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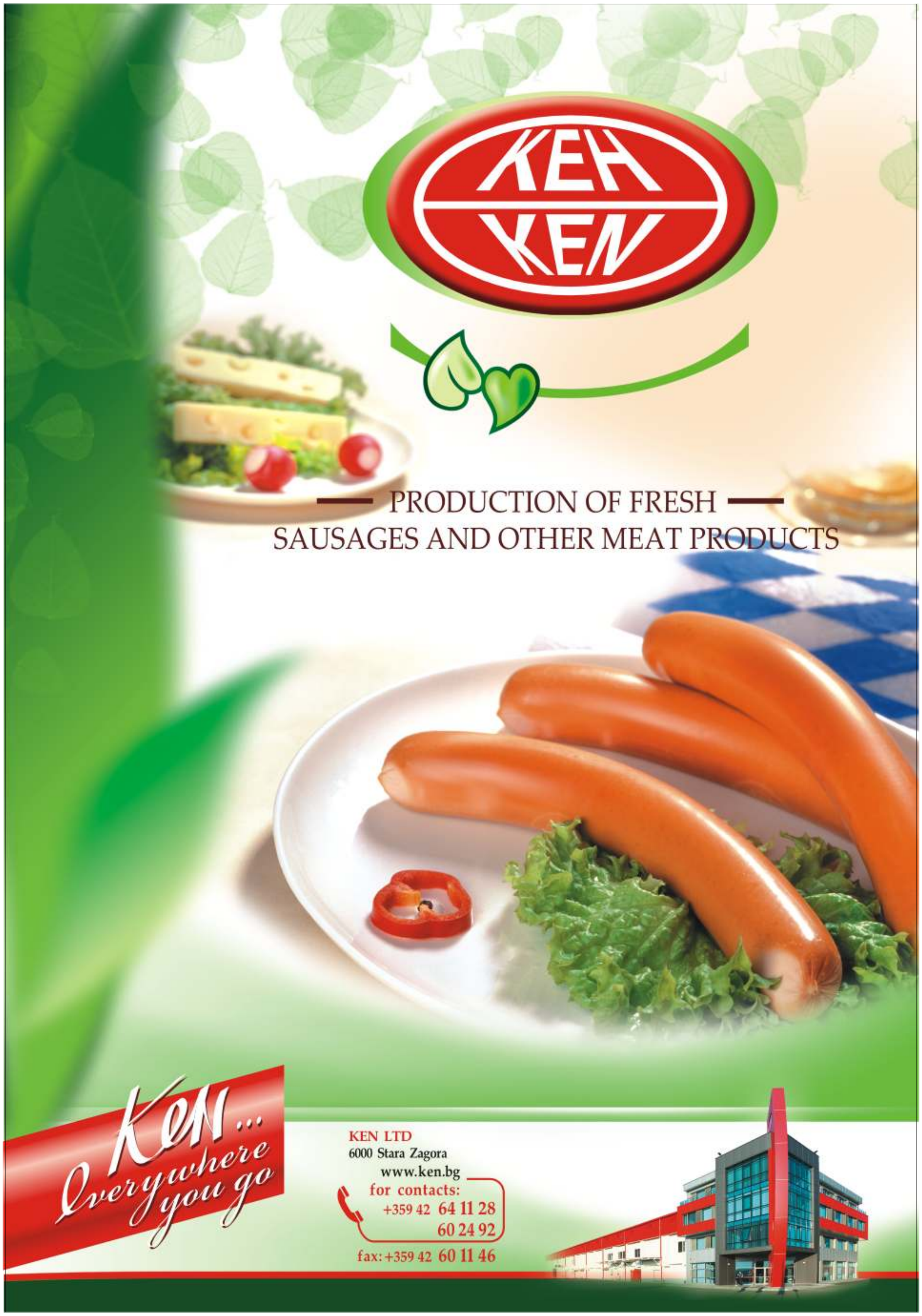
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Path analysis of body weight and morphometric traits of Nigerian indigenous Muscovy ducks

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Abstract.*Body weight and seven biometric traits namely, body length, breast circumference, thigh circumference, bill length, neck length, foot length and wing length of 221 adult Nigerian Muscovy ducks were subjected to path analysis. The ducks, reared under the traditional scavenging system, were randomly selected in Nasarawa State, north central Nigeria. The investigation aimed at determining the explanatory variables that most effectively influenced the body weight of indigenous ducks of both sexes. Sex-associated differences (P<0.05) were observed in all the studied traits, with superior values recorded for males (drakes). Bivariate correlations between body weight and linear body measurements in drakes ranged from 0.743-0.919. Correspondingly, a range of 0.745-0.894 was obtained in female ducks. The path analysis revealed that thigh circumference had the strongest direct effect on body weight of drakes, followed by body length, wing length and foot length (path coefficient = 0.326, 0.312, 0.286 and 0.115 respectively). However, a different trend was observed in females, where the influence of wing length on body weight was greatest, followed by thigh circumference, bill length and foot length (path coefficient = 0.340, 0.289, 0.217 and 0.171, respectively). The optimum linear multiple regression model in drakes included forecast indices such as thigh circumference, body length, wing length and foot length, with a determination coefficient (R2) of 0.962 and determination coefficient of error of 0.038. The corresponding indices in female ducks were wing length, thigh circumference, bill length and foot length with R2 value of 0.917 and determination coefficient of error of 0.083. These models could be useful in weight estimation in the field and for selection purposes.*

Keywords: Muscovy ducks, live weight, body dimensions, path analysis, Nigeria

Abbreviations: BWT-body weight, BDL- body length, BTC-breast circumference, THC-thigh circumference, BLL-bill length, NKL-neck length, FTL-foot length, WNL- wing length.

Introduction

Ducks are probably the most adaptable birds in a scavenger system because they possess a remarkable ability to glean and subsist on feeding materials that are not used by humans or that are not retrievable by chickens or other domestic animals (Banga-Nboko et al. 2007). The duck is very prolific and hardy (NRC, 1991), and quite promising among indigenous poultry species because of their rapid growth rate and dressed weight of drakes. Knowledge on the objective description of body size and skeletal proportions of native stock is imperative in Nigeria because of the introduction of exotic ducks such as Pekins and Khaki Campbell into the country which, as a result of interbreeding, could lead to the erosion of the genetic resource of the indigenous Muscovy ducks. Body growth in livestock may be evaluated with body components such as live weight and body measurements (Saatci and Tilki, 2007). Knowing the body weight of ducks is important for a number of reasons such as breeding, correct feeding and health. In the absence of weighing scales, especially in rural communities, examining relationships between live weight and linear body measurements of ducks can assist in decision making and husbandry. However, using simple correlation coefficients between body weight and morphometric traits may not explain the complex relationships in all aspects and may be inadequate in investigating the causal effects among the biologically related variables (Keskin et al., 2005). In order to address this limitation, path analysis could be more suitable.

Path analysis is a subset of Structural Equation Modelling (SEM), that allows examination of a set of relationships between one or more independent variables either continuous or discrete and one or more dependent variables, either continuous or discrete (Ullman, 1996). In this wise, overall correlation between two variables is decomposed into the direct effects of one on the other, indirect effects mediated by other variables, and spurious effects due to common causes. The computed path coefficients indicate the amount of change expected in the dependent variable as a result of a unit change in the independent variable (Smith et al., 1997).

In Nigeria, there is dearth of information in the literature on the relationships between the body weight and body measurements of Muscovy ducks using a classical multivariate statistical tool such as path analysis. The present investigation therefore, aimed at estimating body weight from biometric traits of Nigerian autochthonous ducks. The results obtained could be exploited by poultry farmers, researchers and rural extension workers for weight estimation in the field and as a selection criterion.

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Material and methods

Location of study and experimental animals

Data were obtained from two hundred and twenty one (221) randomly selected adult African Muscovy ducks of both sexes (95 males and 126 females respectively). The birds, which were over one year old, were selected in their rearing environment in certain smallholder farms in Nasarawa State, north central Nigeria from December, 2008 to May, 2009. Information on the age of both drakes and ducks was given by the farmers, and this was consolidated by the researchers using wing plumage. Randomization involved simple random sampling, and was done in such a way that there was a good representation of both sexes from each farm (this was to remove bias and increase the accuracy of the population parameter estimates). The State falls within the guinea savanna agro-ecological zone, and is found between latitudes 7052?N and 8056?N and longitudes 7025?E and 9037?E respectively. It has two distinct seasons. The wet season lasts from about the beginning of May and ends in October. The dry season is experienced between November and April. Annual rainfall figures range from 1100 to 2000mm. The mean monthly temperatures in the State range between 20o and 34oC, with the hottest months being March/April and the coolest months being December/January (Lyam, 2000). The birds were managed through the traditional scavenging system.

Measured traits

Body weight (BWT) and seven primary biometric traits (body length, breast circumference, thigh circumference, bill length, neck length, foot length and wing length) were measured on each adult African Muscovy duck. Measurements were restricted to apparently healthy birds that conformed to the species' classification descriptors. The body parts measured were, body length (BDL), length between the tip of the Rostrum maxillare (bill) and that of the Cauda (tail, without feathers); breast circumference (BTC), taken under the wings at the edge of the sternum; thigh circumference (THC), measured as the circumference of the drumstick at the coxa region; bill length (BLL), measured as distance from the rectal apterium to the maxillary nail; neck length (NKL), distance between the occipital condyle and the cephalic borders of the coracoids; foot length (FTL), distance from the shank joint to the extremity of the Digitus pedis and wing length (WNL), taken from the shoulder joint to the extremity of the terminal phalanx, digit 111 (Teguai et al., 2008).

Statistical analysis

Means, standard deviations (SD) and coefficients of variation (CV) of body weight and linear type traits were computed. Pairwise correlations among body weight and morphometric characters were also determined. Standardized partial regression coefficients called path coefficients (beta weights) were calculated. This was to allow direct comparison of values to reflect the relative importance of independent variables to explain variation in the dependent variable. The path coefficient from an explanatory variable (X) to a response variable (Y) as described by Mendes et al. (2005) is shown below:

$$P_{Y.Xi} - b_i \frac{S_{Xi}}{S_Y}$$

where,

$P_{Y.Xi}$ - path coefficient from X_i to Y (i= BDL, BTC, THC, BLL, NKL, FTL, WNL)

b_i - partial regression coefficient

S_{xi} - standard deviation of X_i

S_Y - standard deviation of Y

The multiple linear regression model adopted was:

$$Y - a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + e$$

where,

Y - endogenous variable (body weight)

a - intercept

b's - regression coefficients

X's - exogenous variables (BDL, BTC, THC, BLL, NKL, FTL, WNL)

e - error term, normally distributed with mean zero and variance

The significance of each path coefficient in the multiple linear regression model was tested by t-statistic using the following model (Sangun et al., 2009):

$$t_j = \frac{b_j ? \beta_j}{\sqrt{var(b_j)}} ? t_{\alpha\,(n?p-1)}\ ;\ j = 1,2,\text{------------}, P$$

where,

$var(b_j)$ - the diagonal member of matrix $s^2\,(X'X)^{-1}$

s^2 - mean square of residual obtained from ANOVA

The indirect effects of X_i on Y through X_j were calculated as follows:

$$IE_{YXi} - r_{xixj}P_{Y.Xj}$$

where,

IE_{YXi} - the direct effect of X_i via X_j on Y

r_{xixj} - correlation coefficient between ith and jth independent variables

$P_{Y.Xj}$ - path coefficient that indicates the direct effect of jth independent (exogenous) variable on the dependent (endogenous) variable

Coefficient of determination (R^2) was partitioned into its components using path analysis as follows:

$$\begin{aligned} R^2 = {} & P^2_{Y.X1} + P^2_{Y.X2} + P^2_{Y.X3} + P^2_{Y.X4} + P^2_{Y.X5} + P^2_{Y.X6} + P^2_{Y.X7} + 2r_{X1X2}P_{Y.X1}P_{Y.X2} \\ + {} & 2r_{X1X3}P_{Y.X1}P_{Y.X3} + 2r_{X1X4}P_{Y.X1}P_{Y.X4} + 2r_{X1X5}P_{Y.X1}P_{Y.X5} + 2r_{X1X6}P_{Y.X1}P_{Y.X6} + \\ & 2r_{X1X7}P_{Y.X1}P_{Y.X7} + 2r_{X2X3}P_{Y.X2}P_{Y.X3} + 2r_{X2X4}P_{Y.X2}P_{Y.X4} + 2r_{X2X5}P_{Y.X2}P_{Y.X5} + \\ & 2r_{X2X6}P_{Y.X2}P_{Y.X6} + 2r_{X2X7}P_{Y.X2}P_{Y.X7} + 2r_{X3X4}P_{Y.X3}P_{Y.X4} + 2r_{X3X5}P_{Y.X3}P_{Y.X5} + \\ & 2r_{X3X6}P_{Y.X3}P_{Y.X6} + 2r_{X3X7}P_{Y.X3}P_{Y.X7} + 2r_{X4X5}P_{Y.X4}P_{Y.X5} + 2r_{X4X6}P_{Y.X4}P_{Y.X6} \\ & + 2r_{X4X7}P_{Y.X4}P_{Y.X7} + 2r_{X5X6}P_{Y.X5}P_{Y.X6} + 2r_{X5X7}P_{Y.X5}P_{Y.X7} + 2r_{X6X7}P_{Y.X6}P_{Y.X7} \end{aligned}$$

where,

$P^2_{Y.Xi}$ - direct effects of explanatory variables (BDL, BTC, THC, BLL, NKL, FTL, WNL) in contributing to the variation of Y (body weight).

$2r_{xixj}(P_{Y.Xi})(P_{Y.Xj})$ - combined effects of explanatory variables (BDL, BTC, THC, BLL, NKL, FTL, WNL) in contributing to the variation of (body weight).

SPSS (2001) statistical package was employed in the analysis.

Results and Discussion

Body weight and morphological characters

The means, standard deviations and coefficients of variation of the body parameters of African Muscovy ducks are presented in Table 1. Sex-associated differences were found in all the body traits and indices investigated. Males (drakes) had significantly ($P<0.05$) higher body weight, body length, breast circumference, thigh circumference, bill length, neck length, foot length and wing length. The present findings on body weight and linear body measurements of both sexes are consistent with the reports of earlier workers (Teguia *et al*., 2008). This sexual dimorphism is attributable to the usual between-sex differential hormonal action (Baeza *et al*., 2001) which invariably leads to differential growth rates. The appearance of extreme sex-related differences in the biometrics of Muscovy ducks could also be as a result of the strong female selection for high quality males or competition among males for limited access to females which led to fixation of larger body size and other secondary sexual characters in males (McCracken *et al*., 2000). The greater difference in bill length between the sexes suggests that the trait may play an important role, probably in sexual display and territorial defence by males (Chochi *et al*., 2002). Additionally, the superiority of males over females could be as a result of their ability to feed at greater depth and better feed conversion efficiency (Gillespie, 1985; Bochno *et al*., 1994). The higher variability of body weight in both sexes is an indication of the high environmental sensitivity of this primary production trait.

Pairwise correlations

Bivariate correlations among body weight and linear type traits are presented in Table 2. Moderate and high positive correlation coefficients were recorded among the various body parameters. In drakes, the coefficients of correlation between body weight and body dimensions ranged from 0.743-0.919; while in females, a range of 0.745-0.894 was obtained. High positive relationships among traits suggest that they are under the same gene action and can also be predicted from one another singly or in combinations (Ngapongora *et al*., 2004; Ogah *et al*., 2009; Yakubu, 2009). The varying phenotypic correlation coefficients in the two sexes suggest sexual differences in the genetic architecture of the birds. According to Jensen *et al*. (2003), additive genetic variance-covariance structure of the morphological traits differs between sexes.

Table 1. Descriptive statistics of the body weight (kg) and linear body measurements (cm) of adult African Muscovy ducks according to sex.

	Male ducks (n=95)			Female ducks (n=126)		
Traits	Mean	SD	CV	Mean	SD	CV
BWT	2.73[a]	0.58	21.25	1.52[b]	0.42	27.63
BDL	47.86[a]	5.94	12.41	38.35[b]	6.01	15.67
BTC	38.83[a]	4.29	11.08	31.28[b]	3.91	12.50
THC	9.32[a]	1.89	20.28	6.07[b]	0.96	15.82
BLL	4.98[a]	0.77	15.46	3.75[b]	0.52	13.87
NKL	18.10[a]	2.38	13.15	14.33[b]	1.22	8.51
FTL	4.74[a]	0.79	16.67	4.01[b]	0.46	11.47
WNL	25.68[a]	3.99	15.54	16.43[b]	3.03	18.44

Path coefficients of explanatory variables

Path coefficients of the independent variables are presented in Table 3. Path analysis permits the partitioning of correlation coefficient into component parts (Topal and Esenbuga, 2001; Woods *et al*., 2003). The first component is the path coefficient (beta weight) that measures the direct effect of the predictor variable on the response variable. The second component estimates the indirect effect of the predictor variable on the response variable through other predictor variables (Pfeiffer and Morris, 1994).

In drakes (Table 3), the path analysis revealed that thigh circumference had the highest direct effect on body weight (path coefficient = 0.326; P<0.01). This implies that one unit change in standard deviation of thigh circumference results in 0.326 unit change in standard deviation of body weight. The direct effects of body length, wing length and foot length were equally significant (0.312, 0.286 and 0.115; P<0.01, respectively). The direct effects of bill length, breast circumference and neck length were non-significant (0.023, 0.023 and-0.009; P>0.01, respectively). These traits were realized indirectly mostly via thigh circumference, body length and wing length. Conversely, in female ducks (Table 4), the highest direct contribution to body weight was made by wing length, closely followed by thigh circumference, bill length and foot length (path coefficient = 0.340, 0.289, 0.217 and 0.171; P<0.01, respectively). The direct effects of body length, breast circumference and neck length on body weight were non-significant (path coefficient = 0.080, 0.019 and 0.011, respectively). Mendes *et al*. (2005) used path analysis to quantify the association between body weight and body measures of American Bronze Turkeys. In a related study, Wu *et al.* (2008), showed the relationship between body weight and body dimensions of rabbits using path analysis.

Coefficients of determination and establishment of preliminary *regression equations*

The direct and combined effects of morphometric traits on the variation of body weight are presented in Table 5. In drakes, the highest direct contribution to the variation in body weight was made by thigh circumference (R^2 = 0.106). Combined effects of thigh circumference and body length were the highest among the variable pairs (R^2 = 0.154). The sum of determination coefficients of any independent variable and two independent variables' interaction in the present study was: Σ d - 0.958. According to path analysis principle, the sum of determination coefficients plus the determination coefficient of error is 1 (Wu *et al*., 2008). In the present study therefore, the determination coefficient of error was 1- Σ d= 0.042. The preliminary multiple regression equation for drakes was: Y= -1.289 + 0.030BDL + 0.003BTC+ 0.100THC + 0.017BLL - 0.002NKL + 0.084FTL + 0.042WNL

In female ducks however, the highest single contribution to the variation in body weight was by wing length (R^2 = 0.116). The combination of wing length and thigh circumference was the highest (R^2 = 0.150). The sum of determination coefficients was 0.919 while the determination coefficient of error was 0.081. The preliminary linear model for female ducks was:

Y= -1.621 + 0.006BDL + 0.002BTC+ 0.125THC + 0.176BLL + 0.004NKL + 0.154FTL + 0.047WNL

Table 2. Phenotypic correlations among body weight and biometric traits of Muscovy ducks according to sex*

Traits	BW	BDL	BTC	THC	BLL	NKL	FTL	WNL
BWT		0.919	0.762	0.891	0.802	0.743	0.787	0.916
BDL	0.745		0.786	0.759	0.772	0.730	0.763	0.847
BTC	0.747	0.772		0.736	0.589	0.750	0.466	0.676
THC	0.838	0.636	0.630		0.750	0.768	0.641	0.792
BLL	0.768	0.666	0.745	0.533		0.680	0.713	0.711
NKL	0.667	0.601	0.622	0.507	0.695		0.471	0.650
FTL	0.749	0.495	0.558	0.622	0.532	0.576		0.703
WNL	0.894	0.679	0.647	0.762	0.678	0.588	0.665	

*Significant at P<0.01 for all correlation coefficients. Upper diagonal: Male ducks. Lower diagonal: Female ducks

Table 3. Direct and indirect effects of biometric traits on body weight of male Muscovy ducks

Traits	Correlation coefficient with body weight	Direct effect	Indirect effect							
			BDL	BTC	THC	BLL	NKL	FTL	WNL	Total
BDL	0.919**	0.312**		0.018	0.247	0.018	-0.007	0.088	0.242	0.606
BTC	0.762**	0.023^{ns}	0.245		0.240	0.014	-0.007	0.054	0.193	0.739
THC	0.891**	0.326**	0.237	0.017		0.017	-0.007	0.074	0.227	0.565
BLL	0.802**	0.023^{ns}	0.241	0.014	0.245		-0.006	0.082	0.203	0.779
NKL	0.743**	-0.009^{ns}	0.228	0.017	0.250	0.016		0.054	0.186	0.751
FTL	0.787**	0.115**	0.238	0.011	0.209	0.016	-0.004		0.201	0.671
WNL	0.916**	0.286**	0.264	0.016	0.258	0.016	-0.006	0.081		0.629

** Significant at P<0.01; * Significant at P<0.05; ns: not significant

Table 4. Direct and indirect effects of biometric traits on body weight of female Muscovy ducks

Traits	Correlation coefficient with body weight	Direct effect	Indirect effect							
			BDL	BTC	THC	BLL	NKL	FTL	WNL	Total
BDL	0.745**	0.080ns		0.015	0.184	0.145	0.007	0.085	0.231	0.667
BTC	0.747**	0.019ns	0.062		0.182	0.162	0.007	0.095	0.220	0.728
THC	0.838**	0.289**	0.051	0.012		0.116	0.006	0.106	0.259	0.550
BLL	0.768**	0.217**	0.053	0.014	0.154		0.008	0.091	0.231	0.551
NKL	0.667**	0.011ns	0.048	0.012	0.147	0.151		0.098	0.200	0.656
FTL	0.749**	0.171**	0.040	0.011	0.180	0.115	0.006		0.226	0.578
WNL	0.894**	0.340**	0.054	0.012	0.220	0.147	0.006	0.114		0.553

** Significant at P<0.01; * Significant at P<0.05; ns: not significant

Deletion of less significant variables in the estimation of body weight

The path coefficients of bill length, breast circumference and neck length in drakes were statistically non-significant as revealed by the t-test. These traits were realized considerably and indirectly via thigh circumference, body length and wing length. Thus, they were expunged from the regression model to obtain a much more simplified equation. However, in female ducks, body length, breast circumference and neck length were removed from the regression equation.

Establishment of optimum regression models for the prediction of body weight in African Muscovy ducks

After the deletion of three of the predictor variables (BKL, BTC AND NKL) in drakes, the path coefficients for the remaining four exogenous variables [thigh circumference (THC), body length (BL), wing length (WNL) and foot length (FTL)] were calculated again. The path coefficients obtained in this wise were: 0.339, 0.334, 0.284 and 0.115 for THC, BDL, WNL and FTL, respectively, and were found to be highly significant (P<0.01). The direct effects of THC, BDL, WNL and FTL in contributing to the variation in body weight were: R^2 = 0.115, 0.112, 0.081 and 0.013, respectively. The combined effects gave R^2 value of 0.641 (THC&BDL= 0.172, BDL&WNL= 0.161, THC&WNL= 0.153, BDL&FTL = 0.059, THC&FTL = 0.050 and FTL&WNL= 0.046). The sum of determination coefficient was 0.962 while the determination coefficient of error was 0.038. The optimum multiple regression model for drakes was:

Y= -1.249 + 0.033BDL + 0.104THC + 0.084FTL + 0.041WNL

The new path coefficients obtained for female ducks were: 0.359, 0.317, 0.263 and 0.173 for WNL, THC, BLL and FTL. The respective direct effects were 0.129, 0.100, 0.069 and 0.030, and these together accounted for 0.328 of the variation in body weight. The combined effects contributed to 0.589 of the observed variation. The optimum linear regression model for female ducks was:

Y= -1.554 + 0.213BLL + 0.137THC + 0.156FTL + 0.049WNL

The sum of determination in this case was 0.917 while the determination coefficient of error was 0.083.

The present findings further highlight the significance of body measurements in body weight estimation. These are consistent with the reports of earlier workers (Ngapongora *et al*., 2004; Teguai *et al*., 2008).

Conclusion

Sexual dimorphism was observed in body weight and zoometrical variables of Nigerian Muscovy ducks, with higher values recorded for drakes. Pairwise correlations between body weight and linear type traits ranged from moderate to high values in both sexes. Path analysis however, revealed that thigh circumference had the highest direct effect on body weight of drakes, followed by body length, wing length and foot length respectively. The direct effects of bill length, breast circumference and neck length were non-significant. In female ducks, the direct effects of wing length, thigh circumference, bill length and foot length on body weight were positive and significant. Body length, breast circumference and neck length however, did not directly impact on body weight. The optimum regression equation in males included forecast indices such as thigh circumference, body length, wing length and foot length. Correspondingly, wing length, thigh circumference, bill length and foot length were included in the optimum multiple regression model for female ducks. In the absence of weighing scales therefore, the prediction equations obtained in this study could serve as a useful practical tool for livestock farmers, researchers and rural development workers for weight estimation in the field and for selection purposes.

Table 5. Direct and combined effects of the independent variables contributing to the variation of body weight of Muscovy ducks

Traits	Components of Coefficient of determination (R^2)	
	Male ducks	Female ducks
Direct effects		
$P^2_{Y.X1}$	0.097	0.006
$P^2_{Y.X2}$	0.001	0.000
$P^2_{Y.X3}$	0.106	0.084
$P^2_{Y.X4}$	0.001	0.047
$P^2_{Y.X5}$	0.000	0.000
$P^2_{Y.X6}$	0.013	0.029
$P^2_{Y.X7}$	0.082	0.116
Combined effects		
X1 (BDL) and X2 (BTC)	0.011	0.002
X1 (BDL) and X3 (THC)	0.154	0.029
X1 (BDL) and X4 (BLL)	0.011	0.023
X1 (BDL) and X5 (NKL)	-0.004	0.001
X1 (BDL) and X6 (FTL)	0.055	0.014
X1 (BDL) and X7 (WNL)	0.151	0.037
X2 (BTC) and X3 (THC)	0.011	0.007
X2 (BTC) and X4 (BLL)	0.001	0.006
X2 (BTC) and X5 (NKL)	-0.000	0.000
X2 (BTC) and X6 (FTL)	0.002	0.004
X2 (BTC) and X7 (WNL)	0.009	0.008
X3 (THC) and X4 (BLL)	0.011	0.067
X3 (THC) and X5 (NKL)	-0.005	0.003
X3 (THC) and X6 (FTL)	0.048	0.061
X3 (THC) and X7 (WNL)	0.148	0.150
X4 (BLL) and X5 (NKL)	-0.000	0.003
X4 (BLL) and X6 (FTL)	0.004	0.039
X4 (BLL) and X7 (WNL)	0.009	0.100
X5 (NKL) and X6 (FTL)	-0.001	0.002
X5 (NKL) and X7 (WNL)	-0.003	0.004
X6 (FTL) and X7 (WNL)	0.046	0.077
Sum total	0.958	0.919

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