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Quantitative analysis of egg quality traits of indigenous free-range chickens in Kabwe, Zambia

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Abstract
This study was conducted to understand egg quality traits of Zambian indigenous chicken eggs in Kabwe as a way to create an inventory of the genetic potential of these chickens. This is the inventory that may be used to design breeding programs for the improvement of egg quality traits of indigenous free-range chickens in Kabwe, Zambia. 316 eggs of uncharacterized indigenous chickens were collected from around small scale farmers and used in this study. Egg weight was 48.63g, egg length and width were 54.26mm and 40.22mm respectively. The egg weight had positive correlation with all traits measured, meaning that if selection is made for any of these traits it would result in a corresponding increase in egg weight. Three principal components were extracted that accounted for 79.05% of the total variance. We hypothesized that PC1 was a size factor and PC2 shell quality factor. These results indicate that there exists high potential for egg quality improvements in Kabwe through proper breeding and selection methods.

Keywords: Egg quality traits, zambian indigenous chickens, egg shape index, principal component analysis

1. Introduction

Eggs are a living structure envisioned by nature for reproduction. These are special cells found in females and most animal produce them. The difference is that some animals produce them internally while others produce them externally. For a long time Eggs from poultry have been known to play an important nutritional role to humans and are also a nutritional reservoir for the developing embryo [1, 2]. A chief product of poultry, eggs by mass are composed of albumin (58%), yolk (31%) and egg shell (11%) [3].

Egg quality traits have a direct influence on the price of eggs in commercial birds as well as in egg processing plants. The egg quality attributes *i.e.* egg weight, albumin, yolk and shell thickness affect the amount and market price of an egg [4]. Therefore, the monetary achievement of a laying flock exclusively depends on the quantity of quality eggs [5]. Several factors can affect egg quality traits. These may be age of the laying hen, genetic makeup, reproduction cycle, environment and nutrition [6]. It has been established that the size and weight of the egg increases with increasing age of hen [7].

Just like in most unindustrialized countries, the native chicken egg production in Zambia is still yet to develop [2]. And in this area, there is very limited commercialization such that only 0.5% of the entire indigenous chicken population being under commercialized farming systems [8]. Likelihoods of improving this sector are so slim owing to among numerous causes the poor genetic potential of indigenous chickens. The output of Indigenous chickens averages 20 and 80 eggs per year. This is so low equated to the commercial equivalents that average 300 eggs per year [9-11]. This can however, be improved by design and implementation of proper breeding programs.

Understanding egg quality traits of local chicken breeds in the ordinary breeding environment has a principal importance in designing and implementing selection and breeding strategies that are holistic for genetic improvement [12]. In order to breed towards improving egg quality, there exists need to understand the relation that exists between these traits. Several works have been done to study the variations in egg quality traits [1-3, 12, 13]. In understanding these relationships, breeders find themselves in circumstances where they deal with huge numbers of correlated traits and this data would be complex to handle. Principal component analysis (PCA), a multivariate scrutiny method comes in handy to analyze these data. Where observations are defined by a lot of inter-correlated measurable dependent variables PCA can analyze such data [14].

PCA diminishes the dimensionality of data sets with a massive magnitude of associated variables at the same time retaining as much discrepancy in the data as there can be. This is accomplished by altering to an unalike set of variables, (the principal components, PCs) which are not correlated but ordered so much that the maximum of the distinction present in the original variables is conserved in the first few components [15]. PCA has been used several times to study variations in egg traits [6, 16, 17].

This study intended at characterizing and analyzing indigenous free chicken eggs in Kabwe, Zambia. And by use of PCA to scrutinize these characteristics to establish the relationships between egg phenotypes of these chickens. The outcomes of the current study would work as an inventory of the egg production genetic potential possessed by these chickens on which resolutions on the scheming of breeding programs as well as selection and breeding would be grounded.

2. Materials and Methods

This study was conducted in Kabwe district the administrative capital of Zambia's central province in August 2018. Kabwe is located on coordinates latitude 14°26′ south and longitude 28°27′ east. Kabwe is at an elevation of 1191m above sea level (www.worldatlas.com). The samples were collected in the eastern parts of Kabwe around Mpima and its surrounding areas. The study region typifies an out of urban type of backyard poultry production where extensive type of poultry production is practiced. Mpima is a concentration of small scale poultry farmers and there is very minimal influence on poultry rearing by urban affiliated poultry production systems mainly prevalent in most urban setups.

316 eggs of mixed breeds of indigenous chickens were collected from small scale farmers in Kabwe's Mpima and its surrounding areas. All the eggs were collected from Zambian indigenous chickens that were under extensive management system where limited investment was made in the production. These chickens were of a mixed uncharacterized breeds. Upon arrival, eggs were individually weighed with a digital scale with a 0.01g sensitivity. An electronic digital Vernier calipers with a sensitivity of 0.01mm was used to measure the length of the egg and its width. Both in millimeters. The shape of the egg (shape index) was calculated using the equation below.

$$\text{Egg shape index} = \frac{\text{egg width}}{\text{egg length}} \times 100$$ [12]

The surface area (in cm^2) was calculated by the formula; Surface area $=4\pi r^2$ where r is the radius of the egg calculated in centimeters by the formula; Radius (r) $= \frac{1}{4} \text{x} \ (length + breath)$ [18].

After carefully breaking the egg ensuring the internal contents don't mix, the undried shells were discretely weighed with the membranes inside using an electronic balance in grams. The shell thickness was then measured using a micrometer gauge at the narrow end, broad ends and the middle with their average recorded as shell thickness in millimeters. After carefully opening the egg and ensuring the internal contents don't mix, the weights of the yolk and albumin were measured in petri dishes using an electronic balance. While the yolk stood in the petri dish, the Verner caliper height gauge was used to measure the height of the yolk while the Vernier calipers measured the yolk width. Other parameters were calculated as below.

$$\text{Shell ratio (\%)} = \frac{\text{shell weight}}{\text{egg weight}} \times 100$$

$$\text{Albumin ratio (\%)} = \frac{\text{albumin weight}}{\text{egg weight}} \times 100$$

$$\text{Yolk ratio (\%)} = \frac{\text{yolk weight}}{\text{egg weight}} \times 100$$

$$\text{Shell index (\%)} = \frac{\text{yolk height}}{\text{yolk width}} \times 100$$

Minitab version 18 was used to calculate all the phenotypic means and standard errors of different internal and external egg traits. Pearson correlation was used to ascertain the relationship that exists between these traits. The said Minitab V18 was used in principal component analysis. The appropriateness of the sample for PCA was verified using Bartlett's test of sphericity. This was further tested by Kaiser-Meyer-Olkin (KMO) degree of sampling competence. The factor loading was founded on Eigen values of 1 and above. The factor loading factors below 0.3 were suppressed. Verimax orthogonal rotation was utilized in the rotation of the factor matrix.

3. Results

The results of the different egg quality traits are presented in Table 1. The egg weight averaged 48.63 g, with the length of the egg being 54.26 mm. The eggs were 40.22 mm wide. The egg shape index (%), egg radius (cm), egg surface area (cm^2) were calculated as 74.18, 2.36 and 70.20 correspondingly. The egg shells weighed 6.33 g. The egg shells were 0.34 mm thick with shell ratio (%) being 13.09. In this study, several internal traits were also measured. The albumin weight was 28.09 g. The albumin ratio was 57.76% while the albumin ratio was (%) 57.76±0.35. Yolk traits measured included the yolk height, yolk width and yolk weight. The yolk height was 16.05 mm, yolk width was 40.52 mm and the yolk weight registered 16.92 g. Yolk ratio and yolk index as percentages were 34.80 and 40.03 respectively.

Table 1: Descriptive statistics of egg quality traits of Zambian indigenous chickens in kabwe.

Trait	Mean ± SE
External traits	
Egg Weight (g)	48.63±0.31
Egg Length (mm)	54.26±0.16
Egg width (mm)	40.22±0.09
Egg Shape Index (%)	74.18±0.17
Egg Radius (cm)	2.36±0.01
Egg Surface Area (cm^2)	70.20±0.34
Shell Weight (g)	6.33±0.05
Shell Thickness (mm)	0.34±0.01
Shell Ratio (mm)	13.09±0.13
Internal traits	
Albumin Weight (g)	28.09±0.25
Albumin Ratio (%)	57.76±0.35
Yolk Height (mm)	16.05±0.10
Yolk Width (mm)	40.52±0.33
Yolk weight (g)	16.92±0.17
Yolk Ratio (%)	34.80±0.27
Yolk Index (%)	40.03±0.43

Table 2 shows a correlation matrix between the different eggs traits measured. Correlations ranged from r=0.010 to r=0.957. Significant (*P*<0.01) and positive strong to moderate correlations were observed between egg weight with egg length, egg width, egg surface area, albumin weight, yolk height, yolk width, and yolk weight. Negative correlations were observed between egg weight and egg shape index, shell thickness, shell ratio, yolk ratio and yolk index. Egg length had a positive significant (*P*<0.01) relation with egg width, surface area, albumin weight, yolk width, and yolk weight. Egg length showed a negative but significant (*P*<0.01) correlation with egg shape index, shell ratio and yolk index. Strong correlation were observed between shell weight and shell thickness as well as with shell ratio. Shell weight had moderate significant (*P*<0.01) correlations with yolk width, yolk weight and yolk ratio. The albumin weight registered a significant (*P*<0.01) positive correlation with albumin ratio, yolk height, yolk width and yolk weight.

Table 2: Correlation matrix of egg quality traits of Zambian Indigenous chickens in Kabwe.

	Egg weight	**Egg Length**	**Egg Width**	**Egg shape Index**	**Surface area**	**shell Weight**	**Shell Thickness**	**Shell Ratio**	**Albumin Weight**	**Albumin Ratio**	**Yolk Height**	**Yolk Width**	**Yolk Weight**	**Yolk Ratio**
Egg Length	0.857**													
Egg Width	0.915**	0.666**												
Egg shape Index	-0.225**	-0.666**	0.111											
Surface area	0.957**	0.956**	0.855**	-0.418**										
shell Weight	0.151	-0.112	0.131	0.289**	-0.02									
Shell Thickness	-0.147	-0.276**	-0.133	0.245**	-0.241**	0.564**								
Shell Ratio	-0.541**	-0.678**	-0.509**	0.403**	-0.666**	0.747**	0.581**							
Albumin Weight	0.721**	0.757**	0.666**	-0.350**	0.785**	0.107	-0.064	-0.422**						
Albumin Ratio	0.018	0.236**	0.018	-0.309**	0.165*	-0.043	0.032	-0.093	0.704**					
Yolk Height	0.225**	0.248**	0.12	-0.213**	0.222**	-0.019	-0.170*	-0.171*	0.231**	0.101				
Yolk Width	0.578**	0.623**	0.452**	-0.370**	0.611**	-0.233**	0.07	-0.575**	0.407**	0.02	0.019			
Yolk Weight	0.596**	0.679**	0.418**	-0.479**	0.638**	-0.306**	-0.186*	-0.636**	0.256**	-0.214**	0.193*	0.756**		
Yolk Ratio	-0.067	0.156	-0.218**	-0.420**	0.024	-0.495**	-0.107	-0.351**	-0.242**	-0.250**	0.078	0.468**	0.760**	
Yolk Index	-0.330**	-0.341**	-0.293**	0.153	-0.351**	0.163*	-0.197*	0.350**	-0.213**	0.01	0.543**	-0.822**	-0.479**	-0.315**

* Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed)

The Barlett's test was highly significant (P=0.000) for the data used in this study. The Kaiser-Meyer-Olkin (KMO) amount of sampling sufficiency in this study was 0.60. Table 3 shows the extracted principal components, Eigen values and communalities. In this study three (3) principal components were extracted. The communalities ranged from 0.48 to 0.94. The three extracted principal components collectively accounted for 79% of total variance. PC1 had an Eigen value of 4.25 accounting for 47.25% of the total variance. This had high loadings on egg weight (0.95), egg length (0.90), egg width (0.85), albumin weight (0.78), yolk width (0.75) and yolk weight (0.70). The second factor (PC2) had an Eigen value of 1.70 and accounted for 18.94% of variance in totality. This had high positive loading shell weight (0.92) and shell thickness (0.70). The third of the three extracted components (PC3) had an Eigen value of 1.16 and accounted for 12.86% of the entire variation present in these egg traits. This had a negative loading on shell thickness (-0.56) and a positive loading yolk weight (0.56).

Table 3: Principal Component Analysis, Eigen values and communalities of Egg Quality traits of Zambian Indigenous Chickens in Kabwe

	PC1	PC2	PC3	communalities
Egg weight	0.95			0.94
Egg Length	0.90			0.88
Egg width	0.85			0.77
Albumin Weight	0.78			0.73
Yolk Width	0.75			0.87
Yolk Weight	0.70			0.79
shell Weight		0.92		0.86
Shell Thickness		0.70	-0.56	0.80
Yolk Height			0.66	0.48
Eigen values	4.25	1.70	1.16	
% var	47.25	18.94	12.86	
cumulative var	47.25	66.19	79.05	

4. Discussion

The physical egg quality characteristics are a vital factor in embryonic development and subsequent hatching [19]. There are a number of these quality traits. The most influential ones are egg weight, shell thicknesses and thickness, albumin weight, and yolk weight [20]. The results gotten in this study are comparable to what other researchers documented in other places. When compared to other eggs of indigenous chickens, the egg weight obtained in this study was higher than that obtained in Ethiopian chickens but lower than that obtained in South African chickens [13]. However the egg weight in this study was comparable to that obtained in Botswana's indigenous chickens [21]. When compared to the commercial egg laying breed, the leghorns, the egg weight obtained in our study was inferior [18]. From the finding of the same authors, the egg length and egg width of the eggs in this study are comparable to the one found in leghorns. The discrepancies in external egg traits could be attributed to the differences in nutrition in the sampled chickens. Genetic variability may also not be ruled out [2].

The egg shape index obtained in this study is indicative that these eggs are oval in shape and are of a good grade as they fall within the range (72-26) within which eggs are termed oval and can be graded AA a top grade [22]. Eggs with a shell thickness of 0.33 mm are strong enough to stand minimal handling and won't break during transportation [23]. This study recorded a shell thickness of 0.34 mm indicating that the eggs in Kabwe have shells strong enough for minimal handling.

The albumin weight of the eggs in our study was found to be slightly higher than what was found in white leghorns and Onagadori breeds in Japan [24]. In a study to compare egg traits in Nicobari and cross Nicobari raised in intensive and backyard systems of management, Choudhuri, *et al.* [25] found higher albumin weights in intensive systems of managements, higher than in both the backyard system as well as in our findings. Our findings however, show higher albumin weight than the eggs obtained from the backyard type of management. The findings by Kayo [13] indicate superiority of our results to both the Ethiopian and South African chickens. Taken together, this would indicate that the albumin weight may be breed specific but also may be affected by the management type. The yolk weight in our study is comparable to the one found by Sun *et al.* [1] and Goto *et al.* [24] but what we found was higher than that found in all the three types of Tswana chickens (naked neck, normal feathered and Dwarf) studied by Kgwatalala *et al.* [21] in Botswana. This could also indicate that this trait is also breed specific and management can be implicated too.

The findings in this study are not in isolation as they are akin to what other authors published with regards to correlation among egg traits. Our study established that there exists a positive correlation between egg weight and all the egg traits we measured. This is an indication that if selection for breeding is made in any one of these traits, it would result in a correspondingly increase in the other traits. This was the case in eggs of Japanese quails [26], in eggs of Tswana chickens [21] and in eggs of Partridge [27]. The strong and significant relationship between egg weight and egg width is because the bulky of egg's internal contents occupy the broader part of the egg translating into a heavier egg. This study established a positive relationship between egg length and egg width, surface area, albumin weight, yolk width, and yolk weight a finding that is in agreement with results obtained by Kgwatalala *et al.* [21] in Botswana chickens. The Substantial correlation existing between egg length, width, egg surface area are because egg width and egg length define the volume and holding capability of an egg. That is consequently suggestive of egg surface area and egg weight [28]. The negative correlation established between egg length and egg shape index in this study is comparable to that established by Markos *et al.* [12] in Ethiopian chickens and by Kgwatalala *et al.* [21] in Tswana chickens**.** This is indicative of the fact that egg shape index is a function of the egg length. The strong correlation was observed between albumin weight and with albumin ratio a result that agrees with that found in the midlands and highlands ecotype chickens in Ethiopia [12].

The data used in this study was suitable for PCA because the Barlett's test was highly significant (P=0.000). The Kaiser-Meyer-Olkin (KMO) amount of sampling sufficiency was 0.60. A sample whose KMO value is 0.60 and above is considered an adequate sample [29]. In this study three (3) principal components were extracted. The communalities ranged from 0.48 to 0.94 signifying that the majority of variance was accounted for. The three extracted principal components collectively accounted for 79% of total variance.

PC1 had high loadings on egg weight, egg length, egg width, albumin weight, yolk width and yolk weight. We hypothesize from the trend that the first principal component is a descriptor of size as it had more loadings on traits connected to egg size. The second factor (PC2) had high positive loading on shell weight and shell thickness. From this, we postulate that the second factor in our study is descriptor of shell quality as this highly affected the shell properties. The third of the three extracted components (PC3) showed a negative loading on shell thickness and a positive loading yolk weight. This could be a descriptor of internal quality trait.

In a study of egg traits of ISA brown layer chickens in Nigeria**,** Ukwu *et al.* [16] just like us extracted three principal components which cumulatively accounted for 85.80% variation of the total variance. A similar study in native duct breeds of china, two principal components were extracted that accounted for 65.32% of total variance [6].

5. Conclusion

In order to initiate good breeding programs, one ought to know what resources are available in a particular flock population by a way of characterization. This study successfully characterized and analyzed the eggs of Zambian chickens in Kabwe. The eggs in Kabwe possess good quality traits. However, there is huge potential for improvements. Having documented these traits in this study, and looking at how the traits relate to each other it can be concluded that with proper selection and breeding programs the quality of eggs in Kabwe can be improved.

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