one-day old were wing-banded and floor brooded and reared in semi-closed houses up to the age of 16 weeks (11 chicks per 1 m^2). Temperature was somewhat controlled using separate electric heaters and air-conditioners, while the ventilation was controlled (17-32°C) using electric extractor fans. Chicks were vaccinated against New Castle disease via the drinking water during the first week (strain Hitchner) and at 8 weeks (strain Lassota) and they were regularly vaccinated thereafter every three months. All chicks were subjected to the same managerial, hygienic and climatic conditions. They were treated and medicated similarly and regularly. At the age of 5 months, pullets were individually housed in breeding pens in three-tier batteries equipped with feeding hoppers and drinking nipples. The pedigreed eggs from each individual hen were collected and recorded regularly. Hens were reared under identical managerial and nutritional regimens.

During the brooding and rearing periods, all chicks were fed ***ad-libitum*** using a standard starter ration (21% crude protein and 12.1 MJ Metabolizable energy per kg of feed) up to 8 weeks of age and a finisher ration thereafter (14% crude protein and 11.1 MJ Metabolizable energy per kg of feed).

Data and multi-trait animal model of analysis

Data on 1989 eggs for egg weight (**EW**) and weights of albumen (**AW**), yolk (**YW**) and shell (**SW**) were collected. Individual egg weights were recorded to the nearest 0.1 gram. Eggs were broken and weights of albumen, yolk and shell were recorded to the nearest 0.01 gram. The multivariate animal model used by running of **MTDFREML** program (Boldman *et al.*, 1995) was:

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix} = \begin{bmatrix} X_1 & 0 & 0 & 0 \\ 0 & X_2 & 0 & 0 \\ 0 & 0 & X_3 & 0 \\ 0 & 0 & 0 & X_4 \end{bmatrix} \begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \end{bmatrix} + \begin{bmatrix} Z_{a1} & 0 & 0 & 0 \\ 0 & Z_{a2} & 0 & 0 \\ 0 & 0 & Z_{a3} & 0 \\ 0 & 0 & 0 & Z_{a4} \end{bmatrix} \begin{bmatrix} u_{a1} \\ u_{a2} \\ u_{a3} \\ u_{a4} \end{bmatrix} + \begin{bmatrix} e_1 \\ e_2 \\ e_3 \\ e_4 \end{bmatrix}$$

Where: $\mathbf{y_i}$ = vector of observations for the ith egg trait of birds; b_i = vector of fixed effect of genetic group and month of egg sampling for the ith trait; u_{ai} = vector of random effects of the bird for the ith trait; X_i and Z_{ai} are incidence matrices relating records of the ith trait to fixed effect and additive genetic effect of the bird, respectively, and $\mathbf{e_i}$= Vector of random residual effects for the ith trait. Inbreeding coefficients for hens, sires and dams were calculated using **MTDFREML** program of Boldman *et al.*. (1995). Pedigree information was used as far as it existed. Variance (co) components obtained by multi-trait animal model were used to estimate heritabilities (h^2) and corelations (r_{xy}) as:

$$h^2 = \frac{\sigma^2_A}{\sigma^2_A + \sigma^2_e}$$

$$r_{xy} = \frac{Cov_{(xy)_{ij}}}{\sqrt{x_{ii}\, y_{jj}}}$$

Where:

σ^2_A and σ^2_e = The variances due to the effects of direct additive genetic and random error, respectively

$Cov_{(xy)_{ij}}$ = The additive genetic (a) and environmental (e) covariances between any two traits.

x_{ii} and y_{jj} = The additive (a) and environmental (e) variances for the first and second trait, respectively.

Genetic model and estimation of crossbreeding effects

The multi-trait animal model was used to demonstrate the calculation of linear contrasts, sampling variances and expectations of solutions for the effect of genetic group for different traits under the study. Using the **MTDFRUN** package (Boldman *et al.*, 1995), the Dickerson`s genetic model (Dickerson, 1992) permits to derive three sets of linear contrasts for egg component traits as:

Direct additive effect (G^I):

$(G^I_L - G^I_S) = \{[(L \times L) - (S \times S)] - [(S \times L) - (L \times S]\}$

Maternal breed effect (G^M):

$(G^M_L - G^M_S) = [(S \times L) - (L \times S]$

Direct heterosis (H^I):

H^I_{LxS} in units = $1/2[(L \times S + S \times L) - (L \times L + S \times S)]$

H^I_{LxS} in percentage = $\{[(LxS + SxL) - (LxL + SxS)]/ (LxL + SxS)\} \times 100$

Where $\mathbf{G^I}$ and $\mathbf{G^M}$ represent direct additive and maternal additive effects, respectively, of the subscripted genetic group. Each single degree of freedom contrast was tested for significance with the Student's t-test.

RESULTS AND DISCUSSION

Genetic-groups comparison

Least-squares means for egg components in different genetic groups are presented in Table 2. The **LXL** genetic group resulted in heavier weights of egg, albumen, yolk and shell compared to the **SXS** mating. Results given in Table 2 evidenced that breed of **L** had superior performance in all egg traits studied compared to the **S** chickens. Clear differences of 8.3 gram, 4.5 gram, 3.0 gram and 0.83 gram for **EW**, **AW**, **YW** and **SW** were in favour of **L** breed, respectively.

Table 2. Purebred and crossbred means (gram±SE) for egg component traits[+]

Hen genotype[+]	Egg weight (EW)	Albumen weight (AW)	Yolk weight (YW)	Shell weight (SW)
	Mean±SE	Mean±SE	Mean±SE	Mean±SE
Leghorn (L)	56.6±0.65	29.8±0.34	19.1±0.27	6.85±0.11
Saudi (S)	48.3±0.71	25.3±0.37	16.1±0.29	6.02±0.12
LS	47.2±0.71	25.0±0.37	14.9±0.29	6.37±0.12
SL	50.4±0.61	26.3±0.32	16.4±0.25	6.66±0.11
Significance	***	***	***	***

[+] Breed of cock is mentioned first as shown in Table 1.
*** = P<0.001.

Variance components and heritabilities

Components of direct additive genetic (σ^2_A) and error variance (σ^2_e) estimated by **DFREML** method using multi-trait animal model are presented in Table 3. Percentages of direct additive genetic variance (σ^2_A) or heritabilities for all egg traits were moderate. Wei and Van Der Werf (1993) using an animal model reported similar results for egg weight traits. The substantial estimates obtained in this experiment lead us to select birds of the subsequent generations of this experiment according to egg weight traits. However, heritabilities of the present study were nearly similar to those reported in the literature (e.g. Ahmad *et al.*, 1993; Danbaro *et al.*, 1995; Koerhuis and Mckay, 1996; Francesch *et al.*, 1997; Koerhuis *et al.*, 1997; Shebl, 1998; Hartmann *et al.*, 2000; Singh *et al.*, 2000b). The estimates published for egg component traits in chickens estimated by multi-trait animal model are few (e.g. Besbes *et al.*, 1992; Wei and Van Der Werf, 1993; Danbaro *et al.*, 1995; Koerhuis and Mckay, 1996; Koerhuis *et al.*, 1997; Hartmann *et al.*, 2000). In genetic analysis of pure- and strain-cross pullets of White Leghorn in India, Singh *et al.* (1996) indicated higher heritabilities in crosses than in pures for egg weight traits. They attributed such higher heritabilities in crosses to higher additive genetic variance along with lower environmental variation compared with the pures. For purebreds and crossbreds in Britain, Wei and Van Der Werf (1995) using multi-variate sire model (accounting for additive relationships between sires) reported that heritabilities for egg weight traits in purebreds ranged from 0.5 to 0.91, while the respective heritabilities for crossbreds ranged from 0.23 to 0.45. However, highly heritable egg traits would be exhibited less heterosis compared to lowly heritable traits.

Table 3. Components of additive genetic variance (σ^2_A) and error variance (σ^2_e) and heritabilities (h^2) estimated by multi-traits animal model for egg component traits

Trait	σ^2_A	σ^2_e	h^2
Egg weight	8.43	20.94	0.29
Albumen weight	2.30	6.85	0.25
Yolk weight	1.40	4.40	0.24
Shell weight	0.25	0.89	0.22

Genetic (r_G) and environmental (r_E) correlations

Estimates of genetic correlations among egg component traits showed that all of these associations were positive and similar in sign to the corresponding estimates of environmental correlation (Table 4). However, genetic correlations among all egg components were higher than their corresponding environmental correlations. This indicates that genes, which influence egg components, are more persistent in their effects than the environmental factors which they are more temporary in nature, i.e. genetic factors of all egg components were closely additively related. These high estimates of genetic correlations indicated that measure of one egg component could be used as good indicator of the genetic value for the other egg components.

Table 4. Genetic and environmental correlations estimated by multi-traits animal model for egg component traits

Traits correlated	Genetic correlation	Environnemental correlation
Egg weight & albumen weight	0.93	0.90
Egg weight & yolk weight	0.89	0.86
Yolk weight & shell weight	0.69	0.43
Albumen weight & yolk weight	0.78	0.62
Albumen weight & shell weight	0.59	0.21
Yolk weight & shell weight	0.53	0.23

All estimates of genetic correlations among egg components were high and ranged from 0.53 to 0.93 (Table 4). Egg weight was strongly correlated with albumen weight (0.93) and yolk weight (0.89). Albumen weight was also strongly genetically associated with yolk weight (0.78). But, all combinations including shell weight showed lower estimates of genetic correlations (0.53 to 0.69). This trend indicated that selection for better shell quality is likely to be associated with little gain in egg weight (albumen and yolk). However, estimates of genetic correlations obtained in the present study fall within the range of those reported in the recent literature (Hartmann *et al.*, 2000; Singh *et al.*, 2000b). Hartmann *et al.* (2000) reported that genetic correlations among egg weight, yolk weight and albumen weight were high and ranged from 0.52 to 0.74. Also, Singh *et al.* (2000b) found that egg weight was positively genetically correlated with shape index, egg mass and specific gravity.

In practice, the best criterion of selection for egg component traits in our developing countries seems to be egg weight, as it is economically important trait, heritable and highly correlated with the other traits of egg quality.

Direct (G^I) and maternal (G^M) additive effect

Results of G^I and G^M for egg traits are presented in Table 5. The linear contrasts of G^I for all traits ranged from 8.2 to 11.7% and in favour of the **L** breed. **L**-sired hens had higher values of direct additive effects than **S**-sired hens for all traits studied. The values of G^I for all egg traits (Table 5) are not only moderate but also important which were similar to the values reported by Francesch *et al.*. (1997) and Koerhuis *et al.*. (1997). The observed direct additive effects recorded for the **L** breed for all egg traits lead us to suggest that **L** chickens could be used as a terminal sire-breed in any crossbreeding program to improve egg weight traits of local chickens in Saudi Arabia.

Table 5. Estimates of direct (G^I) and maternal (G^M) breed additive effects for egg component traits

Trait	Direct additive		Maternal additive	
	Units ±SE	$G^I\%^+$	Units±SE	$G^M\%^{++}$
Egg weight	5.1±0.42***	9.8	3.18±0.29**	6.7
Albumen weight	3.2±0.24***	11.7	1.34±0.16**	5.3
Yolk weight	1.5±0.19***	8.8	1.52±0.13**	9.8
Shell weight	0.54±0.08***	8.2	0.29±0.06**	4.7

$^+G^I\%$= [G^I in units / (average of **L** + **L**-sired crosses)]x100

$^{++}G^M\%$= [G^M in units / (average of **S** + S-dammed crosses)]x100

** = P<0.01; *** = P < 0.001.

The contrasts of G^M were mainly in favour of the **L** breed (Table 5). The estimates also showed that additive breed maternity had a meaningful effect on the variations of egg components, i.e. daughters of **L** dams recorded better egg components than daughters of **S** dams. The favourable maternity recorded for the **L** breed may be attributable to better pre-ovipositional maternal effects in terms of oviductal factors such as egg size, egg weight, shell component and yolk composition.

The percentages of G^M for egg traits ranged from 4.7 to 9.8% and were mostly in favour of the **L** breed (Table 5). Accordingly, hens produced from the **SXL** mating had generally better egg components than those from **LXS** mating.

Direct heterosis (H^I)

Percentages of direct heterosis for most egg components (**EW**, **WW** and **YW**) were negative (Table 6). The negative percentages of H^I for egg components ranged from 7.0 to 1.2%. These negative estimates of H^I may reveal that crossing **L** with **S** was associated, unfortunately, with adverse heterotic effects on the performance of the crossbred hens in egg components. This observation was also reported in the other results obtained from crossing of local chickens with the exotic ones in most studies of the developing countries (e.g Abdel-Hammed, 1997; Singh *et al.*, 2000a). In Egypt, Zatter (1994) reported that estimates of heterosis for egg weight of the first 90-day of production for all crosses of Matrouh, Alexandria and Norfa ranged from -3.3% for

Alexandria X Norfa to 3.7% for Matrouh X Alexandria. Estimates reported by Abdel-Hammed (1997) for egg weight of the first 90-day of production obtained by crossing of Mandarah, Hi-Sex, Dokki-4 and Dandarawi ranged from 12.5% for cross of Hi-Sex sires mated to Dokki-4 dams to 14.9% for cross of Hi-Sex sires mated to Mandarah dams. Similarly, negative or small estimates of direct heterosis were reported by El-Safty (1999) for crossing of Mandarah (**M**) with Golden Montszah (**G**) where the estimates of heterosis for weights of egg, albumen, yolk and shell were 1.1, 1.97, 3.15 and 4.4 % for the cross of **MXG** and 0.66, 0.18, 3.94 and 4.5 % for the cross of **GXM**, respectively.

Table 6. Estimates of direct heterosis (H^I) calculated in actual units and percentages for egg component traits

Trait	Direct heterosis (H^I)	
	Units ±SE	H^I %+
Egg weight	-3.66±0.12**	-7.0
Albumen weight	-1.91±0.21**	-7.0
Yolk weight	-1.89±0.09*	-5.4
Shell weight	0.08±0.04NS	1.2

+ H^I % = (H^I in units / midparents) x 100

NS = Non-significant; * = P<0.05; ** = P < 0.01.

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التقيـــيم الوراثي باستخدام نموذج الحيوان متعدد الصفات لبعض صفات جودة البيض في تجربة لخلط الدجاج السعودي مع دجاج اللجهورن الأبيض

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أجريـــت تجربة لمدة عامين في منطقة القصيم بالمملكة العربية السعودية لخلط الدجاج الســعودي بدجاج اللجهورن الأبيض لتقييم صفات جودة البيض في الخلطان الناتجة٠ تم تجمــيع ١٩٨٩ بيضـــة كعيـــنة عشوائية من دجاجات تجربة الخلط لدراسة صفات وزن البيضـــة، وزن البـــياض، وزن الصفار، وزن القشرة. تم تقدير مكونات التباين والمكافئ الوراثي والارتباطات الوراثية والبيئية لهذه الصفات باستخدام طريقة DFREML لنموذج الحـــيوان مـــتعدد الصفات. أستخدم نموذج ديكرسون الوراثي تحت نموذج الحيوان متعدد الصـــفات Multi-trait animal model لـــتقدير مكونات الخلط المتمثلة في التأثير التجمعي المباشر، التأثير التجمعي الأمي، قوة الخلط المباشرة.

أظهـــرت دجاجات اللجهورن تفوقا في صفات جودة البيض مقارنة بالدجاج السعودي٠ وقـــد كانـــت قـــيم المكافئ الوراثي متوسطة وتراوحت بين ٠,٢٢ إلي ٠,٢٩. كانت قيم الأرتـــباطات الوراثـــية بيـــن صفات جودة البيضة عالية وتراوحت بين ٠,٥٣ إلي ٠,٩٣ تأثـــرت كـــل صـــفات البـــيض بدرجـــة ملحوظة بالتأثير التجمعي المباشر حيث أظهرت الدجاجـــات ذات الأب اللجهـــورن تأثـــيرا تجمعياً مباشراً أعلى من الدجاجات ذات الأب الســـعودي. كذلك تأثرت هذه الصفات بدرجة كبيرة بالتأثيرات التجمعية الأمية والتي كانت في صـالح سلالة اللجهورن. تراوحت نسب التأثيرات التجمعية المباشرة لصفات البيض بين ١٦,٨ إلى ٢٦,٩ % بينما تراوحت نسب التأثيرات التجمعية الأمية بين ٧,٤ إلى ٩,٨ %. سجلت الدجاجات الخليطة قيم سالبة لقوة الخلط لمعظم صفات جودة البيض حيث تراوحت قيم قوة الخلط بين -١٤,٠ إلى ٢,٥% .