South African Journal of Animal Science 2021, 51 (No. 3)

Genetic effects on growth and egg production traits in two-way crosses of Egyptian and commercial layer chickens

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(Received 1 February 2021; Accepted 16 March 2021; Published 19 May 2021)

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Abstract

A crossbreeding experiment was conducted between the Sinai (SI), an indigenous Egyptian strain, and the exotic Lohmann Brown (LB) breeds of chickens. A total of 790 chicks were produced in four genetic groups, namely SI x SI, LB x LB, SI x LB, and LB x SI. The objective was to estimate the direct additive effect (g^i), individual heterosis (h^i), and maternal additive effect (g^m) for growth and reproduction traits. Direct additive effects were positive (P ≤0.01) for bodyweight (BW) at 4, 8, and 12 weeks old in favour of SI. For egg production traits, g^i was positive for age at sexual maturity (ASM) and age at which the first 10 eggs were produced (P10), but negative for mean 10 egg production (MP10), egg number at 90 days (EN90),mean egg number at 90 days (MEN90), and egg mass (EM). The estimates of heterosis (%) were high for BW and daily gain except for BW0. Maternal effect estimates of BW and daily weight gain were significant (P <0.05) only for bodyweight at hatching (BW0), bodyweight at 4 weeks old (BW4) and daily weight gain from four to eight weeks old (DWG4-8). Thus, the Sinai and Lohmann Brown crossbreed produced favourable heterosis on the growth of the chicks. As an adapted indigenous strain, SI should be regarded as a dam line in crossing with LB, which has greater genetic potential for growth. Use of LB as a sire strain in conjunction with Sinai would increase egg production from the resulting hybrid chickens.

Keywords: crossing, direct effect, Egyptian Sinai, heterosis, Lohmann Brown, maternal effect
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Introduction

Crossbreeding is widely used in poultry breeding programmes because it increases the numbers of heterozygous loci and results in heterosis for traits such as growth and egg production (Amuzu-Aweh *et al.*, 2015). Positive heterosis or hybrid vigour is a phenomenon according to which crossbred offspring exhibit better performance than the average of the parental breeds because the interaction of alleles from the sire and dam results in effects of dominance and epistasis (Fairfull *et al.*,1985, 1987). But heterosis from epistatic effects is unlikely to be predictable owing to the numerous unknown interactions among loci (Iraqi *et al.*, 2005).

Indigenous chickens have desirable traits such as disease resistance, pleasantly flavoured meat and eggs, and the ability to withstand adverse environmental conditions (Ramadan *et al.*, 2011; Padhi, 2016). Crossing indigenous strains with exotic commercial ones could take advantage of high egg production in the exotic strain and the adaptation of the indigenous strain to the Egyptian environment. Crossbreds that result from the best performing parental breeds could lead to the production of birds that were superior in growth and egg production in a tropical environment. In addition, hybrid vigour could be used to develop new hybrid strains of chickens. Currently, efforts are being made in Egypt to improve the egg production of native chickens through crossbreeding (Saadey *et al.*, 2008; Iraqi *et al.*, 2012; El-Tahawy, 2020). The SI is a mongrel fowl that is raised in the Sinai peninsula desert and is adapted to the hot climate (Soltan *et al.*, 2018). It could be included in crossbreeding programmes to improve the performance of the local chicken population (El-Tahawy, 2020). Lohmann Brown is a composite breed of commercial chicken, developed in Germany, and noted for egg quality, production efficiency and adaptability.

Therefore, the objectives of this study were to evaluate indigenous SI chickens crossed with the LB strain and to estimate the genetic effects on egg production and growth traits.

URL: http://www.sasas.co.za
ISSN 0375-1589 (print), ISSN 2221-4062 (online)
Publisher: South African Society for Animal Science
http://dx.doi.org/10.4314/sajas.v51i3.8

Materials and Methods

All experimental procedures were approved by Animal and Poultry Production Scientific and Ethics Committee, Faculty of Agriculture, Damanhour University, Egypt. The handling and care of the animals were performed so as to maintaini their rights,ensure their welfare, and cause minimal stress, according to International Guidelines for research involving animals (Directive 2010/63/EU). The study was carried out at the Poultry research unit (EL-Bostan farm) Department of Animal and Poultry Production, Faculty of Agriculture, Damanhour University. Indigenous SI and LB strains were used and pullets of each strain were assigned to two groups. The first group mated with eight cocks from the same strain, whereas the second group was mated with cocks from the other strain. Eggs from the four mating groups were collected from each breeding pen and incubated at 37.6 °C with relative humidity of 55% during the first 18 days of incubation. Eggs were turned automatically every hour. Ventilation channels were opened and closed automatically according to temperature fluctuation. The ventilator was limited to 0.5 to 3.0 ventilation units until the 18th day of incubation and then to 1.5 to 4.0 units. Incubated eggs were transferred on day 18 to hatchers at 37.1 °C with relative humidity of 70%. Three hatchers were used to produce the birds for this study. At hatching, all chicks were wing banded according to genetic group and distributed to floor brooders at a starting temperature of 32 °C for the first week, which was then decreased by 3 °C each week. All birds were housed in the same room and had the same management and environmental conditions throughout the experiment. All birds were fed ad libitum with a commercial diet containing 21% crude protein and 2.9 Kcal metabolizable energy/kg up to 7 weeks old. Then they received a diet containing 18% crude protein and 2.8 kcal metabolizable energy /kg feed until 18 weeks old. At 18 weeks old pullets were moved to individual laying cages (20 x 45 x 40 cm). During egg production, hens received a diet containing 16% crude protein and 2.75 kcal metabolizable energy/kg feed, 3.5% calcium and 0.5% available phosphorus. Light intensity was provided for 16 hours per day during the laying period. The numbers of sires and dams and their purebred or crossbred progeny are shown in Table 1.

Table 1 Groups of Sinai and Lohmann Brown chicks, numbers of purebred and crossbred progeny, and numbers of sires and dams used in their production

Genetic group of chicks	N of chicks	Genetic group of sires	N of sires	Genetic group of dams	N of dams
Sinai (SI)	294	SI	8	SI	59
Lohmann Brown (LB)	156	LB	8	LB	49
SI x LB	139	SI	8	LB	43
LB x SI	201	LB	8	SI	52
Total	790		32		203

Bodyweight was recorded to the nearest 0.1 g at hatching (BW0), at four weeks old (BW4), eight weeks old (BW8) and 12 weeks old (BW12). Bodyweight gain was estimated from 4 to 8 weeks, 8 to 12 weeks and from 4 to 12 weeks. Age at the first egg laid or sexual maturity (ASM) was defined as the number of days from hatching to the first laid egg. For each hen, the duration of laying the first 10 eggs (P10) and their weight (EW10) were recorded, as were the number of eggs laid during the 90-day laying period (N90) and the average weight of the eggs produced through 90 days of laying (EW90). Egg mass (EM) was calculated for each hen.

The data were analysed with the GLM procedure of SAS (SAS Institute Inc., Cary, North Carolina, USA). Individual bodyweights and bodyweight gain were analysed with the linear model:

$$y_{ijk} = \mu + G_i + H_j + GH_{ij} + e_{ijk}$$

where: y_{ijk}= an observation on chicken ijk, μ = the overall mean, G_i= the fixed effect of the ith genetic group, H_j = the fixed effect of the jth hatch, GH_{ij}= the interaction of the ith genetic group with the jth hatch, and e_{ijk}= random residual error. Direct and maternal additive effects on growth and egg production traits were estimated using a set of linear contrasts of the genetic group means (Dickerson, 1993).

Direct additive effect: $g^i = 0.5x((SIxSI) + (SIxLB) - (LBxLB) - (LBxSI))$

$$\text{Maternal additive effect: } g^m = (SIxLB) - (LBxSI)$$

$$\text{Individual heterosis: } h^i = \frac{0.5(SIxLB + LBxSI)}{0.5(SI + LB)}$$

Results and Discussion

Means, standard deviations (SD), and coefficients of variation (CV) expressed as a percentage for the growth and egg production traits are summarized in Table 2.

Table 2 Descriptive statistics for bodyweight, bodyweight gain and egg production traits

Trait	Mean	SD	CV
Body weight (g)			
At hatching	36.1	2.7	7.4
4 weeks	232.8	57.3	24.6
8 weeks	581.7	112.8	19.4
12 weeks	918.5	188.3	20.5
Bodyweight gain (g/d)			
4 - 8 weeks	12.5	3.6	29.2
8 - 12 weeks	12.0	5.1	42.6
4 - 12 weeks	12.2	3.2	26.1
Egg production trait			
Age at first egg, days	149.7	11.9	8.0
Time to produce the first 10 eggs, days	15.1	3.9	25.9
Average weight of the first 10 eggs, g	46.1	6.0	13.1
Number of eggs produced in 90 days	50.2	14.9	29.7
Average weight of eggs produced in 90 days, g	51.6	7.9	15.3
Egg mass, g	2634.0	1066.2	40.5

Lohmann Brown birds were heavier at hatching (*P* <0.0001), but the more rapid growth of the SI chickens from 4 to 8, 8 to 12, and 4 to 12 weeks old produced the observed differences in BW at later ages (*P* <0.0001). Least square means of BW at various ages of the four genetic groups are shown in Table 3.

Table 3 Least squares means (± SE) for bodyweight and daily weight gain of indigenous Sinai, Lohmann Brown chickens and their reciprocal crosses

Trait	Genetic group				*P* -value
	Sinai (SI)	Lohmann Brown (LB)	LB x SI	SI x LB	
Number	294	156	201	139	<0.0001
Body weight, g					
At hatch	35.8 ± 0.2	36.7 ± 0.2	35.7 ± 0.2	36.6 ± 0.2	<0.0001
4 weeks	225.6 ± 2.7	203.3 ± 2.3	243.8 ± 3.7	265.2 ± 7.0	<0.0001
8 weeks	586.6 ± 6.4	505.1 ± 6.6	615.2 ±7.5	609.1 ± 10.2	<0.0001
12 weeks	925.6 ± 9.8	757.5 ± 7.7	983.8 ± 13.9	989.7 ± 15.9	<0.0001
Average daily gain, g/d					
Weeks 4 to 8	12.89 ± 0.20	10.78 ± 0.28	13.26 ± 0.24	12.28 ± 0.29	<0.0001
Weeks 8 to 12	12.10 ± 0.28	9.01 ± 0.39	13.16 ± 0.34	13.59 ± 0.41	<0.0001
Weeks 4 to 12	12.50 ± 0.17	9.89 ± 0.23	13.21 ± 0.21	12.93 ± 0.25	<0.0001

The LB chickens produced the first egg at a younger age, generated 10 eggs more quickly, produced more eggs in the 90-day laying period, and had heavier eggs than the SI chickens (Table 4). Previous studies likewise reported significant differences in the performance of SI and LB strains of chickens (Iraqi *et al.*, 2003; Lalev *et al.*, 2014 ; Soliman *et al.*, 2020; El-Tahawy, 2020).

Table 4 Least squares means (± SE) for egg production traits of indigenous Sinai, Lohmann Brown chickens and their reciprocal crosses

Trait	Genetic group				*P*-value
	Sinai (SI)	Lohmann Brown (LB)	LB x SI	SI x LB	
Number	294	156	201	139	<0.0001
ASM, days	154.56 ± 0.82	144.94 ± 0.91	148.21 ± 1.04	149.51 ± 1.13	<0.0001
P10, days	16.05 ± 0.27	13.89 ± 0.31	15.51 ± 0.35	14.83 ± 0.38	<0.0001
EW10, g	42.54 ± 0.37	50.41 ± 0.42	45.56 ± 0.48	46.86 ± 0.52	<0.0001
N90	41.56 ± 0.92	61.26 ± 1.02	49.72 ± 1.18	50.12 ± 1.28	<0.0001
EW90, g	47.06 ± 0.51	56.45 ± 0.55	53.44 ± 0.64	50.71 ± 0.70	<0.0001
EM, g	1960.90 ± 64.08	3494.86 ± 70.72	2562.77 ± 81.66	2653.6 ± 88.77	<0.0001

ASM: age at first egg, P10: time to produce the first 10 eggs, EW10: average weight of the first 10 eggs, N90: number of eggs produced in 90 days, EW90: average weight of eggs produced in 90 days, EM: egg mass, g

A pureline difference measures the difference in the sums of direct and maternal additive effects for SI and LB chickens. The pureline difference ranged from 0.21% to 20.69% for bodyweight and 9.46% to 33.35% for daily gain, respectively. The g^i effects was positive (P ≤0.001) for bodyweight at 4, 8 and 12 weeks old, indicating the greater genetic potential for growth of the SI chicken genotype compared with that of the LB. Other studies reported positive direct additive effects that ranged from 2.22% to 15.23% for growth and from 3.5% to 14.6% for daily gain (Khalil *et al.*, 1999; Iraqi *et al.*, 2013; Lalev *et al.*, 2014). In a study that crossed Fayoumi and Rhode Island Red chickens, Saleh *et al.* (2020) reported that the percentage of direct additive effect, relative to the pureline mean, ranged from 1.8% to 9.2% for bodyweight and from 4.2% to 17.3% for daily gain. Comparable estimates from this study indicate the relative magnitude of the direct additive effects on growth traits to average 9.9%. Estimates of the genetic effects on growth and egg production traits are shown in Table 5.

The g^i effects on ASM and P10 were positive, indicating the additive genetic potential for earlier sexual maturity and greater rate of egg production by the LB genotype. Direct additive effects on the measures of egg weight and rate of lay also favoured the LB genotype (Table 5). Therefore, LB sired chickens could be used as breeding stock to improve these traits.

Maternal additive effects were not different from zero for all traits except BW0, BW4, the rate of gain from hatching to four weeks and average egg weight over the 90-day laying period (Table 5). Chicks from LB dams had favourable growth early in life compared with those from SI dams, which was consistent with the results reported by Soliman *et al.* (2020). The hens had no direct contact with their chicks after hatching, which might reflect an in ovo difference between the strains. Also because the hens were separated from their eggs prior to hatching the lack of significant maternal genetic effects is not surprising. Iraqi (2008) and Razuki and Al-Shaheen (2011) also found a lack of maternal effects on egg production and egg weight.

Estimates of h^i were significantly positive for BW and daily gain except at hatching. The variability in the estimates of percentage of direct heterosis relative to the mean of the purelines supports the reports by Lamont and Deeb (2001) and El-Tahawy (2020) that the hybrid vigour for bodyweight depends on age. Several other reports demonstrated that bodyweights of crossbred chickens displayed positive hybrid vigour at different ages (Khalil *et al.*, 1999; Sabri *et al.*, 2000; Iraqi *et al.*, 2013). For daily gain, estimates of h^i varied from 0.94 g/d to 2.82 g/d.

Table 5 Genetic effects on bodyweight, daily weight gain and egg production traits in crossing Sinai and Lohmann Brown chickens

Trait	Pure line difference	Direct additive effect	Maternal additive effect	Heterosis	Heterosis %
Bodyweight, g					
At hatch	-0.98 ± 0.26***	0.08 ± 0.39 ns	-0.91 ± 0.29***	-0.10 ± 0.39 ns	-0.28
Week 4	22.32 ± 5.32***	21.85 ± 3.98***	-21.39 ± 5.92**	50.05 ± 3.98***	23.34
Week 8	81.44 ± 10.47***	37.70 ± 7.84***	6.10 ± .66 ns	66.30 ± 7.84***	12.15
Week 12	168.14 ± 26.35***	87.00 ± 12.50***	-5.99 ± 18.60 ns	145.2 ± 12.50***	17.25
Daily weight gain, g/d					
Weeks 4 to 8	2.11 ± 0.35***	0.57 ± 0.26*	0.98 ± 0.39**	0.94 ± 0.26***	7.94
Weeks 8 to 12	3.09 ± 0.48***	1.76 ± 0.36***	-0.43 ± 0.53 ns	2.82 ± 0.36***	26.72
Weeks 4 to 12	2.60 ± 0.29***	1.17 ± 0.22***	0.27 ± 0.33 ns	1.88 ± 0.22***	16.79
Egg production					
ASM, days	9.62 ± 1.22***	5.46 ± 0.98***	-1.29 ± 1.54 ns	-0.89 ±1.96 ns	-0.59
P10, days	2.16 ± 0.41***	0.74 ± 0.33 *	0.67 ± 0.52 ns	0.20 ± 0.66 ns	1.34
EW10, g	-7.86 ± 0.56***	-3.29 ± 0.46***	-1.29 ± 0.71 ns	-0.27 ± 0.91 ns	-0.58
N90	-19.69 ± 1.38***	-9.65 ± 1.11***	-0.39 ± 1.74 ns	-1.49 ± 2.23 ns	-2.90
EW90, g	-9.38 ± 0.75***	-6.06 ± 0.61***	2.73±0.95 **	0.32 ±1.21 ns	0.62
EM, g	-1534 .± 95.***	-722.± 77.***	-91 ±121 ns	-120 ±153.8 ns	-4.40

ns: *P* >0.05, *: *P* <0.05, **: *P* < 0.001, ***: *P* <0.0001
ASM: age at sexual mating, P10: the first 10 egg production, MP10: mean of egg production for 10 eggs, EN90: egg number at 90 day, MEN90: mean of egg numbers at 90 days; EM: egg mass

Positive heterosis for BW and DG owing to dominance and epistasis effects contributed to improved growth characteristics (Fairfull & Gowe, 1990). Therefore, exploiting heterosis in crossing Egyptian local chicken with foreign breeds could increase the growth of chickens being reared in Egypt. The present results agree with those obtained by crossing Fayoumi (local breed) and Rhode Island Red (foreign breed) to produce positive heterosis that ranged from 0.4% to 7.7% for bodyweight and 1.3% to 6.0% for daily gain (Saleh *et al.*, 2020). Lalev *et al.* (2014) found that heterosis estimates were positive and highly significant, with percentages from 3.76% to 22.33% for bodyweight when two lines of White Plymouth Rock chickens were crossed. Estimates of heterosis for egg production traits were not different from zero. Soliman *et al.* (2020) likewise did not observe significant heterosis effects for egg production traits.

Conclusion

The cross between SI and LB strains of chicken was associated with a favourable heterotic effects for producing fast growing and heavy chicks. As an adapted indigenous strain, SI should be considered as a dam line in crossing with LB, which has greater genetic potential for growth. Use of LB as a sire strain in conjunction with SI should increase egg production from the hybrid chickens.

Authors' Contributions

WSE designed the experiment and collected data. WSH (ORCID ID: 0000-0002-2009-5145) analysed the data and interpreted the results. WSE wrote the draft manuscript and both authors cooperated in revising and finalizing the manuscript.

Conflict of Interest Declaration

The authors have declared that there are no competing interests.

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