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PHENOTYPIC VARIATION, TRAIT INTERRELATIONSHIPS, AND GEOMETRIC PREDICTION OF EGG WEIGHT IN JAPANESE QUAIL (COTURNIX JAPONICA)

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Abstract. In this study we studied phenotypic variation and relationships between external and internal egg quality traits in a sample of eggs from Japanese quail and whether the egg weight could be predicted from non-destructive external measurements. We had 274 individual egg records and 12 egg features (egg weight, egg length, egg breadth, eggshell thickness, egg shape index, component weight, calculated egg volume, egg density). One egg was considered structurally irregular and was removed without imputation because it had a breadth larger than the length and a shape index of 114.97%. This left us with 273 eggs for inferential analysis. The average egg weight was 7.28 ± 0.84 g, with mean length 29.83 mm, breadth 23.84 mm, shell thickness 0.221 mm, and shape index 80.03%. The egg mass was 30.81% yolk, 60.65% albumen and 8.54% shell. Egg weight was correlated strongly with breadth ($r = 0.942$), length ($r = 0.849$), yolk weight ($r = 0.859$) and albumen weight ($r = 0.899$; $P < 0.001$), whereas shell thickness was not related to egg weight ($P = 0.958$). In a parsimonious geometric model $L \times B^2$, egg weight was predicted as $EW = 0.284 + 0.000411\ (L \times B^2)$ and $R^2 = 0.970$. The excellent reliability of the cross validation ($R^2 = 0.969$, RMSE = 0.149 g and MAE = 0.099 g) was also demonstrated with the successful prediction of a 10-fold cross validation. The results show that there is a high amount of observed variation that can be summarized with simple egg dimension and can be used for non-destructive and rapid phenotyping of Japanese quail. Without age, genotype, diet or management metadata, it is difficult to interpret causality and to make group inference.

Key words: Japanese quail; Coturnix japonica; egg quality; egg weight; phenotypic correlation; shape index; non-destructive prediction; egg geometry.

Introduction

Japanese quail are a prominent small-bodied poultry species that are used for egg and meat production and as a biological model. Egg quality is a multidimensional trait with several external attributes as well as internal characteristics (yolk and albumen) of the egg. These are the factors that affect marketability, processing, hatchability and breeding and are influenced by genetic and environmental factors. Recent studies have shown that egg quality indices are affected by housing and diet, and eggshell color, genetic line, age and selection history can also be relevant to characterizing phenotypic differences in eggs [1-4].

The relationship between egg traits is especially important because quality traits are related. Studies in Japanese quail show moderate-to-strong phenotypic or genetic associations between egg weight, dimensions and shell traits and internal components [5–11]. Egg weight is a good indicator of how well egg weight is measured and is often used to see the value of the yolk and albumen mass. But it is advisable to be careful to interpret correlations between components because the total egg weight is the arithmetic sum of yolk, albumen and shell weight. These correlations between the total and its components have a built-in compositional relationship.

There is a second practical application for trait relationships. Egg geometry can provide information about volume and mass of the egg. Recent mathematical studies have shown that combinations of egg length and breadth can predict the egg weight and other physical parameters of quail eggs very accurately [12,13]. These methods can shorten handling time, preserve eggs for incubation and support large-scale phenotyping in situations where destructive internal quality measurements are not feasible.

The aim of this study was therefore to identify the distribution of external and internal egg quality characteristics in the Japanese quail dataset, to identify the phenotypic correlations with egg weight, determine the proportion of components, and to compare simple non-destructive models for predicting egg weight from external dimensions. Since the data did not capture treatment, age, strain, sex, replicate, or husbandry information, the study was conducted in an observational manner and not as treatment-comparison.

Materials and Methods

The study investigated the association between external and internal egg quality and developed statistical models to predict egg weight of Japanese quail (Coturnix japonica). There were 274 individual egg records with 12 variables: egg weight, egg length, egg breadth, shell thickness, egg shape index, yolk weight, albumen weight, shell weight, yolk volume, albumen volume, yolk density, and albumen density. Egg weight and component weights were also expressed in grams (g) and egg length, breadth, and shell thickness in mm. Before analyzing the data, the relationship between egg length, breadth, and shape index was checked using the usual expression: Shape index (%) = [Egg breadth (mm) / Egg length (mm)] × 100. We calculated the relative proportions of the three major egg components based on their respective weights and total egg weight: Yolk percentage (%) = [Yolk weight (g) / Egg weight (g)] × 100, Albumen percentage (%) = [Albumen weight (g) / Egg weight (g)] × 100, Shell percentage (%) = [Shell weight (g) / Egg weight (g)] × 100. We calculated the geometric size index (mm^3) for the measured external dimensions: where L is egg length (mm) and B is egg breadth (mm). The resulting index is a geometric proxy for egg size and should not be interpreted as a direct measure of egg

volume.

For each measured and calculated variable, descriptive statistics were given as the arithmetic mean, standard deviation (SD), coefficient of variation (CV), minimum, and maximum. The coefficients of variation were given as: CV (%) = (SD / Mean) × 100. Pearson correlation coefficients (r) were estimated to quantify linear associations between egg weight and the remaining egg quality variables. Correlations were considered associations, not causality. We compared two linear regression models. The first analysis was multivariable and included egg length, egg breadth, and shell thickness as predictors. It was parameterized as: $EW = \beta_0 + \beta_1 L + \beta_2 B + \beta_3 ST + \varepsilon$, where EW is egg weight (g), L is egg length (mm), B is egg breadth (mm), ST is shell thickness (mm), β_0 is the intercept, β_1–β_3 are regression coefficients, and ε is the residual error. The second analysis was less detailed but used geometric index as the only predictor, namely: $EW = \beta_0 + \beta_1(L \times B^2) + \varepsilon$, where only egg length and breadth are described in the description as external dimensions.

Whether shell thickness was measured nondestructively was not documented and so the first model should not be considered as fully nondestructive until the measurement procedure is confirmed. The statistical analysis was carried out with IBM SPSS Statistics. Descriptive statistics, Pearson correlation analysis, as well as linear regression model analysis were performed in SPSS. Statistical significance was checked for $P < 0.05$.

Results

After quality control, 273 eggs were available for analysis. Mean egg weight was 7.277 g (CV 11.6%), ranging from 5.606 to 11.775 g. Mean egg length and breadth were 29.83 and 23.84 mm, respectively, while mean shape index was 80.03%. Shell thickness averaged 0.221 mm. Yolk, albumen, and shell represented 30.81%, 60.65%, and 8.54% of total egg mass, respectively (Table 1). Among the directly measured traits, yolk weight showed the greatest relative variability (CV 18.4%), whereas breadth and shape index were comparatively stable (CV < 4%).

Table 1. Descriptive statistics for external and internal egg-quality traits (n = 273).

Trait	n	Mean	SD	CV (%)	Minimum	Maximum
Egg weight (g)	273	7.277	0.844	11.59	5.606	11.775
Egg length (mm)	273	29.829	1.516	5.08	26.100	37.150
Egg breadth (mm)	273	23.843	0.918	3.85	21.810	27.010
Shell thickness (mm)	273	0.221	0.033	14.92	0.140	0.370
Shape index (%)	273	80.030	2.967	3.71	72.705	88.767
Yolk weight (g)	273	2.252	0.414	18.39	1.392	5.037
Albumen weight (g)	273	4.407	0.495	11.22	3.242	5.934
Shell weight (g)	273	0.618	0.074	11.91	0.440	0.853

Trait	n	Mean	SD	CV (%)	Minimum	Maximum
Yolk volume (dataset units)	273	1.601	0.317	19.79	0.863	3.652
Albumen volume (dataset units)	273	3.431	0.416	12.14	2.414	4.540
Yolk density (calculated)	273	1.414	0.103	7.31	1.224	1.862
Albumen density (calculated)	273	1.287	0.048	3.75	1.142	1.555
Yolk ratio (%)	273	30.809	3.098	10.06	24.010	42.777
Albumen ratio (%)	273	60.655	3.069	5.06	50.395	67.810
Shell ratio (%)	273	8.536	0.881	10.32	6.082	11.814

Egg weight showed its strongest association with egg breadth ($r = 0.942$, $P < 0.001$), followed by albumen weight ($r = 0.899$), yolk weight ($r = 0.859$), and egg length ($r = 0.849$; all $P < 0.001$). Shell weight was moderately related to egg weight ($r = 0.587$, $P < 0.001$), whereas shell thickness showed essentially no relationship with total egg weight ($r = -0.003$, $P = 0.958$). Shape index was weakly and negatively associated with egg weight ($r = -0.181$, $P = 0.003$). Shell thickness and shell weight were positively correlated ($r = 0.425$, $P < 0.001$). As expected from its mathematical construction, shape index was strongly and inversely related to egg length ($r = -0.655$, $P < 0.001$). Table 2 summarizes correlations of egg weight with the remaining variables.

Table 2. Pearson correlations between egg weight and other egg-quality traits (n = 273).

Trait	r with egg weight	P value	Interpretation
Egg length	0.849	<0.001	Strong positive
Egg breadth	0.942	<0.001	Strong positive
Shell thickness	-0.003	0.958	Very weak negative
Shape index	-0.181	0.003	Very weak negative
Yolk weight	0.859	<0.001	Strong positive
Albumen weight	0.899	<0.001	Strong positive
Shell weight	0.587	<0.001	Moderate positive
Yolk volume	0.801	<0.001	Strong positive
Albumen volume	0.861	<0.001	Strong positive
Yolk density	-0.004	0.945	Very weak negative
Albumen density	-0.106	0.081	Very weak negative
Yolk ratio	0.369	<0.001	Weak positive
Albumen ratio	-0.256	<0.001	Weak negative
Shell ratio	-0.406	<0.001	Moderate negative

The multiple external-measurement model was $EW = -14.087 + 0.211(L) + 0.626(B) + 0.611(ST)$, with $R^2 = 0.965$ and adjusted $R^2 = 0.964$. Ten-fold cross-validation produced $R^2 = 0.962$, RMSE = 0.165 g, and MAE = 0.104 g. A simpler geometric model using $L \times B^2$ performed slightly better: $EW = 0.284 +$

0.000411(L×B²), with R² = 0.970. Cross-validated performance remained high (R² = 0.969, RMSE = 0.149 g, MAE = 0.099 g). Because this model used only two non-destructive dimensions and achieved the lowest prediction error, it was considered the preferred model for this dataset (Table 3; Figures 1 and 2).

Table 3. Egg-weight prediction models and 10-fold cross-validation performance.

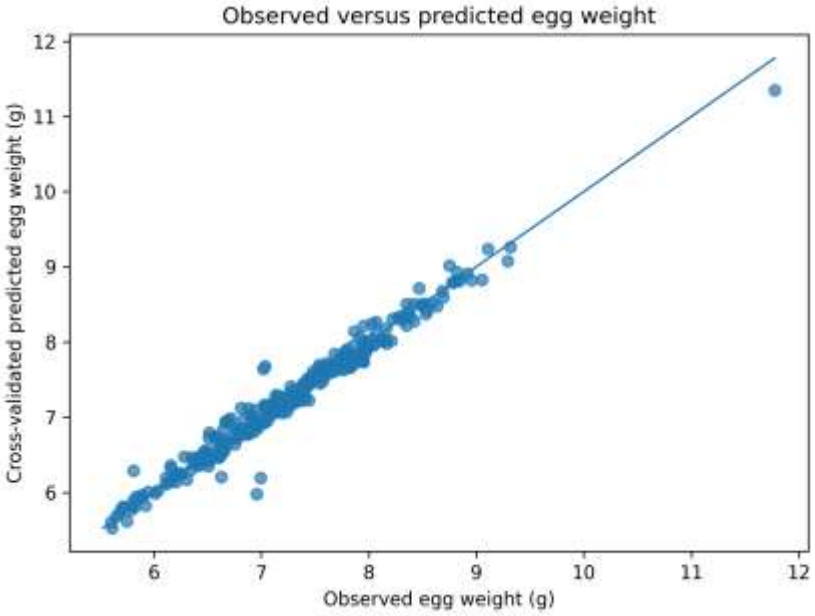


Figure 1. Cross-validated predicted versus observed egg weight using the geometric L×B² model. The diagonal line represents perfect agreement.

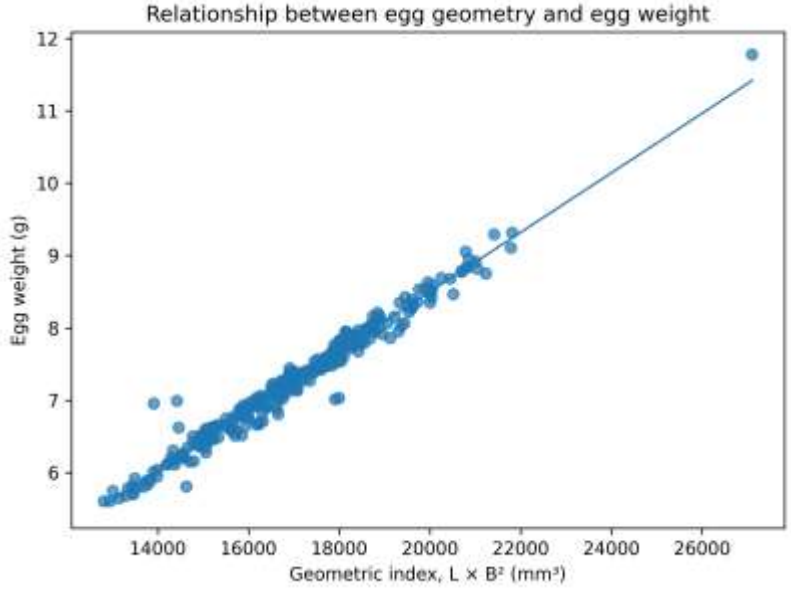


Figure 2. Relationship between the geometric index (egg length × breadth²) and egg weight in Japanese quail. The fitted line represents the ordinary least-squares geometric model.

Discussion

The present data showed that significant but systematic differences existed in the egg quality of Japanese quail. The mean egg weight of 7.28 g was lower than the values around 11–13 g, which have been reported for several adult Japanese quail populations [4,7,12] but like lower-weight populations which had been reported

previously. The supplied file did not contain age, strain, diet and management, so it is not possible to determine the cause of the lower absolute egg mass. All of these are potential sources of variation which have been found to influence egg characteristics [4–6,9] and housing, diet and eggshell phenotype can also influence quality traits [1–3,14].

Although the absolute egg weight was relatively low, the proportional composition was biologically adequate. The yolk, white and shell accounted for about 30.8%, 60.7% and 8.5% of egg mass, respectively. The proportions of these are like those recently obtained from selected Japanese quail lines, in which the mean proportions of yolk and albumen were approximately 30% and 60%, respectively [4]. This indicates that whereas the weight of the eggs in the present data set was decreased, the partitioning of the weight among the major components was essentially normal.

The external trait most highly correlated with egg weight was egg breadth ($r = 0.942$) followed by egg length ($r = 0.849$). Favorable correlations between egg mass and linear dimensions have been studied in quail several times [7,10–12]. Geometrically this is to be expected since the volume of the egg is roughly proportional to one dimension and the square of another. An existing model ($L \times B^2$) took advantage of this relationship and accounted for 97.0% of the variance in egg weight observed. It has a cross validated R^2 of 0.969, which is not a coincidence that it fit the data in the in-sample. In recent studies, the importance of egg geometry and non-destructive prediction of quail phenotyping has also been highlighted [12,13,15].

The positive and significant correlation between total egg weight and albumen weight ($r = 0.899$) and yolk weight ($r = 0.859$) are in the same direction as obtained by earlier studies [7,11]. These associations, however, should not be interpreted as being statistically independent as a biological effect because the data supplied indicate that egg weight is equal to yolk weight plus albumen weight plus shell weight for each record. The correlations are thus relations between the variations in total mass and its partitioning. There was moderate correlation between yolk weights and albumen weights ($r = 0.556$), suggesting that larger eggs were correlated with greater increase in yolk weight and not just albumen weight.

Shell thickness was different than shell weight. Shell thickness had no correlation with the total egg weight in the present data set ($r = -0.003$); shell weight had a moderate positive correlation to egg weight. The shell thickness and the weight of shell were positively correlated ($r = 0.425$). Shell characteristics have also been demonstrated to be genetically and phenotypically distinct in previous studies [5,6,9], and to have varying heritabilities and correlations. Therefore, shell thickness cannot be replaceable by shell weight to judge the quality of shell.

The mean shape index of 80.03% showed that the egg shape was relatively rounded when compared with some of the populations mentioned in the literature [4,7]. There was weak negative correlation of shape index with egg weight and strong negative correlation with egg length. The latter is partially mathematical since it involves length in the denominator of its formula for shape index. Therefore, shape index should be used primarily as a relative shape measure and not as a true size measure. The one observation excluded because its shape index was greater than 100% highlights the need to verify that the measurements along the axis they are using are consistent before constructing geometric models; it was not attempted to make an inference or replace the probable incorrect value.

The implication in practice is that the length and breadth of the egg could be used as a quick screening technique for egg mass without breaking the egg. This could be beneficial for selection programs, for egg grading in hatcheries, automated imaging and processing lines. This should be considered as a population-specific equation, however, until it is externally validated by an independent study. Prediction equations may vary with age, line, housing system, feed and the size of eggs laid [1,4,12,13] and may create systematic error when transferred between flocks.

Conclusion

The results showed clear phenotypic structure among egg-quality traits. Egg breadth and length were strongly associated with egg weight, whereas shell thickness was not. A simple geometric model based only on $L \times B^2$ predicted egg weight with high accuracy (cross-validated $R^2 = 0.969$; RMSE = 0.149 g), supporting the potential of non-destructive dimensional measurements for rapid egg phenotyping. Average mass partitioning was approximately 30.8% yolk, 60.7% albumen, and 8.5% shell.

References

[1] Ludoški, M., Grković, N., Suvajdžić, B., Vićić, I., Branković Lazić, I., Baltić, T., & Čobanović, N. (2026). Eggshell colour affecting the safety and quality of Japanese quail eggs (Coturnix coturnix japonica). *British Poultry Science* 67(1), 60–72. https://doi.org/10.1080/00071668.2025.2527225

[2] Hossain, M. A., Mahbub, A. S. M., & Belal, S. A. (2024). Housing and dietary effects on production performance, quality index, and chemical composition of Japanese quail eggs. *Veterinary and Animal Science* 23, 100340. https://doi.org/10.1016/j.vas.2024.100340

[3] Ismael, N. A., Abdelmonem, U. M., El-Kholy, M. S., El Nagar, A. G., Ahmed, A. F., Almalki, M., El-Tarabily, K. A., & Reda, F. M. (2024). The relationship between eggshell color, hatching traits, fertility, mortality, and some qualitative aspects of Japanese quail (Coturnix japonica) eggs. *Poultry Science* 103(2), 103298. https://doi.org/10.1016/j.psj.2023.103298

[4] Arslan, E., Şamlı, M. Ş., Kirbaş, G., Kaya, Z. K., Tok, M., & Kırıkçı, K. (2025). Growth performance, egg production, and egg quality characteristics of Japanese quail lines obtained by selection according to feather color. *Brazilian Journal of Poultry Science* 27(3), eRBCA-2025-2072. https://doi.org/10.1590/1806-9061-2025-2072

[5] Narinc, D., Aygun, A., Karaman, E., & Aksoy, T. (2015). Egg shell quality in Japanese quail: Characteristics, heritabilities and genetic and phenotypic relationships. *Animal* 9(7), 1091–1096. https://doi.org/10.1017/S1751731115000506

[6] Sari, M., Tilki, M., & Saatci, M. (2016). Genetic parameters of egg quality traits in long-term pedigree recorded Japanese quail. *Poultry Science* 95(8), 1743–1749. https://doi.org/10.3382/ps/pew118

[7] Kul, S., & Seker, I. (2004). Phenotypic correlations between some external and internal egg quality traits in the Japanese quail (Coturnix coturnix japonica). *International Journal of Poultry Science* 3(6), 400–405.

https://doi.org/10.3923/ijps.2004.400.405

[8] Alkan, S., Karabağ, K., Galiç, A., Karslı, T., & Balcıoğlu, M. S. (2010). Effects of selection for body weight and egg production on egg quality traits in Japanese quails (Coturnix coturnix japonica) of different lines and relationships between these traits. *Kafkas Üniversitesi Veteriner Fakültesi Dergisi* 16(2), 239–244. https://doi.org/10.9775/kvfd.2009.633

[9] Daikwo, S. I., Dim, N. I., & Momoh, O. M. (2013). Inheritance of egg quality traits in the Japanese quail. *International Journal of Poultry Science* 12(3), 153–156. https://doi.org/10.3923/ijps.2013.153.156

[10] Alaşahan, S., Çopur Akpınar, G., Canoğulları, S., & Baylan, M. (2015). Determination of some external and internal quality traits of Japanese quail (Coturnix coturnix japonica) eggs on the basis of eggshell colour and spot colour. *Eurasian Journal of Veterinary Sciences* 31(4), 235–241. https://doi.org/10.15312/EurasianJVetSci.2015413529

[11] Çelik, Ş., Eyduran, E., Şengül, A. Y., & Şengül, T. (2021). Relationship among egg quality traits in Japanese quails and prediction of egg weight and color using data mining algorithms. *Tropical Animal Health and Production* 53(3), 382. https://doi.org/10.1007/s11250-021-02811-2

[12] Arslan, E., Güler, S., Çetin, O., Sarı, M. M., & Yonar, H. (2023). Egg weight estimation and the effect of age and plumage colors on some egg quality traits in Japanese quails (Coturnix coturnix japonica). *Emirates Journal of Food and Agriculture* 35(6), 569–576. https://doi.org/10.9755/ejfa.2023.v35.i6.3104

[13] Narushin, V. G., Volkova, N. A., Vetokh, A. N., Sotnikov, D. A., Volkova, L. A., Griffin, D. K., Romanov, M. N., & Zinovieva, N. A. (2024). 'Eggology' and mathematics of a quail egg: An innovative non-destructive technology for evaluating egg parameters in Japanese quail. *Food and Bioproducts Processing* 146, 49–57. https://doi.org/10.1016/j.fbp.2024.04.007

[14] Gümüş, E., Sevim, B., Sırakaya, S., İriş, C., Kahraman, O., & Sarmiento-García, A. (2025). Evaluation of the effect of red cabbage waste on performance, egg quality, and yolk oxidative stability of laying Japanese quails (Coturnix coturnix Japonica). *Tropical Animal Health and Production* 57, 82. https://doi.org/10.1007/s11250-025-04336-4

[15] Narushin, V. G., Volkova, N. A., Dzhagaev, A. Y., Gagieva, Z. V., Volkova, L. A., Griffin, D. K., Romanov, M. N., & Zinovieva, N. A. (2025). Shell quality parameters of Japanese quail (Coturnix japonica) eggs as estimated by non-destructive testing technology. *Journal of Food Process Engineering* 48(10), e70219. https://doi.org/10.1111/jfpe.70219

[16] De Ketelaere, B., Bamelis, F., Kemps, B., Decuypere, E., & De Baerdemaeker, J. (2004). Non-destructive measurements of the egg quality. *World's Poultry Science Journal* 60, 289–302. https://doi.org/10.1079/WPS200417

[17] IBM Corp. (2017). *IBM SPSS Statistics for Windows* (Version 19.0) [Computer software]. IBM Corp. https://www.ibm.com/products/spss-statistics