Crossbreeding components in age at first egg and egg production for crossing Saudi chickens with White Leghorn

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Abstract

Two-generations of crossbreeding experiment involving Baladi Saudi (**S**) and White Leghorn (**L**) chickens were evaluated for age at first egg (**AFE**), first three-month egg production (**EP3**) and annual egg production (**AEP**). Six genetic groups of **LxL**, **SxS**, **LxS**, **SxL**, **LxSL** and **SxLS** were produced in this experiment (two pures, two F_1 crosses and two backcrosses). Variance components and heritabilities for these egg traits were estimated using **DFREML** procedure of multi-trait animal model. The genetic model of **Dickerson** was used to estimate the genetic components of this experiment in terms of direct (G^I) and maternal (G^M) additive effects, direct (H^I) and maternal (H^M) heterosis, and direct recombination loss (R^I). Backcross of **Lx¾L¼S** recorded higher egg production than other crossbred groups. Heritabilities for **AFE**, **EP3** and **AEP** were 0.55, 0.31 and 0.54, respectively. Direct additive effects (G^I) for **AFE**, **EP3** and **AEP** were considerable and in favour of the **L** breed. **L**-sired hens had high G^I compared to the **S**-sired hens for the traits. For maternal additive effects (G^M), a reversible trend was recorded in favour of **S** breed. Crossbred hens recorded positive estimate of H^I for **AEP** and negative estimate for **AFE**. The estimates of H^I were -2.7 % for **AFE** and 2.7% for **AEP**. Estimates of H^M in daughters of crossbred dams for **EP3** and **AEP** were positive, while the estimate for **AFE** was negative and favourable. The estimates of H^M were -16.4% for **AFE**, 19.1% for **EP3** and 12.3% for **AEP**. Estimates of R^I in crossbred hens for **AFE, EP3** and **AEP** were 1.6 days, -11.9 egg and -28.3 egg, respectively: R^I for age at first egg was limited, while the two estimates for egg production were high.

Keywords: *age at first egg, animal model, crossbreeding, egg production, heterosis, recombination effect, Saudi chickens, White Leghorn.*

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, direct and maternal heterosis, and direct recombination effects from crossbreeding experiments including Saudi chickens were expected to be important, especially for economic traits such as age at first egg and egg production. In hot climate countries, White Leghorn was found to exhibit an outstanding maternal ability (Al-Sobayel 1985; Thakur et al 1989; Sharma et al 1992; Ahmed et al 1993; Singh et al 2000b). To judge the genetic potential of different crosses including Saudi genes, it is necessary to characterize their ages at first egg along with their egg production. Therefore, this study was conducted to quantify direct and maternal additive effects, direct and maternal heterosis and direct recombination effects for age at first egg, first 90-day egg production and the annual egg production in a crossbreeding experiment involving local Saudi chickens and egg-type breed of White Leghorn.

Materials and methods

Three-year crossbreeding experiment of two generations 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. The experiment was started in January 1997.

Breeding plan

Hens used in this study represented two generations of crossbreeding of one local breed (Baladi Saudi, **S**) with world wide used (White Leghorn, **L**). Chicks of the parental stock were raised up to the age of five months in the rearing house. In the first generation of the crossbreeding experiment, half-sib hens of each of the two breeds were randomly divided into two breeding groups. The first group of half-sib hens of each of the two breeds was artificially mated with cocks from their own breed (pure line mating), while the second group was artificially mated with cocks from the other breed (cross line mating). The cocks were randomly assigned to mate the hens with a restriction to avoid the mating of birds with common grandparents, i.e. related birds are not mated. Accordingly, four genetic groups of **LxL**, **SxS**, **LxS** and **SxL** hens were obtained. Birds of the first generation were hatched on 1/1/1997 and started their egg production in May 1997. In the second generation, the same four genetic groups of hens of the first generation were produced in addition to the hens produced from mating of **LxSL** and **SxLS**. Birds of this second generation hatched on 14/11/1997 and began their season of egg production during April 1998. Throughout the two generations, each sire was mated with about four dams and each dam was represented randomly by one daughter to attain half-sib hens, i.e. paternal half-sib hens in different genetic groups were choosen randomly. The distribution of breeding sires and dams and number of hens used in the genetic groups are presented in Table 1. Eggs in both generations were collected when the birds were approximately 24 weeks of age and continued for 12 months, i.e. eggs collected represented the annual egg production of the hen.

Table 1. Number of sires and their paternal half-sib hens used in different genetic groups of the study

Genetic group[+]	First generation		Second generation	
	Sires	Hens[++]	Sires	Hens[++]
L x L	28	111	28	78
S x S	32	143	31	64
S x L	9	37	8	29
L x S	10	45	14	75
Sx(LxS)	-	-	31	60
Lx(SxL)	-	-	30	54
Total	79	336	142	360

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

[++] *Paternal half-sib hens.*

Management and feeding

All one-day old chicks were wing-banded and floor brooded and reared in semi-closed houses up to the age of 16 weeks (11 chicks per m^2). Temperature was controlled (17-32 °C) using separate electric heaters and air-conditioners, while the ventilation was controlled 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 treated and medicated similarly and regularly. They were subjected to the same management, hygienic and climatic conditions

At the age of 5 months, pullets were individually housed in three-tier batteries equipped with feeding hoppers and drinking nipples. The pedigreed eggs from each individual hen were collected and recorded daily.

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 (14% crude protein and 11.1 MJ Metabolizable energy per kg of feed) thereafter up to 18 weeks. During the laying period, all hens were fed ***ad-libitum*** using a ration containing 17% crude protein, 3.6% calcium and 11.9 MJ Metabolizable energy per kg of feed.

Data and multi-trait animal model of analysis

Data of age at first egg (**AFE**), first three-month of egg production (**EP3**) and annual egg production (**AEP**) were collected from 696 hens over the two generations. Data of egg components (egg weight, yolk weight, albumen weight, shell weight) for this experiment was published previously (Khalil et al 2002). Data were analysed using the following animal model:

Where:

$\mathbf{y_i}$ = vector of observations for the ith egg trait of hens;
b_i= vector of fixed effects (represented by genetic groups and generations) for the ith trait;
u_{ai}= vector of random effects of the hen for the ith trait;$\mathbf{X_i}$
Z_{ai} are incidence matrices relating records of the ith trait to fixed effects and additive genetic effect of the hen, respectively, and
$\mathbf{e_i}$= Vector of random residual effects for the ith trait.

Data was analyzed by running **MTDFREML** program of Boldman et al (1995). The inverse of the numerator relationship matrix $(\mathbf{A^{-1}})$ was considered; Var(a)= As^2_a and Var(e)= Is^2_e. Variance components obtained by multi-trait animal model were used to estimate heritabilities as:

Where s^2_A and s^2_e are variances for direct additive genetic and random error effects, respectively.

Genetic model and estimation of crossbreeding effects

The animal model was used to demonstrate the calculation of linear contrasts for the effect of genetic group for different traits under study. The Dickerson's genetic model (Dickerson 1992) was used to derive the following linear contrasts:

Individual (direct) additive effect of the hen $(\mathbf{G^I})$:
$G^I = G^I_L - G^I_S = LL - SS - SL - LS$

Maternal additive effect of the dam of hen $(\mathbf{G^M})$:
$\mathbf{G^M = G^M_L - G^M_S = SL - LS}$

Direct heterosis in the crossbred hen $(\mathbf{H^I})$:
$\mathbf{H^I = [SS + ¾L¼S] - [LL - ¾S¼L]}$

Maternal heterosis in the crossbred dam $(\mathbf{H^M})$:
$\mathbf{H^M = [¾L¼S + ¾S¼L] - ¼[LL + SS + SL + LS]}$

Direct recombination effect in the individual hen (R^I):

$R^I = ½ [LL + LS - SS - SL]$

Coefficients presented in Table 2 for the expected contribution of genetic effects (in **S** or **L** and their crosses) were computed according to Dickerson (1992). The standard errors were computed for all the genetic effects using the inverse matrix of the sub-class numbers and the error standard deviation.

Table 2. Coefficients of expected contribution for genetic effects in different groups of purebreds and crossbreds

Sire genotype	Dam genotype	Hen genotype⁺	Direct Additive		Maternal Additive		Direct heterosis, H^I	Maternal heterosis, H^M	Recombination effect (R^I)
			L	S	L	S			
L	L	L	1	0	1	0	0	0	0
S	S	S	0	1	0	1	0	0	0
S	L	½S½L	½	½	0	1	1	0	0
L	S	½L½S	½	½	1	0	1	0	0
S	½L½S	¾S¼L	¾	¼	½	½	½	1	¼
L	½S½L	¾L¼S	¼	¾	½	½	½	1	¼

L = Leghorn ; S = Saudi ; ⁺ *Sire-breed listed first*

Results and discussion

Genetic-groups comparison

Least-squares means for **AFE**, **EP3** and **AEP** in different genetic groups are presented in Table 3. The **LxL** genetic group showed a higher egg production and later age at first egg compared to the **SxS** mating. However, the estimates for Leghorn chickens are lower than those estimates reported in most studies of developed countries. These results were expected and reflect that **L** used in this study might be affected by hot climatic conditions in Saudi Arabia. Clear differences of 7.6 day, 13.7 egg and 38.6 egg for **AFE**, **EP3** and **AEP** ($P<0.001$) were in favour of **L** breed, respectively. Genetic group of **¾L¼S** surpassed other crossbreds in egg production. Abdel-Hamied (1993) in Egypt stated that crossbreds of Golden Montazah X New Hampshire were slightly exceed their parental purebreds in egg production during the first 3 or 6 months of laying.

Table 3. Purebred and crossbred means (±SE) for age at first egg (AFE), the first three-month egg production (EP3), and the annual egg production (AEP)

Hen genotype⁺	AFE, Day	EP3, Egg	AEP, Egg
L	175.2±7.6	66.4±1.3	215.9±4.4
S	167.6±9.1	52.7±1.2	177.3±5.1
½S½L	179.3±12.8	54.3±2.1	191.3±7.5
½L½S	168.5±12.7	64.5±1.7	209.4±7.1
¾S¼L	157.5±3.4	64.6±1.7	204.6±3.9
¾L¼S	159.6±3.4	65.8±1.7	216.5±4.1
Significance	***	***	***

L = Leghorn ; S = Saudi

⁺ *Leghorn mentioned first;* *** = *P<0.001.*

Heritabilities

Heritabilities estimated by multi-trait animal model for egg traits were moderate or high (Table 4). The estimate for **AFE** was 0.55, while the estimates for **EP3** and **AEP** were 0.31 and 0.54, respectively. These moderate or high estimates may be attributed to the existence of covariances among traits (Wei and Van Der Werf 1993). The substantial estimates obtained in this experiment lead us to select birds of the subsequent generations of the experiment according to **AFE** and **EP3**. These results indicate also that early selection of hens themselves may be effective for the improvement of performance of egg production under such crossbreeding experiment.

Table 4. Heritabilities (h^2) and the ratio of variance of non-genetic effects to phenotypic variance (e^2) estimated by animal model for age at first egg (AFE), the first three-month egg production (EP3), and the annual egg production (AEP)

Trait	h^2	e^2
AFE	0.55	0.45
EP3	0.31	0.69
AEP	0.54	0.46

Heritabilities of the present study were nearly similar to those reported in the literature although published heritabilities estimated by animal model for egg traits in chickens are few (e.g. Besbes et al 1992; Ahmed et al 1993; Wei and Van Der Werf 1993; Wezyk and Szwaczkowski 1993; Danabaro et al 1995; Koerhuis and Mckay 1996; Francesch et al 1997; Koerhuis et al 1997; Singh et al 2000b). In genetic analysis of purebred and crossbred pullets of White Leghorn in India, Singh et al (1996) indicated that heritabilities for egg number traits in crosses were higher than in purebreds (resulted from higher additive genetic variance). Accounting for additive relationship between sires, Wei and Van Der Werf (1993) in Britain using multi-variate sire model reported that heritabilities for egg number traits in crossbreds ranged from 0.40 to 0.51. However, highly heritable egg traits would exhibit less heterosis compared to lowly highly heritable traits.

Genetic and environmental correlations

Estimates of genetic correlations among the three traits showed that all of these associations were similar in sign and magnitude to the corresponding estimates of environmental correlations (Table 5). As expected, correlations among egg production during the first three-month and annual egg production were positive and high, i.e. part-whole relationship. Therefore, the first three month egg production could be used as indicator for early selection.

Table 5. Estimates of genetic and environmental correlations among traits

Traits correlated	Genetic correlations	Environmental correlations
AFE and EP3	-0.39	-0.31
AFE and AEP	-0.36	-0.32
EP3 and AEP	0.81	0.62

Age at first egg was negatively moderately genetically correlated with the first three-month egg production (-0.39) and the annual egg production (-0.36). This favourable trend indicated that selection for earlier age at first egg is likely to be associated with moderate gain in egg production. Negative estimates of genetic correlations between age at maturity and egg production were also reported by Thakur et al (1989) in India (-0.691) and by Koerhuis and Mckay (1996) in Netherlands (-0.76).

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

The linear contrasts of direct additive effects for egg production were in favour of the **L** breed (Table 6). **L**-sired hens had higher values of direct additive effects than **S**-sired hens for all traits. Francesch et al (1997) and Koerhuis et al (1997) reported that direct additive genetic effects were important for egg traits. The percentages of $\mathbf{G^I}$ {$\mathbf{G^I\%}$= [G^I in units/ (average of **L** + **L**-sired crosses)] x 100} for egg production were high. The estimates were 36.4 % for **EP3** and 26.5% for **AEP** (P<0.001). These considerable direct additive effects recorded for **L** breed for egg production traits lead us to suggest that **L** chickens could be used as a terminal sire-breed in any crossbreeding program to improve egg production of local chickens in Saudi Arabia.

Table 6. Estimates of direct (G^I) and maternal (G^M) additive effects for age at first egg (AFE), the first three-month egg production (EP3), and the annual egg production (AEP)

Trait⁺	Direct additive		Maternal additive	
	Units ±SE	G^I%	Units ±SE	G^M%
AFE	-3.2±1.	-1.9*	10.8±1.4	6.5***
EP3	23.9±1.6	36.4***	-10.1±1.3	-16.6***
AEP	56.7±3.8	26.5***	-18.1±3.2	-9.0***

G^I%= [G^I in units / (average of L + L-sired crosses)]x100
G^M%= [G^M in units / (average of S + S-maternal crosses)]x100
**** = P<0.001*

The estimates of $\mathbf{G^M}$ for **EP3** and **AEP** were in favour of the **S** dams (Table 6), i.e. hens produced from the **½L½S** dams had generally better egg production than those from **½S½L** dams. The percentages of $\mathbf{G^M}$ for egg production {$\mathbf{G^M\%}$= [G^M in units/ (average of **S** + S-maternal crosses)]x100} were moderate (Table 6). The percentages were -16.6% for **EP3** and -9.0% for **AEP**. The estimates obtained showed that additive breed maternity had a meaningful effect on the variations of egg production. These results indicate also that daughters of **S** dams showed higher egg production and longer **AFE** than daughters of **S** dams, i.e. additive maternity of **S** dams showed later **AFE** and higher egg production than additive maternity of **S** dams. Siewerdt and Dionello (1990) and Sharma et al (1992) observed an evidence for the significant maternal effects on egg production traits.

Direct (H^I) and maternal (H^M) heterosis

Negative estimate of $\mathbf{H^I}$ (-2.7%) for **AFE** (Table 7) suggests that crossing of **L** and **S** chickens gave a decrease in age of hen at first egg. Most of the estimates available in literature (e.g. Siewerdt and Dionello 1990; Singh et al 2000a) gave an evidence for such negative estimate of $\mathbf{H^I}$ for **AFE**. Zatter (1994) reported that estimates of heterosis for age at sexual maturity in Norfa X Matrouh and Matrouh X Alexandria crossbreds in Egypt were -5.8% and 6.54 %, respectively. For all possible crosses of Alexandria, Silver Montazah, Mandra and Gimmiza in Egypt, El-Hanoun (1995) found that the estimates of heterosis for **AFE** ranged from -4.9% for Silver Montazah X Gimmiza to 2.6% for Mandra X Silver Montazah. El-Safty (1999) found that estimates of heterosis for **AFE** were -1.19% for the cross of Mandarah X Golden Montazah and -1.82% for the cross of Golden Montazah X Mandarah.

Table 7. Estimates of direct (H^I) and maternal (H^M) heterosis calculated in actual units and percentages for age at first egg (AFE), the first three-month egg production (EP3), and the annual egg production (AEP)

Trait	Direct heterosis		Maternal heterosis	
	Units ±SE	H^I, %	Units ±SE	H^M, %
AFE	4.6±2.1	-2.7*	-28.2±2.1	-16.4***
EP3	-0.8±0.19	-1.3^{NS}	11.4±1.9	19.1***
AEP	-0.8±0.19	2.7^{NS}	24.1±4.8	12.3***

*NS = Non-significant; * = P < 0.05; *** = P<0.001*

Estimates of direct heterosis were -1.3% for **EP3** and 2.7% for **AEP** (Table 7). The positive estimate of $\mathbf{H^I}$ for **AEP** and the negative estimate for **AFE** suggest that crossing **L** with **S** in adverse environment was associated with a little increase in egg production along with a reduction in age at first egg. Fairfull et al (1987) with different crosses of White Leghorn found that estimates of heterosis for 497-day egg production ranged from 5.8 to 11.9%. Flock et al (1991) indicated that heterosis for egg production was considerably low which was interpreted as a consequence of pure line selection. In Egypt, Zatter (1994) with Matrouh, Alexandria and Norfa reported that estimates of heterosis for egg number laid during the first 90 days of production of F_1 crosses and their reciprocal lines ranged from 19.6% to 24.1%. For all possible crosses of Alexandria, Silver montazah, Mandra and Gimmiza, heterosis estimates reported by El-Hanoun (1995) for the first 90-day of egg production ranged from -4.6% for Silver Montazah X Mandra to 27.2% for Mandra X Alexandria. El-Safty (1999) found that estimates of heterosis for **EP3** were -3.76 % for the cross of Mandarah X Golden Montazah and -10.85 % for the cross of Golden Montazah X Mandarah.

The trends of estimates of $\mathbf{H^M}$ for **AFE** and **AEP** are in agreement with those estimates of direct heterosis (Table 7). Significant and negative estimate of $\mathbf{H^M}$ for **AFE** (-16.4%) shows that crossbred dams had earlier **AFE** than their crossbred daughters. However, negative estimate of $\mathbf{H^M}$ for **AFE** along with positive estimates of $\mathbf{H^M}$ for **EP3** (19.1%, P<0.001) and **AEP** (12.3%, P<0.001) would be favourable for the poultry producers in developing countries to use crossbred hens on commercial scale. This indicates also that crossbred dams showed earlier **AFE** together with higher egg production in their crossbred daughters than in their purebred dams.

Direct recombination effect (R^I)

The estimates of R^I for **AFE**, **EP3** and **AEP** were 1.6±0.85 day (P>0.05), -11.9±0.79 egg and 28.3±1.9 egg (P<0.001), respectively. Estimates of R^I for **EP3** and **AEP** were different to those estimates of direct heterosis, which implies that the dominance effects on these traits were of considerable importance. The parental epistasis may be responsible for the low residual heterosis in F_2. Negative R^I for **AFE** revealed that crossbred hens with **L** genes could mother hens with shorter **AFE** than purebred **L** hens when both groups of hens were mated to cocks from the same **L** purebred. In general, the two-locus model of heterosis reflects dominance and half additive-by-additive interaction effects, whereas the recombination effect included only half of the additive-by-additive interaction effects. In this respect, Szwaczkowski (1999) stated that those additive-by-additive epistatic effects on age at first egg, egg weight and egg production traits were important.

Conclusion

Since maternal heterosis for different traits were favourable, this will be an encouraging factor for the producer in Saudi Arabia to obtain crossbred hens characterized by high egg production rate. Therefore, there is advantage to use crossbred dams resulting from crossing Leghorn with Saudi chickens to develop parental strains to be used in crossbreeding stratification systems in hot climate regions particularly in Saudi Arabia.

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