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EVALUATION OF EGG QUALITY TRAITS OF SHIKABROWN® PARENTS

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ABSTRACT

This study was carried out in order to measure the internal and external egg quality traits of Shikabrown®. The eggs were obtained from a population of selected lines (sire and dam) and were denoted as strain A and strain B, respectively. (indicate the methodologies used in obtaining the responses you are reporting!) Egg quality traits were similar for most of the internal and external quality parameters and the differences between the strains were not significant (P>0.05). However, strain affected (P<0.05) egg length. Strain B had longer egg length (5.61±0.06 cm) than Strain A (5.44±0.04 cm). The positive and high phenotypic correlations between egg weight and most internal and external egg measurements in Shikabrown® indicated that egg weight is directly proportional to the increase of other egg quality traits (egg length, egg width, shell thickness, shell weight, albumen weight, albumen height, albumen width, yolk weight, yolk index). This implies that any of the traits can be used as selection index for the improvement of egg weight. Egg weight of Strain B (50.00±1.14 g) was significantly (P>0.05) superior to strain A (48.60±0.93). Average egg length (5.61±0.06mm) and average egg width (4.04±0.03mm) in strain B were strongly and positively correlated with egg weight in Shikabrown®. In conclusion, selection for egg length and egg width will improve egg weight. Based on these traits, strain B should be employed as selection criteria to improve egg weight of Shikabrown®. The improvement of strain B is recommended based on the higher (126.80) percentage of the total variance than strain A 103.10%.

Key words: Egg quality traits, PCA, Strains, internal egg quality traits and external egg quality traits.

INTRODUCTION

Egg quality traits had received considerable attention by breeders because of their economic importance in the poultry industry, Orunmuyi (2007). Sarica *et al.* (2012) noted that egg quality is important for both layer and breeder flocks. The quality of egg-related traits is important from the viewpoints of conservation and industrial use. Modern consumers are concerned with freshness, but they also demand quality and this extends to appearance, colour and freedom from extraneous material of any kind, Orunmuyi (2007). The production of high quality eggs is the responsibility of the poultry and egg producers and such quality must be preserved for consumers' acceptability (Kabir *et al.*, 2014). Albumen height and Haugh units are traits used to evaluate albumen quality,

which also deteriorates with age (Liljedahl *et al.*, 1999). The Haugh unit is considered to be related to freshness of the egg and attracts high premium in some specific markets. It characterizes the albumen height for a constant egg weight and is measured during the whole production cycle with fresh eggs. The use of Haugh unit has been accepted as a measure of egg quality and fresh eggs decreases with increasing storage time (Thierry, 2012 and Buba *et al*., 2013).

Correlations permit prediction of direction and magnitude of change in the dependent trait as a correlated response to direct selection of the principal trait (Laxmi *et al*., 2002). Thus, correlations are of great interest to the breeder. The uniformity of the external and internal egg quality has become one of the major traits in selection (Thierry 2012). Egg weight is highly positively correlated to most other egg variables (Abanikannda and Leigh 2007). Kabir *et al*. 2014 reported positive and high correlation coefficient between egg weight and some external egg quality traits. This revealed that egg weight had effect on most of the external and internal egg quality parameters and agrees with the submissions of Abutu *et al.* (2008).

Principal component analysis is performed with the main objective of reducing the information on the breeding values for variables to a smaller number of orthogonal latent variables, called principal components, with a minimal loss of information (Hair *et al*., 2009, Venturini *et al*., 2013). The first principal component (PC1) explains the largest percentage of the total additive genetic variance. The second principal component (PC2) explains the second largest percentage and so on, until the whole variance is explained (Savegnago *et al*., 2011). The principal component analysis using egg traits can generate more intense data from multivariate. Phenotypic variation present in a population arises due to genotypic and environmental effects, and the magnitude of phenotypic variability differs under different environmental conditions Moses *et al*. 2011. Twenty- two egg quality traits measured by (Tatsuhiko *et al.*, 2015) using principal component analysis and eigenvectors were calculated. Many factors are known to influence egg quality traits. These include breeds or strain of birds, temperature, storage methods, relative humidity, rearing practices and season (Washburn, 1990, Buba *et al*., 2013). Classification of these traits into components could be very helpful in constructing a robust selection index for breeder birds. The use of multivariate techniques in classification of egg quality traits into components of related qualities is essential for selection of Shikabrown® parents. This study was therefore designed to subject egg quality traits of Shikabrown® parents to multivariate analysis in other to obtain related components that are manageable for improvement of egg quality.

MATERIALS AND METHODS

Experimental Site

The research was conducted at the Breeding Unit of Poultry Research Programme of National Animal Production Research Institute (NAPRI), Shika, Zaria. The institute is geographically situated between latitude 11^{o}12´16.78´´N and longitude 7^{o}33´39.18´´E latitude at an altitude of 640M above sea level (Ovimaps, 2015). It is located 22km Northeast of Zaria-City and in the Northern Guinea Savannah zone of Nigeria. Detailed description of Shika climate has been given elsewhere by Kabir and Muhammad (2012).

Experimental Animals and Management

Eggs from two strains of Shikabrown® parents (sire and dam) were used for the study. The birds were obtained from a population of selected lines (sire and dam lines) and were denoted as strain A and strain B, respectively. Strain A was identified with a gold plumage while strain B with a silver plumage. Selected birds were fed grower ration which contained 16.5 % Crude Protein (CP) and 2737 Kcal ME/Kg from 8 weeks to point of lay at 20 weeks of age. At point of lay, breeder mash containing 18% Crude Protein (CP) with 2724kcal ME/Kg was

offered to the birds. Feed and water were given *ad libitum* while fresh feed was offered every day.

Data Collection

Thirty (30) eggs from each of the two strains were used to measure the internal and external egg quality traits. Eggs used to measure these traits were sampled on their day of lay and measurements were taken from them on the same day. The weights were taken to the nearest 0.05g with sensitive electronic scale (Electronic compact scale, KERRO BL20001) and 0.01mm with the Vernier caliper was used to measure egg length, yolk width, albumen and yolk heights. Micrometer screw gauge was used to measure shell thickness.

External egg quality traits measured

i. Egg length (ELT) and Egg width (EWD) were measured in cm by measuring the longest length and width of the egg using vernier caliper.

ii. Eggshell thickness (SHT) (mm): Was measured together with shell membranes at the equatorial parts of the egg using a micrometer screw gauge.

iii. Egg shell weight (SHWT) (g): The shell was carefully dried with tissue paper to remove the remains of albumen white membrane. It was measured using sensitive electronic scale.

Internal egg quality traits measured

i. Yolk height (YHT) and Albumen height (AHT): Were measured when the eggs were broken and the content gently poured out into clean petri dishes. The measurements were taken using vernier caliper in cm.

ii. Yolk width (YWD) and Albumen width (AWD): Were measured when the eggs were broken and the content gently poured out into clean petri dishes. The measurements were taken using vernier caliper in mm.

iii. Yolk weight (YWT) (g) and Albumen weight (AWT) (g) were gently separated and scooped with tablespoon and poured in clean petri dishes and measured using sensitive electronic scale.

iv. Yolk index (YIDX) (%)**:** Was calculated according to the formula described by Olawumi and Ogunlade (2009):

$$Yolkindex = \frac{Yolkheight(mm)x\ 100\ \%}{Yolkwidth\ (mm)}$$

v. Haugh unit (%) was calculated using the values obtained for the egg weight and albumen height using the formula given below:

Haugh unit (HU) = 100 log ($H+7.5-1.7W^{0.37}$) Haugh (1937)

Where:

H: albumen height in mm.

W: egg weight in gram.

Data Analysis

General Linear Model Procedure of SAS (SAS, 2004) was used to analyze the effect of strains on egg quality traits of Shikabrown® parent. The model used was $Y_{ij} = \mu + S_i + \varepsilon_{ij}$; where Y_{ij} = observable egg quality traits, S_i = the i^{th} effect of strain on egg quality traits and ε_{ij}= the residual error. Correlation procedure was used to establish relationships among egg quality traits. The Kaiser criterion (Kaiser, 1958) was used to choose principal components that explained most of the variation in the data set. This criterion obtains principal components with eigen values greater than one. This analysis was done using varimax rotation using IBM® SPSS® Version 21 (SPSS, 2004). Result of Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy showed the suitability of the data for principal component analysis.

RESULTS

Table 1 shows the least squares means (±SE) and coefficients of variation for egg quality traits in the two strains of Shikabrown® parent. Strain of birds did not affect (P>0.05) most of the egg quality traits studied. Strain

however affected (P<0.05) egg length. Strain B had longer egg length (5.61±0.06 cm) than strain A (5.44±0.04 cm).

Table 1: Least square means (±SE) and coefficient of variation for egg quality traits for strains A and B

	Strain A		Strain B	
Traits	LSM±SE	C.V (%)	LSM±SE	C.V (%)
External egg quality traits				
EWT (g)	48.60±0.93	6.10	50.00±1.14	7.18
ELT (mm)	5.44±0.04^{b}	2.40	5.61±0.06^{a}	3.39
EWD (mm)	3.98±0.03	2.51	4.04±0.03	2.48
SHT (mm)	0.37±0.10	48.65	0.29±0.02	34.48
SHWT (g)	4.30±0.33	24.65	4.10±0.20	5.01
Internal egg quality traits				
AWT (g)	29.60±1.7	18.38	29.60±0.73	7.84
AWD (mm)	1.84±0.10	12.50	2.22±0.28	39.19
AHT (cm)	0.73±0.03	12.33	0.86±0.11	40.70
YWT (g)	14.80±0.55	11.82	13.80±0.42	9.57
YHT (cm)	1.53±0.11	23.53	1.57±0.03	6.37
YWD (mm)	4.08±0.55	42.89	3.52±0.11	7.95
YIDX (%)	42.76±6.48	47.92	44.71±0.03	0.83
H-U (%)	118.13±4.26	11.39	120.48±0.77	21.46

EWT = Egg Weight: ELT = Egg Length: EWD = Egg Width: AWT = Albumen Weight: AWD = Albumen Width: AHT = Albumen Height: YWT = Yolk Weight: YHT= Yolk Height: YWD= Yolk Width: SHT = Shell Thickness: H-U = H-unit: YIDX = Yolk Index: SHWT = Shell Weight. C.V= Coefficient of Variation. LSM- Least Squares Mean, SE–Standard Error Means with different superscripts on the same row are significantly different (P<0.05).

Table 2: Phenotypic correlation coefficient of egg quality traits for strain A

Traits	EWT	ELT	EWD	SHT	SHWT	AWT	AWD	AHT	YWT	YHT	YWD	YIDX	H-U
EWT (g)													
ELT (cm)	0.60**												
EWD (cm)	0.66**	0.22*											
SHT (mm)	0.48**	0.11	0.52**										
SHWT (g)	0.04	-0.33*	0.26*	-0.32*									
AWT (g)	0.23*	0.36*	0.18	-0.12	-0.11								
AWD (cm)	0.11	0.23*	-0.01	0.28*	-0.33*	-0.42*							
AHT (cm)	0.37*	0.16	0.18	-0.08	0.56**	0.09	-0.16						
YWT (g)	-0.30*	-0.31*	0.01	-0.09	0.13	-0.02	-0.49*	0.36*					
YHT (cm)	0.33*	-0.10	0.50**	0.29*	0.35*	0.26*	-0.22	0.66**	0.60**				
YWD (cm)	0.01	0.17	0.03	-0.06	-0.58*	0.03	0.24*	-0.24*	0.15	-0.14			
YIDX	0.27*	-0.16	0.37*	0.14	0.68**	0.09	0.01	0.56**	0.07	0.70**	-0.66**		
H-U	0.25*	-0.14	0.41*	0.26*	0.27*	0.23*	-0.24*	0.61*	0.68**	1.00**	-0.08	0.63**	

Traits: EWT: Egg weight, ELT: Egg length, EWD: Egg width, AWT: Albumen height, YWT: Yolk weight, YHT: Yolk width, SHT: Shell thickness, H-U: Haugh unit, YIDX: Yolk index, SHWT: Shell weight. (*P< = 0.05, **P< = 0.001)

Table 3: Phenotypic correlation coefficient of egg quality traits for strain B

Traits	EWT	ELT	EWD	SHT	SHWT	AWT	AWD	AHT	YWT	YHT	YWD	YIDX	H-U
EWT (g)													
ELT (cm)	0.69**												
EWD (cm)	0.80**	0.33*											
SHT (mm)	0.87**	0.62**	0.68**										
SHWT (g)	0.30*	-0.14	0.58**	0.34*									
AWT (g)	0.23*	0.12	0.32*	0.01	0.38*								
AWD (cm)	0.82**	0.52**	0.77**	0.77**	0.29*	-0.14							
AHT (cm)	0.39*	0.02	0.51**	0.09	0.28*	-0.18	0.48*						
YWT (g)	0.66**	0.46*	0.51**	0.41**	-0.08	-0.22*	0.56**	0.78*					
YHT (cm)	-0.71*	-0.57*	-0.33*	-0.62*	0.24*	-0.11	-0.40*	-0.06	-0.55*				
YWD (cm)	0.21*	-0.12	0.36*	-0.09	0.23*	-0.24*	0.33*	0.98**	0.70**	0.09			
YIDX	-0.57*	0.72**	-0.21*	-0.49*	0.48*	0.10	-0.31*	-0.09	-0.68*	0.82**	0.03		
H-U	0.11	0.12	-0.05	0.13	0.42*	-0.13	0.31*	0.17	-0.10	0.30*	0.18	0.40*	

Traits: EWT: Egg weight, ELT: Egg length, EWD: Egg width, AWT: Albumen height, YWT: Yolk weight, YHT: Yolk width, SHT: Shell thickness, H-U: Haugh unit, YIDX: Yolk index, SHWT: Shell weight. (*P< = 0.05, **P< = 0.001)

Table 4 and 5 showed the principal component analysis for strain A and B. Four mathematical principal components were generated for both strains. In strain A, external egg quality traits increased with increasing PC1 while internal egg quality traits increased with increasing PC2. This implies that PC1 accounted for external egg quality traits (AHT 0.75, YHT 0.93, YINDX 0.82 and H-U 0.88) and is termed as generalized principal component for internal egg quality traits. PC2 accounted mainly for external egg quality traits (EWT 0.81, ELT 0.72, EWD 0.57 and SHT 0.63 and is termed as generalized principal component for external egg quality traits. PC3 and PC4 loaded for few egg quality traits. PC3 loaded for internal egg quality traits` (AWT 0.35, YWT 0.65 and YWD 0.70) and followed PC2 trend of loading for internal egg quality traits. PC4 loaded for AWD only. PC1 in strain B loaded for three external egg quality traits (EWT 0.96, ELT 0.69 and EWD 0.79) and internal egg quality traits (AWT 0.81, YWT 0.85 and YWD 0.82), respectively. Internal egg quality traits in strain B increased with increasing PC2 (AWD 0.68, YHT 0.66, YINDX 0.66 and H-U. PC2 in strain B loaded internal egg quality traits as opposed to PC2 in strain A. AHT increase with increasing PC3 and SHWT increased with increasing PC4. PC3 and PC4 in strain B loaded for only one egg quality traits each.

Table 4: Eigenvalues and share of total variance along with factor loadings and communalities of egg quality traits of strain A

Trait	PC1	PC2	PC3	PC4	Communality
EWT (g)	0.41**	**0.81****	-0.11	-0.18	0.74
ELT (mm)	-0.07	**0.72****	0.07	-0.48**	0.81
EWD (mm)	0.55**	**0.57****	-0.00	0.09	0.90
SHT (mm)	0.21*	**0.63****	-0.01	0.54**	0.68
SHWT (g)	**0.61****	-0.42*	-0.51**	-0.16	0.86
AWT (g)	0.24*	0.21*	**0.35***	-0.71**	0.79
AWD (mm)	-0.32*	0.47**	-0.32*	**0.49****	0.75
AHT (cm)	**0.75****	-0.04	-0.04	-0.18	0.64
YWT (g)	0.47**	-0.47**	**0.65****	0.22*	0.83
YHT (cm)	**0.93****	0.04	0.26*	0.17	0.81
YWD (mm)	-0.39*	0.26*	**0.70****	0.15	0.75
YIDX (%)	**0.82****	-0.05	-0.47**	0.06	0.74
H-U	**0.88****	-0.12	0.36*	0.21*	0.72
Eigenvalue	4.32	2.64	1.84	1.51	
%Variance	43.2	26.4	18.4	15.1	

Trait: EWT: Egg weight, ELT: Egg length, EWD: Egg width, AWT: Albumen weight, AWD: Albumen width, AHT: Albumen height, YHT: Yolk height, YWD: Yolk width, SHT: Shell thickness, H-U: Haugh unit, YIDX, Yolk index, SHWT: Shell weight.

Table 5: Eigenvalues and share of total variance along with factor loadings and communalities of egg quality traits of strain B

Trait	PC1	PC2	PC3	PC4	Communality
EWT (g)	**0.96****	-0.04	0.24*	-0.01	0.83
ELT (mm)	**0.69****	-0.43*	0.14	0.27*	0.87
EWD (mm)	**0.79****	0.31*	0.31*	-0.32*	0.89
SHT (mm)	-0.69**	0.57**	0.04	0.12	0.77
SHWT (g)	0.05	0.52**	0.27*	**0.71****	0.85
AWT (g)	**0.81****	-0.15	0.39*	0.23*	0.83
AWD (mm)	0.20*	**0.68****	0.62**	-0.13	0.80
AHT (cm)	0.03	-0.06	**0.63****	-0.63**	0.92
YWT (g)	**0.85****	0.22*	0.13	0.29*	0.85
YHT (cm)	0.55**	**0.66****	-0.48*	-0.15	0.93
YWD (mm)	**0.82****	0.08	-0.54**	-0.10	0.74
YIDX	-0.65**	**0.66****	0.32*	0.03	0.89
H-U	0.38*	**0.71****	-0.56**	-0.15	0.82
Eigenvalue	5.45	2.80	2.14	1.29	
%Variance	54.50	28.00	21.40	12.90	

Trait: EWT: Egg weight, ELT: Egg length, EWD: Egg width, AWT: Albumen weight, AWD: Albumen width, AHT: Albumen height, YHT: Yolk height, YWD: Yolk width, SHT: Shell thickness, Hu: Haugh unit, YIDX, Yolk index, SHWT: Shell weight.

DISCUSSIONS

Internal and external egg quality traits in both strains

Egg quality traits were similar for most of the internal and external quality parameters and the differences among the strains were not significant (P>0.05). Values obtained for egg weight in the present study were between (48.60g) for strain A and (50.00g) for strain B. The value is within the range (51.35g) obtained by (Abeke *et al*., 2008) and 54.39g obtained by Orunmuyi (2007) from same Shikabrown® layers. However, the value obtained is numerically lower than 58.71g, 54.03g and 58.06g reported by (Nwagu *et al*., 2010; Buba *et al*., 2013 and Kabir *et al*., 2014) in Hubbard, Shikabrown® and Isa Brown breeds. Egg weight values is in agreement with the value of 46.6–49 g recorded by Aganga *et al*., (2003) in Tswana laying chickens and Abeke *et al.* (2008) for Broiler breeder chickens in NAPRI. The Haugh unit obtained in this study (118.13± 4.26) and (120.48± 0.77) for strain A and strain B, respectively is numerically higher than 74 % and 61.73 % reported by Buba *et al*. 2013 for Shikabrown® and Kabir *et al*. 2014 for Isa Brown. Egg length in strain B had higher LSMSE (5.61±0.5 cm) than in strain A (5.44±0.5 cm). Egg length obtained in this study is within the range (5.46±0.04 cm) obtained by Nwagu *et al*. (2010) in Hubbard breed. Egg length is a good

estimator of egg weight Obike and Azu (2012). This indicates that egg weight in strain B can be improved phenotypically through selection.

Phenotypic correlated coefficient for egg quality traits in both strains

Correlation coefficients between egg weight and some external egg quality obtained for both strain was positive and high. However, the values were numerically higher than the values reported by Kabir *et al*. 2014 between EW and EL (0.60; 0.37), EW and EWD (0.66; 0.02), EW and SHT (0.48; 0.23), except the correlation coefficient between EW and SHWT (0.04; 0.34). This revealed that EW had effect on most of the external egg quality parameters and agrees with the findings of Abutu *et al.* (2008). The strong and positive (r_p) correlation among egg weight and external egg qualities especially egg length (r_p=0.60 in strain A; and r_p= 0.69 in strain B P<0.05), is similar with the reports (r_p =0.62; P<0.05) of (Obike and Azu 2012). This indicates that egg length is a good determinant of egg weight. Egg length had also been reported to significantly (P<0.05) affect egg weight (Momira *et al*., 2003). The association between egg width and egg weight were stronger (r_p=0.66 in strain A and r_p= 0.88 in strain B; P<0.05). This may be attributed to the fact that the denser part (yolk) of the egg occupies the width area, thereby translating to heavier weight for eggs. This result corroborated the report of Abanikannda *et al*. (2007). These authors reported a phenotypic correlation of 0.78 and 0.84 between egg weight, egg length and egg width respectively, of Harco heavy breed layers of chicken. Based on the correlations, they concluded that egg length and egg width were good predictors of egg weight. It also agrees with the reports of Nwagu *et al*. (2010) who found highly significant correlations between egg weight, egg length and egg width (r_p = 0.74 and 0.79; P<0.05) respectively, of Anak and Hubbard breeder grandparent stock.

Principal component analysis in both strains

Four principal components (PC1-PC4) explained most of the variation in the data set for the two strains because they attended the Kaiser criterion when eigenvalues were higher than one (Kaiser, 1958). This finding is in agreement with the findings of Savegnago *et al*. (2011) who recorded four informative components. In this study, first four principal components explained 103.10 % and 116.80% additive variance in strains A and B respectively, which is higher than the value (80.04 %) reported by Savegnago *et al*. (2011). However, the four principal components generated in this study did not agree with the result of Tatsuhiko *et al*, 2015, who revealed five principal components explaining 79.70% of the total phenotypic

variance from 22 egg quality traits. Yakubu and Ayoade (2009) reported (97 %) in broiler chickens. Lin *et al.* (2004) performed PCA to give an overview of the multidimensional data in egg weight, shell length and width. They reported that the first two components explained 80% of the total variation. This study is justified as the first two components in Strains A and B explained 69.60 % and 82.59 % respectively.

This was supported by Kaiser-Meyer- Olkin measure of adequacy obtained from the correlation, revealing the proportion of the variance in the egg quality traits caused by the underlying factor. This was found to be sufficiently high for all the egg traits in both strains (0.676 for strain A, and 0.598 for strain B) as shown in (Table 4) and (Table 5). This is similar but numerically lower compared to the report of 0.951 and 0.950 reported by Akinsola (2012). The communalities, which represent the proportion of the variance in the original variables that is accounted for by the factor

solution, ranged from (0.64-0.90) for strain A in (Table 4) and (0.74–0.93) for strain B in (Table 5) respectively. The factor pattern coefficients were used to assess the relative contributions of the various egg traits in determining the numerical value of the corresponding factor (principal component). These coefficients show the relative contribution of each trait to a particular principal component (factor) for the two strains.

The egg quality traits associated with PC1 are good estimators of general egg weight, egg length and egg width (0.96, 0.69 and 0.79) in strain B, and that the first factor explained the highest percentage of total variance. PC1 was termed as general principal component for external egg quality traits. This result agrees with the report of (Venturini *et al*., 2013), they reported that the first principal component explains the greatest part of the total additive genetic variance. The second principal component explains the second greatest part of the total additive genetic variance and so on, until all of the variances are explained. PC2 in strain A on the other hand loaded more for internal egg quality traits; albumen width, yolk height, yolk index and haugh unit (0.68, 0.66, 0.66 and 0.71), and was termed as general principal component of internal egg quality traits. Inverse relationship is seen to exist between PC1 and PC2 for external and internal egg quality traits in both strains. In the selection for egg quality traits (external and internal), traits like shell thickness, are used as selection parameters to provide improvement, Sarica *et al*. (2012). Also, Albumen height may be used for the selection of internal quality traits. This measure is incorporated into egg grading standards and accepted in markets, Sarica *et al*. (2012).

CONCLUSIONS

Egg weight of strain A (48.75±0.17g) was si gnificantly superior to strain B (47.92±0.17g) . Average egg length (5.61±0.06mm) and av erage egg width (4.04±0.03mm) were strongly and positively correlated with egg weight of Shikabrown®. Strain B had longer egg length and egg width than strain A, selection for egg length and egg width will invariably select eggs with heavier phenotypic weight. Based on these traits, strain B should be employed as selection criteria to improve egg weight of Shikabrown®. Four principal components (PC1, PC2, PC3 and PC4) were extracted for strain A which accounted for 103.10 % of the total variance and 126.80% in strain B respectively. This implies that selection can be possible by determining not all but some traits to improve the external and internal traits.

RECOMMENDATIONS

Egg weight of strain A is significantly higher than strain B, therefore strain A is recommended to consumers and commercial producers as this will influence egg grading, price and consumer preference. Strain B had longer egg length and egg width than strain A. Therefore, selection for egg length and egg width will invariably select eggs with heavier phenotypic weight. Based on these traits, strain B should be employed as selection criteria to improve egg weight of Shikabrown®.

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