Genetic Properties of Productive Traits in Iranian Native Fowl: Genetic Relationship between Performance and Egg Quality Traits

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ABSTRACT

The present study was conducted to estimate correlations among performance and egg quality traits in Iranian native fowl. Data were collected from 21,679 birds at the Isfahan Native Fowl Breeding Center to derive genetic parameters for performance traits and egg quality traits were measured on eggs of 1,020 birds. Genetic correlations of performance and egg quality traits were estimated with a bivariate animal model using ASREML software. Body weight at hatch, 8, and 12 weeks of age (BW_0, BW_8 and BW_{12}, respectively) positively (0.05 to 0.82) correlated with egg weight (EW), shell weight (SW), specific gravity (SG), yolk height (YH) and albumen weight (AW). BW_0 and BW_{12} negatively (-0.10 to -0.26) correlated with shell strength (SS) and shell thickness (ST). Genetic correlations of BW_8 and BW_{12} with albumen height (AH) and Haugh unit (HU) were highly negative (-0.45 to -0.55), whereas BW_{12} showed positive correlation with shape index (SI) (0.22). Shell weight showed high positive genetic correlation with age at sexual maturity (ASM) (0.75), while its genetic correlation with egg number (EN) was highly negative (-0.71). EN also showed high negative correlation with yolk and albumen weight (-0.91 and -0.75, respectively). Based on the present results, selection for higher BW will lead to production of eggs with higher internal quality. In contrast, this kind of selection will reduce the shell strength and shell thickness. Therefore, selection should be based on an index including performance and egg quality traits. This will help to develop indigenous strain of meat-cum-egg type chicken.

Keywords: Age at sexual maturity, Haugh unit, Specific gravity.

INTRODUCTION

There is renewed interest among farmers and consumers in native breeds because of the unique hardiness of the breeds and the desirable taste and flavor of their eggs and meat (Haunshi *et al*., 2010). Indigenous chickens, despite their low growth rate and egg production, are generally better in disease resistance and could maintain higher levels of performance under poor nutrition and high environmental temperatures compared to commercial strains under village systems (Horst, 1989). Breeding of native fowl is important for small farmers to produce more income and also to conserve genetic variation of native breeds (Emamgholi Begli *et al*., 2010). Indigenous chickens have a great potential for genetic improvement. Hence, genetic characterization of indigenous breeds is of high importance.

Iranian indigenous chickens are meat-cum-egg type and, therefore, egg quality

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beside the performance characteristics is important in these breeds. Good egg quality is not only important for reproductive performance but also for human consumption (Liu *et al*., 2011). The quality of produced eggs impacts consumer preferences. The egg of a chicken is a biological structure intended by nature for reproduction and it also provides a complete diet for the developing embryo (Shi *et al*., 2009). Poor egg quality causes economic losses at all production stages (Tuiskula-Haavisto *et al*., 2002), while egg weight is important for broiler breeders because of high correlation between egg size and chick weight (Kamali *et al*., 2007). The egg quality traits can be discussed under two broad categories, namely, "external" and "internal" quality (Monira *et al*., 2003). External egg quality, which is mainly related to shell quality, can be measured by some characteristics such as shell strength, shell thickness, and specific gravity. Specific gravity measures the relative proportion of shell in the egg based on its density (Wolc *et al*., 2010) and the percentage of eggshell has a major influence on the specific gravity of the whole egg. The eggs with low specific gravity hatch poorly with increased embryo mortality. Furthermore, optimal shell thickness has economic importance not only in reducing transportation losses (Sazanov *et al*., 2007), but also in reducing the percentage of cracked eggs during handling. Haugh unit, egg weight and height of albumen and yolk can be used to evaluate internal egg quality. The Haugh unit is a measure of albumen integrity (Wolc *et al*., 2010).

Egg quality traits are a major selection criterion in poultry breeding. Due to lack of attention to egg quality traits in selection programs, a high incidence of downgraded eggs occurs, causing economic loss for the egg industry. Presence of pee-wee eggs may originate from intensive selection on sexual maturity and egg production (Poggenpoel and Duckitt, 1988), leading to a reduction in age at first egg and production by immature individuals (Wolc *et al*., 2012). Kirikci *et al*.

(2007) found that body weight of partridges significantly affected egg weight, yolk weight, specific gravity, shell weight, shell thickness, Haugh unit and albumen weight. Attention to egg quality traits, together with performance traits in selection programs will be useful to develop more effective improvement in poultry production. Detailed characterization in performance traits with respect to egg quality traits is rarely available in native chicken consisting of a pool of heterogeneous individuals. Knowledge on genetic correlation among traits is essential for any genetic improvement program. The purpose of this study was to estimate the genetic correlations among performance and egg quality traits in a population of Iranian native fowl.

MATERIALS AND METHODS

The records for performance and egg quality traits were collected from native fowl of Isfahan Breeding Center. Isfahan province is located in the center of Iran with a dry and hot climate, temperatures averaging more than 40°C and humidity lower than 25% during the summer. Isfahan Native Fowl Breeding Center was established in 1980 and started to collecting native fowl based on their phenotypic characteristics, from far rural areas. . Native fowl of this area have acceptable production performance, because of their adaptation to dry and high temperature conditions. The base population was generated from 200 native fowl (100 of each sex), and the first generation was produced by random mating of the base population. From the first generation, data were collected for 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 BW_{12}. After 20 weeks of age, hens were transferred into individual

cages and their egg production was recorded for 12 weeks. During 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, whereafter 800 hens and 100 cocks were selected to produce the next generation. Fourteen generations have been generated in Isfahan Breeding Center. Data were collected for the performance traits included BW_0, BW_8, BW_{12}, ASM, WSM, and EN of generations 12, 13, and 14 and used in the analyses.

Egg quality traits were also measured on eggs of 1,020 birds from generation 15 in the spring of 2012 at the age of 28 weeks. The eggs were labeled to identify the parents and transferred to laboratory. Egg quality traits were recorded during 4 days. Cracked and double-yolked eggs were eliminated. An electronic scale with an accuracy of 0.01 g was used to weigh the eggs (EW) and the short and long lengths of each egg (SL and LL, respectively) were measured using Egg Form Coefficient Measuring Gauge. The 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. Subsequently, yolk and albumen were carefully separated and yolk weight (YW) and albumen weight (AW) were measured. Shell weight (SW) was measured after 72 hours exposure to dry air. Shell thickness was measured with a Shell Thickness Meter (calibrated in mm) at the pointed end, equator and blunt end of shells and average values were used.

Shape index (SI), specific gravity (SG) and Haugh unit (HU) were calculated using the following formulas:

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

SG= [EW/(0.968 EW-0.4759 SW)] (Kul and Seker, 2004)

HU= 100×(Log AH −1.7 $EW^{0.37}$+7.57) (Haugh, 1937)

External egg quality traits, egg weight (EW), shape index (SI), shell strength (SS), shell weight (SW), shell thickness (ST), specific gravity (SG) and internal egg quality traits, albumen height (AH), yolk height (YH), Haugh unit (HU), albumen weight (AW) and yolk weight (YW), together with performance traits including body weight at hatch, 8 and 12 weeks of age (BW_0, BW_8 and BW_{12}), age and weight at sexual maturity (ASM and WSM) and egg number (EN) were used in the analyses.

Statistical Analyses

The UNIVARIATE and GLM procedures of the SAS software (SAS Institute, 2001) were performed to obtain the descriptive statistics and to determine the significance of fixed effects.

The estimates of genetic correlations were obtained using a bivariate animal model with restricted maximum likelihood method. The analyses were done using ASREML software (Gilmour *et al*., 2000). The following model was used:

y= Xb+Za+e

Where, *y* is the vector of observations, *b* is the vector of fixed effects, *a* is the vector of random genetic effects, *e* is the vector of random residual effect, and *X* and *Z* are the incidence matrices relating the observations to the fixed and random genetic effects, respectively. Fixed effects of the model were a combination of generation and hatch (10 levels only for performance traits), sex (2 levels only for body weight traits) and hatch (4 levels only for egg quality traits). Days of production and day of recording were considered as covariates for egg number and egg quality traits, respectively.

RESULTS AND DISCUSSION

Descriptive statistics and significance of fixed effects for the performance traits and egg quality traits are presented in Tables 1 and 2, respectively.

Table 1. Descriptive statistics and test of significance of fixed effects for performance traits.

Trait	Number	Minimum	Maximum	Mean	SD [g]	Sex [h]	GH [i]
BW_0 (g) [a]	21489	32	47	37.30	3.30	0.55[***]	***
BW_8 (g) [b]	19250	750	1200	928.19	128.82	147.48[***]	***
BW_{12} (g) [c]	16005	1200	1930	1482.19	207.97	319.62[***]	***
ASM (Day) [d]	5892	156	219	176.50	12.64	-	***
WSM (g) [e]	5881	1700	2340	1974.70	158.71	-	***
EN (Number) [f]	5495	42	80	56.35	9.13	-	***

[a] Body Weight at hatch; [b] Body Weight at 8 weeks of age; [c] Body Weight at 12 weeks of age, [d] Age at Sexual Maturity; [e] Weight at Sexual Maturity, [f] Egg Number. [g] Standard Deviation. [h] Difference of male and female for each trait was shown as sex effect. [i] GH is the combination of generation and hatch effects. ***: $P \leq 0.001$.

Table 2. Descriptive statistics and test of significance of fixed effects for egg quality traits.

Trait	Number	Minimum	Maximum	Mean	SD [l]	Hatch
External						
EW (g) [a]	969	46.18	63.03	54.60	3.60	**
SI (%) [b]	951	71.01	84.95	77.91	2.84	**
SS (kg cm^{-2}) [c]	929	1.76	5.27	3.44	0.70	ns
SW (g) [d]	981	3.50	6.18	5.00	0.51	**
ST (mm) [e]	975	0.31	0.45	0.38	0.02	ns
SG [f]	964	1.072	1.091	1.082	0.004	ns
Internal						
YW (g) [g]	939	13.51	19.42	16.36	1.15	***
AW (g) [h]	953	24.25	38.54	30.94	2.83	ns
YH (mm) [i]	947	14.68	19.33	16.97	0.97	ns
AH (mm) [j]	959	2.73	7.79	5.16	1.07	**
HU [k]	951	50.06	91.83	71.87	8.67	**

[a] Egg Weight; [b] Shape Index; [c] Shell Strength; [d] Shell Weight; [e] Shell Thickness; [f] Specific Gravity; [g] Yolk Weight; [h] Albumen Weight; [i] Yolk Height; [j] Albumen Height; [k] Haugh Unit. [l] Standard Deviation. ***: $P \leq 0.001$; **: $P \leq 0.01$, ns: Not significant.

Due to missing and outlier data, the numbers of observations differ among traits. The effects of sex, and the combination of generation and hatch (GH) were significant ($P \leq 0.001$) for all performance traits. The mean values of BW_0, BW_8, BW_{12}, and WSM were 37.3, 928.2, 1,482.2 and 1,974.7 g, respectively, while the mean body weights at hatch, 8, and 12 weeks were 24.7, 241.8, and 428.0 g, respectively. These body weights were higher compared to those reported for an indigenous population of Ethiopia (Dana *et al.*, 2010), with body weight at hatch also higher than that reported by Norris and Ngambi (2006) in local Venda chicken (34 g). The mean values of ASM and EN were 176.50 d and 56.35, respectively. Age of sexual maturity in Isafahan native fowl corresponds with values reported by Haunshi *et al.* (2010) for two important native Indian breeds (175 and 176 d), but it was lower than that reported by Dana *et al.* (2010) for an indigenous population of Ethiopia (190 d). The effect of hatch was significant for EW, SI, SW ($P \leq 0.01$), YW ($P \leq 0.001$), AH and HU ($P \leq 0.01$) (Table 2). The mean value of egg weight was 54.60 g, in agreement with the value of 53.85 g reported by Zhang *et al.* (2005) for dwarf layers. The mean value for specific gravity was 1.082, while it was 1.009 and 1.103 for the two native Indian breeds (Haunshi *et al.*, 2010). Specific gravity is highly related to the incidence of breakage and cracks. The incidence of breakage is above normal if the

specific gravity of a flock averages less than 1.080 (Hunton 2005).

The mean value of shape index (77.91) was similar to that reported for the two native Indian breeds (77.36 and 76.39) by Haunshi *et al*. (2010). The mean value for shell strength obtained in this study (3.44 kg cm^{-2}) was slightly higher than that (3.25 kg cm^{-2}) reported by Zhang *et al*. (2005).

The mean values of albumen weight, albumen height, yolk weight and yolk height (30.94 g, 5.16 mm, 16.36 g, and 16.97 mm, respectively) were higher than values reported by Fayeye *et al*. (2005) in Fulani-ecotype chicken (20.33 g, 4.92 mm, 13.03 g and 14.27 mm, respectively). The mean values for Haugh unit, shell weight and shell thickness (71.87, 5.00 and 0.38, respectively) were lower than values in Fulani-ecotype chicken (73.43, 5.04 and 0.58, respectively). The mean value of Haugh unit (71.87) was also lower than that (86.20) reported by Zhang *et al*. (2005). According to Ihekoronye and Ngoddy (1985), high quality eggs generally have Haugh unit of 70 and above.

The difference found in the mean values of the studied traits may be partially attributed to the breed, nutrition, and environment. However, the results show that Isfahan native fowl can produce high quality eggs. This is due to genetic potential of this population for producing high quality eggs and favorable environmental and nutritional conditions.

The estimated genetic correlations between performance and external egg quality traits are shown in Table 3.

Body weight at hatch, 8, and 12 weeks of ages, showed positive and significant genetic correlations with egg weight, shape index, shell weight and specific gravity (between 0.05 and 0.75). Body weight at hatch negatively correlated with shell strength and shell thickness (-0.10 and -0.16, respectively). There were high positive genetic correlations between age at sexual maturity and shell weight and specific gravity (0.75 and 0.53, respectively). This shows that selection for reducing age at first egg leads to reduced shell quality. Shell quality not only determines product safety but also preserves the quality of the internal components of egg. Poor shell quality limits product acceptability and compromises the quantity of processed egg products available from a given number of eggs (Wolc *et al*., 2012). Weight at sexual maturity positively correlated with egg weight and all external egg quality traits. In contrast, egg number showed moderate to high negative genetic correlation with egg weight, shell weight, and specific gravity (-0.39, -0.71 and -0.14, respectively).

The estimated genetic correlations between performance traits and internal egg quality traits are presented in Table 4.

As shown in Table 4, the genetic correlations between hatch weight and all internal egg quality traits were positive (from 0.20 to 0.60), while body weight at older ages showed both positive and negative genetic correlations with internal egg quality traits. Body weight at 8 weeks of age was negatively correlated with yolk weight, albumen height, and Haugh unit (-0.56, -0.54

Table 3. Genetic correlations (se) between external egg quality and performance traits.

Trait	EW (g) [g]	SI (%) [h]	SS (kg cm^{-2}) [i]	SW (g) [j]	ST(mm) [k]	SG [l]
BW$_0$ (g) [a]	0.47±0.18	0.05±0.03	-0.10±0.07	0.07±0.04	-0.16±0.12	0.05±0.02
BW$_8$ (g) [b]	0.26±0.13	0.09±0.06	0.21±0.02	0.18±0.03	NC [m]	0.22±0.08
BW$_{12}$ (g) [c]	0.75±0.18	0.22±0.11	-0.26±0.20	0.25±0.21	NC	0.29±0.12
WSM (g) [d]	0.68±0.12	0.04±0.02	0.34±0.15	0.43±0.20	0.16±0.04	0.36±0.11
ASM (Day) [e]	0.28±0.08	-0.01±0.06	0.08±0.03	0.75±0.17	-0.09±0.02	0.53±0.17
EN (Number) [f]	-0.39±0.13	0.08±0.07	0.23±0.12	-0.71±0.11	0.24±0.14	-0.14±0.06

[a] Body Weight at hatch; [b] Body Weight at 8 weeks of age; [c] Body Weight at 12 weeks of age, [d] Weight at Sexual Maturity; [e] Age at Sexual Maturity; [f] Egg Number; [g] Egg Weight; [h] Shape Index; [i] Shell Strength; [j] Shell Weight; [k] Shell Thickness, [l] Specific Gravity, [m] Not converged.

Table 4. Genetic correlations (se) between internal egg quality and performance traits.

Trait	YW (g)[g]	AW (g)[h]	YH (mm)[i]	AH (mm)[j]	HU[k]
BW_0 (g)[a]	0.20±0.09	0.54±0.19	0.21±0.08	0.33±0.08	0.60±0.14
BW_8 (g)[b]	-0.56±0.13	0.47±0.13	0.05±0.03	-0.54±0.12	-0.45±0.11
BW_{12} (g)[c]	0.35±0.19	0.82±0.16	0.22±0.11	-0.46±0.17	-0.55±0.11
ASM (Day)[d]	0.42±0.27	0.79±0.19	0.43±0.16	0.45±0.11	0.05±0.03
WSM (g)[e]	0.13±0.07	0.53±0.24	0.35±0.05	0.02±0.02	-0.22±0.11
EN (Number)[f]	-0.91±0.14	-0.75±0.17	-0.46±0.13	-0.55±0.07	-0.56±0.14

[a] Body Weight at hatch; [b] Body Weight at 8 weeks of age; [c] Body Weight at 12 weeks of age, [d] Age at Sexual Maturity; [e] Weight at Sexual Maturity; [f] Egg Number; [g] Yolk Weight; [h] Albumen Weight; [i] Yolk Height; [j] Albumen Height, [k] Haugh Unit.

and -0.45, respectively). Body weight at 12 weeks of age showed negative genetic correlation with albumen height and Haugh unit (-0.46 and -0.55, respectively), indicating that selection for increased body weight at 8 and 12 weeks of ages may result in a decrease in albumen height and Haugh unit. Weight at sexual maturity was negatively correlated with Haugh unit, while in contrast, the correlations between weight at sexual maturity and other internal egg quality traits were positive (from 0.02 to 0.53). The correlation between age at sexual maturity and all internal egg quality traits were positive. Wolc *et al.* (2012) found positive genetic correlation between albumen height and sexual maturity (0.12) in laying hens.

This shows that selection for reducing age at sexual maturity leads to production of eggs with lower quality. The genetic correlation between egg number with internal egg quality traits were highly negative (-0.46 to -0.91). This shows that selection for increased egg number will lead to production of eggs with lower internal egg quality.

CONCLUSIONS

The study results demonstrated that selection for increased egg number will reduce most of external and all of internal egg quality traits in Iranian native fowl. In addition, selection for higher BW will lead to production of eggs with higher albumen and yolk weight but with lower egg shell quality. Therefore, a selection index consisting of BW, egg number, and shell quality is necessary for a desirable genetic improvement in Iranian native fowl.

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خصوصیات ژنتیکی صفات تولیدی در مرغ‌های بومی ایران: ارتباط ژنتیکی صفات عملکردی با صفات کیفیت تخم‌مرغ

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چکیده

تحقیق حاضر به منظور تخمین همبستگی‌های میان صفات عملکردی و صفات کیفیت تخم‌مرغ در مرغ‌های بومی ایران انجام شد. برای صفات عملکردی داده‌های ۲۱۶۷۹ پرنده در مرکز مرغ‌های بومی اصفهان مورد استفاده قرار گرفتند. صفات کیفیت تخم‌مرغ نیز با استفاده از تخم‌مرغ‌های ۱۰۲۰ عدد پرنده از این مرکز اندازه‌گیری شدند. همبستگی‌های ژنتیکی صفات عملکردی و کیفیت تخم‌مرغ با استفاده از مدل حیوانی ۲ صفتی و به وسیله نرم‌افزار ASREML تخمین زده شدند. وزن بدن در زمان هچ، ۸ و ۱۲ هفتگی با صفات وزن تخم‌مرغ، وزن پوسته، وزن مخصوص تخم‌مرغ، ارتفاع زرده و وزن سفیده همبستگی ژنتیکی مثبت (۰/۰۵ تا ۰/۸۲) نشان دادند. وزن بدن در زمان هچ و ۱۲ هفتگی با ضخامت و مقاومت پوسته تخم‌مرغ همبستگی ژنتیکی منفی داشتند (۰/۱۰- تا ۰/۲۶-). همبستگی‌های ژنتیکی وزن بدن در ۸ و ۱۲ هفتگی با ارتفاع سفیده و واحد هاو منفی بود (۰/۴۵- تا ۰/۵۵-) در حالیکه وزن بدن در ۱۲ هفتگی با شاخص شکل همبستگی ژنتیکی مثبت (۰/۲۲) نشان داد. همبستگی ژنتیکی وزن پوسته با سن بلوغ جنسی مثبت و بالا (۰/۷۵)، اما با تعداد تخم‌مرغ منفی و بالا (۰/۷۱-) بود. تعداد تخم‌مرغ با ارتفاع زرده و سفیده نیز همبستگی منفی بالایی نشان داد (به ترتیب ۰/۹۱- و ۰/۷۵-). بر اساس نتایج حاضر، انتخاب برای وزن بدن بالاتر منجر به تولید تخم‌مرغ‌های با کیفیت داخلی بیشتری خواهد شد. در مقابل، این نوع انتخاب مقاومت و ضخامت پوسته را کاهش خواهد داد. بنابراین انتخاب باید بر اساس یک شاخص دربرگیرنده‌ی صفات عملکردی و صفات کیفیت تخم‌مرغ انجام گیرد. چنین برنامه انتخابی منجر به توسعه سویه‌های دو منظوره مرغ‌های بومی خواهد شد.