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ABG 012: Comparison of live weight and body measurements of broiler Strains using Bartlett Factor Scores in Multiple Regression

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Abstract
In order to compare live weight and body conformation of Arbor Acres (AA) and Annak (AN) broilers under same management and environment, the body weight and body dimensions of a population of one hundred each of Arbor Acres and Annak broilers were collected in a 56-day trial in Ibadan, Nigeria. Eight zoometric measurements namely Live weight (g), Abdominal Circumference, Abdominal length, Breast width, leg length, Height, Wing length and Thigh circumference (all in cm) were recorded for the study. Descriptive statistics, Bartlett Factor scores in multiple linear regression procedure with stepwise method of SPSS Version 17 were employed to compare body parameters of strains. Results indicated that Arbor Acres was heavier by 23.5%, and possessed wider breast by 4.9% than Annak strain at 8 weeks. Regressed normal equations had high Variance Inflation Factor (VIF) values indicating multi-collinearity among independent variables, thus reducing its predictive ability. The loading structure revealed basic differences in body conformation structure between AA (Body and Thigh Factors) and AN (Breast and Height Factors) strain and for the mixed data of both broilers as an index for broilers generally (Thigh/Breast and Body Factors). Bartlett factor scores in multiple linear regression equations yielded highly significant comparative equations with $p<0.0001$; and intercept of 825.51, 788.69 and 807.10 indicating differences in growth of Arbor Acres, Annak and for mixed population of both strains of broilers.

Key words: Arbor Acres, Annak, Live body measurements; Bartlett Factor Scores, Stepwise Regression.

Introduction
Poultry industry is one of the fastest growing segments in the agricultural sector and it undoubtedly plays an important role in the economy of tropical countries (1). Currently several broiler strains are being imported by secondary breeding companies without any dedicated enforcement of laws controlling the industry. Commercial strains under farm conditions are recording variable performances and sometimes below the declared standard. It is also known that different strains of birds respond differently to environmental stresses, thus producing different and specific reactions due to genotype by environment interaction resulting from different sensitivities of genotype to environment (2). The foregoing thus necessitated the need to evaluate growth potential in two strains of broilers to generate baseline information for commercial broiler production in the environment. The Multiple Linear Regression (MLR) is being proposed for estimating, predicting and comparative purposes. The procedure can be used to evaluate growth in modern broilers. Factor score regression method is a three-step approach (3) built on the assumption that scores resulting from factor rotation will be independent and uncorrelated. It thus maximizes validity by producing factor scores that are highly correlated with specific variables. The scores, when used as standardized observed values of the original variables constituting the estimated factors to regress linear equations, give higher precision and predictive ability in subsequent MLR equations (4). This research was designed to compare the live weight and body conformation of two broiler strains using Bartlett Factor Scores (BFS) in Multiple Linear Regression equations.

Materials and Methods

100 day-old chicks each of Arbor Acres (AA) and Anak (AN) broilers were purchased from 2 different Hatcheries in Ibadan Nigeria. Both strains were subjected to same standard management practices prescribed for broiler chickens from day-old to 56th day. Vaccinations were administered as recommended. Feed and water were offered daily to each strain *ad-libitum*. Formulated feed was utilized. The calculated protein contents of the Starter and Finisher diets were 23.80 and 20.01 % while the energy contents were 3025.00 and 2607.00 KCal/kg respectively. Body weight of chicks at day-old was taken by weighing individually with a sensitive egg scale while body weight from second week to the 8th week was determined with a 5-kg capacity Camry dial spring scale. Weekly body measurements were taken early in the morning before feeding at the appointed day and time. Measurements were taken from 20 birds by random sampling from each strain, until all measurements were completed successfully before replacement. Linear measurements were made with a thin thread and the lengths were determined on a metric ruler in centimeters. The eight (8) biometric measurements recorded were: live body weight (LBW), Breast width (BRW), Wing length (WGL), Abdominal length (ADL), Abdominal Circumference (ADC), Leg length (LGL), Thigh circumference (TCF) and Height (HT). The experimental design was completely randomized design (CRD). All measurements taken at 8 weeks were subjected to means procedure and T-test ($p<0.05$) while all linear measurements recorded were subjected to Multiple Linear Regression (MLR) analyses in order to predict body weight at eight weeks for each strain. Secondly, all body measurements for each strain were subjected to Principal Component Analysis (PCA) to extract two Factors and then generate Factor Scores by Bartlett's method for use as independent variables in the subsequent MLR, to obtain parameters for comparison between strains. Live weight to be estimated was excluded from factor analysis. Factor Scores obtained were then used as independent variables in MLR procedure for the regression of body weight on Factor scores (growth equation) for each strain. The software of SPSS version 17 (5) was used for the analysis. The model for the normal regression of body weight on other body measurements was: $Y_{ijkl} = a + b_1 X_1 + b_2 X_2 + b_3 X_3 + .. + b_n X_n + \varepsilon_{ijkl.}$ Where Y = Response in body weight (g); a = Constant for strain; b = Coefficient of trait $_{i,}$ for i = 1 to n; X= Body trait $_{i}$, for i = 1 to n; while 1 to n = number of traits extracted by the stepwise method. The comparative standard model for the regression of body weight on Bartlett Factor scores was: $y = \mu + \beta_1 * BF_1 + \beta_2 * BF_2 + \varepsilon$. Where y = Live broiler finisher weight (g), μ = Strain Constant, β = Standardized/Unstandardized coefficients of estimated parameters obtained from the regression of LBW on BFS. BF = Bartlett Factor values obtained from an independent data set of similar body measurements from any strain in the same environment. Ɛ = error term of the model. The hypothesis tested was that there was no significant difference between live weight and body conformation of Arbor Acre and Annak 2000 strains at 8 weeks.

Results and Discussion

Table 1 shows the result of descriptive analysis. ANOVA of data at 8 weeks from both broiler strains revealed that AA had significantly ($p<0.05$) higher maximum live weight than Annak (2470 vs 2000 g), but no significant ($p>0.05$) superiority in mean values of LBW, ADC, HT, ADL, BRW, LGL, WGL and TCF between the two strains. Maximum weight values revealed that AA was significantly ($p<0.05$) heavier than AN by 23.5%. This might be due to genetic superiority of AA over AN. The result of AA was above the 8th week bodyweight of 2445g for Ross, 2340g for Annak, 2100g for Marshal (6), but below 2811.3g reported for Arbor Acres strain (7). The high SD (292 vs 165) for LBW in both strains were indications of high variability of body weight in the environment. SD for ADC in both strains and ADL in AA strain also signified low levels of variability. The low CV (<1.00) values implied that each strain had been strictly bred to high level of uniformity in weight, shape and body conformation.

Table 1: Mean values of live weight and other body traits at 8 weeks for Arbor Acres and Annak Broilers

Param.	Strain	Mean	SE	SD	CV	Min	Max
LBW	AA	1991.00	92.30	291.87	0.15	1650.00	2470.00[a]
	AN	1748.00	52.32	165.45	0.09	1500.00	2000.00[b]
ADC	AA	46.72	0.79	2.50	0.05	42.00	50.00
	AN	47.35	0.79	2.51	0.05	43.00	51.00
HT	AA	23.00	0.26	0.82	0.04	22.00	24.00
	AN	22.40	0.35	1.10	0.05	21.00	24.00
ADL	AA	22.75	0.40	1.28	0.06	21.00	24.50
	AN	22.15	0.77	2.43	0.11	19.00	26.50
BRW	AA	21.35	0.56	1.78	0.08	18.00	24.50
	AN	20.35	0.47	1.48	0.07	18.00	22.30
LGL	AA	18.95	0.26	0.83	0.04	17.50	20.00
	AN	18.20	0.52	1.64	0.09	16.00	20.50
WGL	AA	17.55	0.30	0.96	0.05	16.00	19.00
	AN	18.15	0.40	1.25	0.07	16.00	20.00
TCF	AA	13.03	0.19	0.59	0.04	12.00	14.00
	AN	12.38	0.38	1.20	0.10	10.00	14.00

NOTE: AA=Arbor Acres; AN=Anak; SE = Standard Error; SD = Standard Deviation; CV = Coefficient of variation; Min = Minimum Value; Max = Maximum Value; LBW = Live Weight; BRW = Breast Width; LGL = Leg Length; WGL = Wing Length; ADC = Abdominal Circumference; ADL = Abdominal Length; TCF = Thigh Circumference; HT = Height. Means in same cell with different superscripts are significantly different ($P<0.05$).

The results of normal MLR on raw data from both strains revealed high R^2 (0.93 vs 0.96), and high Variance Inflation Factor, VIF (12.26 vs 13.98) larger than 10 for both equations of AA and AN strains. Corresponding estimates for combined data were 0.93 and 15.00 (results not shown). Due to these high VIF indicating multi-collinearity among independent variables in the normal regression equations, LBW was regressed on standardized BFS in MLR equations for both strains. Table 2 presents the predicted BFS variance matrix, for body measurements of AA and AN strains. Both factors extracted by the procedure were responsible for 96.3% and 95.1% of the shared variations among linear body measurements. AA scores were equally loaded between BF1 (Body; 48.26) and BF2 (Thigh; 48.04) while AN scores were primarily loaded on BF1 (Breast; 92.97). The combined data produced 95.54% of variability with equally loaded Factor 1 (Thigh and Breast; 48.56) and Factor 2 (Body; 46.98). The extracted Factor score values obtained for combined data revealed a unique and balanced body conformation structure for broilers compared to egg-laying breeds such as guinea fowl-56.3 & 20.9 (8); male Muscovy duck-72.7 & 14.5 (9), female Turkey, 78.0 & 11.6, (10) and Naked Neck chicken-80.9 & 30.4 (11). The loading structures obtained in this work revealed the weight and importance of the extracted factors in describing body conformation, and the basic underlining differences in body shape and size between AA and AN strains. The distribution of weights between extracted Factors could be dependent on weight distribution among component traits and genetic adaptation to physiological needs (12). Results meant that AA could best be examined for conformation using Body and Thigh, and AN, using Breast and Height composite traits. The results also identified Thigh/Breast and Body as two general composite traits that could be used to compare and evaluate conformation in broilers.

Table 2: Predicted Rotated Bartlett Factor Scores for Component Traits of Arbor Acres and Annak Broilers

STRAIN	ARBOR ACRES		ANAK		Combined data	
Traits/Factors	BFS1	BFS2	BFS1	BFS2	BSF1	BFS2
BRW	0.620	0.753	0.844	0.507	0.761	0.613
LGL	0.536	0.826	0.814	0.157	0.836	0.517
WGL	0.741	0.644	0.784	0.578	0.665	0.716

ADC	0.717	0.670	0.775	0.586	0.707	0.673
ADL	0.835	0.531	0.703	0.655	0.537	0.824
TCF	0.594	0.773	0.797	0.564	0.756	0.615
HT	0.770	0.609	0.525	0.843	0.566	0.789
% Variance (RSS)	48.264	48.040	57.065	38.010	48.559	46.982
Total Variance Predicted		96.304		95.075		95.541
Factor Name	Body	Thigh	Breast	Height	Thigh/Breast	Body

Table 3 shows MLR equations with BFS as independent predictors. This procedure yielded VIF values lower than 10, little reductions in DW (1.90, 1.48 vs 1.95, 1.97) and R^2 (0.92, 0.94 vs 0.93, 0.96). There was however slight increase in Standard Error of Estimates (SEE), (180.49, 140.09 vs 174.59, 108.88) compared with normal regression equations. The combined data parameters were 1.46, 0.93 and 165.25 respectively. The two Factor Scores extracted amounted to 96.30, 95.08 and 95.54 for AA, AN and combined data and were higher than 65.0, 74.76 and 85.23 for AA, Marshall and Ross obtained by (13) to define body size in broilers. Values were also higher than 70.58% of variability obtained by (14) from three orthogonal Factors employed to study underlining relationship between production and environmental variables in layer chickens on the deep-litter, and 87.2% and 90.9% from male and female Muscovy duck reported by (15). Live weight was expected to increase as ADL and LGL (in AA); BRW and Height (in AN) and LGL/BRW and ADL (in combined data) increase. The selected Factors had significant and positive linear relationships with live weight ($P<0.0001$), while R^2 though lower, implied that equations could estimate above 92 % of variability in the data set for respective strains. R^2 values obtained were higher than 86.4 and 75.3% obtained for male and female native chickens (16). Comparison between intercepts of equations showed improvement from -7.13, -10.88 and -11.18 to 38.27, 46.12 and 57.79 respectively, revealing progressive improvement in the predictive ability of regressed equations, although these figures were lower than 674.96 and 1197.14 reported for native male and female chickens (16). The regression coefficients were higher than 0.48 and 0.03 (17). Bartlett Factor Scores in MLR procedure thus yielded standard regression models for AA, AN and combined data which could be used to estimate LBW from different broiler data sets in similar environment.

Table 3: Multiple Linear Regression Equations based on Bartlett Factor Scores for Prediction of Live weight for Arbor Acres and Annak Broilers.

Strain	Predicting Factor	Unstd. Coeff.	Std. Coeff. (β)	SE	t-value	P-value	VIF
Arbor Acres	Constant	825.51	-	21.57	38.27	0.0001	-
	BFS1	347.55	0.533	21.73	15.99	0.0001	1.00
	BFS2	521.57	0.801	21.73	24.00	0.0001	1.00
Annak	Constant	788.69	-	17.10	46.12	0.0001	-
	BFS1	453.86	0.808	17.22	26.35	0.0001	1.00
	BFS2	299.50	0.533	17.22	17.39	0.0001	1.00
Combined	Constant	807.10	-	13.97	57.79	0.0001	-
	BFS1	474.76	0.783	14.02	33.87	0.0001	1.00
	BFS2	339.68	0.560	14.02	24.23	0.0001	1.00

Adj. R^2= 0.923/0.935/0.926, SEE=180.49/143.07/165.25, DW= 1.946/1.093/1.467, Model sig. P = 0.0001 /0.0001/0.0001. BFS = Bartlett Factor Score. Values stated are for Arbor Acres/Annak/ combined data of Broilers. Unstd, = Unstandardized, Std.= Standardized.

Conclusion and Application

BFS in MLR compared adequately between AA and AN strains for growth performances. Study also revealed differences in body conformation structure and the basal growth difference between Arbor Acres and Annak broiler strains. The result could be applied to selection between strains and for evaluation of the numerous broiler strains in the commercial world.

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