

Relationship between External and Internal Egg Quality Traits of Isa Brown Hen Raised in the Tropics

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Abstract

This experiment was conducted to evaluate the correlations between external and internal egg quality traits of Isa Brown hens raised in the Tropics. A total of 90 eggs were randomly sampled within the period of nine weeks for external and internal egg quality measurement at the Poultry unit of Akwa Ibom State University, Akwa Ibom State Nigeria. The external egg qualities studied were egg weight, egg length, egg width, and shell thickness, while internal egg qualities were albumen height, albumen width, albumen ratio, albumen length, yolk width, yolk ratio, yolk weight, yolk height and haugh unit. All external and internal egg trait data collected were subjected to descriptive statistics (means, standard deviation, standard error and coefficient of variation). The correlations amongst external and internal egg parameters as well as correlations between internal and external traits were determined. Simple linear and multiple regressions were employed to predict egg weight and internal egg traits. Results on the correlation amongst external egg quality traits showed that egg weight had a very high positive significant ($P < 001$) correlation with egg width (0.936) and shell weight (0.973). A highly significant ($P < 001$) negative correlation (-0.997) was observed between egg width and shell ratio. Result on the correlation amongst internal parameters showed that the relationship between Albumen height with Albumen width (-0.29), Albumen ratio (-0.19), yolk ratio (-0.27) and Haugh unit (-0.99) were negative. The results also indicated that combination of egg width and egg length gave the best fit for egg weight and other internal egg parameters. This implies that any improvement made on egg length and egg width can positively influence internal egg qualities. Hence, it was concluded that egg external quality traits (egg length and egg width) could be used as selection criteria to improve internal egg quality traits.

Key words: Correlation, Egg quality, Isa Brown Hen, Tropics

1.0 Introduction

One of the major goals of developing countries is to bridge the short fall between the increasing population and production of sufficient food (Sam, 2012; Essien *et al.*, 2022). Studies have shown that an average Nigerian protein intake is less than the recommended protein intake (0.80g per kg body weight per day (FAO, 2004). This short fall is particularly protein sourced from animal origin which has better value than those from plant origin which are deficient in some major amino acid; needed mainly by the body for development and repairs of worn out tissues (FAO, 2004; Alphonsus *et al.*, 2010; Williams *et al.*, 2017; Sam and Akpa 2017). The aforementioned qualities of amino acids present in animal products (meats and eggs) must be conserved in animal nutrition. The acceptability of chicken and chicken products has been on the increase due to its availability, great quality of nutrients (amino acids) embedded in them and the relatively low cost of these products (Alphonsus *et al.*, 2012; Idiong and Christopher 2006; Sam *et al.*,2010).

Poultry industry in Nigeria is worth about eighty billion naira, that is about six hundred million US dollars. This industry is made up of about 165 million birds producing about 650,000 metric tonnes of eggs and 290,000 metric tonnes of meat annually (Heise *et al.*, 2015). In Africa, Nigeria is the largest producer of chicken eggs (Alders *et al.*, 2019). Eggs, being an excellent source of protein, have reduced the rate of unemployment particularly among the youths, thus increasing income to farmers and improving their living conditions (Dorah, 2007). Poultry droppings are a major source of organic fertilizer for the improvement of crops; and are increasingly used for vegetable production in Nigeria (Efretuei *et al.*, 2023). Poultry farming creates employment all year round since it is not seasonal in nature (Hamilton,1982).

Egg quality has been defined as those characteristics that affect its acceptability to consumers. These characteristics also influence the prices in which eggs are sold; as well as affect the hatchability of eggs (Stadelman 1995). Size and shell qualities are the measures of external egg qualities while yolk and albumen qualities are the measures of internal egg qualities (Stadelman, 1995). The quality of an egg shell determines its profitability; this is because inferior egg shells cannot withstand the stress of transportation from the farm to the end users (Yakubu *et al.*, 2008). It has been reported by the Bobbo *et al.*, (2013) that about 7-8% of eggs are broken on transits from the farm to consumers, and this leads to serious loss. Egg shell is also important because it prevents microbes from penetrating the eggs and thus reduces the risk of food poisoning (Coutts et al 2006). The internal egg traits (albumen and yolk) are the major sources of protein which contributes to nutrition, health and antimicrobial effects (Coutts et al 2006).

It has been reported that eggs with the heaviest yolks and the largest yolk to albumen ratios have higher cholesterol content (Hussein *et al.*, 2013). In view of the aforementioned eggs with smaller portion of yolk and large albumen could be more efficient as table eggs, while those with larger proportion of yolk could be more appropriate for food industries (mayonnaise, baking products, creams and omelet) in which the yolk is the main ingredient. The knowledge of these traits and how they relate with each other is important in improvement of these egg quality traits (Agreahu *et al.*, 2018). Therefore, this study was conducted to evaluate the correlation between external and internal egg quality traits of Isa Brown hens reared in the tropics.

2.0 Materials and Methods

2.1 Location of the Experiment

This research was conducted at the Poultry Unit of the Teaching and Research Farm of the Department of Animal Science, Akwa Ibom State University, Obio Akpa Campus, Oruk Anam Local Government, and Nigeria. The University lies between latitudes 50 17' N and 70 27' N and longitudes 70 30' E and 70 58' E of the Greenwich Meridian. The climate is humid and tropical and has a relative humidity between 56.01 to 90 %. Annual rainfall ranges from 1680 to 1700 mm while annual temperature falls between 22 to 37⁰C (AKSG, 2018).

2.2 Experimental Birds and Management

A total of 100 birds were used for this experiment at the second phase of lay between weeks 31 to 39. The birds were raised and managed on a deep litter system. Commercial layer diets containing 17% crude protein and 2800KCal metabolizable energy and water were given to the birds ad libitum.

2.3 Experimental Design/ Measurement of the External and Internal Egg Quality Traits

The eggs were picked randomly for the measurements using Completely Randomized Design. Samples of eggs were collected within nine week intervals (ten eggs per week) beginning at the 31st to 39th week of age. A total of 90 eggs were used to measure the external egg quality traits. Egg weight, egg length, egg width, shell thickness, shell ratio and shell weight were the external egg traits measured.. Egg weights were determined by weighing individual eggs using Camry electronic pocket digital weighing balance in grams whereas the length and width of the eggs were determined using a digital vernier caliper in millimeters. The eggshells and their membranes were dried in open-air and weighed with a digital weighing balance. The shell weight was divided by the egg weight to give the shell ratio. The thickness of shells was obtained using a digital micrometer screw gauge.

The same eggs used to determine the external egg characteristics were also used to evaluate the internal egg quality traits. Albumen weight, albumen height, albumen width, albumen ratio, albumen length, albumen weight, yolk weight, yolk height, yolk width, yolk ratio, yolk index, yolk diameter, yolk weight and Haugh unit were the internal egg parameters evaluated. The internal egg quality measurements were obtained by carefully breaking the egg followed by separation of the albumen and the yolk contents. The Albumen height, Albumen width, Albumen length and yolk width were determined using digital vernier calipers. The albumen weight was determined by weighing the total internal egg weight (i.e. yolk weight + albumen weight) and subtracting the yolk weight from it. The albumen and yolk weight were measured with a digital weighing balance. Albumen and yolk ratios were calculated by taking the ratio of their weights to the total egg weight. Haugh Unit (HU) was determined using the equation by Haugh (1937); the average albumen height and egg weight were fitted in the equation: $HU=100 \log (H + 7.57 - 1.7W^{0.37})$, where: H = Albumen height and W = Egg weight.

2.4 Statistical Analysis

Descriptive statistics (mean, standard deviation, standard error and coefficient of variation) were used to summarize all external and internal egg traits collected. The relationships between internal and external egg characteristics were determined with correlation analysis using SPSS version 23 (2000). Linear and multiple regressions were employed to predict egg weight and internal egg traits using the same statistical package. The choice of the best fitted regression model was selected using coefficient of determination (R^2) and mean standard error (MSE).

3.0 Results and Discussion

The mean values of the external and internal egg quality traits of Isa Brown hens in the present study are shown in Table 3.1. The results obtained showed that the mean egg weight, egg length, egg width, shell thickness, shell ratio, and shell weight were 58.92 ± 0.29 mm, 52.18 ± 0.18 mm, 41.85 ± 0.41 , 0.35 ± 0.01 mm, 8.19 ± 0.03 mm and 4.83 ± 0.01 mm, respectively. The mean egg weight 58.92 ± 0.29 mm obtained in this study was similar to the report of Asuquo *et al.* (1992) who reported egg weight of 58.18g. Kocevski *et al.*, (2011) also recorded similar egg weight (59.68g) for the same breed of layer chicken. The results obtained for egg length, egg width and shell weight were similar to reports of Yakubu *et al.*, (2008) but differ from Olawunmi and Ogunlade (2008) who reported 5.62g egg shell weight for exotic Isa brown chicken. The variations seen in various reports for external egg quality can be linked to variations in the genetic makeup of the birds used. Some other factors responsible for this variation include the content of the diet fed (nutrition), age of the birds as well as management practices. Some environmental influences such as temperature and humidity indices have been reported to have a negative impact on external egg quality traits (Asuquo *et al.* 1992). The results derived for shell thickness was within the limit reported by Asuquo *et al.* (1992). The ability of eggs to withstand transportation stress without cracking or fracture depends on shell structure which has to do with the thickness of the shell (Altan *et al.*, 1998).

The coefficient of variation (CV%) for external egg quality traits were generally low less than ten percent except for shell thickness which agreed with the reports of Olawumi and Babatope (2016) of low CV for egg quality characteristics. The higher coefficient of variation 68% shown by shell thickness suggests that this trait could respond to selection. The results for albumen weight, height, length, yolk weight, and yolk height in this study were 34.91 ± 0.03 g, 7.50 ± 0.35 , 73.33 ± 3.30 mm, 19.17 ± 0.25 and 14.95 ± 0.41 mm respectively (Table 3.1). These results were similar to the reports by Asuquo *et al.* (1992), but lower than those reported by Olawumi and Babatope (2016). The variance observed in different reports may be related to different manner in which genes are expressed by different breeds of birds under different management conditions. The quantity and quality of feed adopted also play a significant role in the internal egg qualities of hen.

Table 3.1: Mean Values of egg quality traits of Isa Brown Chicken

Egg traits	Means \pm SE	Standard deviation	Coefficient of Variation (%)
Egg quality Traits			
Egg weight(g)	58.92 \pm 0.29	0.718	1.21
Egg length(mm)	52.18 \pm 0.18	0.44	0.84
Egg width(mm)	41.85 \pm 0.41	1.01	2.41
Shell thickness(mm)	0.35 \pm 0.01	0.24	68.57
Shell ratio	0.08 \pm 0.03	0.07	0.85
Shell weight(g)	4.83 \pm 0.01	0.01	0.20
Internal egg quality			
Albumen weight(g)	34.91 \pm 0.03	0.08	0.22
Albumen height(mm)	7.50 \pm 0.35	0.87	11.60
Albumen length(mm)	73.33 \pm 3.30	8.09	11.03
Yolk weight(g)	19.17 \pm 0.25	0.62	3.23
Yolk height (mm)	14.95 \pm 0.41	1.01	6.75

SE=Standard error of the mean

3.1 Phenotypic Correlation amongst External Egg Traits of Isa Brown Hen

The correlation coefficient (r) among the external egg quality characteristics are indicated in Table 2. The results indicated that egg weight had a very high positive significant ($p < 0.01$) correlation with egg width (0.936) and shell weight (0.973). A highly significant ($p < 0.01$) negative correlation (-0.997) was observed between egg weight and shell ratio. Similar relationship between egg width and shell ratio (-0.935) was observed. Most of the other relationships among external egg quality characteristics were not significant ($p > 0.05$). The high correlation between egg weight and the egg width is similar to reports by Olawumi and Babatope (2016) who recorded 0.880 correlation coefficient for these traits. This result also conforms with the study by Etiola *et al.* (2004) who reported significant positive correlation between egg weight and shell weight. The positive relationship between egg width and shell thickness (0.251) had earlier been reported by Agaviezor *et al.*, (2007).

Table 3.2: Correlation amongst the external egg qualities

Traits	EW	EL	EWdt	ST	SR	SW
EW (g)	1					
EL (mm)	-0.011	1				
Ewdt (mm)	0.936 ^{xx}	-0.127	1			
ST (mm)	0.025	0.222	0.251	1		
SR	-0.997 ^{xx}	-0.03	-0.935 ^{xx}	-0.013	1	
SW (g)	0.973 ^{xx}	-0.127	0.923 ^{xx}	0.059	-0.954 ^{xx}	1

^{xx} Correlation is significant at the 0.01 level, EW=Egg weight, EL= Egg length, Ewdt= Egg width, ST= Shell thickness, SR=Shell ratio, SW= Shell weight

3.2 Phenotypic Correlation amongst Internal egg Qualities

The phenotypic correlation amongst internal egg traits of Isa Brown hen is shown in Table 3.3. The results indicate that the relationship between albumen height with albumen width (-0.29), albumen ratio (-0.19), yolk ratio (-0.27) and Haugh unit (-0.99) was negative. Inca *et al.*, (2020) also found a negative and a significant ($P < 0.01$) correlation between albumen height and albumen width. While the correlation between albumen height with albumen index (0.99), albumen length (0.05), albumen weight (0.46) yolk width (0.12), yolk index (0.05), yolk diameter (0.32) and yolk weight (0.23) were positive. Inca *et al.*, 2020 also observed moderate and positive phenotypic correlations between albumen height with albumen weight, albumen length and yolk index. Negative and significant ($P < 0.05$) relationship existed between albumen ratio with all other egg internal traits. This conforms to the findings of Inca *et al.*, (2020), who observed a non-significant ($P > 0.01$) correlation between albumen ratio with yolk index, yolk weight, yolk height, albumen index and albumen length. The relationship that existed between albumen weight with yolk diameter (0.86), yolk weight (0.91) and yolk height (0.85) were significant ($P < 0.05$) and positive. This agrees with Adams (2007), who found a highly significant ($P < 0.05$) moderate and positive correlation between albumen weight with yolk width, yolk index and yolk height. The correlations between yolk weight and other yolk characteristics in this study is in line with the reports obtained from earlier work; Olawumi and Ogunlade (2008) reported a moderate positive correlation (0.64) between yolk weight and yolk ratio. Ojo *et al.*, (2011) reported a moderate positive correlation (0.64) between yolk weight and yolk height.

3.3 Relationship Between Internal and External Egg Qualities

The relationship between internal and external egg quality is indicated in Table 3.4. It was observed that the relationship between egg weight and egg width had highly significant ($p < 0.001$) correlation ($r = 0.257 - 0.999$) with all the internal egg characteristics. This suggests that any improvement made on egg length and egg width can positively influence egg internal egg traits. It therefore means that these egg quality characteristics are controlled by similar genes actions. This also implies that the length and width of eggs can be used as selection tools to improve internal egg qualities. This report supports the work of Bernacki *et al.* (2013) and shafy *et al.*, (2015) who reported high significance ($p < 0.01$) and positive correlation between Egg Width and egg weight as well as egg width and albumen weight. The relationship of egg length with albumen weight and yolk weight indicated that increase in egg length will lead to increase in albumen weight while yolk weight would reduce. Olawumi and Ogunlade (2007) had the same observation in their study, a positive correlation of (0.64) between egg length and albumen weight. In this study it was observed that egg size had a positive impact on albumen quality characteristics but negative influence on yolk quality characteristics. Egg length had low to moderate correlation with albumen weight (0.129) albumen height (0.419) and albumen length (0.512) but was negatively correlated with yolk weight (-0.028) and yolk height (-0.188). The negative correlations observed suggest that improvement in one trait would lead to reduction in the other traits.

Shell weight also had very high and significant ($p < 0.001$) correlation with all the internal traits except a relationship with albumen height (0.209). The results of this study are in consonance with reports by Ukwu *et al.* (2017) who also found positive correlation between shell weight and internal egg qualities of Isa brown hen.

Table 3.3: Correlation amongst the internal egg qualities

Traits	AH	AWdt	AR	AI	AL	AWt	YWd	YR	YI	YD	YWt	YH	Haugh unit
Albumen Height(mm)	1												
Albumen Width (mm)	-0.292	1											
Albumen ratio	-0.199	0.483	1										
Albumen index (%)	0.992 ^{xx}	-0.409	-0.252	1									
Albumen length (mm)	0.053	-0.462	-0.743	0.106	1								
Albumen Weight (g)	0.463	-0.367	-0.889 ^x	0.487	0.692	1							
Yolk width (mm)	0.124	0.188	-0.555	0.097	-0.053	0.564	1						
Yolk ratio	-0.275	-0.23	-0.874 ^x	-0.234	0.662	0.69	0.578	1					
Yolk index (%)	0.053	-0.196	-0.632	0.072	0.452	0.781	0.583	0.684	1				
Yolk diameter (mm)	0.320	-0.186	-0.915 ^x	0.334	0.515	0.862 ^x	0.768	0.768	0.551	1			
Yolk weight (g)	0.226	-0.471	-	0.276	0.75	0.910 ^x	0.558	0.865 ^x	0.652	0.919 ^{xx}	1		
Yolk height (mm)	0.116	-0.0212	-0.735	0.136	0.499	0.857 ^x	0.661	0.748	0.986 ^{xx}	0.68	0.754	1`	
Haugh unit	-	0.315	0.124	-	0.006	-0.411	-0.063	0.344	-0.054	-0.228	-0.152	-0.098	1
	0.992 ^{xx}			0.987 ^{xx}									

^{xx} Correlation is significant at the 0.01 level, ^x Correlation is significant at the 0.05 level, AH-Albumen height, AWdt,=Albumen width, AR=Albumen ratio, AI=Albumen index, AI= Albumen index, AL= Albumen length, AWt=Albumen weight, YWd=Yolk width, YR=Yolk ratio, YI=Yolk index, YD= Yolk diameter, YWt=Yolk weight, YH=Yolk height

Table 3.4: Phenotypic correlation between internal and external egg traits of Isa Brown Hen

External egg Quality Traits	Internal Egg Quality Traits				
	AWt	AH	AL	YWt	YH
EWt	0.930**	0.257	0.749**	0.999**	0.774**
EL	0.129	0.415	0.512	-0.028	-0.188
EWDT	0.559**	0.290	0.599	0.922**	0.934**
ST	0.216	-0.085	0.237	-0.003	0.512
SW	0.868	0.209	0.665**	0.975	0.765

EWt=Egg weighth, EL=Egg length, EWDT=Egg width, ST=Shell thickness, SW=Shell weight, AWt = Albumen weight, AH= Albumen height, AL= Albumen length, YWt= Yolk weight, YH=Yolk height, **= P < 0.001

3.4 Prediction of Egg Weight and Internal Egg Quality Traits from External Egg Qualities

The prediction equation to estimate egg weight, shell weight, albumen weight, yolk weight and yolk height from egg length and egg width is shown in Table 3.5. The results showed that in estimating egg weight and internal egg qualities, the use of egg width and combination of egg length and egg width gave a better estimate compared to the use of egg length alone. This was seen in the value of coefficient of determinations (R^2) obtained in the estimates. More so, mean square error values also indicated higher values for egg length than egg width and combination of egg length and egg width.

The coefficient of determination (R^2) values obtained in using egg length, egg width and combination of egg length and egg width to estimate egg weight were 0.011, 0.888 and 0.876 respectively. This is an indication that 1.1%, 88.8% and 87.6% of the variance in egg weight was explained by the egg length, egg width and the combination of egg length and egg width models, respectively. In all the parameters estimated, egg width and combination of egg width and egg length gave a better fit than egg length alone. However, the lowest value of R^2 was obtained in estimation of albumen height. The R^2 values were 0.172, 0.084, and 0.291 for egg length, egg width and combination of egg length and egg width respectively. The mean square error values were also very high (0.893 ,0.940 and 0.954 for egg length, egg width and combination of egg length and egg width respectively

Table 3.5: Regression Equations for Predicting Egg Weight, Shell Weight and Internal Egg Quality Using External Egg Quality Traits

Equation No	Equation	R ²	MSE
Egg Weight			
1.	EWT = 59.89 +(-0.19) EL	0.011	0.803
2.	EWT = 31.100+0.665(EWDT)	0.888	0.310
3	EWT = 21.505+0.176(EL)+0.675(EWDT)	0.876	0.283
Shell weight			
4	SW = 5.041 +(-0.004) EL	0.016	0.015
5	SW = 4.290+0.013(EWDT)	0.852	0.006
6	SW = 4.308+0.00(EL)+0.013(EWDT)	0.862	0.007
Albumen weight			
7	AWt = 33.607 +0.025(EL)	0.016	0.097
8	AWt = 33.90+0.024(EWDT)	0.864	0.036
9	AWt = 28.730+0.027(EL)+0.114(EWDT)	0.883	0.388
Yolk weight			
10	YWt = 21.246 +(-0.40) EL	0.001	0.696
11	YWt = 4.618+0.569(EWDT)	0.851	0.269
12	YWt = -11.508+0.126(EL)+0.576(EWDT)	0.859	0.302
Albumen Height			
13	AH = -35.267 +(0.820) EL	0.172	0.893
14	AH = 3.020+0.252(EWDT)	0.084	0.940
15	AH = -52.49+0.907(EL)+0.303(EWDT)	0.291	0.954
Albumen length			
16	AL = -413.67 +(9.330) EL	0.262	7.770
17	AL = - 125.00 +4.760(EWDT)	0.359	7.251
18	AL = 720.902 + 10.890(EL)+5.400(EWDT)	0.710	5.62
Shell Thickness			
19	ST = -0.266 +0.012EL	0.049	0.026
20	ST = 0.309+0.001(EWDT)	0.001	0.268
21	ST = 0.672+0.014(EL)+0.097(EWDT)	0.128	0.028

EWT=Egg weight, SW= Shell weight, AWt= Albumen weight, YWt= Yolk weight, AH= Albumen height, AL= Albumen length, SH= Shell thickness

3.5 Comparison between Actual and Predicted Values of Egg Weight and Internal Egg Traits

The actual and predicted values of egg weight and internal egg quality characteristics are indicated in Table 6. The actual and predicted egg weight and internal egg qualities were similar, except the use of egg length to predicted yolk weight. This confirmed the fact that egg weight, shell weight and internal egg qualities (albumen weight, yolk weight, albumen height, albumen length and shell thickness) can be predicted from external egg traits (egg length and egg width) with accuracy. Multiple traits (egg length and egg width) best predicted egg weight and internal parameters. A comparison between actual and predicted egg weight, shell weight and other internal parameters showed that there were no significant differences (except the use of egg

length to predict yolk weight). This suggests that both egg length and egg width can predict egg weight, shell weight and other internal egg qualities.

Table 4.6: Comparison between actual and predicted Egg weight and internal egg traits

Traits	Actual	Predicted	LOS
Egg weight			
EL	58.92	49.98	NS
EWDT	58.92	58.93	NS
EL + EWDT	58.92	58.93	NS
Shell weight			
EL	4.83	5.23	NS
EWDT	4.83	4.83	NS
EL + EWDT	4.83	4.84	NS
Albumen weight			
EL	39.91	34.91	NS
EWDT	39.91	34.90	NS
EL + EWDT	39.91	34.91	NS
Yolk weight			
EL	19.17	0.374	**
EWDT	19.17	19.19	NS
EL + EWDT	19.17	19.17	NS
Albumen Height			
EL	7.50	7.52	NS
EWDT	7.50	7.52	NS
EL + EWDT	7.50	7.52	NS
Albumen length			
EL	73.33	73.17	NS
EWDT	73.33	73.30	NS
EL + EWDT	73.33	73.33	NS
Shell Thickness			
EL	0.35	0.36	NS
EWDT	0.35	0.35	NS
EL + EWDT	0.35	0.35	NS

EL= Egg length, EWDT= Egg width, LOS= Level of Significance, NS=Not Significant, **= significant

4.0 Conclusion

The egg quality parameters obtained from the birds used for this experiment were within the normal range for birds in the age range. The phenotypic correlation amongst external egg traits of Isa brown hen in this study indicated that egg weight had a positive significant ($P < 0.01$) correlation with egg width and shell. This suggests that an increase in egg weight would lead to a corresponding increase in egg width and shell weight. The correlation between internal and external egg quality showed that egg weight and egg width had a positive and significant ($P < 0.01$) correlation with all the internal egg quality traits. This implies that any improvement made on egg length and egg width would positively influence internal egg quality traits. The

prediction of egg weight and internal egg quality traits from external egg quality traits indicated that the use of egg width and combination with egg length in estimating egg weight and internal qualities gave a better estimate. This suggests that both egg length and egg width can predict egg weight, shell weight and other internal egg quality traits. It is therefore recommended that some external egg quality traits such as: egg length and egg width could be used as selection criteria to improve internal egg quality traits.

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