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Genetic Analyses of Egg Quality in Khorasan Razavi Native Fowl Using the Bayesian Method

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Abstract
This study was conducted to estimate the genetic parameters influencing egg quality in Khorasan Razavi native fowl. (Co)Variance components were estimated by the Bayesian statistical method *via* Gibbs sampling in GIBBS3F90 software. 1000 eggs (28-29 weeks old) were collected from 775 hens of the ninth generation of Khorasan-Razavi Province native fowl breeding center. External (egg weight, specific gravity, long length, short length, shape index, shell strength, shell weight, shell thickness) and internal (yolk diameter, yolk height, yolk weight, yolk index, albumen diameter, albumen height, albumen weight, albumen index, Haugh unit) egg quality traits were measured. Six univariate animal models were used for estimation of genetic parameters and the best model for each trait was determined by deviance information criterion (DIC). Genetic and phenotypic correlations between traits were estimated using bivariate animal model. Direct heritability estimates ranged from 0.10 (egg width) to 0.39 (yolk index). For all traits except albumen diameter and albumen index, the inclusion of maternal effects in the model resulted in considerable reduction in direct heritability. Genetic correlations of egg weight with shell strength and shell thickness were negative. In conclusion, due to genetic correlations among external and internal egg quality traits, selection based on egg weight and shell thickness may improve external and internal egg quality traits. Also, including maternal effects in the form of genetic or permanent environment in the statistical model resulted in more accurate estimates for most traits.

Introduction

Native fowl are valuable genetic resources due to their adaptability to harsh conditions in rural areas. The genetic characterization of indigenous breeds can serve protective purposes and benefit breeding and development of breeding programs. Lack of information on genetic variances and genetic parameters limits genetic improvement, because these kinds of knowledge are crucial for accurate estimation of breeding values, optimum combination of traits in a selection program, optimization of breeding schemes, and enhanced prediction of response to selection (Prado-González *et al.*, 2003; Adeogun and Adeoye., 2004; Norris *et al.*, 2004).

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Indigenous chickens have great potential for genetic improvement and it is vitally important to consider maternal effects in genetic evaluation of native breeds (Liu *et al*., 2011). Maternal effects are defined as any influence of a dam on the phenotype of her offspring in addition to her directly transmitted genes (Willham, 1980). Maternal effects in birds are different from mammals because any maternal effects on chicks, incubated artificially, must be the residual effect of dam reflected in egg features at laying (Siegel and Dunnington, 1997).

Considering maternal effects in analyses reduces the amount of bias in the estimation of genetic variance (Meyer, 1997). If maternal genetic effects exist but are not considered in the model, heritability can be over-estimated (Clément *et al*., 2001; Praharani, 2009). Many studies have been carried out to determine maternal effects in domestic mammals (Willham, 1980; Mohiuddin, 1993; Robinson, 1996), but little is known about the role of maternal effects in poultry.

Egg quality is one of the most important traits of laying hens as it influences hatching, reproductive performance, and human consumption. Accurate determination of genetic parameters and breeding values are required in obtaining genetic gains by selection. Therefore, profitability of commercial and local flocks of hens depends on the quality of eggs. The higher the egg quality, the higher its marketability (Zhang *et al*., 2005). Hence, this study was designed to estimate genetic parameters for egg quality traits and to determine the influence of maternal additive genetic and permanent environmental effects in Khorasan Razavi native fowl.

Materials and Methods

Birds and data

The records for egg quality traits were collected from native fowl of Khorasan Razavi breeding center located in northeast Iran. Similar to other native fowl breeding centers in the country, the base population was generated from 200 native fowl (100 male and 100 female chicks). The first generation was produced by random mating of the base population. From the first generation, numerous measurements were made (body weight at 12 weeks of age (BW 12), age (ASM) and weight (WSM) at sexual maturity, number of eggs during the first 12 weeks of laying period (EN), and average egg weight at 28th, 30th and 32nd weeks (EW)).

Birds were selected as the parents of the next generation in two steps. In the first step, females and males were selected based on their BW12. After 20 weeks of age, hens were transferred into individual cages and their egg production was recorded for 12 weeks. In the second step, hens were selected based on ASM, WSM, EN, and EW, and cocks were selected based on the performance of their sisters. Average selection proportion of about 40% for hens and 5% for cocks were applied in each generation, where after 800 hens and 100 cocks were selected to produce next generations. 1000 eggs were collected from 775 hens of the ninth generation of Khorasan-Razavi Province native fowl breeding center at the age of 28 to 29 weeks and transferred to the laboratory to measure external (egg weight, specific gravity, long length, short length, shape index, shell strength, shell weight, shell thickness) and internal (yolk diameter, yolk height, yolk weight, yolk index, albumen diameter, albumen height, albumen weight, albumen index, Haugh unit) egg quality traits. Eggs with soft-shell, double-yolk, and/or were cracked were removed from data collection. An electronic scale with an accuracy of 0.01 g was used to weigh the eggs (EW). The short and long lengths of each egg (SL and LL, respectively) were measured using Egg Form Coefficient Measuring Gauge. Eggs were broken using an Egg Shell Strength Tester to measure shell strength (SS). The height of yolk and albumen (YH and AH, respectively) were measured using a tripod micrometer (calibrated in mm) and a dial caliper to the nearest 0.01 mm was used to measure albumen and yolk diameters (AD and YD, respectively). Subsequently, yolk and albumen were carefully separated and yolk weight (YW) and albumen weight (AW) were measured. Shell weight (SW) was measured 72 hrs after exposure to dry air. Shell thickness (ST) was measured with a Shell Thickness Meter (calibrated in mm) at the pointed end, equator, and blunt end of shell, and the average value was used. Shape index (SI), specific gravity (SG), Haugh unit (HU), yolk index (YI), and albumen index (AI) were calculated using the following formulas:

SI = (SL / LL) X 100 (Haunshi *et al*., 2010)

SG = [EW / (EW - EW_1)] (Hempe *et al*., 1988)

(EW_1 = Egg weight in water)

$HU = 100 \log (AH + 7.57 - (1.7 \times (EW)^{0.37})$ (Haugh, 1937)

$YI = (YH / YD) \times 100$

$AI = (AH / AD) \times 100$

Statistical analysis

The UNIVARIATE and GLM procedures of SAS software (SAS Institute, 2001) were used to obtain the descriptive statistics and to determine the significance of hatch (fixed effect). Egg quality traits were measured over three days. To take this effect into account, day of measurement was considered as a covariate in the models. Genetic parameters were estimated by univariate and bivariate animal models using the Bayesian method. The analyses were done using GIBBS3F90 software (Misztal, 1999). In each analysis, 500 000 rounds of Gibbs sampling were conducted. The first 50 000 steps were discarded as a burn-in period, and the thinning interval was constant at 100 cycles. Flat distribution and scaled inverted χ2 were used as prior for fixed effect and variance components, respectively. Uniform priors were used for all parameters.

Six animal models were used to estimate (co)variance components and genetic parameters of egg quality traits, as following (Meyer, 1997):

$\mathbf{y = Xb + Z_1a + e}$ Model 1

$\mathbf{y = Xb + Z_1a + Wc + e}$ Model 2

$\mathbf{y = Xb + Z_1a + Z_2m + e}$ $\quad cov_{(a,m)} = 0$ Model 3

$\mathbf{y = Xb + Z_1a + Z_2m + e}$ $\quad cov_{(a,m)} \neq 0$ Model 4

$\mathbf{y = Xb + Z_1a + Z_2m + Wc + e}$ $\quad cov_{(a,m)} = 0$ Model 5

$\mathbf{y = Xb + Z_1a + Z_2m + Wc + e}$ $\quad cov_{(a,m)} \neq 0$ Model 6

Model 1 was a simple animal model consisting of direct genetic effect (a) as the only random effect. Model 2 consisted of the maternal permanent environment effect (c) as a second random effect. Model 3 consisted of maternal genetic effect (m) as a second random effect having no covariance with direct genetic effect (σ_{am}= 0). In model 4, the covariance between these random genetic effects was set as not to be zero. In models 5 and 6, both permanent environment and maternal genetic effects were included beside direct genetic effect. Covariance between direct and maternal genetic effects was set as to be zero in model 5 and not to be zero in model 6. In these models, **y** = vector of observations, **b** = vector of fixed effect (hatching effect with three levels), **a** = vector of direct genetic effects, **m**= vector of maternal genetic effects, **e** = vector of residual effects, **X** = incidence matrix relating observations to fixed effect and $\mathbf{Z_1}$, $\mathbf{Z_2}$ and **W** were incidence matrices relating observation to the direct, maternal genetic and permanent environment effects, respectively. The (co)variance structure of the full model (model 6) was as following:

$$V \begin{bmatrix} \mathbf{A} \\ \mathbf{m} \\ \mathbf{c} \\ \mathbf{e} \end{bmatrix} = \begin{pmatrix} \mathbf{A\sigma^2_a} & \mathbf{A\sigma^2_{am}} & \mathbf{0} & \mathbf{0} \\ \mathbf{A\sigma^2_{am}} & \mathbf{A\sigma^2_m} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{I\sigma^2_c} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{I\sigma^2_e} \end{pmatrix}$$

where $\boldsymbol{\sigma^2_a}$ = direct genetic variance, $\boldsymbol{\sigma^2_m}$ = the maternal genetic variance, $\boldsymbol{\sigma^2_{am}}$ = covariance between direct and maternal genetic effects, $\boldsymbol{\sigma^2_c}$ =maternal permanent environment variance and $\boldsymbol{\sigma^2_e}$ = residual variance. The means of model components were:

$$\mathbf{E [y] = Xb;\ E [a] = 0;\ E [c] = 0 \text{ and } E [e] = 0}$$

Total phenotypic variance (σ^2_P) was estimated by cumulating all variance components. Direct heritability (h^2), maternal genetic heritability (h^2_m), and proportion of maternal permanent environmental variance to phenotypic variance (c^2) were also calculated. Models were compared using Deviance Information Criterion (DIC) to find the best model for each trait. This selection criterion combines Bayesian measures of model complexity and fit. DIC was calculated as:

$DIC = D(\theta) + pD$

In this equation, D (θ) is a measure of fit of the model:

$D(\theta) = E\theta | y\{-2 \log p(y | \theta)\}$

where y denotes data and θ are parameters within the parametric density $p(\cdot | \theta)$.

pD is also a measure of the effective number of parameters in a model:

$pD = E\theta | y\{-2 \log p(y | \theta)\} + 2 \log p(y \bar{|} \theta)$

Models with the smallest DIC were considered as the best model (Misztal, 1999). Genetic correlations between studied traits were estimated using model 1.

Results and Discussion

Descriptive statistics of egg quality traits

Descriptive statistics and the significance of fixed effect for egg quality traits are presented in Table 1. The effect of hatch was significant for most traits. The average weights of egg, yolk, and albumen in this study were lower than commercial layers (49.66 *vs.* 53.85 - 57.78 g, 14.07 *vs.* 14.35 - 16.17 g, and 28.11 *vs.* 32.02 - 35.94 g, respectively) which have been reported by others (Zhang *et al.*, 2005; Olawumi and Ogunlade, 2008; Rath *et al.,* 2015). The mean value of albumen height and yolk height in this local breed were also lower than commercial layers (6.41 *vs.* 8.6 - 8.41 mm, and 17.53 *vs.* 17.7 - 18.22 mm, respectively) which have similarly been reported by Olawumi and Ogunlade (2008) and Rath *et al.* (2015). Rath *et al.* (2015) reported the mean values of yolk diameter (44.72 mm), yolk index (40.24), albumen diameter (76.91 mm), and albumen index (9.98) in white Leghorn. Except for yolk index, other traits were higher than those found in this study.

Iranian native fowl are meat-cum-egg breeds and consequently their albumen and yolk weights are lower than that of commercial layers because of little attention for egg quality improvement. The mean value of Haugh unit (82.59) was lower than that reported by Zhang *et al.* (2005) (86.20), but it was higher than that reported by Salehinasab *et al.* (2014) (71.87). According to Ihekoronye and Ngoddy (1985), eggs with high quality generally have Haugh unit of 70 and above. The mean value for specific gravity in present study was 1.089. Specific gravity is an important parameter of shell quality as it indicates the amount of shell relative to other egg components. Hunton (2005) demonstrated that shell is more likely to fracture if its average specific gravity in a hen house is lower than 1.080.

Table 1. Descriptive statistics, test of significance for hatch effect, and indicators of normal distribution for egg quality traits in native chickens

	Mean	SD	CV (%)	Hatch	Skewness	Kurtosis
External traits						
Egg weight (g)	49.66	3.8	7.65	***	0.02	0.35
Specific gravity	1.089	0.806	0.74	NS	0.16	-0.20
Long length (mm)	53.46	2.18	4.07	NS	0.02	-1.16
Short length (mm)	40.95	1.52	3.71	NS	0.11	-0.57
Shape index (%)	76.92	3.05	3.96	NS	0.42	-0.21
Shell strength (kg/cm^2)	4.24	0.7	16.5	NS	-0.03	-0.50
Shell weight (g)	5.19	0.45	8.67	*	-0.13	-0.59
Shell thickness (mm)	0.43	0.027	4.65	*	-0.01	-0.30
Internal traits						
Yolk diameter (mm)	38.78	1.97	5.07	NS	-0.02	-0.60
Yolk height (mm)	17.53	0.91	5.19	*	0.02	-0.69
Yolk weight (g)	14.07	1.04	7.39	***	-0.03	-0.48
Yolk index (%)	45.99	4.16	9.04	***	0.29	-0.19
Albumen diameter (mm)	73.39	6.27	8.42	**	0.08	-0.08
Albumen height (mm)	6.41	1.18	18.4	*	0.18	-0.47
Albumen weight (g)	28.11	2.88	10.24	*	0.14	-0.58
Albumen index (%)	8.66	1.94	22.4	***	0.33	-0.19
Haugh unit	82.59	7.58	9.17	**	-0.23	-0.34

SD = Standard Deviation; CV = Coefficient of Variation.

***: $P \leq 0.001$; **: $P \leq 0.01$; *: $P \leq 0.05$, NS: Not significant.

The mean value of shape index (76.92) was similar to that reported by Haunshi *et al.* (2010) for two native Indian breeds (77.36 and 76.39). In contrast to internal egg quality traits, we found that shell thickness of our native fowl was higher than commercial layers (0.43 *vs.* 0.27-0.34 mm) which has been reported by other researchers (Zhang *et al.*, 2005; Olawumi and Ogunlade, 2008; Rath *et al.,* 2015). The mean value for shell strength, shell weight, and shell thickness were also higher than those reported by Salehinasab *et al.* (2014) as well as Emamgholi Begli *et al.* (2010) in two other Iranian native fowl (4.24 *vs.* 3.44 and 3.71 kg/cm^2, 5.19 *vs.* 5 and 4.45 g, 0.43 *vs.* 0.38 and 0.41 mm, respectively). Shell thickness and strength are major indices of egg shell quality. Egg shell must be sufficiently strong and thick to protect the embryo against environmental conditions and physical damage including handling, packaging, and transportation (Narushin *et al*., 2004). A negative correlation between egg production and shell thickness has been reported by Kermanshahi and Zardast (2011). Therefore, the thick egg shell of Khorasan Razavi native fowl may be due to their low egg production compared to commercial chicken.

Heritably estimates

The best model for each trait, the direct and maternal heritability estimates, and the proportion of maternal permanent environment to phenotypic variance are shown in Table 2. For the majority of traits, estimates of direct heritability were influenced by the statistical model. Heritability values were overestimated when the simple animal model (Model 1) was used. Including maternal effects (genetic and environmental) in the models caused a significant reduction in direct heritability, especially for albumen height. In contrast to other traits, model 1 was the best model for albumen diameter and albumen index. The heritability estimates for egg weight and shell thickness in present study were lower than those reported by Emamgholi Begli *et al*. (2010) in Yazd native fowl (0.28 *vs.* 0.45, and 0.18 *vs.* 0.57, respectively). Heritability for shell strength was similar to the value reported by Zhang *et al.* (2005). The heritability of specific gravity in broiler breeders reported by Wolc *et al.* (2010) was much higher than our estimate in Khorasan Razavi native fowl (0.53 *vs.* 0.24, respectively). Heritability estimates for long length and short length in the present study were lower than those reported by Alipanah *et al.* (2013) in Khazak layers (0.16 *vs.* 0.36, and 0.12 *vs.* 0.49, respectively).

Table 2. Heritability obtained from model 1, the best model, direct and maternal genetic heritability estimates, and proportion of maternal permanent environment to phenotypic variance (c^2 ± standard error) for egg quality traits in native chickens

Trait	$h^2_{direct\ (model\ 1)}$	Best model	$h^2_{suitable\ model}$	$h^2_{maternal}$	C^2
Egg weight	0.35± 0.09	2	0.28±0.07	-----	0.05±0.02
Specific gravity	0.29±0.05	2	0.24±0.04	-----	0.03±0.01
Long length	0.19± 0.07	2	0.16±0.03	-----	0.05±0.09
Short length	0.10± 0.06	6	0.12±0.06	0.1±0.05	0.02±0.02
Shape index	0.16±0.05	2	0.11±0.001	-----	0.03±0.006
Shell strength	0.17±0.04	5	0.12±0.04	0.04±0.01	0.02±0.01
Shell weight	0.25±0.08	6	0.28±0.07	0.13±0.05	0.02±0.03
Shell thickness	0.26±0.05	6	0.18±0.05	0.05±0.03	0.01±0.01
Yolk diameter	0.11±0.07	2	0.11±0.005	-----	0.02±0.04
Yolk height	0.14±0.05	6	0.13±0.06	0.1±0.05	0.02±0.02
Yolk weight	0.20±0.05	5	0.15±0.05	0.05±0.02	0.02±0.02
Yolk index	0.39±0.08	6	0.27±0.07	0. 3±0.05	0.1±0.02
Albumen diameter	0.22±0.05	1	0.22±0.05	-----	-----
Albumen height	0.16±0.05	6	0.08±0.05	0.13±0.04	0.04±0.01
Albumen weight	0.23±0.08	3	0.18±0.07	0.07±0.04	-----
Albumen index	0.14±0.06	1	0.14±0.06	-----	-----
Haugh unit	0.11±0.05	2	0.10±0.02	-----	0.03±0.01

Model 1 = model with direct genetic effects, model 2 = model with direct genetic and maternal permanent environmental effects, model 3 = model with direct genetic and maternal genetic effects, model 5 = model with direct genetic and maternal genetic effects and maternal permanent environmental effects. (Cov_{am} = 0), model 6 = model with including direct genetic and maternal genetic effects and maternal permanent environmental effects. ($Cov_{am} \neq 0$)

The heritability estimate for shell weight was lower than the value obtained by Zhang *et al.* (2005) (0.28 *vs.* 0.64). For internal egg quality traits, the lowest heritability estimates were for yolk diameter and Haugh unit (0.11 and 0.11, respectively) and the highest heritability was estimated for yolk index (0.39). Wolc *et al*. (2010) reported the heritability for Haugh unit for broiler chickens to be 0.38. Heritability estimates for albumen height and yolk weight in this study were lower than values reported by Wolc *et al* (2012) in laying hens (0.16 *vs* 0.55, and 0.20 *vs* 0.47, respectively). Heritability estimates for yolk height, yolk diameter, and albumen index were lower than values obtained by Emamgholi Begli *et al*. (2010) (0.13 *vs.* 0.37, 0.11 *vs.* 0.17, and 0.14 *vs.* 0.57, respectively). Similar to present results, Kuhalvandi *et al.* (2014) reported that model 2 is suitable for egg weight as well as long length, with heritability estimates of 0.17 and 0.18, respectively. In contrast to our results, Kuhalvandi *et al.* (2014) reported that model 3 is the best model for short length, shell thickness, shell weight, and shell strength traits.

For albumen height and yolk index, direct heritability estimates were lower than maternal heritability estimates (0.08 *vs.* 0.13, and 0.27 *vs.* 0.3, respectively). Maternal heritabilities were low for some traits such as shell strength, shell thickness, yolk weight, and albumen weight. Similar to our results, maternal heritabilities were also low (0.01 to 0.1) for short length, shell strength, and shell weight in another study (Kuhalvandi *et al.*, 2014). Maternal heritability for yolk weight of Fars native fowl was higher than what we found (0.05 *vs.* 0.24) (Abbasi *et al.*, 2015). Maternal genetic and permanent environmental effects play an important role in improving yolk index trait in this population. However, different genetic structure, management conditions, and methods of estimation could explain some differences in genetic parameters estimation (Ghafouri-Kesbi *et al.*, 2008). Observed differences in genetic and non-genetic parameters obtained by different models indicate the importance of model choice for accurate estimates used in breeding schemes. In addition, ignoring maternal effects, either genetic or environmental can result in overestimation of direct heritability of traits.

Genetic and phenotypic correlations

Genetic correlations among external egg quality traits are shown in Table 3. Genetic correlations between egg weight and shell weight and short length were the highest among external egg quality traits. Egg shape index showed negative genetic correlation with long length (-0.01) and positive genetic correlation with short length (0.35). Therefore, selection for increased egg shape index may increase the width of egg. Shape of egg is important in marketability and incubation. Since genetic factors are involved in the expression of this trait, selection and breeding can be used for egg shape uniformity. Egg weight showed unfavorable genetic correlations with shell strength (-0.19) and shell thickness (-0.38), so selection for higher egg weight can lead to eggs with lower eggshell thickness and strength. Similar results were reported by Sreenivas *et al.* (2013) and De Ketelaere *et al.* (2002). In contrast, results obtained by Okonkwo (2014) and Emamgholi Begli *et al.* (2010) showed positive genetic correlation of egg weight with eggshell thickness and strength. Positive correlation was found between shape index with shell thickness (0.55) and shell weight (0.19). Therefore, by selecting for higher shape index, egg shell quality can be improved. Also, selecting for increasing egg weight and shell thickness or shape index will result in improved weight and egg shell quality at the same time.

Table 3. Genetic (above diagonal) and phenotypic (below diagonal) correlations (± standard error) of external egg quality traits in native chickens

Trait	Egg weight	Specific gravity	Long length	Short length	Shape index	Shell strength	Shell weight	Shell thickness
Egg weight		0.21±0.06	0.18±0.11	0.85±0.17	0.26±0.13	-0.19±0.3	0.93±0.19	-0.38±0.15
Specific gravity	-0.05±0.1		0.45±0.14	0.33±0.14	0.43±0.17	0.29±0.17	0.77±0.09	0.56±0.06
Long length	0.02±0.02	0.03±0.02		0.09±0.02	-0.01±0.12	0.28±0.13	0.03±0.11	-0.49±0.18
Short length	0.61±0.01	-0.04±0.08	0.03±0.09		0.35±0.18	0.30±0.06	0.64±0.2	0.75±0.02
Shape index	0.004±0.3	-0.06±0.03	-0.04±0.04	0.22±0.03		-0.05±0.12	0.19±0.08	0.55±0.07
Shell strength	0.04±0.01	0.35±0.05	0.05±0.06	0.04±0.06	-0.05±0.03		0.42±0.21	058±0.14
Shell weight	0.63±0.02	0.35±0.02	0.04±0.07	0.33±0.03	-0.01±0.04	0.39±0.03		0.86±0.06
Shell thickness	0.14±0.03	0.45±0.01	0.09±0.03	0.07±0.02	-0.06±0.03	0.48±0.02	0.62±0.01	

Genetic correlations among internal egg quality traits are shown in Table 4. The highest genetic correlation was between albumen height and Haugh unit (0.98). Albumen weight had a negative genetic correlation (-0.12) with albumen index and showed a positive genetic correlation with other traits. In a study of 10 strains of broiler chickens, average genetic correlation of albumen weight with albumen height and yolk weight were 0.18 and 0.01, respectively (Wolanski *et al.*, 2007). Genetic correlation between yolk diameter and yolk index was high but negative, which is in agreement with findings from Zhang *et al.* (2005) and Afifi *et al.* (2010). Alipanah *et al.* (2013) found genetic correlations between yolk weight and albumen weight (0.10) and height (0.26). Due to favorable genetic correlations between yolk weight and albumen weight with most internal egg quality traits, selecting for these two traits can improve the internal quality of eggs.

Table 4. Genetic (above diagonal) and phenotypic (below diagonal) correlations (± standard error) of internal egg quality traits in native chickens

Trait	Yolk				Albumen				Haugh unit
	weight	height	diameter	index	weight	height	diameter	index	
Yolk:									
weight		0.47±0.12	0.61±0.17	0.34±0.13	0.37±0.18	0.09±0.03	-0.02±0.10	0.04±0. 07	-0.07±0.02
height	0.18±0.07		0.64±0.15	043±0.11	0.62±0.19	0.81±0.15	-0.53±0.16	0.87±0.18	0.82±0.15
diameter	0.26±0.03	-0.01±0.03		-0.57±0.15	0.46±0.09	0.42±0.10	0.25±0.05	0.36±0.14	0.21±0.01
index	0.01±0.02	0.65±0.02	-0.6±0.04		0.01±0.02	-0.11±0.18	-0.37±0.10	0.34±0.13	0.54±0.09
Albumen:									
weight	0.01±0.01	0.19±0.03	0.18±0.03	0.02±0.09		0.63±0.03	0.51±0.01	-0.12±0.3	0.48±0.10
height	-0.01±0.02	0.36±0.03	0.08±0.01	0.20±0.03	0.23±0.03		-0.39±0.09	0.92±0.01	0.98±0.01
diameter	-0.05±0.05	-0.21±0.04	0.12±0.02	-0.25±0.07	0.17±0.01	0.33±0.02		-0.75±0.05	-0.46±0.02
index	-0.02±0.04	0.33±0.05	0.02±0.01	0.24±0.01	0.07±0.02	0.89±0.01	-0.62±0.12		0.95±0.04
Haugh unit	-0.02±0.02	0.29±0.07	0.05±0.03	0.20±0.05	0.11±0.02	0.97±0.02	-0.37±0.15	0.89±0.00	

Genetic correlations between external and internal egg quality traits are shown in Table 5. Egg weight showed a high positive correlation with albumen weight but negatively correlated with albumen index and Haugh unit. Similar results were reported by Alipanah *et al.* (2013). Therefore, selecting for egg weight in this population can lead to increased albumen weight but reduced Hugh unit. Albumen weight had a positive genetic correlation with shell weight and shell thickness. Wolanski *et al.* (2007) found positive genetic correlations among these traits in ten strains of broiler chickens. Genetic correlations in different populations may differ due to different genetic structures. However, factors such as statistical model may also affect the amount of correlation among traits. Selection for higher egg weight will result in higher yolk and albumin weights, but may result in birds with poor shell strength. This situation may reduce hatchability and economic benefits from the sale of eggs. Therefore, in order to avoid problems of thin-shelled eggs, thickness of the shell should also consider in breeding programs.

Table 5. Genetic correlations (± standard error) between external and internal egg quality traits in native chickens

Trait	Yolk				Albumen			Haugh unit
	weight	height	diameter	index	weight	height	index	
Egg weight	0.74±0.18	0.68±0.14	0.68±0.16	-0.03±0.16	0.98±0.08	0.71±0.11	-0.48±0.15	-0.54±0.11
Specific gravity	0.03±0.2	-0.14±0.15	-0.46±0.18	0.02±0.2	0.41±0.23	-0.21±012	-0.37±0.19	-.036±0.17
Long length	0.24±0.10	0.33±0.14	0.28±0.14	0.01±0.02	0.25±0.10	0.04±0.18	0.30±0.20	-0.46±0.17
Short length	0.42±0.09	0.50±0.18	0.45±0.13	0.06±0.13	0.63±0.19	-0.25±0.12	-0.32±0.19	0.24±0.11
Shape index	0.03±0.12	0.55±0.12	-0.43±0.19	-0.67±0.11	0.39±0.11	0.09±0.14	0.49±0.11	0.22±0.12
Shell strength	-0.45±0.13	0.17±0.10	0.61±0.14	-0.51±0.12	0.42±0.19	-0.26±0.12	-0.32±0.12	-0.25±013
Shell weight	0.01±013	0.25±0.14	0.42±0.12	-0.16±0.13	0.92±0.11	0.36±0.14	-0.10±0.12	0.13±0.14
Shell thickness	0.40±0.12	0.38±0.15	0.56±0.18	-0.28±0.14	0.18±0.16	0.16±0.14	-0.30±0.16	-0.13±0.16

Conclusion

Due to genetic correlations among external and internal egg quality traits, simultaneous selection based on higher egg weight and shell thickness can lead to improve egg quality traits. External egg quality traits are more preferable than internal quality traits to include in a selection index due to ease of measurement. Generally, our results indicate that egg quality traits are influenced by maternal genetic and environmental effects. Including maternal genetic effect in statistical models may reduce bias in estimation of genetic parameters since the models with non-zero covariance between the direct and maternal effects resulted in more accurate estimates for most traits.

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