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PHENOTYPIC CORRELATIONS BETWEEN EGG QUALITY TRAITS AMID THE LAYING PHASE OF BROILER BREEDER HENS

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SUMMARY

In order to determine phenotypic correlations between the quality traits of eggs from 41-week-old broiler breeder hens (Cobb 500), a total of 105 eggs suitable for incubation were analyzed using descriptive statistics and Pearson's correlation coefficient. The average values of egg weight, egg length, egg width, egg shape index, shell thickness, shell weight, and shell ratio were 66.90 g, 60.00 mm, 44.81 mm, 74.70%, 0.37 mm, 6.07 g, and 9.07%, respectively. Moreover, the average values of yolk weight, albumen weight, yolk ratio, albumen ratio, Haugh units, yolk index, and yolk-to-albumen ratio were 20.04 g, 40.80 g, 29.97%, 60.95%, 82.12, 46.17%, and 0.49, respectively. A significant positive correlation ($p < 0.01$) was found between the egg weight and the egg length (0.75), egg width (0.80), shell (0.55), yolk (0.60), albumen weight (0.91), and albumen ratio (0.25). However, a significant negative correlation ($p < 0.01$) was found between the egg weight and both the yolk ratio (-0.20) and yolk-to-albumen ratio (-0.23). The egg shape index proved not to be significantly correlated with any of the internal egg quality traits considered. The shell thickness was in a significant positive correlation ($p < 0.01$) with the shell weight (0.83) and ratio (0.86), whereas a significant negative correlation ($p < 0.05$) was found between the shell thickness and yolk ratio (-0.23). The Haugh units were in a significant positive correlation ($p < 0.05$) with the albumen ratio (0.24) and yolk index (0.27), whereas a significant negative correlation ($p<0.05$) was found between the Haugh units and both the yolk ratio (-0.22) and yolk-to-albumen ratio (-0.23). The results obtained confirm significant phenotypic correlations not only between egg weight and the egg quality traits considered, but also between a number of external and internal quality traits of broiler hatching eggs.

Key words: *hatching egg, egg quality traits, phenotypic correlation*

INTRODUCTION

Hatching eggs are the main commercial product of broiler breeder flocks. Therefore, equal attention should be devoted to producing high-quality eggs and achieving a satisfactory laying capacity of the flock (Biesiada-Drzazga, 2020). In addition to storage and incubation conditions, egg quality is considered one of the most important factors in hatching and chick quality (King'ori, 2011). There are also other factors, varying according to the breeder flock and hatchery, which can affect incubation results (Yassin et al., 2008). The practical assessment of quality and suitability of eggs for incubation on breeder farms is mainly carried out according to external egg quality traits such as egg weight, shape, shell structure and condition, as well as internal egg quality properties such as albumen and yolk quality (Peruzzi et al., 2012; Biesiada-Drzazga, 2020). External egg quality traits can be generally assessed by visual inspection in a non-destructive manner. However, the quality assessment of albumen and yolk require destructive methods, implying the loss of hatching eggs (Narushin & Romanov, 2002). Almost all external and internal egg quality traits change during the laying period of broiler breeder hens. With the advance of the laying period, egg weight increases (mainly due to increasing yolk weight), whereas egg shape index, shell ratio, shell thickness, yolk

index and Haugh units decrease (Đermanović et al., 2010; Kontecka et al., 2012; Favero et al., 2013) (which generally indicates a deterioration in egg quality as the laying period progresses). In addition to the age of hens, the quality of eggs is also influenced by numerous genetic and non-genetic factors varying across different broiler breeder flocks and farms, the most important of which are the genotype, nutrition, health status and ambient conditions (King'ori, 2011).
Egg quality and phenotypic correlations between egg quality traits were the subject of studies conducted on table egg layers of both commercial strains and different indigenous breeds (Şekeroğlu & Altuntaş, 2009; Moula et al., 2010; Debnath & Ghosh, 2015; Kgwatalala et al., 2016; Molnár et al., 2016; Ukwu et al., 2017; Sirri et al., 2018; Inca et al., 2020). However, the results obtained in such studies are rarely available in the literature. Wolanski et al. (2007) conducted research involving ten different broiler breeder strains and found a significant correlation between egg weight and egg shell, albumen and yolk weight (the correlation between egg weight an shell thickness was found non-significant). Olawumi & Ogunlade (2008) found a significant correlation between almost all internal egg quality traits and egg weight in one commercial layer breed. The existence of collinearity in the assessment of basic parts of eggs from broiler breeders (namely egg weight, length, width, and egg shape index) was evaluated by Shafey et al. (2015). Differences in egg quality and correlations between egg quality traits in the maternal and paternal strains of layer breeds was examined by Ahmadu et al. (2018).
The purpose of this study is to determine the values of and phenotypic correlations between the quality traits of eggs from 41-week-old broiler breeder hens (Cobb 500).

MATERIAL AND METHODS

Egg quality determination

A total of 105 hatching eggs, collected from a single 41 week-old broiler breeder flock (Cobb 500) reared on a commercial farm, were enrolled in this study. All the eggs collected were typical of the laying period and suitable for incubation according to their external quality traits.
Upon marking each egg for identification, their quality traits were determined. The egg weight was determined first, using a technical scale Kern EMB 200-2 (with an accuracy of ± 0.01 g), followed by the egg length and width, using a digital caliper Horex (with an accuracy of ± 0.01 mm). Upon cracking the eggs on a flat surface, the height of the thick egg albumen was determined, using a Baxlo Precision tripod micrometer (with an accuracy of ± 0.1 mm). The height and diameter of the yolk were measured using a Horex digital caliper (with an accuracy of ± 0.01 mm). Thereafter, the yolks were carefully separated from the egg albumen and rolled in a paper towel to remove albumen residues before weight measurements using a Kern EMB 200-2 technical scale (with an accuracy of ± 0.01 g). The egg shells with shell membranes were washed in water to remove the albumen and, after three days of drying at room temperature, the weight of egg shells was determined using a Kern EMB 200-2 scale (with an accuracy of ± 0.01 g). The thickness of the egg shell with membranes was also determined after three days by performing measurements at three different locations in the equatorial region of the shell (using a micrometer with an accuracy of ± 0.01 mm), upon which the average value of the measurements was computed. The data obtained by direct measurement were used to calculate the following egg quality traits, using the equations from Olawumi & Ogunlade (2008), Moula et al. (2010) and Inca et al. (2020):

Egg shape index (%) = (egg width (mm) / egg length (mm)) x 100
Shell ratio (%) = (shell weight (g) / egg weight (g)) x 100
Albumen weight (g) = egg weight (g) – (yolk weight (g) + shell weight (g))
Albumen ratio (%) = (albumen weight (g) / egg weight (g)) x 100
Yolk ratio (%) = (yolk weight (g) / egg weight (g)) x 100
Yolk index (%) = (yolk height (mm) / yolk diameter (mm)) x 100
Yolk-to-albumen ratio = yolk weight (g) / albumen weight (g)
Haugh unit = $100 \times \log (H + 7.57 - 1.7 \times W^{0.37})$, where are: H – albumen height (mm), W – egg weight (g).

Statistical analysis

The data obtained were processed using descriptive statistics. Accordingly, the standard deviation, minimum, maximum, and coefficient of variation were calculated for each egg quality trait. A linear correlation analysis was performed to calculate the Pearson correlation coefficients between the egg quality traits examined (statistically significant at $p < 0.05$ and $p < 0.01$).

RESULTS AND DISCUSSION

Descriptive statistics of the egg quality traits considered

Hatching eggs should be fertilized and stored within a reasonable time before incubation (King'ori, 2011). They should also meet certain quality criteria necessary for the normal embryonic development, thus resulting in satisfactory hatchability and chick quality (Narushin & Romanov, 2002; Biesiada-Drzazga, 2020). The external and internal egg quality traits determined in this study are shown in Table 1.

Table 1. Descriptive statistics of the external and internal egg quality traits considered

Egg quality traits	M	SD	Min	Max	CV
Egg weight (g)	66.90	3.64	59.26	75.15	5.44
Egg length (mm)	60.00	1.53	56.78	64.40	2.54
Egg width (mm)	44.81	0.83	42.93	46.72	1.84
Egg shape index (%)	74.70	1.71	69.52	77.46	2.29
Shell thickness (mm)	0.37	0.02	0.32	0.42	5.88
Shell weight (g)	6.07	0.48	4.90	7.61	7.92
Shell ratio (%)	9.07	0.61	7.96	10.95	6.71
Yolk weight (g)	20.04	1.45	17.25	23.20	7.21
Albumen weight (g)	40.80	2.77	34.16	47.80	6.78
Yolk ratio (%)	29.97	1.78	26.29	34.97	5.94
Albumen ratio (%)	60.95	1.82	55.79	65.17	2.98
Haugh unit	82.12	3.63	70.75	89.29	4.42
Yolk index (%)	46.17	2.77	39.75	54.85	6.00
Yolk-to-albumen ratio	0.49	0.04	0.40	0.63	8.89

Legend: M – mean; SD – standard deviation; Min – minimum; Max – maximum; CV – coefficient of variation

Kontecka et al. (2012) analyzed the egg quality of a Cobb 500 parent flock of the same age and obtained similar values for egg weight (66.4 g), egg shape index (75.3%), shell weight (5.54 g), and shell ratio (8.35%), whereas the shell thickness values (0.328 mm) were somewhat lower than those obtained in this study. Peruzzi et al. (2012) also reported similar values for egg weight (66.80 g) and shell thickness (0.388 mm), and Đermanović et al. (2010) measured lower egg weight values (62.68 g) in a Cobb 500 flock of the same age. Silva et al. (2008) examined the quality of eggs from a 44-week-old flock of the same hybrid and obtained similar values for egg weight (66.29 g), whereas shell thickness values were higher (0.43 mm). Kontecka et al. (2012) reported similar values for yolk traits (19.71 g and 29.75%), albumen traits (41.11 g and 61.90%) and Haugh units (82.88), whereas the yolk index was found lower (41.53%). Silva et al. (2008) obtained similar values for the ratio of albumen, yolk and shell (namely 61.10, 29.79 and 9.11%, respectively), the same as Peruzzi et al. (2012) for the yolk-to-albumen ratio (0.495). Egg weight, shell porosity, shell thickness, egg shape index and egg content consistency are the physical traits of eggs that exert significant effects on incubation success, and their optimal values generally correspond to the average values obtained for the given genotype and age of hens (Narushin & Romanov, 2002; Peruzzi et al. 2012; Biesiada-Drzazga, 2020).

Phenotypic correlations between the external egg quality traits considered

The coefficients of phenotypic correlations between the external egg quality traits considered are shown in Table 2.

Table 2.Coefficients of phenotypic correlations between the external egg quality traits considered

Egg quality traits	Egg length	Egg width	Egg shape index	Shell thickness	Shell weight	Shell ratio
Egg weight	0.75^{**}	0.80^{**}	-0.19^{ns}	0.15^{ns}	0.55^{**}	-0.17^{ns}
Egg length		0.48^{**}	-0.71^{**}	0.02^{ns}	0.33^{**}	-0.22^{*}
Egg width			0.28^{**}	0.08^{ns}	0.44^{**}	-0.13^{ns}
Egg shape index				0.04^{ns}	-0.02^{ns}	0.13^{ns}
Shell thickness					0.83^{**}	0.86^{**}
Shell weight						0.73^{**}

Legend: ^{ns} - non-significant; * $p < 0.05$; ** $p < 0.01$

A significant positive phenotypic correlation ($p < 0.01$) was found between the egg weight and the egg length (0.75), egg width (0.80), and shell weight (0.55), whereas no significant correlation was found between the egg weight and the egg shape index, shell thickness, and shell ratio. A significant positive correlation between egg weight and egg length and width has been confirmed in a number of previous studies (Moula et al., 2010; Kgwatalala et al., 2016; Ukwu et al., 2017; Ahmadu et al., 2018; Inca et al., 2020). Moreover, a positive correlation between egg weight and shell weight has also been reported in numerous studies (Suk & Park, 2001; Wolanski et al., 2007; Moula et al., 2010; Shafey et al., 2015; Molnár et al., 2016; Sirri et al., 2018; Inca et al., 2020). The established absence of significant correlation between egg weight and shape index is consistent with the results of Şekeroğlu & Altuntaş (2009), Shafey et al. (2015), Kgwatalala et al. (2016), and Ukwu et al. (2017). The positive correlation found by Moula et al. (2010) stands in contrast to the negative correlation reported by Debnath & Ghosh (2015) and Inca et al. (2020). The absence of significant correlation between egg weight and shell thickness found in this study was also reported by Wolanski et al. (2007), Molnár et al. (2016) and Inca et al. (2020), which stands in contrast to the positive correlations reported by Moula et al. (2010), Debnath & Ghosh (2015), Molnár et al. (2016), Ahmadu et al. (2018). The correlation between egg weight and shell ratio was statistically negative in the research of Moula et al. (2010) and Inca et al. (2020), whereas a positive correlation was found by Debnath & Ghosh (2015). A significant negative correlation ($p < 0.01$) was found between the egg shape index and length (-0.71), whereas the egg shape index was found positively correlated with egg width (0.28). An identical relationship between the egg shape index and egg dimensions was established by Olawumi & Ogunlade (2008) and Inca et al. (2020). Although no significant correlation between the shape index and egg weight was found in this study, Sirri et al. (2018) reported a negative correlation, whereas Moula et al. (2010) and Duman et al. (2016) established a positive correlation between these two traits. A significant positive correlation ($p < 0.01$) was found between the shell weight and the egg length (0.33), width (0.44), shell thickness (0.83), and shell ratio (0.73). A significant positive correlation ($p < 0.01$) was found between the shell thickness and the shell weight (0.83) and ratio (0.86), which is consistent with the results of Olawumi & Ogunlade (2008) and Inca et al. (2020).

Phenotypic correlations between the internal egg quality traits considered

The coefficients of phenotypic correlations between the internal egg quality traits considered are shown in Table 3.

Table 3.Coefficients of phenotypic correlations between the internal egg quality traits considered

Egg quality traits	Albumen weight	Yolk ratio	Albumen ratio	Haugh unit	Yolk index	Yolk-to-albumen ratio
Yolk weight	0.23^{*}	0.66^{**}	-0.58^{**}	-0.17^{ns}	-0.07	0.64^{**}
Albumen weight		-0.57^{**}	0.63^{**}	0.11^{ns}	0.26^{**}	-0.60^{**}
Yolk ratio			-0.94^{**}	-0.22^{*}	-0.27^{**}	0.99^{**}
Albumen ratio				0.24^{*}	0.22^{*}	-0.97^{**}
Haugh unit					0.27^{**}	-0.23^{*}
Yolk index						-0.26^{**}

Legend: ^{ns} - non-significant; * $p < 0.05$; ** $p < 0.01$

A significant positive correlation ($p < 0.01$) was found between the yolk weight and ratio (0.66), as well as between the albumen weight and ratio (0.63), which is in agreement with the results of Debnath & Ghosh (2015) and Inca et al. (2020). A significant positive correlation ($p < 0.05$) was found between the yolk and albumen weight (0.23), which is consistent with the results of Debnath & Ghosh (2015) and Molnár et al. (2016), whereas Olawumi & Ogunlade (2008) reported the lack of statistical significance. The statistically significant negative correlation ($p < 0.01$) found between the yolk and albumen ratio (-0.94) was also confirmed by Debnath & Ghosh (2015) and Inca et al. (2020). The yolk index was found positively correlated with the albumen weight (0.26, $p < 0.01$), ratio (0.22, $p < 0.05$), and Haugh units (0.27, $p < 0.01$), but negatively correlated ($p < 0.01$) with the yolk ratio (-0.27) and yolk to albumen ratio (-0.26). In like fashion, Inca et al. (2020) reported that the yolk index was negatively correlated with the yolk-to-albumen ratio. The Haugh units obtained in this study were positively correlated with the albumen ratio (0.24), whereas a significant negative correlation ($p < 0.05$) was found between the Haugh units and the yolk ratio (-0.22) and yolk-to-albumen ratio (-0.23). The Haugh units were positively correlated with the albumen weight and ratio in the study by Debnath & Ghosh (2015), as well as with the yolk ratio, but negatively correlated with the albumen ratio according to Inca et al. (2020). However, Olawumi & Ogunlade (2008) did not find any significant relationship between the Haugh units and the yolk weight and ratio, nor between the Haugh units and the albumen weight and ratio.

Phenotypic correlations between the external and internal egg quality traits considered

The coefficients of phenotypic correlations between the internal and external egg quality traits considered are shown in Table 4.

Table 4.Coefficients of phenotypic correlations between the external and internal egg quality traits considered

Egg quality traits	Yolk weight	Albumen weight	Yolk ratio	Albumen ratio	Haugh units	Yolk index	Yolk-to-albumen ratio
Egg weight	0.60^{**}	0.91^{**}	-0.20^{*}	0.25^{*}	0.01^{ns}	0.20^{*}	-0.23^{*}
Egg length	0.51^{**}	0.67^{**}	-0.07^{ns}	0.15^{ns}	-0.07^{ns}	0.07	-0.10^{ns}
Egg width	0.53^{**}	0.70^{**}	-0.09^{ns}	0.14^{ns}	-0.01^{ns}	0.18	-0.11^{ns}
Egg shape index	-0.13^{ns}	-0.17^{ns}	0.01^{ns}	-0.05^{ns}	0.06^{ns}	0.07	0.02^{ns}
Shell thickness	-0.09^{ns}	0.09^{ns}	-0.23^{*}	-0.06^{ns}	0.00^{ns}	0.20^{*}	-0.14^{ns}
Shell weight	0.22^{*}	0.44^{**}	-0.24^{*}	-0.01^{ns}	-0.04^{ns}	0.29^{**}	-0.16^{ns}
Shell ratio	-0.22^{*}	-0.23^{*}	-0.11^{ns}	-0.23^{*}	-0.06^{ns}	0.13	0.00^{ns}

Legend: ^{ns} - non-significant; * $p < 0.05$; ** $p < 0.01$

A significant positive correlation ($p < 0.01$) was found between the egg weight and both the yolk weight (0.60) and albumen weight (0.91), which is consistent with the results of most studies (Suk & Park, 2001; Wolanski et al., 2007; Moula et al., 2010; Debnath & Ghosh, 2015; Shafey et al., 2015; Kgwatalala et al., 2016; Molnár et al., 2016; Ahmadu et al., 2018). Furthermore, the egg weight was found negatively correlated ($p < 0.05$) with the yolk ratio (-0.20) and positively correlated with the albumen ratio (0.25), which is also consistent with the results of a number of studies (Olawumi & Ogunlade, 2008; Moula et al., 2010; Debnath & Ghosh, 2015; Shafey et al., 2015; Inca et al., 2020). The significant positive correlation between the egg weight and yolk index (0.20, $p < 0.05$) found in this study is congruent with the results of Şekeroğlu & Altuntaş (2009), but stands in contrast to the results of Ukwu et al. (2017) and Inca et al. (2020), who found an insignificant correlation between these two traits. Moreover, the significant negative correlation between egg weight and yolk-to-albumen ratio (-0.23, $p < 0.05$) found in this study is consistent with the findings of Moula et al. (2010) and Suk & Park (2001). The correlation between the egg weight and Haugh units was not statistically significant, which was also reported by other researchers (Olawumi & Ogunlade, 2008; Şekeroğlu & Altuntaş, 2009; Debnath & Ghosh, 2015; Ukwu et al., 2017; Ahmadu et al., 2018). A statistically insignificant correlation between the Haugh units and egg shape index was also found by Olawumi & Ogunlade (2008) and Debnath & Ghosh (2015), which stands in contrast to the findings of Duman et al. (2016), who reported a significant positive correlation between these two traits. A significant positive correlation was found between the egg length and width ($p < 0.01$), yolk weight (0.51 and 0.53, respectively), and albumen weight (0.67 and 0.70, respectively), which is consistent with the results of Olawumi & Ogunlade (2008), Kgwatalala et al. (2016) and Inca et al. (2020). The yolk ratio was found negatively correlated ($p < 0.05$) with the shell thickness (-0.23,) and shell weight (-0.24), which is in contrast to the results of Olawumi & Ogunlade (2008), Debnath & Ghosh (2015) and Inca et al. (2020), who did not find a significant correlation between these traits. The shell weight was found positively correlated with the yolk weight (0.22, $p<0.05$) and albumen weight (0.44, $p<0.01$), which was also confirmed by Olawumi & Ogunlade (2008) and Inca et al. (2020). The shell ratio was negatively correlated ($p < 0.05$) with the yolk weight (-0.22), and albumen weight (-0.23), and ratio (-0.23). Olawumi & Ogunlade (2008) and Moula et al. (2010) also found a negative correlation between the shell ratio and the yolk and albumen weight, whereas Inca et al. (2020) found a negative correlation between the shell ratio and the albumen weight and ratio. Debnath & Ghosh (2015) reported a negative correlation between the shell ratio and albumen weight. In addition to the egg weight, the yolk index was found positively correlated with the shell weight (0.29, $p < 0.01$) and shell thickness (0.20, $p<0.05$). Inca et al. (2020) did not find any relationship between the yolk index and external quality traits examined, whereas Ahmadu et al. (2018) reported a significant correlation between the yolk index and the egg weight, egg width, and shell weight.

CONCLUSION

The results obtained indicate that there are significant phenotypic correlations between the external and internal quality traits of eggs laid amid the laying phase of broiler breeder hens. A significant positive correlation was found between the egg weigh, as one of the most important quality traits of hatching eggs, and the egg length, shell, albumen and yolk weight, albumen ratio, and yolk index. Moreover, the egg weight was found negatively correlated with the yolk ratio and yolk-to-albumen ratio. The egg shape index, as one of the most observable egg traits, was not significantly correlated with the shell thickness, as well as with any of the internal egg quality traits considered. The shell thickness was found positively correlated only with the shell weight and ratio of all the external traits considered, as well as with the yolk index, whereas a significant negative correlation was found between the shell thickness and the yolk ratio of all the internal egg traits considered. The Haugh units, as an important indicator of internal egg quality, were significantly and positively correlated with the albumen ratio and yolk index, whereas a significant negative correlation was found between the Haugh units and the yolk ratio and yolk-to-albumen ratio.

Conflict of interest: The authors declare that they have no conflict of interest.

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