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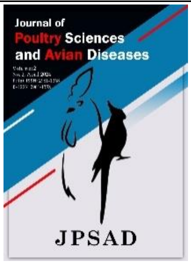

Heritability of fertility, hatchability, and their relationship with egg quality traits in Japanese quail

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A B S T R A C T

The heritability of fertility, hatchability, and their relationship with egg quality traits was studied in fully pedigreed records of a Japanese quail population. A restricted maximum likelihood (REML) procedure was applied in univariate and bivariate analyses. According to the heritability values of FERT, HFE, and HTE in this population of Japanese quail, the role of genes is low, and it is feasible to improve these traits through environmental conditions effectively. Percentage of fertility (FERT) showed positive genetic correlations with AH, YH, YW, and YI (from 0.18 to 0.65) and negative genetic correlations with AW (-0.21). The high genetic correlations were obtained between HFE and ESI (0.62), between HFE and EST (0.56), between HTE and ESI (0.53), and between HTE and EST (0.51). In conclusion, reproductive traits (fertility and hatchability) can improve through selection for high egg quality traits such as EST, ESI, YH, YW, and YI in Japanese quail.

Keywords: *Heritability, genetic correlation, egg quality, fertility, hatchability*

1 Introduction

There are many reports on the segregation of single loci determining egg production (1, 2), meat production (3, 4), and feed efficiency (5). Contrasting these traits, knowledge of genetic determination of fertility and hatchability still needs to be more superficial. However, fertility and hatchability are important traits in a breeding program that have a tremendous economic impact on hatcheries. Also, it has a strong effect on chick output. Several environmental effects affect hatchability, such as storage length and conditions, the dam's age, and the egg's quality (6). The quality of produced eggs is an important factor in fertility and hatchability. Only clean and good-quality broiler breeder-hatching eggs should be sent to the hatchery for incubation. From the breeder's perspective, the relationship between fertility and hatchability with egg quality is important. Generally, the success of hatchery management is monitored by the percentage of eggs set that are hatched (hatchability) and the number of chicks placed

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for grow-out (saleable chicks). It is well known that fertility and hatchability are lowly heritable, less than10% in most studies (7-9).

In consequence, selection effectiveness is decreased. Moreover, the biological backgrounds of these traits are complex. The objective of the present study was to estimate genetic parameters for reproductive traits (FERT, HFE, and HTE) and their genetic correlation with egg quality traits in a pedigreed Japanese quail population.

2 Materials and Methods

2.1 *Stock, Egg Collection, Incubation, and Hatching*

The study involved 9505 eggs from 603 birds' full pedigree of breeding stock of Japanese quails, a variety of *Coturnix coturnix japonica*, in the third month of age. The majority of the 603 females had three records on average, thus resulting in 1620 observations. The stock was fed a 20% crude protein diet and 12.56 MJ/kg. The temperature of the hen house was around 20ºC, and the light was given 15 hrs per day (from 6:00 AM until 9:00 PM).

Hatching eggs were collected and stored in a storage room at 16°C and 65% relative humidity. Eggs had been stored for up to 6 days when set. Before setting the eggs into the incubator, cracked eggs, thin shells, dirty eggs, and abnormal size or shape were condemned. Pedigreed Eggs were incubated at a temperature of 37.9ºC relative humidity of 65%, and during incubation, the eggs were turned automatically every hour. On day 14 of incubation (336h), egg turning was stopped, and eggs were transferred to the hatchery, which maintained a lower temperature (37.4) and higher humidity until the hatch. At the end of the incubation period, the hatched chicks were removed from the rearing house, while non-hatched eggs were broken and examined for fertility. Fertility (FERT), hatchability of fertile eggs (HFE), and hatchability of incubated eggs (HTE) were calculated as follows:

FERT = (number of fertilized eggs/ total number of eggs placed into incubator) × 100;

HFE = (number of released chicks/number of fertilized eggs placed in an incubator) × 100.

HTE = (number of released chicks/total number of eggs placed in incubator) × 100;

2.2 *Egg Characteristics*

Egg quality traits were measured weekly, and the average for three weeks was used as the value for each quail. External egg quality traits, including egg weight (EW), egg shape index (ESI), eggshell thickness (EST), eggshell strength (ESS), and eggshell weight (ESW), were measured. Internal egg quality traits including albumen height (AH), albumen weight (AW), albumen index (AI), albumen ratio (AR), yolk height (YH), yolk weight (YW), yolk index (YI) and yolk ratio (YR) were also measured. A sensitive electronic scale (0.01 g) was used to weigh the eggs and their components, such as albumen, yolk, and eggshell. Each egg's short and long lengths (ESL, ELL, respectively) were measured using an Egg Form Coefficient Measuring Gauge (Ogawa Seiki Co., Tokyo, Japan). The ESI was calculated by dividing ESL by ELL. The eggs were broken gently using an Egg Shell Strength Tester (Ogawa Seiki Co., Tokyo, Japan) to measure ESS. The height of the yolk and albumen were measured using a tripod micrometer, and a dial caliper was used to measure the albumen and yolk diameters. Shell weight was measured after six hours on dried shells. Other internal and external egg quality traits were calculated using the following formulas:

AI = (AH/AD) × 100

YI = (YH/YD) × 100

AP = (AW/EW) × 100

YP= (YW/EW) × 100

Where AD = the average of albumen long and short diameters

The EST was measured by a Shell Thickness Meter (Ogawa Seiki Co., Tokyo, Japan) from each egg's pointed, blunt end, and waist regions to obtain average values.

2.3 *Statistical analysis*

The indices for analysis were the average of the values for studied traits from each hen over the 3 wk. The SAS (10) statistical package was used for preliminary data analyses. A general linear model (GLM) was applied to define the fixed effect of the hatch to be included in the mixed model (p<0.05). A repeatability model was not used because some birds had only one or two records. Therefore, the following model as an animal model was used to estimate the genetic parameters of studied traits.

$Y_{ijk} = \mu + h_i + a_j + e_{ijk}$

Where Yijk is the observations of each bird, μ is the value of the mean, hj =fixed effect of ith hatch (i = 1, 2, ..., 5), aj = random direct genetic effect of males, and Dijk = random residual effect.

Univariate and bivariate analyses were used to estimate heritability and genetic correlations among all combinations of traits. Parameter estimates were obtained using ASREML software (11).

3 Results & Discussion

The statistical descriptions of the reproductive traits are presented in Table 1. The fixed effect from the hatch was significant (p<0.05) for all traits. The mean values of FERT, HFE, and HTE were obtained at 93.17, 83.28, and 70.98, respectively. A range of 87.85 to 96.79% for fertility and 69.34 to 82.25 for hatchability were reported by Magda et al. (2010) in Japanese quail and by Savegnago et al. (2011) in an F2 reciprocal cross chicken population, which was consistent with the current study (12, 13). Bennewitz et al. (2007) reported a lower mean hatchability of fertile eggs (48%) than what was found in the current study (83.28%) (14). The high differences could be due to the genetics of birds, environmental effects, and management, such as storage length and conditions, damage, and egg quality (6).

Table 1. Descriptive statistics of fertility (FERT), hatchability of fertile eggs (HFE) and hatchability of total eggs (HTE).

Traits	Mean	SD	Hatch[1]
FERT	93.17	11.89	*
HFE	83.28	14.46	**
HTE	70.98	17.29	*

$^{*}p\leq 0.05$, $^{**}p\leq 0.01$, $^{***}p\leq 0.001$.

Genetic parameters for reproductive traits are presented in Table 2. Heritability estimates for FERT, HFE, and HTE were moderate to low (0.19, 0.24, and 0.18, respectively). This means these traits' phenotypes are considerably not associated with additive genetic effects, and improvement is feasible through environmental conditions. Although there is little published information on these traits (FERT, HFE, and HTE) in Japanese quail, the results of the present study were generally within the range reported for an unselected population in the study of Magda et al. (2010) in Japanese quail and by Poivey et al. (2001) in brown Tsaiya ducks artificially inseminated with semen from muscovy drakes (12, 15). The current estimate of heritability for FERT (0.19) was higher than those reported in similar research on the chicken population (8, 13, 14). Heritability for a particular trait can take different values depending on the population, environmental conditions, and estimation method (16).

Table 2. Estimated heritabilities (diagonal, in bold), genetic (above diagonal), and phenotypic (below diagonal) correlations with their approximate SE (in parentheses)

Traits	FERT	HFE	HTE
FERT	**0.19 (0.09)**	**0.29 (0.12)**	**0.41 (0.19)**
HFE	**-0.26 (0.05)**	**0.24 (0.06)**	**0.79 (0.07)**
HTE	**0.38 (0.11)**	**0.51 (0.09)**	**0.18 (0.07)**

FERT=fertility, HFE= hatchability of fertile eggs and HTE= hatchability of total eggs

The genetic correlation between FERT and HFE was positive and small (0.32). A high genetic correlation was observed between HFE and HTE (0.79). No genetic correlation estimates were found for these traits in Japanese quail, but moderate to high estimates were reported in broiler strains (7, 8, 17). It was shown that any of these traits can be improved genetically by selecting one of them.

The estimated genetic correlations for reproductive traits with external and internal egg quality traits have been shown in Table 3 and Table 4, respectively. Percentage of fertility (FERT) showed positive genetic correlations with AH, YH, YW, and YI (from 0.18 to 0.65) and negative genetic correlations with AW (-0.21). Genetic relationships between fertility, hatchability, and egg quality traits in Japanese quail could not be compared with similar studies because no published results have been found for these traits. The results illustrated no relationship between fertility and external egg quality traits. However, a moderate to up (0.38-0.65) positive genetic correlation was observed between FERT and internal egg quality, especially yolk-related traits (YH, YW, YI, and YP)—generally, both males and females play an important role in fertility. Factors affecting fertility origin from the males include sperm quality traits (18) and egg quality traits from females (19).

Table 3. Genetic correlations between reproductive traits (FERT, HFE, HTE) and external traits

Traits	EW	ESI	EST	ESS	ESW
FERT	0.23 (0.21)	NC [2]	0.11 (0.09)	0.08 (0.11)	0.22 (0.12)
HFE	0.13 (0.11)	0.62 (0.20)	0.56 (0.24)	0.33 (0.15)	0.29 (0.15)
HTE	-0.22 (0.13)	0.53 (0.16)	0.51 (0.23)	0.38 (0.19)	0.37 (0.21)

FERT=fertility, HFE= hatchability of fertile eggs and HTE= hatchability of total eggs, EW=egg weight, ESI=egg shape index, EST=eggshell thickness, ESS=eggshell strength, ESW=eggshell weight, NC= not converged.

Table 4. Genetic correlations between reproductive traits (FERT, HFE, HTE) and internal traits

Traits	AH	AW	AI	AP	YH	YW	YI	YP
FERT	0.18 (0.12)	-0.21 (0.15)	0.04 (0.14)	NC	0.65 (0.17)	0.49 (0.19)	0.43 (0.11)	0.38 (0.09)
HFE	0.23 (0.20)	0.19 (0.17)	NC	0.31 (0.21)	0.53 (0.14)	0.56 (0.24)	0.54 (0.17)	-0.16 (0.11)
HTE	0.27 (0.19)	0.24 (0.13)	0.16 (0.11)	0.35 (0.32)	0.32 (0.19)	0.37 (0.12)	0.41 (0.13)	-0.19 (0.14)

FERT=fertility, HFE= hatchability of fertile eggs and HTE= hatchability of total eggs, AH=albumen height, AW=albumen weight, AI=albumen index, AP=albumen percentage, YH=yolk high, YW=yolk weight, YI=yolk index, YP=yolk percentage, NC= not converged.

The genetic correlation between HTE and EW was negative and poor. Although the negative genetic correlation with hatchability was low, the selection of higher egg weight may not help to improve hatchability. Szczerbinska & Zubrecki (1999) reported that the highest hatchability of fertile eggs was found in the middle egg weight group. These researchers also determined that the hatchability of fertile eggs was lower in heavy than in lighter quail eggs (20). However, Seker et al. (2004) reported that embryo mortality was higher in the low-weight group than in the heavy-egg-weight group in the Japanese quarter (21).

The high genetic correlations were obtained between HFE and ESI (0.62), between HFE and EST (0.56), between HTE and ESI (0.53), and between HTE and EST (0.51). Because of positive genetic correlations of hatchability with most egg quality traits, selection for higher egg quality traits such as (ESI, EST, and YI) could be recommended. Egg shape index and eggshell thickness are important characteristics from the point of mechanical handling of eggs in hatchability. Narushin et al. (2002) reported that the shell must be thick and strong enough to protect the developing embryo against adverse environmental conditions and physical damage, and the shell must have sufficient pores to exchange O_2/CO_2 and moisture while preventing disease-causing microorganisms from entering the egg (22).

In conclusion, reproductive traits (fertility and hatchability) can improve through the selection of high-quality eggs such as EST, ESI, YH, YW, and YI in Japanese quail.

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Conflict of Interest

The authors declared no conflicts of interest.

Author Contributions

All authors contributed to the original idea and study design.

Data Availability Statement

The datasets generated during and analyzed during the current study are not publicly available but are available from the corresponding author on reasonable request.

Ethical Considerations

This study was conducted at the Department of Animal Science, University of Gonbad-e Qabus, Gonbad-e Qabus, Iran, in accordance with institutional and national animal welfare and ethical guidelines, and all husbandry and sampling procedures were performed to minimize stress and discomfort to the birds.

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References

1. Lotfi E, Zerehdaran S, Azari MA. Estimation of genetic parameters for egg production traits in Japanese quail (Coturnix cot. japonica). Archiv für Geflügelkunde. 2012;76(2):131-5.
2. Mielenz N, Noor RR, Schüler L. Estimation of additive and non-additive genetic variances of body weight, egg weight and egg production for quails (Coturnix coturnix japonica) with an animal model analysis. Archives Animal Breeding. 2006;49(3):300-7. [DOI]
3. Lotfi E, Zerehdaran S, Azari MA. Genetic evaluation of carcass composition and fat deposition in Japanese quail. Poultry science. 2011;90(10):2202-8. [PMID: 21934001] [DOI]
4. Oguz I, Aksit M, Onenc A, Gevrekci Y, Ozdemir D, Altan O. Genetic variability of meat quality characteristics in Japanese quail (Coturnix coturnix japonica). Archiv fur Geflugelkunde. 2004;68(4):176-80.
5. Varkoohi S, Pakdel A, Babak MMS, Javaremi AN, Kause A, Zaghari M. Genetic parameters for feed utilization traits in Japanese quail. Poultry Science. 2011;90(1):42-7. [PMID: 21177442] [DOI]
6. King'Ori A. Review of the factors that influence egg fertility and hatchability in poultry. International Journal of poultry science. 2011;10(6):483-92. [DOI]
7. Beaumont C, Millet N, Le Bihan-Duval E, Kipi A, Dupuy V. Genetic parameters of survival to the different stages of embryonic death in laying hens. Poultry Science. 1997;76(9):1193-6. [PMID: 9276879] [DOI]
8. Sapp R, Rekaya R, Misztal I, Wing T. Male and female fertility and hatchability in chickens: A longitudinal mixed model approach. Poultry Science. 2004;83(8):1253-9. [PMID: 15338998] [DOI]
9. Szwaczkowski T, Wężyk S, Piotrowski P, Cywa-Benko K. Direct and maternal genetic and environmental effects for fertility and hatchability in laying hens. Archiv für Geflügelkunde. 2000;64(3):115-20.
10. SAS S, Guide SUs. Version 8.2. SAS Institute Inc, Cary, NC. 2001.
11. Gilmour A, Cullis B, Welham S, Thompson R. ASReml. NSW Agriculture. Orange, Australia. 2000.
12. Magda I, Samaha A, Sharaf M, Hemeda S. Phenotypic and genetic estimates of some productive and reproductive traits in Japanese quails. Egypt Poult Sci. 2010;30:875-92.
13. Savegnago R, Buzanskas M, Nunes BdN, Ramos S, Ledur M, Nones K, Munari D. Heritabilities and genetic correlations for reproductive traits in an F2 reciprocal cross chicken population. Genetics and Molecular Research. 2011:1337-44. [PMID: 21751160] [DOI]
14. Bennewitz J, Morgades O, Preisinger R, Thaller G, Kalm E. Variance component and breeding value estimation for reproductive traits in laying hens using a Bayesian threshold model. Poultry Science. 2007;86(5):823-8. [PMID: 17435014] [DOI]
15. Poivey J-P, Cheng YS, Rouvier R, Tai C, Wang C, Liu H-L. Genetic parameters of reproductive traits in Brown Tsaiya ducks artificially inseminated with semen from Muscovy drakes. Poultry Science. 2001;80(6):703-9. [PMID: 11441835] [DOI]
16. Falconer DS, T. F. C. Mackay. Introduction to Quantitative Genetics. 4 ed. New York: Addison Wesley Longman; 1996.
17. Ledur MC, Schmidt GS, de Figueiredo ÉAP, de Ávila VS, Fiorentin L. Parâmetros genéticos e fenotípicos em linhagens de aves selecionadas para corte. Pesquisa Agropecuária Brasileira. 1994;29(3):503-8.
18. Bramwell R, McDaniel C, Wilson J, Howarth B. Age effect of male and female broiler breeders on sperm penetration of the perivitelline layer overlying the germinal disc. Poultry science. 1996;75(6):755-62. [PMID: 8737841] [DOI]
19. Siegel P. Genetics of behavior: Selection for mating ability in chickens. Genetics. 1965;52(6):1269. [PMID: 5882198] [PMCID: PMC1210982] [DOI]
20. Szczerbińska D, Żubrecki A. The quail egg weight and their storage period vs. hatching success and rearing performance. Advances in Agricultural Sciences. 1999;6(1):91-100.
21. Seker I, Kul S, Bayraktar M. Effects of parental age and hatching egg weight of Japanese quails on hatchability and chick weight. International Journal of Poultry Science. 2004;3(4):259-65. [DOI]
22. Narushin VG, Romanov MN. Egg physical characteristics and hatchability. World's poultry science journal. 2002;58(3):297-303. [DOI]