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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Direct and indirect contributions of internal and external quality traits on egg weight of Shika Brown layer using Path Coefficient Analysis

Shika kahverengi yumurtacı tavuklarda yumurta ağırlığı üzerine iç ve dış kalite özelliklerinin doğrudan ve dolaylı katkılarının Path Katsayısı Analizi kullanılarak belirlenmesi

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ABSTRACT

Path analysis procedure is a statistical procedure that can be applied to evaluate direct and indirect contributions of independent variables to the dependent variables for better understanding of the relationships between egg quality traits. One hundred and twenty (120) eggs, collected from Shika Brown layers, were used to evaluate the direct and indirect effects of internal and external egg quality parameters on egg weight of Shika Brown layers using Path analysis procedure. Data obtained on individual egg include the following; egg weight (EWT), egg length (ELT), egg width (EWD), shell thickness (STK), shell weight (SWT), albumen weight (AWT) and yolk weight (YWT). Correlation coefficient results show that EWT had a positively significant correlation ($P<0.05$) with ELT (0.715), EWD (0.758), SWT (0.460) and AWT (0.785). ELT had the greatest direct effect (0.360; $P<0.05$) on EWT followed by EWD (0.345; $P<0.05$) while the least of the direct effects on EWT (0.012; $P<0.05$) was from STK. However, the highest total indirect effect (0.487) on EGW was realised largely via EWD. Therefore, EWT of Shika Brown layer strain had a high positive relationship with ELT, EWD and AWT. The path coefficient analysis revealed that ELT, along with EWD contributed highest direct effect on the EWT. This information could be used in selection programme for the improvement of EWT of Shika Brown layer chickens.

ÖZET

Path (Yol) analizi, yumurta kalite özellikleri arasındaki ilişkilerin daha iyi tanımlanması için bağımsız değişkenlerin bağımlı değişkenlere doğrudan ve dolaylı katkılarını değerlendirmek için uygulanabilen istatistiksel bir yöntemdir. Bu çalışmada Shika Kahverengi yumurtacı tavuklardan elde edilmiş 120 adet yumurtada iç ve dış kalite özelliklerinin yumurta ağırlığı üzerine doğrudan yada dolaylı etkisi belirlenmiştir. Tek bir yumurta üzerinden yumurta ağırlığı (YA), yumurta uzunluğu (YU), yumurta genişliği (YG), kabuk kalınlığı (KK), kabuk ağırlığı (KA), ak ağırlığı (AA) ve sarı ağırlığı verileri elde edilmiştir. Korelasyon katsayı sonuçları yumurta ağırlığı ile ile YB (0.715), YE (0.758), KA (0.460) ve AA (0.785) arasında önemli pozitif korelasyon olduğunu göstermektedir ($P<0.05$). Korelasyon katsayı sonuçları YA ile ile YB (0.715), YE (0.758), KA (0.460) ve AA (0.785) arasında önemli pozitif korelasyon olduğunu göstermektedir ($P<0.05$). Yumurta ağırlığı üzerine YU (0.360; $P<0.05$) doğrudan en yüksek etkili olmuş bunu YE (0.345;$P<0.05$) izlerken KK (0.012; $P<0.05$) yumurta ağırlığı üzerine en az doğrudan etkiye sahip olmuştur. Bununla birlikte yumurta ağırlığı üzerine en yüksek dolaylı etki (0.487) büyük ölçüde YE vasıtasıyla gerçekleşmiştir. Bundan dolayı Shika Kahverengi yumurtacı ırkı yumurta uzunluğu, yumurta eni ve yumurta ak ağırlığı yumurta arasında yüksek pozitif bir korelasyona sahiptir. Bu bilgiler Shika Kahverengi Yumurtacı tavuklarda yumurta ağırlığının geliştirilmesi için seleksiyon programlarında kullanılabilir.

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INTRODUCTION

Egg is referred to as a "miracle food" (Dilawar et al., 2021) and is considered to have the same nutritional value as breast milk in humans (Damaziak et al., 2017). Eggs are cheap protein source with high biological value that provide the human body with required nutrients (Zdrojewicz et al., 2016; İskender & Kanbay, 2014; Pérez-Bonilla et al., 2012). The general protein need in the human body is between 75 g to 80 g (Mahendra & Judit, 2021).

The world table egg production is about 76.7 million tonnes in 2018 (FAOSTAT, 2021). Egg production has an important role in the development of countries' economies as well as meeting human nutritional needs worldwide (Mehmet & Suna, 2018).

Egg quality traits refer to various traits that describe the external and internal parameters of eggs. Egg quality traits affect its level of acceptance to consumer (Mehmet & Suna, 2018; Duman et al., 2016). Evaluation of egg quality parameters is essential both for table eggs and for the production of hatching eggs. Egg quality traits are very important in poultry enterprises because of the effects on the yield and the overall breeding progress (Udoh et al*.,* 2020; Silversides & Scott, 2001).

Studies have shown that egg quality parameters are highly correlated and can be used to determine the direction and the level of the association among egg quality traits (Abanikannda et al., 2007).

The correlations coefficient of the association between two or more variables only helps in specifying the magnitude and the direction of the relationships but do not determine the cause-effect associations among the traits (Tyasi et al., 2017). Therefore, there is the need to estimate the direct and indirect contribution of internal and external egg quality parameters on the egg weight using the procedures of path analysis. Path analysis procedure is used to evaluate the direct and indirect contribution of internal and external egg quality parameters on the dependent variables. It is a process of partitioning the correlations among variables into direct and indirect effects.

Some researchers have estimated egg weight using egg quality parameters in; local chickens in Nigeria (Adeolu & Oleforuh-Okoleh 2011), Japanese quail (Chimezie et al., 2017) and Isa Brown chickens (Ukwu et al., 2017). Nevertheless, to the best of our knowledge, there are no sufficient information on application of path analysis procedures to evaluate the contribution of egg quality traits to egg weight in Shika Brown layer chickens hence the findings of this study will provide a base line information for the good of poultry farmers.

The aim of this work, therefore, was to evaluate the direct and indirect contributions of internal and external egg quality traits on egg weight in Shika Brown layer chickens using path analysis procedures. The results obtained from this study will be useful to egg producers towards proper selection of egg quality traits (internal and external) towards the improvement of egg weight in layer chickens.

MATERIALS AND METHODS

One hundred and twenty (120) freshly laid eggs were collected from Shika Brown layer chickens. The eggs were obtained from DARMA Farms, Katsina, Katsina state. Katsina is a city located within Latitude 12^0 59'29'' N and Longitude 7^0 36'06'' E with altitude of 519 m above sea level.

Data collection

Data collected on individual egg include the following;

Egg weight (EWT). Egg weight (in g) was obtained by weighing individual eggs using a sensitive weighing scale to the nearest 0.0lg.

Egg length (ELT). Egg Length (in cm) was obtained by measuring the distance between the broad and the narrow ends of the egg using a venier caliper.

Egg width (EWD). Egg Width (in cm) was determined by measuring the diameter of the egg at the widest cross-sectional region using a venier caliper.
Shell thickness (STK). Egg Shell Thickness (in mm) was determined by measuring individual air-dried egg shell at three different regions of the shell (narrow, middle and broad portions) to the nearest 0.01 mm using a micrometre screw gauge. Average value was taken.
Shell weight (SWT). All the shells of the broken eggs were washed with water, dried at room temperature for 24 hours and weighed using a sensitive weighing scale to the nearest 0.0l g.
Albumen weight (AWT). Albumen weight (in g) was measured as egg weight – (yolk weight + shell weight).
Yolk weight (YWT). Yolk weight (g) was measured using sensitive weighing scale to the nearest 0.0l g
All measurements and evaluations were performmed according to earlier published procedures of Ukwu et al. (2017).

Data analysis
Statistical Package for Social Sciences (IBM SPSS version 23.0.0) was employed for statistical analysis of data. Data obtained were prepared and used to evaluate the means, standard deviations (SD) and coefficients of variation (CV) for Egg weight (EWT), Egg length (ELT), egg width (EWD), shell thickness (STK), Shell weight (SWT), Albumen weight (AWT) and Yolk weight (YWT) were estimated. Pearson's correlation coefficients between egg weight and egg quality traits were evaluated. Variance Inflation Factors (VIF) and Tolerance (T) procedures were applied to check the degree of multi-Collinearity among the independent variable Multiple linear regression procedures was used to obtain regression model for predicting EWT from egg quality traits.
The multiple linear regression model adopted is:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 \ldots + b_iX_i + e$$

Where:
Y = Dependent variable (Egg weight; EWT),
a = Intercept,
b1, b2, b3 … bi = Regression coefficients,
X1, X2, X3, … Xi = Independent or Explanatory variables (ELT, EWD, STK, SWT, AWT, YWT)
e = Residuals

The path coefficients from the independent variable (Xi) to a dependent variable (Y) were evaluated following the procedures described and adopted by Rotimi et al. (2020); Mendes et al. (2005).

$$PY.X_i = bi_{\mathrm{SY}}^{\mathrm{SXi}}$$

Where;
$PY.X_i$ = Path coefficient from X_i to Y (i = ELT, EWD, STK, SWT, AWT, YWT)
b_i = Partial regression coefficient,
SX_i = Standard deviation (SD) of X_i
SY = Standard deviation (SD) of Y

The indirect effects of X_i on Y through X_j were also evaluated using the procedures described by Rotimi et al. (2020). The indirect effects (IE) of X_i on Y through X_j was calculated as described by Rotimi et al. (2020); Norris et al. (2015); Keskin et al. (2005):

$$IE(YX_i) = (rX_iX_j)(PY.X_j)$$

Where:

IE(YX_i)	=	Indirect effect of X_i via X_j on Y,
rX_iX_j	=	Correlation coefficient (r) between ith and jth independent variables,
PY.X_j	=	Path coefficient indicating the direct effect of jth independent variable on the dependent variable.

RESULTS AND DISCUSSION

The descriptive statistics of egg weight (g) and egg quality traits are presented in Table 1. Results indicated mean (±SE) egg weight (g) of 58.36±0.50. This is higher than the reports of Nonga et al. (2010) using Tanzanian chickens and Saroj et al. (2020) using Sakini chicken but similar to the result obtained by Rath et al. (2015) in Potchefstroom Koekoek chicken genotype and this differing in performance could be due to breed differences. According to our study, egg weight from this study can be categorised in the range of large and extra-large (Zeidler, 2002). Result of the phenotypic correlation showed that EWT had a positively significant correlation ($P < 0.05$) with ELT (0.715)., EWD (0.758), SWT (0.460) and AWT (0.785) while STK had a non-significant positive correlation with EWT (0.107) (Table 2). The results are similar to the reports of Saroj et al. (2020) on Sakini chicken, Chimezie et al., (2017) on three varieties of Japanese quail and Adeolu & OleforuhOkoleh (2011) on South-Eastern Nigeria local chicken.

Table 1. Descriptive statistics for different egg quality parameters in Shika Brown layer chicken

Çizelge 1. Shika Brown yumurtacı tavukta farklı yumurta kalite parametreleri için tanımlayıcı istatistikler

Traits	N	Mean	Standard error	Standard deviation	Coefficient of variation (%)
Egg weight (g)	120	58.36	0.50	4.98	8.53
Egg length (cm)	120	54.34	0.23	2.33	4.29
Egg width (cm)	120	40.47	0.14	1.40	3.46
Shell thickness (cm)	120	0.19	0.00	0.04	21.05
Shell weight (g)	120	5.60	0.05	0.49	8.75
Albumen weight (g)	120	35.44	0.40	4.04	11.40
Yolk weight (g)	120	14.97	0.12	1.23	8.22

The positive correlation observed signifies that these traits are controlled by same gene and it is an indication that any of these egg traits could serve as a good predictor of egg weight. According to Ige (2013), correlation coefficients indicate the degree of linear relationship between variables, providing useful information about the traits involved for the purpose of breeding and improvement plans. Thus, ELT, EWD, SWT and AWT can be included for selection and breeding for improvement of EWT in Shika Brown layer hens. However, Ojedapo (2013) recorded a low, non-significant associations between egg weight and external egg quality traits.

There was a negatively non-significant (-0.060) relationship between SWT and STK. The negative correlation signifies that both traits are controlled by different genes, indicating that an improvement in one trait will lead to decrease in the other trait. Thus, the traits are controlled by more than one gene - pleiotrophy (Fayaye 2014).

The phenotypic correlation coefficient of relationship only assists in specifying the magnitude and the direction of the relationships but would not determine the cause-effect associations between the various traits (Tyasi et al., 2017; Lorentz et al., 2011).

Hence the need to evaluate the direct and indirect contribution of internal and external egg quality parameters on EWT in Shika Brown layer strain using path coefficient analysis procedures.

Table 2. Phenotypic correlation among the different egg quality traits of the Shika Brown layer chicken
Çizelge 2. Shika Brown yumurtacı tavuğun farklı yumurta kalite özellikleri arasındaki fenotipik korelasyon

	EWT	ELT	EWD	STK	SWT	AWT
ELT	0.715**	1				
EWD	0.758**	0.426**	1			
STK	0.107	0.095	0.114	1		
SWT	0.460**	0.192	0.364**	-0.060	1	
AWT	0.785**	0.565**	0.639**	0.112	0.396**	1
YWT	0.352**	0.315**	0.429**	-0.091	0.112	0.131

EWT = Egg weight, ELT = Egg length, EWD = Egg width, STK = Shell thickness, SWT = Shell weight, AWT = Albumen weight, YWT = Yolk weight, **Correlation is significant (P < 0.01).

The regression analysis results showing association between egg quality parameters and egg weight for Shika Brown layer chickens is shown in Table 3.

Results revealed that the Variance Inflation Factor (VIF) estimates for the egg quality parameters were lower than 10 (ranging from 1.061 through 2.383) and the tolerance (T) was higher than 0.1, this confirms that there was no multicollinearity problem between independent parameters.

Data collected were subjected to Multiple linear regression analysis (MLRA) method in order to explain total variability in EWT. The prediction equation model equation is as follows:

EWT = -57.055 + 0.770EWD + 1.231ELT + 1.511STK + 1.465SWT + 0.367AWT + 0.151YWT (R^2 = 0.833).

Table 3. Testing the significance of multiple linear regression analysis for Shika Brown laying chicken
Çizelge 3. Shika Brown yumurtacı tavuğu için çoklu doğrusal regresyon analizinin anlamlılığının test edilmesi

		Regression parameters			
Egg traits	Unstandardized Coefficients (B)	Std. Error	P- Values	Tolerance values	VIF
EWD	0.770	0.115	0.000	0.616	1.624
ELT	1.231	0.225	0.000	0.452	2.211
STK	1.511	5.284	0.776	0.943	1.061
SWT	1.465	0.480	0.003	0.807	1.239
AWT	0.367	0.081	0.000	0.420	2.383
YWT	0.151	0.205	0.463	0.701	1.426

Intercept (a) = -57.055, Coefficient of determination (R^2) = 0.833, Mean Square Error (MSE) = 4.403, VIF = Variance Inflation Factor, EWD = Egg width, ELT = Egg length, STK = Shell thickness, SWT = Shell weight, AWT = Albumen weight, YWT = Yolk weight.

From the path coefficients analysis, SWT and YWT were not statistically significant, so were excluded in the final regression equation. The final regression equation, as simplified, is as follow:

EWT = -54.957 + 0.776EWD + 1.409ELT + 0.406AWT (R^2 = 0.816).

The final regression equation revealed that EWD, ELT and AWT explained 81.6% of the total variability in EWT.

Correlation studies in combination with path analysis provide a clearer understanding of the cause-effect relationship of different traits by partitioning correlation coefficients into direct and indirect effects. Path coefficient analysis of egg weight and egg quality in Shika Brown hens are shown in Table 4. The results revealed that ELT exhibited highest significantly positive direct effect (0.360; P<0.01) on EWT followed by EWD (0.345; P<0.01). These results agree with the reports of Hlokoe & Tyasi, (2021) who also reported that egg length had the greatest direct effects on egg weight followed by egg width in Potchefstroom Koekoek chicken. Also, EWT was directly influenced by significantly positive effects of AWT (0.298; P<0.01), this report negates the report of Hlokoe and Tyasi (2021) who recorded that AWT Yolk weight had highly significant (P<0.01) direct effect on the EWT in

Potchefstroom Koekoek chicken. The results revealed that ELT, EWD and AWT contributed the highest influence on EWT of Shika Brown chickens.

The correlation coefficient value observed between egg weight and AWT was highest (0.785; P<0.05) with greater indirect effect (0.487), realized mostly via EWD. The lowest direct effects (0.012; P<0.05) from STK. The results of path analysis findings obtained from this study suggest that EWT in Shika Brown chickens could be estimated using ELT, EWD and AWT. The direct effects of SWT (0.144) and YWT (0.037) were non-significant (P>0.05). However, there is paucity of studies using path analysis to evaluate the correlations between EWT and egg quality parameters in chickens.

Table 4. Path coefficient analysis of egg weight and egg quality traits in Shika Brown chickens

Çizelge 4. Shika kahverengi tavuklarda yumurta ağırlığı ve yumurta kalite özelliklerinin yol katsayı analizi

Egg quality	Correlation coefficient (b)	Indirect effect						
parameters	with EWT	ELT	EWD	STK	SWT	AWT	YWT	Total
ELT (mm)	0.715**	**0.360****	0.147	0.001	0.028	0.168	0.012	0.356
EWD (mm)	0.758**	0.153	**0.345****	0.001	0.052	0.190	0.016	0.412
STK (mm)	0.107	0.034	0.039	**0.012****	-0.009	0.033	-0.003	0.095
SWT (g)	0.460**	0.069	0.126	-0.001	**0.144NS**	0.118	0.004	0.316
AWT (g)	0.785**	0.203	0.220	0.001	0.057	**0.298****	0.005	0.487
YWT (g)	0.352**	0.113	0.148	-0.001	0.016	0.039	**0.037NS**	0.316

Bold = direct effects, **Significant at the 0.01 level (2-tailed), ELT = Egg length, EWD = Egg width, STK = Shell thickness, SWT = Shell weight, AWT = Albumen weight, YWT = Yolk weight.

In conclusion, the results of this study showed that phenotypic correlation relationships exist between egg quality parameters and egg weight of Shika Brown egg layer chicken. It is concluded that EWT of Shika Brown egg layer strain had a high positive relationship with ELT, EWD and AWT. The path coefficient analysis revealed that ELT and EWD contributed the highest direct effect on the EWT. The final regression equation can be utilized by egg producers to forecast EWT. This information could be very important in designing a selection programme for the improvement of egg quality traits of Shika Brown egg layer chickens and similar layer chickens.

STATEMENT OF CONFLICT OF INTEREST

The authors declare no conflict of interest for this study.

AUTHOR'S CONTRIBUTIONS

The contributions of the authors are equal.

STATEMENT OF ETHICS CONSENT

Ethical approval is not applicable, because this article does not contain any studies with human or animal subjects.

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