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Genotype and Phenotype Interactions Influencing External Egg Quality Traits in Wild-Type Japanese Quails Reared in Borno State, Nigeria

Abdulyekeen Olanrewaju Abdulraheem[1], Abba Mohammed[2], Maryam Mustapha Shettima[2], Jimoh Olalekan Aremu[3], Abdulrazaq Onimisi Raji[1], Jibrin Aliyu[1]

[1]Department of Animal Science, Faculty of Agriculture, University of Maiduguri, P.M.B. 1069, Maiduguri, Borno state. aoraji@unimaid.edu.ng, jbrinaliyu@gmail.com
[2]Department of Animal Science, Faculty of Agriculture, Borno state University, P.M.B. 1122, Borno state, Nigeria. banayeyya@yahoo.com, shettimamaryam500@gmail.com
[3]Department of Animal Production, Kwara state University, Malete, 1530, Kwara state, Nigeria
Corresponding author e-mail: yekeeno@yahoo.com

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Abstract

This research estimated genetic and phenotypic correlations between external egg quality traits in Japanese quails reared in Maiduguri, Borno state, Nigeria using Restricted Maximum Likelihood procedures. A total of 1,320 eggs were collected from 110 quail hens, progeny of the base population at weeks 10, 12, 14, 16, 18 and 20 of age and were used for egg quality analysis. Data were collected on 9 external egg traits; egg weight (EW), egg width (WE), egg height (EH), shell weight (SW), shell ratio (SR), average shell thickness (AVGST), egg shape index (ESI), egg surface area (ESA) and shell weight per unit surface area (SWUS). The estimates were low to high (0.01 - 0.99) for the co-efficients. Meanwhile, they were mostly moderate and high in magnitude indicating potentials for improvement. Highest negative correlations (-0.92) were obtained for EW and SR at ages10 and 12 weeks. At all ages, EW expressed positive genetic correlations with other external qualities, notably, EH, WE and SW. Because of high positive correlation between ESI and SR, eggs with round shape may likely have better SW than others. Phenotypic correlations followed similar patterns with attributes in both magnitude and signs.

Keywords: correlations, parameters, egg, quails, external

Introduction

Improvement of farm animals is an embodiment of activities aimed at obtaining individuals with fixed and desired traits (Nwakpu and Nosike, 2024). As poultry production in Nigeria is becoming more recognized as a stable industry with important contribution to economy and protein source (Usman and Musa, 2003), quantitative genetics methods would be useful to bring about improvement in the economic traits of this farm animal species (Ibe, 1998).

The relevance of quail in the poultry industry especially in the developing countries, Nigeria not left out, cannot be over emphasized (Abdulraheem *et al.,* 2024). Quails are hardy and resistant to some common poultry diseases. They have short generation interval as they attain sexual maturity stage at about six weeks post-hatch. Among other credits, the birds are seen as the smallest-farmed avian species, and as such require little space and consume small amount of feed in comparison with domestic fowl. This quality makes the birds more economical to keep especially for the rural dwellers. Although quails are as important as chickens in both egg and meat production, these birds are most often managed for their eggs. Average annual egg production of 300 has been recorded for these birds with adequate management (Abdulraheem *et al.,* 2024).

According to Kul and Saker (2004), preference is given to eggs over meat in developing countries including some parts of Nigeria. Shortly before now, egg is recognized as an economical animal protein source. Its characteristics are determined by external and internal qualities which are known to be inter-correlated (Abdulraheem *et al.,* 2021). External quality of egg plays important roles in resisting fracture in both table and breeding eggs.

Effecting change in these quality traits of eggs is a function of magnitude of genetic parameter estimates. In other words, it is the scale of these parameters that justifies the actual amount of improvement that could be achieved by selection as this is based on accurate estimates of variance components and genetic parameters such as heritability, repeatability and correlations (Aliyu *et al.,* 2024). The knowledge of genetic parameters enables breeders to decide on the best selection-type to achieve rapid genetic progress on a particular economic trait (Ibe, 1998). This study was designed to estimate genetic and phenotypic correlations existing between external quality traits of eggs for Japanese quails reared in Maiduguri, Northeast Nigeria.

Methods, Techniques, Studied Materials and Area of Descriptions

The research was carried out at the Poultry Unit, Livestock Teaching and Research Farm, University of Maiduguri, Maiduguri, Borno state, Nigeria. The co-ordinates of the study area lie on Latitude 11^0 5', and Longitude 13^0 0and on altitude 354 m above sea level in the Northeast Geopolitical zone of Nigeria. The state has three distinct seasons: dry hot (February to May), dry cold (October to January) and wet (June to September). Maiduguri falls within the Sahelian region and characterized with hash climate and dramatic variations in seasonal rainfall (Kwari *et al.,* 2019). According to Afolayan *et al,* (2013), the area is of very short rainfall (3 to 4 months) varying from minimum of 478 to 500 mm and to maximum of 600 to 621 mm with a long dry period of 8 to 9 months. The ambient temperatures fall within the range 35^0 and 40^0 C. This becomes highest by the months of April and May. The relative humidity is minimum in February and March when it drops to as low as 10% and as high as 90% in August (Kellou, 2005).

Eighty Japanese quail chicks of wild-type strain (20 males and 60 females) of four weeks old were purchased from Veterinary Research Institute Farm in Vom, Plateau state, Nigeria. These were used as the base population. 300 eggs were collected from the base population and set for hatching in a forced air incubator (1510 Sportsman Cabinet incubator GQF Manufacturing Company, USA). Eggs from the resulting progeny were used for the egg quality traits analysis. Quail chicks were raised in quail brooder till four weeks of age. Sexing was done at 3 weeks of age as the females can be distinguished from the males by their characteristic light feathers with black speckling on the throat and upper breast (Randal and Bolla, 2008). Birds were randomly placed in cages in a mating ratio of 1:3. The size of the wire mesh cages is 40 x 30 x 30 cm. Period of light to darkness (light:dark cycle) of 12:12 was adopted. The birds were allowed free access to feed and water. They were given quail diet containing 25% CP and 3000 Kcal ME/Kg in the first 6 weeks, which was later reduced to 24% CP and 2750 Kcal ME/kg. Constant sanitation of the pen including the feeder was carried out. Antibiotics were given at regular intervals as described by the manufacturer for preventive measure against poultry diseases irrespective of their hardiness. The research lasted for ten months.

Nested design as described by Becker (1985) was used. Eighty Japanese quails (20 male and 60 female) were randomly caged with a mating ratio 1:3. The birds were used to generate the birds whose eggs were used for analysis. A total of 1.320 eggs were produced by 110 quail hens from the offspring of the base population at 80% hen day egg production. the eggs were collected from 10 weeks of age for a period of 20 weeks at intervals of two weeks (10, 12, 14, 16, 18 and 20 of age).

The egg weight was taken using a 0.01 g sensitive electronic scale. Egg height and width were measured using a Vernier caliper. The egg shell (after removing the internal component) was carefully washed to remove the remnant of albumen and was thereafter air-dried for 24 hours. This was then weighed using the electronic scale (0.01 g sensitive). Samples taken from sharp, blunt and equatorial parts were measured using 0.01 mmm sensitive micrometer screw gauge and the average was obtained from the values of the three parts.

For other traits that were computed, these formulars were adopted following the procedures of Kul and Seker (2004):

$S= 3.9782\ W^{0.75056}$

Where S= egg surface area (cm^2), W=egg weight (g);

Shell weight per unit surface area (mg/cm^2) = shell weight (mg)/ egg surface area (cm^2)

Shell ratio (%) = shell weight (g) / egg weight (g) x 100

Shape index (%) = (egg width (cm)/egg height (cm) x 100)

Variance and covariance components and genetic parameters were estimated using Restricted Maximum Likelihood (REML) procedures software (Harvey, 1990). Genetic correlations of the external egg quality traits were determined: correlations between external egg quality characteristics were estimated from variance and covariance components using the following formular (Becker, 1985):

$$r_{g(s)} = \frac{\text{cov}_s}{\sqrt{\sigma^2_{s(x)}}\sqrt{\sigma^2_{s(y)}}}$$

Phenotypic correlations of the egg quality traits were estimated using the following expression:

$$r_{p(s)} = \frac{\text{cov}_s + \text{cov}_w + \text{cov}_d}{\sqrt{\sigma^2_{w(x)} + \sigma^2_{s(x)} + \sigma^2_{d(x)}}\sqrt{\sigma^2_{w(y)} + \sigma^2_{s(y)} + \sigma^2_{d(y)}}}$$

Where $r_g = genetic\ correlation$

$r_p = phenotypic\ correlation$

$\text{cov} = \text{covariance component}$

$\sigma_x = variance\ component\ of\ trait\ x$

$\sigma_y = variance\ component\ of\ trait\ y$

Results

Genetic correlations between external egg quality characteristics are shown in Tables 1 to 6. Estimates ranged from low to high. Meanwhile, most estimates were moderate and high. The highest positive genetic correlation (0.99) was obtained between egg surface area (ESA) and shell weight per unit surface area (SWUS) at all ages while the lowest value (0.01) was found between egg weight (EW) and egg surface area (ESA) at ten weeks of age. Varied negative coefficients were equally obtained across the traits and ages. Negative correlation values were found between EW and SWUS, egg shape index (ESI) and shell ratio (SR) at all ages. Among the negative correlations, the highest value (-0.92) was recorded for EW and SR at both ten and twelve weeks of age. Lowest negative genetic correlation (-0.05) was found between shell weight (SW) and egg width (WE) and between ESI and average shell thickness (AVGST) both at age ten.

At all ages well, EW expressed positive genetic correlations with other external qualities, notably, egg height (EH), WE and SW. Apart from the inestimable, the positive genetic correlations recorded for EW and other qualities in this study were high except for ESA.

Table 1: Genetic (r_G above diagonal) and phenotypic (r_p below diagonal) correlations between external egg quality characteristics of Japanese quail at 10 weeks

Trait	EW	EH	WE	SW	AVGST	SR	ESA	ESI	SWUS
EW		0.80	0.91	0.50	NA	-0.92	0.01	-0.19	-0.86
EH	0.75		0.30	0.15	0.15	-0.45	0.70	-0.75	0.69
WE	0.76	0.14		-0.05	0.04	-0.30	0.31	0.36	0.29
SW	0.26	0.31	0.23		0.29	0.56	0.17	-0.27	0.18
AVGST	NA	0.09	0.04	0.22		0.20	0.05	-0.05	0.04
SR	-0.61	0.18	-0.21	0.39	-0.01		0.28	-0.43	0.29
ESA	0.01	0.45	0.40	0.58	0.23	-0.50		-0.57	0.99
ESI	-0.17	-0.69	0.41	-0.27	-0.05	0.14	-0.38		-0.58
SWUS	-0.39	0.45	0.40	0.59	0.23	0.49	0.99	-0.38S	

EW=Egg weight, EH=egg height, WE=egg width, SW=shell weight, AVGST=average shell thickness, SR=shell ratio, ESA= egg surface area, ESI=egg shape index, SWUS= shell weigh per unit surface area, NA=not available

Table 2: Genetic (r_G above diagonal) and phenotypic (r_p below diagonal) correlations between external egg quality characteristics of Japanese quail at 12 weeks

Trait	EW	EH	WE	SW	AVGST	SR	ESA	ESI	SWUS
EW		0.81	NA	NA	NA	-0.92	0.03	NA	-0.90
EH	0.77		0.44	0.80	0.27	-0.27	0.54	-0.65	0.53
WE	NA	0.15		0.14	-0.72	-0.34	0.33	-0.37	0.32
SW	NA	0.00	0.39		-0.41	-0.10	0.45	0.33	0.39
AVGST	NA	-0.01	-0.04	0.16		0.59	-0.69	-0.45	-0.69
SR	-0.64	0.08	-0.06	0.55	0.08		-0.92	0.26	-0.95
ESA	0.03	0.21	0.50	0.58	0.10	-0.34		-0.12	1.00
ESI	NA	-0.16	0.08	0.01	-0.01	0.03	-0.01		-0.08
SWUS	-0.31	0.20	0.51	0.58	0.11	-0.34	0.99	-0.02	

EW=Egg weight, EH=egg height, WE=egg width, SW=shell weight, AVGST=average shell thickness, SR=shell ratio, ESA= egg surface area, ESI=egg shape index, SWUS= shell weigh per unit surface area, NA=not available

Table 3: Genetic (r_G above diagonal) and phenotypic (r_p below diagonal) correlations between external egg quality characteristics of Japanese quail at 14 weeks

Trait	EW	EH	WE	SW	AVGST	SR	ESA	ESI	SWUS
EW		0.78	0.94	0.63	NA	-0.90	0.06	-0.12	-0.71
EH	0.60		0.58	0.31	0.61	-0.38	0.87	-0.20	0.86
WE	0.68	0.32		0.49	0.49	0.30	0.14	0.68	0.12
SW	0.23	0.32	0.33		0.67	0.64	0.12	0.21	0.12
AVGST	NA	0.37	0.27	0.66		-0.06	0.72	-0.06	0.73
SR	-0.58	-0.31	0.08	0.56	0.16		-0.67	0.61	-0.67
ESA	0.03	0.70	0.29	0.53	0.58	-0.38		-0.64	0.99
ESI	-0.05	-0.05	0.60	0.03	-0.06	0.33	0.98		-0.65
SWUS	-0.36	0.69	0.29	0.54	0.58	-0.37	NA	-0.30	

EW=Egg weight, EH=egg height, WE=egg width, SW=shell weight, AVGST=average shell thickness, SR=shell ratio, ESA= egg surface area, ESI=egg shape index, SWUS= shell weigh per unit surface area, NA=not available

Table 4: Genetic (r_G above diagonal) and phenotypic (r_p below diagonal) correlations between external egg quality characteristics of Japanese quail at 16 weeks

Trait	EW	EH	WE	SW	AVGST	SR	ESA	ESI	SWUS
EW		0.70	0.90	0.63	-0.27	-0.39	0.10	-0.16	-0.74
EH	0.59		0.53	0.43	-0.31	-0.39	0.79	-0.54	0.74
WE	0.68	0.30		0.61	-0.35	0.18	0.23	0.41	0.21
SW	0.37	0.33	0.26		0.15	0.37	0.31	0.19	0.29
AVGST	0.22	0.01	0.01	0.11		0.25	-0.16	-0.06	-0.16
SR	-0.37	-0.32	0.02	0.47	0.05		-0.75	0.62	-0.76
ESA	0.44	0.65	0.23	0.53	0.05	-0.48		-0.57	0.99
ESI	-0.51	-0.63	0.54	-0.07	0.00	0.27	-0.35		-0.57
SWUS	-0.45	0.64	0.23	0.53	0.05	-0.48	0.99	-0.35	

EW=Egg weight, EH=egg height, WE=egg width, SW=shell weight, AVGST=average shell thickness, SR=shell ratio, ESA= egg surface area, ESI=egg shape index, SWUS= shell weigh per unit surface area, NA=not available

Table 5: Genetic (r_G above diagonal) and phenotypic (r_p below diagonal) correlations between external egg quality characteristics of Japanese quail at 18 weeks

Trait	EW	EH	WE	SW	AVGST	SR	ESA	ESI	SWUS
EW		0.76	0.87	NA	NA	-0.35	0.10	-0.23	-0.75
EH	0.32		0.69	0.42	0.32	-0.31	0.78	-0.39	0.76
WE	0.32	0.28		0.57	0.07	0.08	0.43	0.39	0.40
SW	NA	0.31	0.25		0.20	0.57	0.19	0.14	0.18
AVGST	NA	0.19	0.11	0.40		0.02	0.15	-0.29	0.14
SR	-0.09	-0.21	0.08	0.53	0.15		-0.66	0.46	-0.66
ESA	0.03	0.51	0.13	0.49	0.25	-0.40		-0.43	0.99
ESI	-0.19	-0.52	0.65	-0.01	-0.05	0.21	-0.25		-0.44
SWUS	NA	0.49	0.11	0.48	0.24	-0.39	0.99	-0.25	

EW=Egg weight, EH=egg height, WE=egg width, SW=shell weight, AVGST=average shell thickness, SR=shell ratio, ESA= egg surface area, ESI=egg shape index, SWUS= shell weigh per unit surface area, NA=not available

Table 6: Genetic (r_G above diagonal) and phenotypic (r_p below diagonal) correlations between external egg quality characteristics of Japanese quail at 20 weeks

Trait	EW	EH	WE	SW	AVGST	SR	ESA	ESI	SWUS
EW		0.78	0.84	0.65	NA	-0.24	0.13	-0.24	-0.61
EH	0.43		0.65	0.46	0.25	-0.34	0.85	-0.71	0.84
WE	0.46	0.28		0.62	0.03	0.15	0.43	0.06	0.40
SW	0.23	0.24	0.24		0.58	0.55	0.38	-0.05	0.37
AVGST	NA	0.17	0.16	0.49		0.31	0.23	-0.31	0.22
SR	0.09	-0.26	-0.02	0.50	0.17		-0.55	0.54	-0.56
ESA	-0.04	0.51	0.28	0.57	0.36	-0.41		-0.67	0.99
ESI	-0.18	-0.74	0.41	-0.06	-0.06	0.21	-0.26		-0.69
SWUS	-0.18	0.51	0.28	0.57	0.36	-0.41	1.00	-0.26	

EW=Egg weight, EH=egg height, WE=egg width, SW=shell weight, AVGST=average shell thickness, SR=shell ratio, ESA= egg surface area, ESI=egg shape index, SWUS= shell weigh per unit surface area, NA=not available

Phenotypic Correlation

In a similar manner to the magnitude and signs of genetic correlations, estimates of phenotypic correlation between external egg quality traits at all ages (Tables 1 to 6) ranged low to high with most estimates being moderate and high. Similar to this report, EW had positive phenotypic correlations with other external traits except for SWUS and SR in some of the ages.

Discussion

The moderate to high genetic correlations between external egg traits suggest high pleiotropic effect or very close linkage. Selection for one trait may therefore lead to positive correlated response in the other trait. However, this is not applicable to traits having low heritability. This is because, selection of traits of low heritability may lower the expected gain from a correlated trait. Negative relationships recorded for EW and SWUS at all ages in this study were particularly high. These are expected because SWUS is the ratio of shell weight to egg surface area. The implication of the high negative correlation is that selection made to improve egg weight at all ages may lead to antagonistic effect on SWUS. Among the negative correlations, the highest value (-0.92) was recorded for EW and SR at both ten and twelve weeks of age. This points out that the genes that control these traits have greatest opposite effect on the traits at these ages. Thus, suggesting that selection made to improve SR at these ages may have highest negative impact on the egg size.

On the other hand, the lowest negative genetic correlation (-0.05) found between shell weight (SW) and egg width (WE) and between ESI and average shell thickness (AVGST) both at age ten suggests that improvement on SW and its thickness (AVGST) will not have significant effect on the WE and ESI. In other words, such improvement would not compromise egg width and shape.

At all ages, EW expressed positive genetic correlations with other external qualities, notably, egg height (EH), WE and SW. This result implies that EW appears to be the best trait for improving the external quality characteristics at all ages examined in this study. Similar observations were earlier reported by Sezer (2007) and Kul and Seker (2004) in Japanese quail. In general, the positive genetic correlations observed between SW and all other external qualities at all the ages is an indication that selection made on the external quality traits would have favourable effect on some shell qualities.

The inestimable estimates have earlier been observed by researchers in quail. For instance, the earlier findings of Sezer (2007) in Japanese quails attest to the result of this study. This could imply small data or implying missing data. Genetic correlation of 0.94 recorded for EW and its width (WE) by Sezer (2007) at twelfth week coincides with 0.94 observed at week fourteen in this study. Similar results have equally been reported in domestic fowls by Choprakarn *et al.* (1998). Moderate negative genetic correlations of -0.12 and -0.16 reported in this study at weeks fourteen and sixteen between EW and ESI are similar to -0.14 obtained by Sezer (2007) at twelve weeks of age. EW had positive correlation with both width and height but negatively correlated with ESI. Meanwhile, its magnitude with WE were higher than that with EH indicating that egg size is limited by egg height rather than its width.

High negative correlations of -0.86 and -0.90 recorded between egg weight and shell weight per unit surface area at the tenth and twelfth weeks of age, respectively in this study are not far from the value (-0.88) earlier published for same traits by Sezer (2007) at twelve weeks of age. According to Abdullahi *et al.* (1993), SR and SWUS are more negatively correlated with egg weight and egg height. The authors mentioned that the consequence of this association is that larger eggs would have proportionately less shell weight which would result to low shell weight per unit surface area. Thus, egg with delicate shell could be the outcome of selection for improved EW.

Because of high positive correlation between ESI and SR, eggs with round shape may likely have better SW than those of others. Thereby, crushing strength of the egg is improved; an essential requirement for table eggs. More so, this study also suggests that EW could be used as a descriptor for some egg shell quality while the egg is still unbroken because of the high positive correlations between egg and shell weight. Farooq *et al.* (2001) in their work concluded that EW, height and width could serve as indicators for hatching chicks' weight because of high positive correlations found between hatched chicks' weight; egg height and width.

A range of genetic correlations (0.04 – 0.47) between external qualities of egg reported in Bobwhite quail by Ingram *et al.* (1989) is is lower than our repot in Japanese quail. The variations in our results and those of other researchers might be linked with differences in genetic structures, health conditions, flocks' ages, feeding, care and management of the experimental birds while climatic conditions peculiar to the study areas are equally not left out.

There were similarities in the patterns of genetic and phenotypic correlations of egg quality traits as manifested in both magnitude and signs. Though ESA and ESI were as well negatively correlated with EW in most ages, the magnitude was relatively low. The low to high phenotypic coefficients (0.03 to 0.99) obtained between external quality traits were similar to 0.01 – 0.85 reported by Sezer (2007) between the same traits in Japanese quails at twelve weeks of age. In the same vein, the phenotypic correlations between EW and the external qualities were in conformity with the reports of Kul and Seker (2004) in Japanese quail at twenty weeks of age. However, the values were comparatively higher than the estimates reported by Jibril (2009) in Japanese quail (week eight to twenty). The high correlation of 0.41 obtained between WE and ESI at twenty weeks of age in this study conforms with 0.40 reported by Jibril (2009) at the same age. Meanwhile, lower estimates of 0.34 and 0.28 have been earlier reported by Kul and Seker (2004) and Sezer (2007) in Japanese quail at twenty and twelve weeks of age, in that order.

There is similarity between the positive phenotypic correlation (0.22) reported for egg weight and average shell thickness at age sixteen in this study and 0.21 reported by Kul and Seker (2004). Jibril (2009) reported a higher estimate of 0.31, while lower and negative values (-0.007 and -0.05) were reported by Ingram *et al.* (1989) in Bobwhite quail. A large and particularly the difference in sign could be explained as influence of both genetic and environmental sources of variation on the traits through different physiological mechanisms (Falconer and Mackay, 1996).

Conclusion

EW appears to be the best trait for improving external quality traits and could be a descriptor for some egg shell quality while the egg is still unbroken. Positive correlations between SW and other external qualities could make selection on external quality traits to favour some shell qualities. SR could have high antagonistic impact on egg size. Eggs with round shape may likely have better SW than those of others thus with good crushing strength. The results of this research should therefore be incorporated in designing breeding strategy to improve external egg quality traits of Japanese quails.

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