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Original Research

Whole egg quality trait phenotypic correlations in aged layer chicken genotypes

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ABSTRACT
Phenotypic correlations between egg weight (EW) and length (EL), diameter (ED), surface area (ESA), volume (EV), specific gravity (ESG), and shape index (ESI) were evaluated in Shaver Brown (SB), and Nigerian heavy ecotype (HE) hens using Pearson's correlation method. None zero coefficients were interpreted as perfect, near perfect, very strong, strong, moderate, weak, or very weak. The EW, EL, ED, ESA, EV, and ESG differed significantly between genotypes ($p < 0.000$). Eggs from SB had higher values for these traits except ESG which was higher in HE eggs. Egg weight perfectly correlated with ESA, EV, and ESG, and very weakly with ESI in both genotypes; moderately with EL in HE but strongly with this trait in SB; perfectly with ED in HE, but very weakly with this variable in SB. Egg length had moderate positive correlations with ED, ESA and EV, moderate negative correlation with ESG, and a strong negative correlation with ESI in HE but very weak positive correlation with ED, strong correlations with ESA ($r = -0.718$), EV ($r = 0.706$), and ESG ($r = -0.718$), and weak negative correlation with ESI ($r = -0.267$) in SB. Egg diameter was perfectly correlated with ESA, EV, and ESG in HE but, very weakly with these traits in SB. The observed variations in direction or strength of correlation between genotypes suggest significant genetic effects. Phenotypic correlation could hence be used to understand egg quality trait interrelationships in different layer chicken breeds, and guide non-destructive determination, and genetic improvement of whole egg quality traits.

Keywords: Aged hens, egg quality, layer genotype, phenotypic correlation, strength of correlation

INTRODUCTION
Egg quality refers to egg traits which influence consumer acceptance, price of eggs, and the nutritional, industrial, and reproductive roles of eggs (Baykalir & Aslam, 2020). These traits include whole egg or pre-broken, and egg component or post-broken egg traits. Whole egg quality traits include egg weight, egg length, egg width, egg surface area, egg volume, egg specific gravity, and egg shape index while egg component traits include albumen, yolk, and shell quality traits (Biesiada-Drzazga, 2020). Whole egg quality traits can be evaluated by visual assessment, and measurements without the need to break (destroy) the egg. On the other hand, assessment of egg component traits requires the breaking of the egg implying the loss of table or hatching eggs (Narushin & Romanov, 2002). Whole egg or pre- broken egg traits influence the economics of table and hatching eggs. This is because the financial returns from egg production depend on the rate of lay, and the size, and wholesomeness (integrity) of eggs produced (Kgwatalala *et al.*, 2016; Mustafa *et al.*, 2017). Environmental and genetic factors influence whole egg quality traits (Inca *et al.*, 2020). Environmental factors include ambient temperature, humidity, duration of storage, diet, nutritional status, and age of hen; health and disease, management practices, and husbandry system (Yang *et al.*, 2014). Genetic factors include species, breed or genotype of hen, extent and direction of genetic selection, and selective breeding (Amao *et al.*, 2016; Yahaya *et al.*, 2023). The value of whole egg quality traits has been shown to vary between bird species, hen genotypes, age of laying hens, ecological zones, farms, management, and husbandry systems, and within and between laying cycles (Vekic *et al.*, 2022; Tunsisa & Reda, 2023). In addition, heat stress, nutrient deficiencies, and ageing influence egg size, egg shape, shell strength, and overall quality of the egg (Usman *et al.*, 2014; Shaker *et al.*, 2021). Since numerous environmental factors influence egg quality, there is need to continuously evaluate the quality of eggs produced within each production enterprise.

The age of the laying flock is of particular interest in evaluating egg quality. This is because egg quality changes

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as the laying period advances. Egg weight, surface area, and volume increase with the age of the hen whereas egg specific gravity decreases (Kontecka *et al.,* 2012) due to decrease in shell thickness (Molnar *et al.,* 2016; Park & Sohn, 2018). It has been reported that increase in egg size with the age of the hen is not accompanied by a proportionate increase in shell weight (Alkan *et al.,* 2015; Inca *et al.,* 2020). The reduced shell thickness as egg weight, surface area, and volume increase with advance in age was hence attributed to a less than proportionate increase in shell deposition (Roberts *et al.,* 2013; Park & Sohn, 2018). The negative impacts of stress due to ageing and artificial control measures such as lighting or photoperiod, temperature, humidity, and nutrition on hen performance (Zhang *et al.,* 2021) also contribute to the decrease observed in some whole egg quality traits. These changes could be due to alterations in ovarian regulatory hormone secretion, damage to follicular cells, and lowered oocyte quality (Youris, 2012; Zhang *et al.,* 2022).

The impact of whole egg quality traits on egg integrity and functions has been the subject of intense research over the decades. Egg size, surface area, volume, and shape influence egg nutrient content, and composition, chick embryo nutrition, and development, hatchability and hatchling quality (Hegab & Hanafy, 2019; Kostaman & Sopiyana, 2021). In addition, the traits influence albumen, yolk, and shell quality which in turn impact overall egg quality, food and processing value, embryo development, and hatching rate (Paganelli *et al.,* 1974; Mortola & Al Awam, 2010; Shaker *et al.,* 2021). Egg size, surface area, volume, shape, and shell quality influence the number of eggshell pores which regulate gaseous exchange between the egg and external environment, water, and egg weight loss during storage or incubation (Yamak *et al.,* 2016; Veldsman *et al.,* 2020; Karabulut, 2021). All these impact egg quality, commercial value, and the yield of chicks from hatching eggs.

Egg quality traits are interrelated due to common genetic background (inheritance of genes controlling multiple traits, and/or inheritance of linked genes controlling different traits). The direction and strength of egg quality trait correlations could vary between genotypes, as a result of different genetic backgrounds, selection and breeding history, and genotype x environment interaction effects. Egg quality interrelationships could hence characterize laying flock genetics, age and cycle of production, husbandry system, and production environment. Variations in strength and/or direction of phenotypic correlations between egg quality traits were reported in normal feathered, naked neck, and frizzle feathered native hens (Kgwatalala *et al.,* 2016), three varieties of Japanese quail (Chimezie *et al.,* 2017), varieties of helmeted guinea fowl (Manyeula *et al.,* 2020), and between Pofchestroom koekoek native hens and Hy-Line Silver Brown layers (Tyasi *et al.,* 2022).

The correlation among whole egg quality traits permits the formulation of mathematical models for the determination of traits not directly measurable; and the non-destructive determination of albumen, yolk, and shell quality traits. Furthermore, it gives significant information for the genetic evaluation of flocks, and for predicting the consequences of selection on traits such as egg weight, length, and width on other traits such as egg surface area, volume, and specific gravity which impact the value of table, and hatchery eggs (Oblakova, 2006; Manyeula *et al.,* 2020). Egg weight or size, surface area, volume, and shape influence shell weight, and shell thickness (Karabulut, 2021). Shell thickness determines shell strength, shell porosity, and variables related to gaseous exchange, and water loss (Okuda and Tazzaw, 1988; Jibir *et al.,* 2013; Shaker *et al.,* 2021). Egg length and width enable the calculation of egg surface area, volume, specific gravity, density, shape index; albumen, yolk, and shell quality traits (Copur-Akpinar *et al.,* 2017; Alasahan *et al.,* 2019; Karabulut, 2021).

The phenotypic correlation between egg traits has been extensively reported in exotic chickens, especially in hens in their first laying cycle however, very little emphasis has been given to the strength of association between the traits. In addition, very scanty information exist on the phenotypic correlation between egg traits in aged Nigerian heavy ecotype and Shaver Brown layer chickens, and how this differs between the two layer chicken strains for different traits. Knowing the strength of correlation between egg traits will permit the design of selection schemes for their genetic improvement especially, in the native hens, and/or the formulation of optimal predictor models for their estimation. The present study therefore, evaluated the phenotypic correlation of whole egg traits in aged laying hens with emphasis on the strength and direction of association between traits.

MATERIALS AND METHODS

Forty (40) 85-weeks-old Shaver Brown (SB) and Nigerian heavy ecotype (HE) native hens were used for the study. The SB is a commercial layer hybrid popularly reared in the study environment due to its hardiness, and high egg production potential while the HE is a local chicken genotype which had undergone three generations of multi- trait index selection for improved egg production (Ogbu & Nwosu, 2017). The study complied with the ethical provisions on the use of animals for biomedical research, and was approved by the Academic Board of the Department of Animal Science, Faculty of Agriculture, University of Nigeria Nsukka – an Institutional Review Board.

The birds were 65 weeks in lay at the commencement of the study and were housed in individual cages equipped with feed troughs and water nipples. They were fed a layer ration containing 16.5 % crude protein and 2600 kcal ME/kg at 125 g/bird/day (**Table I**). The feed was divided into two portions and fed at 08:30 h and 14:00 h. Water was given *ad libitum*. The study lasted for 21 days during which egg production was recorded. Egg quality measurement was performed on 120 eggs (80 from SB and 40 from HE hens) collected within the last 5 days of the study period.

DETERMINATION OF EGG QUALITY TRAITS

Egg weight (EW) was measured using a digital scale (Camry, Japan, sensitivity: 0.01g). Egg length (EL, distance between blunt and pointed ends), and egg diameter (ED, distance across the equator of egg) were measured with a vernier calliper (sensitivity: 0.01 cm).

Using data from direct measurements, the following egg quality traits were calculated:

Egg surface area (ESA, cm2) = 3.9782 x EW0.7056 (Nordstrom & Ousterhout, 1982),

Egg volume (EV, cm3) = 0.7608 x EW1.0474 (Carter, 1975),

Egg specific gravity (ESG, g/cm3) = EW/EV (Karabulut, 2021), and

Egg shape index (ESI, %) = ED x 100/EL (Karabulut, 2021).

DATA ANALYSIS

Data obtained were presented using descriptive statistics while comparisons between genotypes were performed using the independent samples t-test. Correlation analysis was executed using the Pearson correlation. All analysis was carried out in SPSS for Windows, version 20.0. Zero correlation coefficient (r) was interpreted as lack of phenotypic association between traits while none zero coefficients were interpreted as perfect (r = 0.95 – 1.00), near perfect (r = 0.85 – 0.94), very strong (r = 0.75 – 0.84), strong (r = 0.65 – 0.74), moderate (r = 0.45 – 0.64), weak (r = 0.25 – 0.44), or very weak (r = 0.10 – 0.24) (**Table II**).

RESULTS

COMPARISON OF WHOLE EGG QUALITY TRAITS BETWEEN GENOTYPES

The descriptive statistics for whole egg quality traits, and the comparison between genotypes were presented in **Tables III** and **IV**, respectively. Among the traits evaluated, ESI showed the highest phenotypic variation (σp2) in the two genotypes while ESG was the least variable egg quality trait (**Table III**). Egg shape index, EW, ESA, and EV were more variable in SB (σp2 = 128.07, 23.91, 16.81, and 22.44, respectively) than in HE eggs (σp2 = 52.43, 13.56, 13.00, and 12.09, respectively). Except ESI, other egg ED and ESI in HE and SB, respectively.
(r = - 0.267) in SB.

quality traits differed significantly between genotypes (**Table IV**). Eggs of SB hens had significantly higher EW, EL, ED, ESA, and EV but lower ESG compared to eggs of HE hens (p < 0.000).

The correlation matrix of whole egg quality parameters were presented in **Table V** for HE (above diagonal) and SB (below diagonal).

Egg weight (EW) had a moderate positive correlation with EL in HE (r = 0.560), but a strong positive correlation in SB eggs (r = 0.708), a perfect positive correlation with ED in HE (r = 0.958), but a very weak positive correlation in SB (r = 0.007), weak correlations with ESI (r = 0.170 versus – 0.203 for HE versus SB), and perfect correlations with ESA (r = 1.000, respectively), EV (r = 1.000, respectively), and ESG (r = - 0.994 versus - 0.993) in both genotypes. Egg length (EL) had moderate positive correlations with ED, ESA and EV, moderate negative correlation with ESG and a strong negative correlation with ESI in HE but, a very weak positive correlation with ED, strong correlations with ESA (r = - 0.718), EV (r = 0.706) and ESG (r = - 0.718), and weak negative correlation with ESI (r = - 0.267) in SB.

Egg diameter (ED) was perfectly correlated with ESA (r = 0.955), EV (r = 0.953), and ESG (r = - 0.953) in HE but, very weakly correlated with the traits in SB (r = 0.008, 0.005, 0.049, respectively). A weak, and perfect positive correlation was observed between traits had perfect

Table I: Composition of layer diet fed to aged Shaver Brown (SB), and heavy ecotype native (HEN) hens

	Composition		
	Proximate of major ingredients		
Ingredients	**Ingredient composition (%)**	**Crude protein (%)**	**Metabolizable energy (kcal/kg)**
Maize	43.0	9.0	3430
Wheat offal	18.0	17.0	1870
Soy bean cake	17.5	44.0	2400
Palm kernel cake	9.0	18.0	2800
Fish meal	2.5	50.0	2700
Bone meal	3.0	-	-
Lysine	0.25	-	-
Methionine	0.25	-	-
Vitamin premix	0.25	-	-
Salt	0.25	-	-
Oyster shell	6.0	-	-
Total	100		
Calculated			
Crude protein (%)	16.5	-	-
Kcal ME/kg	2600	-	-

Egg surface area (ESA) was perfectly and positively correlated with EV abd SB (r= 0.99 versus 1.000) and the two traits had

Table II: Interpretation of coefficient of phenotypic correlation (r)

Coefficient (r)	Strength of association	Inference (considering traits A and B)
0.95 to 1.00	Perfect positive correlation	As A is improved, B improves proportionately.
0.94 to 0.85	Near perfect positive correlation	As A is improved, B improves almost proportionately.
0.84 to 0.75	Very strong positive correlation	Improvement in A leads to substantial improvement in B.
0.74 to 0.65	Strong positive correlation	Improvement in A leads to marked improvement in B.
0.64 to 0.45	Moderate positive correlation	Improvement in A leads to a fair improvement in B.
0.44 to 0.25	Weak positive correlation	Improvement in A leads to a small improvement in B.
0.24 to 0.10	Very weak positive correlation	Improvement in A leads to a minor improvement in B.
0.00	No phenotypic relationship	Traits are phenotypically unrelated.
- 0.10 to - 0.24	Very weak negative correlation	Improvement in A leads to a minor loss in B.
- 0.25 to - 0.44	Weak negative correlation	Improvement in A is accompanied by small decrease in B.
- 0.45 to - 0.64	Moderate negative correlation	Improvement in A is accompanied by a fair decrease in B.
- 0.65 to - 0.74	Strong negative correlation	As A is improved, B decreases remarkably.
- 0.75 to - 0.84	Very strong negative correlation	As A is improved, B decreases substantially.
- 0.85 to - 0.94	Near perfect negative correlation	As A is improved, B decreases almost proportionately.
- 0.95 to - 1.00	Perfect negative correlation	As A is improved, B decreases proportionately.

Table III: Descriptive statistics for whole egg quality traits in Shaver Brown and Heavy ecotype native hens

	Descriptive statistics			
Genotype/trait	**Mean ± SD**	**Minimum**	**maximum**	**Variance (σ_p^2)**
SB				
EW (g)	58.82 ± 4.89	53.70	67.50	23.91
EL (cm)	4.17 ± 0.15	3.95	4.40	0.02
ED (cm)	3.05 ± 0.44	2.22	3.90	0.19
ESA (cm^2)	70.47 ± 4.10	66.12	77.69	16.81
EV (cm^3)	54.29 ± 4.74	49.35	62.71	22.44
ESG (g/cm^3)	1.08 ± 0.00	1.08	1.09	0.00
ESI (%)	73.16 ± 11.32	53.88	95.12	128.07
HE				
EW (g)	37.88 ± 3.68	29.00	42.60	13.56
EL (cm)	3.50 ± 0.29	2.80	3.90	0.08
ED (cm)	2.29 ± 0.12	2.00	2.44	0.02
ESA (cm^2)	51.64 ± 3.61	42.81	56.17	13.00
EV (cm^3)	34.25 ± 3.48	25.88	38.72	12.09
ESG (g/cm^3)	1.07 ± 0.01	1.10	1.12	0.00
ESI (%)	65.92 ± 7.24	57.69	86.43	52.43

SB: Shaver Brown hen, HE: Heavy ecotype native hen, SD: Standard deviation. EW: egg weight, EL: egg length, ED: egg diameter, ESA: egg surface area, EV: egg volume, ESG: egg specific gravity, ESI: egg shape index.

Table IV: Whole egg quality traits in Shaver Brown and Heavy ecotype hens

	Whole egg traits						
Genotype	**EW (g)**	**EL (cm)**	**ED (cm)**	**ESA (cm^2)**	**EV (cm^3)**	**ESG (g/cm^3)**	**ESI (%)**
SB	58.82 ± 1.36[a]	4.17 ± 0.04[a]	3.05 ± 0.12[a]	70.47 ± 1.14[a]	54.29 ± 1.31[a]	1.08 ± 0.00[b]	73.16 ± 3.14
HE	37.88 ± 1.06[b]	3.50 ± 0.08[b]	2.29 ± 0.04[b]	51.64 ± 1.04[b]	34.25 ± 1.00[b]	1.11 ± 0.00[a]	65.92 ± 2.09
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.072

Values are means ± SE, a,b: column means with different superscripts are significantly different. EW: egg weight, EL: egg length, ED: egg diameter, ESA: egg surface area, EV: egg volume, ESG: egg specific gravity, ESI: egg shape index, SB: Shaver Brown hen, HE: Heavy ecotype hen.

negative correlations with ESG in both genotypes. Very weak positive correlations were observed for ESI with ESA (r = 0.176), and EV (r = 0.169) in HE but, very weak negative correlations were observed between the traits in SB (r = - 0.204 and -0.206, respectively). The correlation of ESI with ESG in HE was very weak and negative (r = - 0.184) but weak and positive in SB (r = 0.263).

DISCUSSION

The higher phenotypic variation observed in egg shape index (ESI) in the two genotypes compared to other whole egg traits reflects the wide range of egg shapes possible in the domestic chicken. The result also supports the report that egg shape in avian species is a continuum (Stoddard *et al.,* 2017). The ESI describes normal and abnormally shaped eggs (Shaker *et al.,* 2021). Commonly described egg shapes in the domestic chicken are sharp (ESI: ≤ 72), standard or oval (ESI = 72 - 76), and round (ESI: > 76) (Duman *et al.*, 2016; Shaker *et al.,* 2020). The higher phenotypic variance observed in EW, EL, ED, ESA, EV, and ESI in SB eggs compared to HE eggs indicate that SB hens lay eggs of a wider range of sizes, and shapes than the HE hens. Native (autochthonous) breeds lay predominantly small and medium-sized eggs that are mostly sharp or elongated (Skrbic *et al.*, 2011). On the other hand, commercial hybrids like the SB produce eggs that range in size from small, medium, large, extra-large, to jumbo and these eggs span a wider range of egg shapes. Egg weight in commercial hybrid layers ranges from 45 – 80 g (Shaker *et al.,* 2016; Tumova *et al.,* 2017) but 33 – 57 (Ali *et al.,* 2022; Imouokhome & Omatsuli, 2022) in native chickens depending on genetics. The significantly higher EW and geometrical egg traits (EL, ED, ESA, and EV) in SB eggs compared to HE eggs indicate genetic differences in egg weight or size, and egg dimensions between the genotypes. These observations were in agreement with previous reports (Hanusova *et al.,* 2015; Joubrane *et al.,* 2019). Genetic differences in growth rate, and feed intake between domestic chicken breeds, and genotypes are believed to contribute to genotypic variation in egg size (Ozenturk & Yildiz, 2020). This is in addition to differences in selection history for egg production traits. Some previous studies (Wall *et al.,* 2010; Valentin *et al.,* 2019) however,. observed a non-significant effect of genotype on EW The discrepancy may be associated with the degree of genetic diversity between studied breeds. The Shaver Brown breed is a vastly improved commercial hybrid layer whereas the heavy ecotype chicken is a local strain that is partially improved for egg traits. The lower ESG observed in SB eggs compared to HE eggs agreed with Almeida *et al.* (2021), and this indicates lower shell thickness in SB eggs probably due to the larger eggs from this breed compared to the HE hen. It has been reported that large eggs have lower shell thickness (Molapo & Motselisi, 2020), and ESG (Brunelli *et al.*, 2010; Almeida *et al.*, 2021) compared to small eggs. Even though ESI did not differ significantly between the genotypes, it tended to be higher in SB eggs indicating a rounder egg shape compared to the sharper (more elongated) shape of HE eggs.

The correlation between egg quality traits reveals the direction and strength of association between traits, and this enables improvement, and prediction of some egg quality variables using easier-to-determine counterparts (Narushin *et al.,* 2005; 2022). In the present study, descriptors of strength of phenotypic correlation were adopted to describe the relationship between whole egg traits. The moderate to perfect correlations between EW, EL, ESA, EV and ESG in SB, and EW, EL, ED, ESA, EV, and ESG in HE eggs were consistent with previous studies (Shaker *et al.,* 2016; Tyasi *et al.,* 2022). The near-perfect negative correlation between EW and ESG in both genotypes was in concord with Brunelli *et al.* (2010), and Almeida *et al.* (2021), and this could be attributed to the reduced shell thickness as egg size increases (Favero *et al.,* 2013; Vekic *et al.,* 2022). The perfect positive correlations between EW, ESA and EV indicate a proportionate, and direct relationship between these traits. The results also indicate that EW, ESA and EV can be predicted from one another (Duman *et al.,* 2016; Karabulut, 2021). The very weak correlation of EW with ESI in the two breeds agreed with Shi *et al.* (2009), and Guni *et al.* (2021).

Table V: Correlation coefficients of whole egg quality parameters in heavy ecotype (above diagonal) and Shaver brown (below diagonal) hens

Trait	EW (g)	EL (cm)	ED (cm)	ESA (cm^2)	EV (cm^3)	ESG (g/cm^2)	ESI (%)
EW		0.560*	0.958**	1.000**	1.000**	-0.994**	0.170
EL	0.708**		0.486*	0.555*	0.560*	-0.546*	-0.712**
ED	0.007	0.030		0.955**	0.953**	-0.953**	0.258*
ESA	1.000**	0.709**	0.008		0.999**	-0.997**	0.176
EV	1.000**	0.706**	0.005	1.000**		-0.994**	0.169
ESG	-0.993**	-0.718**	0.049	-0.993**	-0.994**		-0.184
ESI	-0.203	-0.267*	0.955**	-0.204	-0.206	0.263*	

EW: egg weight, EL: egg length, ED: egg diameter, ESA: egg surface area, EV: egg volume, ESG: egg specific gravity, ESI: egg shape index, *: significant at p ≤ 0.05; **: significant at p ≤ 0.01.

The results indicate a minor influence of EW on ESI. Duman *et al.* (2016) also reported a very weak correlation (r = 0.18) between EW and ESI. EL and ED were very poorly correlated in SB, and this aligned with Alkan *et al.* (2015). This could be due to the 'rounder' shape of eggs from this breed while the moderate positive correlation between the two traits in HE eggs concurred with other reports (Guni *et al.,* 2021; Tyasi *et al.,* 2022), and this could be attributed to the more elongated or 'pointer' shape of HE eggs (Skrbic *et al.,* 2011; Rakonjac *et al.,* 2021). The perfect positive correlation of ED with ESA, and EV in HE eggs were in alignment with Alkan *et al.* (2015), and Tyasi *et al.* (2022). This indicates a directly proportional relationship between the variables in HE eggs. ED is used to determine ESA, and EV. The moderate to perfect negative correlations of ESG with geometrical egg traits (EL, and ESA in SB eggs, and EL, ED and ESA in HE eggs) corroborated the findings by Inca *et al.* (2020), and this could be attributed to the reduced shell thickness as these traits increase in value (Favero *et al.,* 2013; Vekic *et al.,* 2022). Egg shape index (ESI) was very weakly correlated with ESA, and EV in SB, and ESA, EV and ESG in HE eggs, and these agreed with previous studies (Aktan, 2005; Altuntas & Sekeroglu, 2008). The results indicate that changes in the values of ESA, and EV in SB, and ESA, EV, and ESG in HE eggs have very minimal influence on ESI. The weak to strong negative correlations of ESI with EL, and positive correlations with ED in both genotypes agreed with Inca *et al.* (2020). Egg length and ED determine ESI however; ED seemed to have a greater influence on ESI in SB eggs (r = 0.955 for ED versus - 0.267 for EL) probably due to the genetic adaptations, or selection for more spherical or oval-shaped eggs namely: poor flight capacity, deeper abdominal cavity, more prominent oviduct, and wider pelvis (Stoddard *et al.,* 2017) in this breed compared to the HE genotypes. On the other hand, EL appeared more important for ESI in HE eggs (r = - 0.712 for EL versus 0.258 for ED) probably owing to the genetic adaptations to lay elongated or pointer eggs (Skrbic *et al.,* 2011) namely: more streamlined body, shallower abdominal cavity, less robust oviduct, higher flight capacity, and narrower pelvis (Stoddard *et al.,* 2017).

CONCLUSION

Egg weight (EW), ESA, EV, and ESI were more varied in both genotypes compared to other traits, and in SB eggs compared to HE eggs. Similar phenotypic correlations were observed between some egg quality traits in HE and SB eggs but also variations in direction and/or strength of correlations between other whole egg traits in the two genotypes. This indicates genotypic effects probably due to differences in genetic background, genetic interaction effects on the egg traits, degree of genetic selection, and selection pathway applied to the genotype. The SB layer is a commercial hybrid derived from highly selected parental lines whereas the heavy ecotype chicken is essentially unimproved. The genetic underpinnings of egg quality traits in the two genotypes could differ in their associations, and interactions resulting in the observed variations in strength and/or direction of phenotypic correlations between the whole egg quality traits.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interests.

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