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Principal Component Analysis of Egg Parameters in Yoruba Ecotype, Sussex and Their Cross Bred Chickens

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Abstract

The egg parameters of Yoruba Ecotype Chicken (YEC), Sussex (SS) and their cross-bred chickens in the humid tropical region of Nigeria were assessed using principal component analysis. The study used 223 eggs, of which 124 YEC and 99 Sussex eggs were collected. Weekly data on the internal and external egg qualities of the hens were gathered using a vernier caliper, measuring tape and digital scale balance. The data acquired by dimension reduction with factor analysis were subjected to principal component analysis and the SPSS statistical package version 21 was also used to correlate the parameters pertaining to egg qualities. The strains' positive correlation with the traits related to egg quality indicated that PC 1 accounted for the largest portion of the overall variation in the characteristics of eggs. In YEC × YEC, 3PCs with high positive loading for egg width, egg number, egg length and shell thickness best described the characteristics of the egg quality. The characteristics of external quality (egg weight, egg width, shell thickness and shell weight) best characterized strain SS × SS. Comparably, strain SS × YEC was characterized by its external traits, whereas strain YEC × SS was characterized by its internal and external traits related to egg quality. It is concluded from this study that crossbreeding of YEC and SS can introduce variation, leading to a mix of internal and external quality characteristics of eggs. This information can be valuable for breeders who can select breeding pairs based on desired egg quality traits.

Keywords: Cross breed, Eggs, Principal component analysis, Sussex, Yoruba ecotype chickens

Introduction

A large number of potentially correlated traits are often dealt with in animal breeding for genetic improvement, making the data set more difficult to handle and interpret. One helpful method for handling and interpreting data problems is principal component analysis. To reduce a set of possibly correlated variables to just one, the principal component, a mathematical procedure known as principal component analysis is utilized (Jolliffe, 2002). For the first few, the way these components are arranged keeps most of the variances that were discovered in the first variables. A multivariate method called principal component analysis looks at a data set where the observations are described by multiple quantitative dependent variables that have a correlation with each other (Abdi *et al*., 2010). The total variance can be explained by each of the principal components, with the first principal component explaining the most of the variance. Principal component analysis (PCA) considers multiple characteristics that might be important for breeding chickens. Studies on indigenous Nigerian chickens (Yakubu *et al*., 2009a) and Broiler chickens (Mendes, 2011; Udeh and Ogbu, 2011; Ajayi *et al*., 2012) have found high "communalities" when using PCA. This means PCA effectively identified a smaller set of factors that capture most of the important information about the chickens. This is helpful for breeders because they can focus on these key factors when selecting breeding stock to achieve desired traits. Principal component analysis has the major benefit of lowering the

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dimensionality of data, which makes it easier to resolve issues with relationship interpretation when many traits are taken into account.

YEC stand out for their hardiness, high fertility and strong hatchability. These qualities, along with their excellent adaptation to tropical environments, showcase their remarkable genetic potential. It is stated that they lay between 58 and 128 eggs annually. But its small stature and low egg weight have made it difficult to use for industrial meat and egg production (Sola-Ojo *et al.*, 2013; Akintunde, 2018; Ademola *et al.*, 2020). In the county of Sussex in England, the Sussex chicken originated more than a century ago. They are a versatile breed of chicken that is well-suited for foraging and is considered a backyard favorite in many nations. An average Sussex hen lays between 240 and 260 eggs $year^{-1}$. Eggs from chickens are a cheap source of protein. Their quality is defined by their internal and external characteristics, many of which are correlated.

Eggs come in different qualities, both on the outside and inside. External features, like weight, length and width, give you a sense of the egg's overall size and shape. Internally, factors like albumin weight (the white part), yolk weight and the haugh unit (a measure of albumen thickness) all contribute to the quality of the egg. However, genetics and other factors can influence how these qualities develop (Ademola *et al.*, 2023; Akintunde *et al.*, 2023; Akintunde and Toye, 2023, 2021). Additionally, correlations between the attributes of the quality of chicken eggs have been documented by Abanikanda *et al*. (2007) and Kabir *et al*. (2014). The objective of this study was to examine the best descriptors among the egg parameters in the two strains of chicken and their cross bred in order to identify which of the egg parameters that would be highly useful for selection best describe these strains. These will be useful for selection practices in improving egg production in these strains.

Materials and Methods

Study Location

The study's location was a private farm in Oyan, Osun state, South-West Nigeria. Latitude 8.05, longitude 4.77 and elevation 422 meters above sea level are the coordinates of the experimental site.

Data Collection

Eggs from the Sussex and YEC strains were gathered and stored in separate battery cages for this investigation. 223 eggs were collected, of which 124 were YEC and 99 were Sussex. The characteristics of egg quality that are described below were measured both internally and externally:

- *Egg Weight (EW)*: Every hen's egg was weighed with an electronic, sensitive scale.
- *Egg Number (EN)*: This was noted as the total number of eggs that each strain of hens laid.
- *Egg length (EL)*: This was measured using a pair of Vernier calipers (calibrated in millimeters) as the distance between the tip of the narrow and broad ends of an egg.
- *Egg width (EWD)*: The measurement was taken with Vernier calipers (calibrated in mm).
- *Shell Weight (SW)*: To determine the weight of the empty shell, the shell was rinsed with warm water and air-dried it for 48 hours. The weight was then measured using a digital scale.
- *Egg Shell Thickness (ST)*: The average thickness of the egg shell was measured at three points: the broad end, middle and narrow end. After removing the egg membrane, the thickness at each point was measured using a micrometer screw gauge (calibrated in mm). The final value reported is the average of these three measurements.
- *Albumen weight (AW) and Yolk weight (YW)*: Using a spatula, the albumen and yolk were carefully separated and weighed individually on a digital scale.

Statistical Analysis

The egg parameter data were examined using dimension reduction with factor analysis in the statistical package for social science (SPSS) version 21.0. Principal Component Analysis (PCA) is a technique that converts a set of correlated variables (X_1, X_2, X_3,..., X_n) into a new set of uncorrelated variables (Y_1, Y_2, Y_3,..., Y_p), according to Everitt *et al.* (2011). Despite having no correlation with one another, these new variables - referred to as principal components - capture the most significant information from the original data. The data variance is primarily explained by the first principal component, with subsequent components explaining progressively less of the variance:

$$Y_1 = a_{11}X_1 + a_{12}X_2 + \dots\dots + a_{1p}X_p$$

$$Y_2 = a_{21}X_1 + a_{22}X_2 + \dots\dots + a_{1p}X_p$$

$$Y_p = a_{p1}X_1 + a_{p2}X_2 + \dots\dots + a_{1p}X_p$$

The Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sphericity were utilized to evaluate whether the data were appropriate for factor analysis. These tests ensured the data meets the assumptions for factor analysis to produce reliable results. Based on eigen values greater than 1.00, factors were extracted. The amount of variance that a factor accounts for is indicated by its eigenvalue. The analysis focuses on factors that capture a significant amount of variation in the original data by choosing those with eigen values greater than 1.

Communalities extraction identified the variables that best contribute to each factor. Communalities indicated how well each original variable is explained by the extracted factors. Values closer to 1.00 represent a stronger contribution. Varimax rotation with orthogonal rotation was used to achieve uncorrelated factors. This simplifies the interpretation of the factors by ensuring they were independent of each other.

Results and Discussion

Table 1 summarized the key findings from the factor analysis of egg quality traits in YEC chickens. It showed three main points as follows.

Variability Explained

The table presented eigen values and the percentage of

Table 1: Eigen values, percentage (%) total variance, cumulative percentage, principal components and communalities of egg parameters in YEC × YEC chicken

Parameters	Principal component 1 (PC1)	Principal component 2 (PC2)	Principal component 3 (PC3)	Communalities
Egg number	0.855	-0.321	0.049	0.836
Egg weight	-0.084	-0.496	-0.420	0.430
Egg length	0.563	-0.338	0.633	0.832
Egg width	0.864	-0.007	0.112	0.759
Shell weight	0.508	0.351	-0.112	0.394
Shell thickness	-0.228	0.577	0.569	0.708
Albumen weight	-0.740	-0.347	0.433	0.856
Yolk weight	0.157	0.796	-0.146	0.680
Estimated Total Variable				
Eigen value	2.684	1.674	1.138	
% Total variance	33.548	20.548	14.223	
Cumulative %	33.548	54.468	68.691	

variance explained by each factor (PC). The eight egg quality parameters analyzed shared a significant portion of their variance (68.69%) across the three extracted factors (PC1, PC2 and PC3).

Importance of Each Factor

Eigen values indicated the importance of each factor. PC1 had the highest eigen value (2.684), explaining 33.55% of the total variance. PC2 (20.55%) and PC3 (14.23%) contributed less but still captured a significant amount of variation.

Interpretation of Factors

The table also showed the “communalities” and “rotated component matrix.” These values helped to identify which egg quality traits were most associated with each factor. PC1 was linked to egg width and number, PC2 was associated with shell thickness and PC3 was related to egg length.

Table 2 focused on the factor analysis results for SS × SS chickens. It highlighted similar key findings to table 1, but with some differences in the specific egg quality traits associated with each factor as follows.

Variability Explained

The table showed eigen values and the percentage of variance explained by each factor (PC). Similar to table 1, the eight egg quality parameters analyzed shared a significant portion of their variance (75.12%) across the three extracted factors (PC1, PC2, PC3).

Importance of Each Factor

The eigen values again indicated the importance of each factor. PC1 had the highest eigen value (2.626), explaining 32.82% of the total variance. Similar to table 1, PC2 (23.22%) and PC3 (19.07%) contributed less but still captured a

Table 2: Explained Eigen values, percentage (%) total variance, cumulative percentage, principal components and communalities of egg parameters in SS × SS chicken

Parameters	Principal component 1 (PC1)	Principal component 2 (PC2)	Principal component 3 (PC3)	Communalities
Egg number	0.290	-0.043	-0.675	0.542
Egg weight	0.832	-0.103	0.276	0.780
Egg length	0.435	0.662	-0.185	0.661
Egg width	-0.249	0.856	0.020	0.795
Shell weight	0.180	0.508	0.695	0.774
Shell thickness	0.826	-0.089	-0.428	0.873
Albumen weight	0.546	0.523	-0.195	0.610
Yolk weight	0.765	-0.366	0.505	0.973
Estimated Total Variable				
Eigen value	2.626	1.858	1.526	
% Total variance	32.823	23.221	19.071	
Cumulative %	32.823	56.044	75.116	

significant amount of variation.

Interpretation of Factors

The "communalities" and "rotated component matrix" helped to identify which egg quality traits were most associated with each factor in SS × SS chickens. PC1 was linked to egg weight and shell thickness, PC2 was associated with egg width and PC3 was related to shell weight. This differed slightly from the associations observed in table 1 for YEC × YEC chickens.

By comparing tables 1 and 2, how the breed of chicken (YEC vs. SS) might influence the relationships between different egg quality traits was observed.

Table 3 explored the factor analysis results for YEC × SS chickens, a cross between the YEC and SS breeds. It has revealed some important findings as follows.

High Shared Variance

Similar to the previous tables, the communality values (0.701-0.901) indicated a significant portion of variance (77.85%) was shared among the eight egg quality parameters across the three extracted factors (PC1, PC2 and PC3).

Importance of Each Factor

The eigen values again highlighted the importance of each factor. PC1 dominated with the highest eigen value (3.173), explaining nearly 40% (39.67%) of the total variance. PC2 (21.10%) and PC3 (17.08%) contributed less but still captured a substantial amount of variation.

Interpretation of Factors

The "communalities" and "rotated component matrix" showed which egg quality traits were most associated with each factor in YEC × SS chickens. Interestingly, this differed slightly from the pure breeds (YEC × YEC and SS × SS) as presented in tables 1 and 2. Here, PC1 was linked to shell weight, PC2 was associated with egg width and PC3 was related to shell thickness.

This suggests that crossing the breeds might influence the relationships between these egg quality traits.

Table 4 dived into the factor analysis results for SS × YEC chickens, another cross between YEC and SS breeds. It has revealed some unique findings compared to the previous tables, as follows.

Shared Variance

The communality values (0.661-0.876) indicated a significant portion of variance (78.86%) was shared among the eight egg quality parameters. Interestingly, four principal components (PC1, PC2, PC3 and PC4) were extracted to explain this variance.

Importance of Each Factor

The eigen values showed the importance of each factor. PC1 took the lead with an eigen value of 2.476, explaining nearly 31% (30.95%) of the total variance. The remaining factors (PC2, PC3 and PC4) contributed less but still captured a substantial amount of variation, ranging from 19.13% to 12.98%.

Interpretation of Factors

The "communalities" and "rotated component matrix" shed light on which egg quality traits were most associated with each factor in SS × YEC chickens. Notably, PC1 was linked to egg weight (with a negative loading, indicating an inverse relationship), PC2 was associated with egg number, PC3 was related to shell weight and PC4 was linked to albumen weight.

This pattern of associations was distinct from what was observed in the pure breeds (YEC × YEC and SS × SS) and the YEC × SS crossbred in table 3. These differences suggested that the breed combination can significantly influence the underlying relationships between egg quality characteristics.

Understanding linear traits in animals is crucial for developing effective breeding programs and improving

Table 3: Explained Eigen values, percentage (%) total variance, cumulative percentage, principal components and communalities of egg parameters in cross bred YEC × SS chicken

Parameters	Principal component 1 (PC1)	Principal component 2 (PC2)	Principal component 3 (PC3)	Communalities
Egg number	-0.860	-0.041	0.191	0.778
Egg weight	0.496	0.349	0.586	0.712
Egg length	0.697	-0.434	-0.340	0.790
Egg width	0.117	0.901	-0.173	0.855
Shell weight	0.856	0.360	0.198	0.901
Shell thickness	-0.525	-0.277	0.624	0.741
Albumen weight	-0.546	0.220	-.0636	0.750
Yolk weight	0.619	-0.557	-0.094	0.701
Estimated Total Variable				
Eigen value	3.173	1.688	1.367	
% Total variance	39.666	21.095	17.084	
Cumulative %	39.666	60.762	77.845	

Table 4: Explained Eigen values, % total variance, cumulative percentage, principal components and communalities of egg parameters in SS × YEC Chicken

Parameters	Principal component 1 (PC1)	Principal component 2 (PC2)	Principal component 3 (PC3)	Principal component 4 (PC4)	Communalities
Egg number	0.282	0.834	0.186	-0.258	0.876
Egg weight	-0.797	0.364	0.266	-0.120	0.852
Egg length	0.774	-0.280	-0.366	0.198	0.851
Egg width	0.788	0.283	0.131	0.061	0.721
Shell weight	0.200	-0.407	0.767	0.113	0.806
Shell thickness	-0.426	-0.139	0.291	0.612	0.661
Albumen weight	-0.357	0.375	-0.488	0.548	0.807
Yolk weight	0.440	0.466	0.309	0.476	0.733
Estimated Total Variable					
Eigen value	2.476	1.530	1.264	1.038	
% Total variance	30.954	19.126	15.798	12.981	
Cumulative %	30.954	50.080	65.878	78.859	

animal well-being, breeders can use this information to select animals with desirable physical characteristics that can be passed on to future generations (Ojedapo *et al.*, 2012; Akintunde *et al.*, 2021). The high communality values (shared variance) across all chicken breeds and crosses indicate that Principal Component Analysis (PCA) was a well-suited technique for analyzing these egg quality datasets. The findings align with previous research, studies on Arbor Acre and Marshall broilers, as well as Yoruba Ecotype chickens (Yakubu *et al*., 2009b; Akintunde *et al*., 2021), all reported high "communalities" in body measurement analyses. This essentially means the chosen method effectively captured the important information from the data, making it a valuable tool for studying body measurements in chickens.

According to Mendes (2009), in many cases, the first principal component (PC1) can capture a significant amount of the variation in the data, often exceeding 50%. This makes it a valuable tool for summarizing the most important information from a complex dataset.

This study examined egg quality traits in four different chicken groups: YEC × YEC, SS × SS, YEC × SS (crossbreed) and SS × YEC (crossbreed). The cross of YEC × YEC, three principal components (PCs) best described their egg quality. These PCs were primarily linked to external characteristics such as egg length, width and number in addition to shell thickness. With regard to the SS × SS cross, this breed prioritized outward appearance features. Egg weight, egg width, shell thickness and shell weight were the most important variables.

In addition, the YEC × SS crossbreed prioritized external traits like egg weight, width, length, and thickness in addition to shell weight. The SS and YEC crossbreed exhibited a combination of internal and external quality traits. Among the important factors were the weight of the albumen and yolk; the length, width, and weight of eggs; and thickness of the egg shell, as well as the quantity of eggs.

The present study's results, which show positive loading for shell thickness across all four strains used, are consistent with those of Sarica *et al*. (2012), who found that, in an experiment involving five hen strains, shell thickness was one of the most useful criteria for egg quality. The present study's results for SS × YEC are consistent with the findings of Ukwu *et al*. (2017), who described the eggs of Isa brown layer chickens using principal components that included both internal and external qualities traits.

Conclusion

In conclusion, this study reveals that breed and crossbreeding can influence the relative importance of various egg quality traits. YEC chickens seem to prioritize egg size and number, while SS chickens focus more on overall weight and shell strength. Crossbreeding can introduce variation, leading to a mix of internal and external quality characteristics being important. This information can be valuable for breeders who can select breeding pairs based on desired egg quality traits.

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