Estimation of heritability and genetic correlation for egg production in Iraqi local chickens under univariate animal model, multi-trait animal model, and random regression model

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Abstract
Several models have been used for genetic evaluation in breeding programs. A study was conducted to estimate the genetic parameters of monthly egg production of Iraqi indigenous brown chickens. Data were descended from 2234 females of six-generation selected for high egg production. Co-variance components were estimated based on the Average Information Restricted Maximum Likelihood (AI-REML) algorithm of Wombat software. Egg numbers were measured every four-week intervals Egg number was 10.07, 20.35, 21.16, 20.12, 19.36, 18.13, Heritability and standard errors under univariate animal model of monthly egg number were 0.39±0.05, 0.29±0.04, 0.18±0.04, 0.36±0.06, 0.22±0.05 and 0.17±0.04 for first, second, third, fourth, fifth and six months respectively. while it was 0.353±0.045, 0.265±0.043, 0.289±0.045, 0.450±0.052, 0.389±0.050 and 0.326±0.047 f for the multi-trait animal model and it was 0.703±0.039, 0.403±0.045, 0.336±0.041, 0.525±0.047, 0.475±0.046 and 0.297±0.044 for random regression model. Genetic correlations between monthly egg numbers ranging from low even negative to high positive estimations. Genetic correlations among monthly egg production ranging from -0.04±1.00 under pairs traits (bivariate animal model), ranging from 0.188 to 0.996 under multi-traits modal, and from -0.387 to 0.919 for random regression model. Based on the current estimation of genetic parameters, heritability for monthly egg production moderate to high and genetic correlation tend to be positive and high especially form third months and afterwards. The very high genetic correlation after the peak period suggests that the selection based on each monthly record from the third month onward is feasible and contributes to improving the egg production in Iraqi local chickens.

Key words: genetic parameters, monthly egg production, local chickens, single animal model, multi-trait animal model, random regression model

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Introduction

Egg production is a crucial single trait in layer breeding because it determines the egg output in a certain period of the hen's lifetime [35]. The trajectory of egg production in layers that select for high egg numbers takes a steady standard shape of the production curve. Compared with the commercial standard layer, the shape of the production curve in Iraqi brown local chickens has not followed the standard three essential stages of production over time. In this regard, some hens that reached sexual maturity at an early age may achieve steady production in one or two months and then decline with little or no egg production which caused higher variation among birds in all production stages (Personal observations). Selection for increasing egg production within local chickens may be a pivot tool to enhance egg production [21, 26, 33]. Many genes influenced and controlled egg production shape during the lifetime of the laying cycle. The gene expression varied with age [19, 36] which caused the variation in egg production at the beginning and the end of the production cycle, and therefore the values of heritability and correlations may vary during the production cycle [36]. The higher heritabilities in the first month of the production cycle were noticed [7, 10[

Several models have been used for estimating genetic parameters. The univariate animal model was used extensively in genetic evaluations due to using one record per animal in each run of the analysis on one hand and it needs the lower capacity of computational on the other hand. Wolc et al [36] concluded that the estimation of genetic parameters based on cumulative egg production as a single trait was not sufficient enough to explain this trait. The egg production can be repeatedly measured at different times of life and can be treated as repeated measurements by accounting for the egg production curve as a covariate function in mixed model analysis [24] Because egg production changed over time, Anang et al. [7] reported that the random regression model appeared favorable model in the analysis of egg production curve trajectory compared to the multi-trait model Heritability is a ratio of genetic variance to phenotypic variance and measure the relation between individual phenotype and its genetic makeup. The present work was initiated in 2014 to improve the egg output of Iraqi brown local chickens through the selection of birds with high egg numbers. Iraqi local chickens are valuable genetic resources and showed good adaptable to the Iraqi harsh climate and have favorable features [4, 1,, 16, 3, 2, 5]. Estimation of genetic parameters are effective tool to aid breeding plan. In selected populations, the mixed model methodology under REML has theoretical advantages for the estimation of genetic parameters [8] On the other hand, Selection based on part records (from onset of lay to 40 weeks of age) to improve annual egg production was achieved [29] because higher and positive genetic and phenotypic correlation between part and annual egg production. Therefore, the current work was conducted on the Iraqi local chicken populations under selection for egg production based on partial records to compare the estimation of genetic parameters for egg

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production via univariate, multi-trait animal, and random regression models based on restricted maximum likelihood algorithm in Wombat program.

Material and Methods

Study site

This was carried out in Poultry Research Station at the Office of Agricultural Research /Ministry of Agriculture was used. The poultry farm is located at Longitude 33˚, 312,313'E and Latitude 44˚, 202,868'N. The birds of the current population were sires and dams of six generation select individually for high egg production.

Chicken Population

The first generation was obtained from the base population reared randomly at the Poultry Research Station\ Office of Agricultural Research \ Ministry of Agriculture. Five families of 10 females and one male were established to compose the first generation. The hatching eggs were collected two weeks after mixing the males with the females and incubated separately for each family. After 21 days of incubation, offspring were obtained and raised in a separate pen to each family until the age of 17 weeks. At 17 weeks of age, they were transferred to the individual cages (40 x 60 x 40 cm) in order to identify the productive performance of each hen. From this generation onwards, artificial insemination was carried out to get hatching eggs. All hatching eggs were numbered and recorded with sire and dam number. All chicks hatched was wing-banded and reared in group based on their sir's and dam's.

Environment and feeding

Birds of this study were reared in floor semi-closed house equipped with brooding heaters, feeders, waterers, and a lighting system. The wood shaving was bedded on the house floor. The temperature and relative humidity were controlled as much as possible to achieve a proper environmental condition for each age in the house. Feed and water were offered freely. Five diets were introduced to chicks from hatch to the production phase. The starter diet (20% CP and 12.13 MJ/kg feed ME) from hatch to 4 weeks, the grower diet (17% CP and 11.51 MJ/kg feed ME) from 4 to 10 weeks, the developer diet (16% CP and 11.51 MJ/kg feed ME) from 10 to 16 weeks, pre-layer (16% CP and 11.51 MJ /kg feed ME) from 17 to 5% egg production and layer diets (17% CP and 11.72 MJ /kg feed ME) from 5% to the end of experiment were fed on mash or crumble form. The compositions of the diets have not appeared in the separate table because changes in ingredients have happened across generations. All birds provided with light regimen with dark and light program according to their age. Birds were vaccinated against Marek disease, ND, IBD, fowl pox, and AE.

Data and studied traits

Data used in this study represent six years of hatch (from 2016 to 2022). Parents of offspring were known for each bird, and six generations of pedigree were available for all birds with records. The overall number of animals in the pedigree file was 2482. The number of animals after pruning was 2449. The 215 animals without records were excluded from analysis Therefore, pedigree records of the remaining 2234 hens were

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tested (Table 1). Egg production (EP) were recorded individually on a daily basis (from starting lay to 43 weeks of age). and data were summarized on monthly interval for EP Hens without record for entire production cycle were excluded from analysis

Table 1. Pedigree information of data used in the genetic parameters estimation

Pedigree information file	N
Number of animals in pedigree file	2480
Number of animals after pruning	2450
Proportion % remaining	98.8
Number of levels without records	216
Number of levels with records	2234
Number of animals without offspring	1449
Number of animals with offspring	1000
Number of animals with record	785
Number of sires	152
Number of dams	849
Generations	6
Hatch	2
Season	4

Statistical analysis

Descriptive statistics on studied traits were analyzed by using SAS software [32]. Three-way analysis of variance without interaction through the generalized linear modeling (GLM) procedure of SAS was used to analyze the quantitative data. Generation, hatch, and season showed highly significant on studied traits and were included in the model as fixed effect. Genetic parameters were estimated based on univariate, multi-trait, and random regression models. The three model was as follows:

The single (univariate) animal model

The estimate variance components with the following model:

$Y = Xb+Za+e$

Where: Y = observation's vector of the trait; b = vector of fixed effects (generation, hatch and season); a, is the vectors of direct additive genetic effect and e = vector of random residual effect; X and, Z are incidence matrices relating records to the fixed and direct additive genetic effect.

The variance components for the random effects were denoted as var (a) = $A\sigma 2a$ and var (e) = $I\sigma 2e$

where A is a numerator relationship matrix. Bivariate animal model was used to estimates genetic and phenotypic correlation between studied traits with the matrix notation of:

)y1¦y2) =(x1¦0 0¦x2)(b1¦b2)+(z1¦0 0¦z2)(a1¦a2)+(e1¦e2(

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Where: y1 and y2 is a vector of observations; b1 and b2 is a fixed effect on traits; a1 and a2 is a random additive genetic effects on traits; e1 and e2 is a random residual error. X and Z is the incidence matrices related to fixed and random effect respectively.

Multi trait animal model

The estimation of genetic parameters via this model was analyzed using the following model:

$Y = (X \times I)\ b\ + (Z \times I)\ a + e$

Where:

Y= vector of observations on t traits; b= vector of fixed effects; a= vector of random additive genetic effects; e=vector of random errors. I is a identity matrix; X and Z is the incidence matrices related to fixed and random effect respectively.

Random regression model

Variance and covariance components were estimated for six different measures of egg production (from onset of lay to 44 weeks of age) of Iraqi local chickens by using the RRM.The fixed effects fitted were generation, hatch and season (twelve levels). All fixed effects were fitted as interactions with age. Homogenous residual variance for six intervals were used. The analysis of RRM based on the univariate RRM as:

Yijklm= Gi+ Hj+ Sk+ ∑_(q=0)^n▒βqZlmq +∑_(q=0)^n▒amqZlm q +∑_(q=0)^n▒pqZlmq +eijklm

In matrix notation the RRM for egg numbers can be written as

$y = Xb + Za + Qp + e$

is the record of hen k in period l with generation-hatch-season i :GHSi is the fixed effect of generation-hatch-season i; bm is the fixed regression coefficient for the m th order of the polynomial of the period; akm is the m th random regression coefficient for the additive genetic effect of animal k; pkm is m th random regression coefficient for the permanent environmental effect of animal k; zklm is the covariate coefficient of Legendre polynomials for period l of animal k; and eikl is the random residual variancet. Variables n1, n2, and n3 are the numbers of covariate coefficients, which are dependent on the order of Legendre polynomials for b, a, and p effects, respectively.

The goodness of fit for various random regression models fitted can be examined using likelihood based criteria and comparison of residual variance. selected model was chosen based on the following criteria:

Akaike’s information criterion (AIC(

AIC = -2Log L + 2p

Bayesian information criterion (BIC(

BIC = -2Log L +p log (N-r(x((

Where,

Log L= log likelihood value

p = The number of parameters estimated

N = The sample size

r(x) = The rank of the coefficient matrix for fixed effects in the model

Based on the lowest values of AIC and BIC the model was advocated. In the analysis of the random regression model, various orders of Legendre polynomials (LP) were fitted and only the fifth order of LP was presented in this

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article, so all estimation of genetic parameters related to RRM was implemented with this model. All estimations of variance component were carried out using the WOMBAT software package [23.[

Results and discussion

Descriptive statistics

Egg production (EP) and their standard deviation, coefficient of variation, and minimum and maximum value were presented in table 2. Egg number was 10.07, 20.46, 21.17, 20.12, 19.37, 18.13 egg\hen from moth 1 to 6 respectively. The standard deviation for monthly EP ranged from 4.79 to 8.15, whereas, it was 21.71 for the overall six months. A higher coefficient of variability (CV%) was shown in the first month which revealed the variations between hens in reaching sexual maturity. The phenotypic traits related to egg number of Iraqi local chickens are somewhat greater than local chickens in other worldwide area. In the current study, egg production increased steadily from the second month to the fifth month. The trend of egg production observed in the present study revealed a positive response to selection on a part-record basis. Selection for early period part-records (from the onset of lay to 40 weeks of age) is a crucial approach for improving egg production in egg-type chicken flocks to make a substantial genetic improvement [11] The range of egg production in some local chickens in Asia [14, 13, 31, 37] or in Africa [22, 21] showed lower part-record egg production than in the current population. In Iranian [17] and Thai [33] indigenous chickens, the egg number laid per hen from the onset of lay to 12 or 17 weeks of the production period was 35.10 or 55 to 59.31 eggs respectively. The production performance of the current population is close to the performance of different lines of white leghorn selected for egg numbers [15.[

Table 2. Descriptive statistics for egg production (number/hen) of Iraqi Indigenous chickens

TRAIT	*Records, n*	*Mean*	*SD*	*Minimum*	*Maximum*	*CV%*
EP1	2234	10.07	8.15	0	33[1]	81.01
EP2	2234	20.46	5.88	0	28	28.73
EP3	2234	21.17	4.79	0	28	22.61
EP4	2234	20.12	4.94	0	28	24.55
EP5	2234	19.37	5.08	0	28	26.25
EP6	2234	18.13	5.64	0	27	31.11

1: this value was higher due to include the age of sexual maturity. EP1-EP6 represent monthly egg production from one month to six months

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Variance component under different models

The genetic, residual, phenotypic, and permanent environment variances are presented in the table 2 and 3. In the univariate animal model (AM), the estimated additive genetic variance for EP ranged from 21.57 egg2 for EP1 to 5.57 egg2 for EP6. Meanwhile, the additive genetic variance under the multi-trait animal model (MTM), and the random regression model (RRM) for EP ranged from 18.01 egg2 for EP1 to 9.97 egg2 to EP6, and 49.32 egg2 for EP1 to 9.52 egg2 to EP6, respectively. The lowest genetic variance was noticed in the third month of EP for all three models. The residual variance for AM, MTM, and RRM ranged from 33.51 egg2 for EP1 to 26.48 egg2 for EP6, 32.99 egg2 for EP1 to 20.64 egg2 to EP6, and 7. 59 egg2 for EP1 to EP6 respectively. The phenotypic variance for AM, MTM, and RRM ranged from 55.09 egg2 for EP1 to 32.06 egg2 for EP6, 51.00 egg2 for EP1 to 30.61 egg2 to EP6, and 70.19 egg2 for EP1 to 32.08 egg2 for EP6 respectively. The permanent environment variance was estimated only in RRM and ranged from 13.28 egg2 for EP1 to 14.97 egg2 for EP6. In the current research, the additive genetic variance was higher in the first month of egg production in all three model and decease gradually. This may relate with variations between birds to reach the sexual maturity. The lowest genetic variance was showed in the third month of the production in all three model due to this month is a peak egg production month which refer to the uniformity oh hens in producing eggs. Wolc et al. [36] was also showed this trend in the genetic variance phenomena.

Table 3. Genetic, and residual variance of monthly of Iraqi local chickens selected on part record (19-43 weeks of age(

TRAIT	*Genetic variance $\sigma^2 a$*			*Residual variance $\sigma^2 e$*		
	AM	MTM	RRM	AM	MTM	RRM
EP1	21.58	18.01	49.32	33.51	32.99	7.59
EP2	9.19	8.77	14.19	22.87	24.32	7.59
EP3	4.01	6.93	8.48	18.81	17.02	7.59
EP4	8.82	11.60	15.16	16.03	14.19	7.59
EP5	5.49	10.38	13.47	19.72	16.34	7.59
EP6	5.57	9.97	9.52	26.48	20.64	7.59

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Table 4. Phenotypic, and permanent environment variance of monthly of Iraqi local chickens selected on part record (19-43 weeks of age(

TRAIT	*Phenotypic variance, $\sigma^2 p$*			*Permanent environment variance, $\sigma^2 pe$*		
	AM	MTM	RRM	AM	MTM	RRM
EP1	55.09	51.00	70.19	-	-	13.28
EP2	32.06	33.09	35.24	-	-	13.46
EP3	22.82	23.96	25.21	-	-	9.14
EP4	24.85	25.79	28.89	-	-	6.14
EP5	25.21	26.73	28.34	-	-	7.28
EP6	32.06	30.61	32.08	-	-	14.97

Heritability estimate

The heritability of egg production traits is shown in Table 4, Heritability and standard errors under the univariate animal model of monthly egg number were 0.39±0.05, 0.29±0.04, 0.18±0.04, 0.36±0.06, 0.22±0.05 and 0.17±0.04 for first, second, third, fourth, fifth and six months respectively. while it was 0.353±0.045, 0.265±0.043, 0.289±0.045, 0.450±0.052, 0.389±0.050 and 0.326±0.047 for the multi-trait animal model and it was 0.703±0.039, 0.403±0.045, 0.336±0.041, 0.525±0.047, 0.475±0.046 and 0.297±0.044 for random regression model. Estimated heritabilities of monthly egg number ranged from high, moderate, and low depending on the month of egg production. In the current study, high heritability in the first month was recorded in all three models. In RRM the h2 recorded in the first month exceeded the other models. Mota et al. [25] found that the heritability estimates using multi-trait models were lower than by using RRM for the evaluated ages. The higher estimation of h2 was recorded using MTM in Thai native chickens [9] The high estimates of h2 in the first month of production were also reported previously [28, 36, 18, 10, 12] In commercial egg-laying chickens [27] heritability ranged from 0.02-0.03 in the repeated model and 0.1 in the cumulative model. The higher and moderate heritability estimated for monthly EP from the second month to the sixth using AM, MT, and RRM in the current study compared to other previous studies [7, 28, 27] may due to the current population of local chickens are not long-term selection for EP. Anang et al. [7] found that the h2 may reach 0.50 in non-selected chicken lines. However, changes in heritability over time may result from the activation of different genes during the production cycle as reported by Anang et al. [6, 34, 10

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Table 5. Heritability (h2) and standard error (se) under univariate animal model, multi-trait animal model, and random regression model of Iraqi local chickens selected on part record (19-43 weeks of age(

TRAIT	*AM*		*MTM*		*RRM*	
	h^2	±se	h^2	±se	h^2	±se
EP1	0.39	0.05	0.35	0.05	0.70	0.04
EP2	0.29	0.04	0.27	0.04	0.40	0.05
EP3	0.18	0.04	0.30	0.05	0.33	0.04
EP4	0.36	0.06	0.45	0.05	0.53	0.05
EP5	0.22	0.05	0.39	0.05	0.48	0.05
EP6	0.17	0.04	0.33	0.05	0.30	0.04

Genetic correlations

Genetic correlations among egg production traits under various models are presented in Table 6. Monthly egg production showed varied genetic correlations in the three models studied. In the bivariate and multi-trait animal model, the first month showed moderate to high genetic correlation with the second and the third months but low and negative with the fourth to the sixth month. Generally, genetic correlations among egg production traits ranged from -0.04 (EP1 with EP5) to 1.00 (EP5 with EP6) in the bivariate animal model. Meanwhile, in the multi-trait animal model, the correlation ranged from 0.04 (EP1 with EP5) to 1.00 (EP5 with EP6), and in the random regression model)RRM), the ranged from -0.39 (EP1 with EP5) to 0.92 (EP4 with EP5). The results showed that the genetic correlation in all three models was weak and negative in some months between the first month and fourth month to the sixth month. Whereas, in the rest month the high and positive genetic correlations were recorded. This trend was also investigated by Anang et al [7, 28, 30, 20, 12, 10] irrespective of model used. We showed the genetic correlation estimates via RRM achieved negative correlation between month one and other months. But in other models (AM, and MTM) it shows low and positive between first month and other month measured. These results are consistent with direction found by

Nurgiartiningsih et al [27]. The weak relation between month one and the rest month revealed that the performance are not influence by the same genes and the selection birds at the first month of production are not valid. On the other hand, the negative relation between the first month and other months estimates using RRM suggest that the first month modelling as a separate trait [30.[

Table 6. Genetic correlations and its standard error (se) between egg production traits of Iraqi brown local chickens under bivariate animal model (AM), multi-trait animal model (MTM), and random regression model (RRM(

Correlations	AM	MTM	RRM
EP1 and EP2	0.67 (0.07)	0.71 (0.069)	0.45 (0.061)
EP1 and EP3	0.25 (0.12)	0.25 (0.104)	-0.19 (0.082)
EP1 and EP4	0.45 (0.061)	0.10 (0.101)	-0.31 (0.072)
EP1 and EP5	-0.04 (0.13)	0.04 (0.104)	-0.39 (0.086)
EP1 and EP6	0.03(0.13)	0.08 (0.108)	0.35 (0.080)
EP2 and EP3	0.53(0.12)	0.41 (0.103)	-0.04 (0.088)
EP2 and EP4	0.24(0.12)	0.22 (0.109)	-0.04 (0.088)
EP2 and EP5	0.34(0.14)	0.19 (0.113)	0.18 (0.086)
EP2 and EP6	0.10(0.14)	0.22 (0.116)	-0.13 (0.105)
EP3 and EP4	0.95(0.04)	0.95 (0.030)	0.90 (0.022)
EP3 and EP5	0.88(0.06)	0.91 (0.044)	0.89 (0.037)
EP3 and EP6	0.95(0.07)	0.93 (0.051)	0.77 (0.058)
EP4 and EP5	0.97(0.02)	0.97 (0.022)	0.92 (0.019)
EP4 and EP6	0.96(0.03)	0.96 (0.031)	0.91 (0.036)
EP5 and EP6	1.00(0.03)	1.00 (0.023)	0.87 (0.034)

:1EP1- EP6 represent the monthly egg production from month one to month sixth.

Conclusion

The results drawn from this study indicated that the heritability estimates through different models ranged from moderate to high. The RRM exhibited higher values of heritability compared to others models , especially for the first month of the production which reflected the effect of variations in hen ages at sexual maturity and the rate of lay before peak. The genetic correlation among all months of the production varied from low even negative and high and positive. The very high genetic correlation after the peak period suggests that

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the selection based on each monthly record from the third month onward is feasible and contributes to improving the egg production in Iraqi local chickens.

Conflict of interest

The authors declare that no conflict of interest

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