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# PRINCIPAL COMPONENT ANALYSIS OF BODY MEASUREMENTS IN THREE STRAINS OF BROILER CHICKEN.

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**ABSTRACT**
**This study was conducted to explore the relationship among body measurements in 3 strains of broilers chicken (Arbor Acre, Marshal and Ross) using principal component analysis with the view of identifying those components that define body conformation in broilers. A total of 180 birds were used, 60 per strain. The parameters recorded at 8 weeks of age were body weight, shank length, thigh length, drumstick length, body length, body width, breast width and wing length. Principal component analysis with variance maximizing orthogonal rotation was used to extract the components. Two principal components were extracted in Arbor Acre which explained 65% of the total variation in the original variables. Similarly three principal components each were extracted in Marshal and Ross strains accounting for 74.76% and 70% of the total variance respectively. Generally, PC1 had the largest share of the total variance and correlated highly with breast width, wing length, thigh length, shank length and body length. PC1 was termed the generalized form of broilers. PC2 had its loadings on drum stick length, breast width, thigh length and wing length while PC3 had positive loading on drumstick length. These components could be used as selection criteria for improving body size of broilers.**

***Key words:*** Body parameters, Broilers, Loadings, Variance maximizing rotation.

**INTRODUCTION**

Growth is a complex trait in animals that is controlled by genetic and non genetic factors. Body weight and body conformations are the two important parameters for measuring growth in the domestic chicken. The mechanisms involved in the control of growth in chickens are too complex to be explained only under univariate analysis because all related traits are biologically correlated due to pleiotropic effect of genes and linkage of loci (Rosario *et al*., 2003). Consequently, multivariate approach is employed to analyze growth data in chicken and other domestic animals. Principal components analysis is a mathematical procedure that transforms a number of possibly correlated variables into a smaller number of uncorrelated variables known as principal components which are ordered so that the first few retain most of the variation present in the original variables (Jolliffe, 2002). From the view point of animal genetics and improvement, principal components simultaneously consider a group of attributes which may be used for selection purpose (Pinto *et al.*, 2006). Principal component analysis has been used to describe the relationship between body measurements and body size in chicken (Ibe, 1989; Yakubu *et al.*, 2009a), duck (Ogah *et al.*, 2009) and turkey (Ogah *et al.*, 2011). Arbor Acre, Marshal and Ross were among the strains of broiler chicken reared by farmers in southern Nigeria. They cope fairly well with the hot season of January to March in Nigeria and reach market weight at about 8 weeks of age. Understanding the interrelationships between body weight and body measurements in these birds will help the farmer predict their body weight at various ages especially in the rural areas where scales may not be available. The objective of this study was to examine the relationship among body measurements in the three strains of broiler chickens with a view of identifying those components that define body conformation. These could be used as selection criteria for improving meatiness in broilers.

**MATERIALS AND METHODS**

**Study location:** The study was conducted at the poultry unit of teaching and research farm, Department of Animal Science, Delta State University, Asaba campus. The Delta State University Asaba campus is located between longitude 60º 45[1] East and latitude 60º 12[1] North.

**Experimental animals and their management:** A total of 210 broiler chicks comprising 70 each of Arbor Acre, Marshal and Ross procured from a reputable hatchery were used for the study. The actual data collection was done using 60 broilers per strain while 10 chicks were provided to take care of mortality. The chicks were housed separately in deep litter pens at day old. The birds were fed *ad libitum* top broiler starter diet from day old to 4 weeks of age and a top feed broiler finisher diet from 4 to 8 weeks of age. Clean drinking water was also made available to the birds all the time. All the necessary vaccines for broiler chicks were administered at the appropriate ages.

**Traits measured:** The body weights of the birds were recorded on weekly basis to 8 weeks of age. The body measurements namely shank length, thigh length, drumstick length, body length, body width, breast width and wing length were measured at 8 weeks of age as described by Monsi (1992) and Udeh *et al.*, (2011).

**Statistical analysis:** Means, standard errors, minimum and maximum of body weight and body measurements of each strain of broilers were obtained using the descriptive statistic of SPSS 16 (2007). One way analysis of variance was used to test the effect of strain of broiler on the parameters. Pearson correlation coefficients among the body measurements were calculated for each strain of broilers and the correlation matrix which was the primary data required for PCA generated. Bartletts test of sphericity was used to test if the correlation matrix was an identity matrix (each variable correlated with itself) or a correlation matrix full of zero. The suitability of the data set to PCA was further tested by Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy. This tested whether the partial correlations among variables were small. A KMO measure of 0.60 and above is considered adequate (Eyduran *et al.*, 2010). Everitt *et al.,* (2001) defined principal component analysis as a method of transforming variables in a multivariate data set, $x_1$, $x_2$, ……..$x_p$ into new uncorrelated variables $y_1$, $y_2$,…….$y_p$ which account for decreasing proportions of the total variance in the original variables defined as

$$y_1=a_{11}x_1+a_{12}x_2+ \ldots\ldots+ a_{1p}x_p.$$
$$y_2=a_{21}x_1+a_{22}x_2+\ldots\ldots+ a_{2p}x_p.$$
$$y_p=a_{p1}x_1+a_{p2}x_2+\ldots\ldots+ a_{pp}x_p.$$

The principal components $y_1$, $y_2$…….$y_p$ account for decreasing proportions of the total variance in the original variables $x_1$, $x_2$,……$x_p$. Variance maximizing orthogonal rotation was used in the linear transformation of the factor pattern matrix in order to make the interpretation of the extracted principal components easier. The principal components analyses were performed using the factor program of SPSS 16 (2007) statistical package.

**RESULTS**

Table 1 presents the descriptive statistics of body weight and body measurements of three strains of broiler chicken at 8 weeks of age. Arbor Acre and Ross attained average body weight of 1.88 kg and 1.81 kg respectively which were superior to Marshal (1.65kg) at 8 weeks of age. Arbor Acre was the most superior in drumstick length and wing length compared to Ross and Marshal strains. The Ross strain was significantly ($p<0.05$) superior to Arbor Acre and Marshal strain in body length while Marshal strain recorded the highest breast width. The three strains of broilers did not differ ($p>0.05$) in shank length and body width.

**TABLE 1. DESCRIPTIVE STATISTICS OF BODYWEIGHT (KG) AND LINEAR BODY MEASUREMENTS (CM) OF THREE STRAINS OF BROILER CHICKEN AT 8 WEEKS OF AGE.**

| Variable | No | Arbor Acre | | | Marshal | | | Ross | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean ± S.E | Min | Max | Meant ± S.E | Min | Max | Mean ± S.E | Min | Max |
| Bodyweight | 60 | 1.88 ± 0.04$^{b}$ | 1.60 | 2.20 | 1.65 ± 0.03$^{a}$ | 1.40 | 1.90 | 1.81 ± 0.03$^{b}$ | 1.60 | 2.00 |
| Shanklength | 60 | 7.80 ± 0.05$^{a}$ | 7.10 | 8.20 | 7.64 ± 0.06$^{a}$ | 7.10 | 8.00 | 7.54 ± 0.06$^{a}$ | 7.10 | 8.00 |
| Thighlength | 60 | 17.16 ±0.06$^{b}$ | 16.70 | 17.60 | 17.39 ± 0.08$^{b}$ | 16.80 | 17.90 | 15.25± 0.04$^{a}$ | 15.00 | 15.60 |
| Drumstick length | 60 | 8.72 ± 0.03$^{c}$ | 8.50 | 9.00 | 7.95 ± 0.05$^{b}$ | 7.50 | 8.40 | 7.46 ± 0.07$^{a}$ | 6.90 | 7.90 |
| Bodylength | 60 | 32.79 ± 0.15$^{b}$ | 31.40 | 33.80 | 31.30 ± 0.16$^{a}$ | 30.50 | 32.50 | 37.12 ± 0.07$^{c}$ | 36.70 | 37.70 |
| Bodywidth | 60 | 16.48 ± 0.05$^{a}$ | 15.90 | 16.90 | 16.45 ± 0.10$^{a}$ | 15.20 | 17.10 | 16.67 ± 0.06$^{a}$ | 16.20 | 17.20 |
| Breastwidth | 60 | 10.53 ± 0.05$^{b}$ | 9.90 | 10.90 | 12.93 ±0.05$^{c}$ | 12.60 | 13.40 | 9.60 ± 0.06$^{a}$ | 8.90 | 9.90 |
| Winglength | 60 | 18.98 ± 0.07$^{c}$ | 18.30 | 19.50 | 17.95 ± 0.06$^{a}$ | 17.50 | 18.50 | 18.57 ± 0.05$^{b}$ | 18.10 | 19.00 |

Mean in the same row bearing different superscript letters are significantly ($p<0.05$) different.

Table 2 presents the coefficient of correlations of body weight and body measurements of the three strains of broiler chicken. The correlation coefficients ranged -0.05-0.76, -0.02-0.56 and -0.28-0.60 in Arbor Acre, Marshal and Ross strains respectively. Relationships between body weight and most of the body measurements were positive and non significant ($p>0.05$) in the three strains of broilers. Highly significant ($p<0.01$) positive correlations were recorded for shank length and breast width (0.62), thigh length and breast width (0.66), thigh length and wing length (0.64) and breast width and wing length (0.76) in Arbor Acre broiler. In Marshal, significant ($p<0.05$) positive relationships were obtained for shank length and body width (0.56), shank length and wing length (0.50) and body width and wing length (0.47). Similarly, in Ross strain, significant ($p<0.05$) positive relationships were observed for thigh length and wing length (0.54), shank length and wing length (0.55) and body width and breast width (0.50). Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy computed for Arbor Acre, Marshal and Ross were 0.60, 0.62 and 0.67 respectively. These values revealed the pattern of correlation among the variables. Though not marvelous, the values indicated that the sample sizes were adequate to apply PCA (Kaiser, 1960). Results of the Bartlett test of sphericity for body measurements of Arbor Acre (chi-square 55.70, $p=0.00$), Marshal (chi-square 37.71, $p<0.01$) and Ross (chi-square 64.97, $p=0.00$) were significant. This implied that PCA was applicable to the data sets.

**TABLE 2. CORRELATION COEFFICIENT OF BODYWEIGHT AND BODY MEASUREMENTS OF ARBOR ACRE, MARSHAL AND ROSS BROILER CHICKEN AT 8 WEEKS OF AGE.**

| TRAIT | BW | SHL | THL | DSL | BDL | BDW | BRW | WL |
|---|---|---|---|---|---|---|---|---|
| **Arbor Acre.** | | | | | | | | |
| BW | 1.00 | | | | | | | |
| SHL | 0.19 | 1.00 | | | | | | |
| THL | 0.11 | 0.31 | 1.00 | | | | | |
| DSL | -0.05 | 0.11 | -0.01 | 1.00 | | | | |
| BDL | -0.43 | 0.12 | 0.31 | 0.34 | 1.00 | | | |
| BDW | 0.10 | -0.08 | 0.26 | 0.45* | 0.09 | 1.00 | | |
| BRW | 0.26 | 0.62** | 0.66** | -031 | -0.04 | 0.09 | 1.00 | |
| WL | 0.18 | 0.49* | 0.64** | -0.30 | 0.09 | 0.12 | 0.76** | 1.00 |
| **Marshal** | | | | | | | | |
| BW | 1.00 | | | | | | | |
| SHL | -0.02 | 1.00 | | | | | | |
| THL | 0.21 | 0.31 | 1.00 | | | | | |
| DSL | 0.27 | -0.53* | -0.52* | 1.00 | | | | |
| BDL | 0.50* | 0.01 | 0.20 | 0.18 | 1.00 | | | |
| BDW | -0.17 | 0.56* | 0.16 | -0.31 | -0.34 | 1.00 | | |
| BRW | -0.31 | 0.20 | -0.42 | 0.05 | -0.15 | -0.04 | 1.00 | |
| WL | -0.15 | 0.50* | 0.19 | -049* | -0.05 | 0.47* | 0.03 | 1.00 |
| **Ross** | | | | | | | | |
| BW | 1.00 | | | | | | | |
| SHL | 0.36 | 1.00 | | | | | | |
| THL | -0.40 | 0.22 | 1.00 | | | | | |
| DSL | 0.39 | -0.22 | -0.23 | 1.00 | | | | |
| BDL | -0.37 | -0.28 | 0.35 | -0.01 | 1.00 | | | |
| BDW | 0.03 | 0.17 | -0.46* | -0.42 | -0.70** | 1.00 | | |
| BRW | 0.60** | 0.44 | -0.48* | 0.23 | -0.71** | 0.50* | 1.00 | |
| WL | 0.17 | 0.55* | 0.54* | -0.37 | 0.09 | -0.08 | -0.06 | 1.00 |

*Significant ($P<0.05$) **Significant ($p<0.01$)

Table 3 presents the eigen values, percentage of the total variance along with the rotated component matrix and communalities of the body measurements of three strains of broiler chicken. The communalities represent estimates of the variance in each variable accounted for by the components. It ranged 0.413-0.883, 0.592-0.894 and 0.760-0.940 in Arbor Acre, Marshal and Ross broilers respectively. The eigen values showed the amount of variance out of the total variance explained by each of the factors.

**TABLE 3. EIGEN VALUES AND PERCENTAGE OF TOTAL VARIANCE ALONG WITH THE ROTATED COMPONENT MATRIX AND COMMUNALITIES OF THE BODY MEASUREMENTS OF ARBOR ACRE, MARSHAL AND ROSS STRAINS OF BROILER CHICKEN.**

| | PC1 | PC2 | PC3 | Communalities |
|---|---|---|---|---|
| **Arbor Acre** | | | | |
| Shank length | 0.675 | 0.078 | - | 0.462 |
| Thigh length | 0.789 | 0.296 | - | 0.710 |
| Drumstick length | -0.245 | 0.852 | - | 0.785 |
| Body length | 0.141 | 0.627 | - | 0.413 |
| Body width | 0.105 | 0.690 | - | 0.488 |
| Breast width | 0.930 | -0.130 | - | 0.883 |
| Wing length | 0.897 | -0.064 | - | 0.808 |
| Eigen values | 2.841 | 1.707 | - | |
| % of the variance | 40.583 | 24.383 | - | |
| **Marshal** | | | | |
| Shank length | 0.885 | 0.112 | 0.062 | 0.800 |
| Thigh length | 0.434 | -0.736 | 0.235 | 0.785 |
| Drumstick length | -0.738 | 0.306 | 0.106 | 0.649 |
| Body length | -0.028 | -0.107 | 0.939 | 0.894 |
| Body width | 0.634 | -0.065 | -0.520 | 0.676 |
| Breast width | 0.168 | 0.899 | 0.029 | 0.837 |
| Wing length | 0.766 | 0.010 | -0.069 | 0.592 |
| Eigen values | 2.677 | 1.549 | 1.007 | |
| % of total variance | 38.237 | 22.132 | 14.388 | |
| **Ross** | | | | |
| Shank length | 0.403 | 0.824 | -0.005 | 0.842 |
| Thigh length | -0.588 | 0.639 | -0.074 | 0.760 |
| Drumstick length | 0.072 | -0.244 | 0.935 | 0.940 |
| Body length | -0.878 | -0.009 | 0.099 | 0.781 |
| Body width | 0.748 | -0.144 | -0.594 | 0.933 |
| Breast width | 0.913 | 0.118 | -0.247 | 0.908 |
| Wing length | -0.124 | 0.863 | -0.206 | 0.803 |
| Eigen value | 2.733 | 2,079 | 1.155 | |
| % of total variance | 39.037 | 29.696 | 16.501 | |

Two principal components were extracted from Arbor Acre broilers with eigen values of 2.841 for the first principal component (PC1) and 1.707 for the second principal component (PC2). The two principal components accounted for 65% of the total variance present in the seven original variables. PC1 had high loadings (correlations between the components and the variables) on breast width (0.930), wing length (0.897) and thigh length (0.789). PC2 was orthogonal to PC1 and loaded heavily on drumstick length (0.852). In Marshal, three principal components were extracted with eigen values of 2.677, 1.549 and 1.007 for PC1, PC2 and PC3 respectively. The three principal components accounted for 74.76% of the total variance present in the original variables. PC1 had high positive loadings on shank length (0.885), wing length (0.766) and a negative loading on drumstick length (-0.735) implying that an increase in shank length and |or wing length will results to correlated decrease in drumstick length of Marshal broiler. A similar situation was obtained in PC2 which loaded heavily on breast width (0.899) and thigh length (-0.736), thus implying that an increase in breast width will results to decrease in thigh length. PC3 was most highly correlated with body length (0.939). In Ross broilers, three principal components were extracted after varimax rotation accounting for 70% of the total variance in the original variables with eigen values of 2.733, 2.079 and 1.155 for PC1, PC2 and PC3 respectively. PC1 was most highly correlated with breast width (0.913), body width (0.748) and body length (-0.878) implying high relationship among the three variables. PC2 had high positive loadings on wing length (0.863) and thigh length (0.824) while PC3 was most highly correlated with drumstick length (0.935).

## DISCUSSION

The average bodyweight of 1.88kg, 1.81kg and 1.65kg attained by Arbor Acre, Ross and Marshal respectively at 8 weeks of age were in line with the report of Akanno *et al*., (2007) that broiler birds attain a market weight of 1300.00-2000.00g at 8-10 weeks of age. Abdullah *et al.,* (2010) reported an average bodyweight of 1801.00g for Ross broilers at 7 weeks of age. The positive and significant correlations among the body measurements observed in the three strains of broilers indicate high predictability among the variables (Pundir *et al.,* 2011).

The positive relationship between bodyweight and most of the body measurements showed that bodyweight can be predicted from body measurements. A similar observation was reported by Ajayi *et al.,* (2008). The values of communalities computed for the three strains of chickens confirm that PCA was appropriate for the data sets. Yakubu *et al.,* (2009b) reported high range of communalities (0.755-0.987) for body measurements of Arbor Acre broilers. Mendes (2011) reported a communality range of 0.785-0.987 for body measurements of Ross broilers which was similar to what was obtained in this study. The lower communality observed for body length (0.413) and shank length (0.462) in Arbor Acre imply that the body parameters were weak in explaining the total variation in the body measurements of Arbor Acre broilers.

Generally in the three strains of chicken, PC1 had the largest share of the total variance and correlated highly with breast width, thigh length and shank length. PC1 could be described as the generalized form of broilers (Salako, 2006). In a principal component analysis of body measurements of broilers, Yakubu *et al.,* (2009b) reported that PC1 had high positive loadings on body weight, breast circumference and thigh length of Arbor Acre and termed PC1 "form factor". Mendes (2011) reported that PC1 had the highest correlation with shank length, breast circumference and bodyweight of Ross 308 broilers. Yakubu *et al.,* (2009a) reported that the first principal component accounted for the largest variance in the morphological traits of three Nigerian chicken genotypes. Ogah *et al.,* (2009) presented data that showed PC1 accounting for the largest variance in the body measurements of ducks with high positive loadings on body width, bill width, shank length, body length, head length and neck length. Pinto *et al.,* (2006) used PCA to analyze performance and carcass traits measured in a population of *Gallus gallus*. The authors reported that the five first principal components explained 93.30% of the total variation and the first component explained 66.00%. They called the first component generalized weight because the largest eigen vectors were associated with bodyweight at 35 and 42 days of age, liver, breast, wing and thigh weights. According to Mendes (2009), the first principal component provides an adequate summary of the data in most cases.

**Conclusion and Recommendation**

In the three strains of broiler chicken, PC1 had the largest share of the total variance and correlated highly with breast width, wing length, thigh length and shank length. PC1 could be used to describe the generalized form of broilers. PC2 was orthogonal to PC1 and loaded heavily on drumstick length, breast width and wing length. The subsequent component, PC3, was highly correlated with body length and drumstick length. The three principal components could be used to define body size of broilers. These components could be used as selection criteria for improving meatiness in broilers. The components could also be used as factor scores for predicting the live weight and carcass weight of broilers.

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