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Morphological Characterization of Five Nigerian Indigenous Chicken Types

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ABSTRACT

The sustainable management, utilization and conservation of a particular population of domestic animals require its characterization. Standard characterization and evaluation of particular populations of domestic animals may be carried out by using different methods, including traditional practices such as the use of descriptor lists of morphological characters. A detailed morphological study was performed on adult birds of five Nigerian indigenous chicken types. The chicken types include: Asa (frizzle feather), Abolorun (naked neck), Onigbaogbe (rose comb), Ibile (wild type), and Opipi (featherless wing). Eight morphological measurements were taken from birds of the different types. Tests of equality of group means revealed significant differences between means of the five types for 5 out of 8 morphological measurements. Morphological measurements were also analysed through discriminant analysis and hierarchical cluster analysis in order to establish relationships among the different types as well as to have a tool to assign new sets of data for unknown types to one of the groups analysed here. The first canonical function accounted for 72.7%, the second, third and fourth accounted for 20.4%, 5.5% and 1.4% respectively, between-group variability. Plotting the first, second and third principal components showed that the observed differences were mainly from all the measurements except jaw width and wing length. Visual examination of the samples along the canonical functions revealed some between-sample differentiations. The rose comb and the wild type were mostly isolated from each other and from all other types. The overall percentage of correctly classified cases was 56.0%. The proportion of individuals correctly classified into their original group was highest in the wild type (78.6%), then naked neck (63.6%) and featherless wing (60.0%), indicating that the wild type is highly divergent from the other types. Application of molecular genetics technique will be useful in confirming the detected phenotypic differentiation.

Key words: *Chicken, Morphological measurements, Discriminant analysis, Canonical function, Nigeria*

INTRODUCTION

Over the past 12,000 years, more than 6,300 breeds of livestock belonging to 30 domesticated species were developed following domestication and selection (Hanotte and Jianlin, 2005). These livestock populations have evolved unique adaptation to their agricultural production system and agro-ecological environments (Padmakumar, 2008). Their genetic diversity has provided the material for the successful breeding improvement programs of the developed world in the 19th and 20th century. This diversity also provides a unique resource to respond to the present and future needs of livestock production in both developed and developing countries (Hanotte and Jianlin, 2005). However, livestock diversity is shrinking rapidly.

The purported wild ancestors of our major livestock species, the repository of genetic diversity, are now either extinct or low in numbers and threatened by extinction. The impingement of these losses, on the global or the local diversity, remains undocumented (ILRI, 2006).

The sustainable management, utilization and conservation of a particular population of domestic animals require its characterization (FAO, 2007). Characterization, in genetic terms, refers to the detection of variation as a result of differences in either DNA sequences or specific genes or modifying factors (de Vicente *et al*., 2005). Standard characterization and evaluation of particular

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populations of domestic animals may be carried out by using different methods, including traditional practices such as the use of descriptor lists of morphological characters (de Vincente *et al*., 2005).

The indigenous chickens in Nigeria, which are mostly found in rural areas, are good scavengers as well as foragers. They have good maternal qualities, hardier when compared to the exotic breeds and have high survival rates with minimal care and attention (Salako and Ige, 2006). Information on the description and diversity of indigenous chickens in Nigeria is scanty. This study therefore unravels the variation found among the Nigerian indigenous chicken types based on morphological characters.

MATERIALS AND METHODS

Study Site

The study was conducted at the Botanical and Zoological Gardens of the University of Lagos, Lagos, Nigeria. The study site is located within latitude 6^o 31'.045 North and longitude 3^o 24'.122 East at altitude of 19 feet above sea level. The site is of wet equatorial climate characterized by rainfall (March to October) and dry season (November to January). The mean annual rainfall is 1620.59mm, average daily temperature is approximately 27.6^{o}C, maximum and minimum daily temperatures are 29.6^{o}C and 24.5^{o}C respectively while the range is 5.1^{o}C.

Management of the Experimental Animals

The indigenous chickens used in this study were managed in the chicken house in the Botanical and Zoological Gardens of the University of Lagos, Lagos, Nigeria. A total of 5 chicken types, that were given names by the rural people based on their phenotypic appearances (Table 2), were used in this study. Chickens were managed under a semi-intensive system and were vaccinated against Newcastle disease, coccidiosis and Marek’s disease. The poultry house (4m X 8m dimension), with all the equipment, was disinfected monthly for a disease-free environment. The house was bedded with woodshavings which was also replaced twice monthly. Chickens were fed on commercial feed and were occasionally supplemented with household wastes, vegetables and other sources of minerals. Antibiotics and multivitamins were administered to all the chickens when disease was suspected.

Table 1: CHICKEN TYPES AND THEIR PHENOTYPIC DESCRIPTIONS

Local name	Phenotypic description	Naming basis
Asa	Frizzle feathers	Feather morphology
Onigbaogbe	Rose comb	Comb type
Abolorun	Naked neck	Feather distribution
Opipi	Featherless wing	Feather distribution
Ibile	Wild type	Most common type

Asa (Frizzle feathered)

Abolorun (Naked neck)

Onigbaogbe (Rose comb)

Opipi (featherless wing)

Ibile (Wild type)

Fig. 1: The different chicken types

Data Collection

A total of 101 adult chickens were characterized under field conditions for morphological traits following FAO standard descriptors (FAO, 2007). Eight morphological measurements were taken on each bird, and these include: wing, back, beak and shank lengths, toe to back length, beak to comb length, body weight, and jaw width (fig. 3).

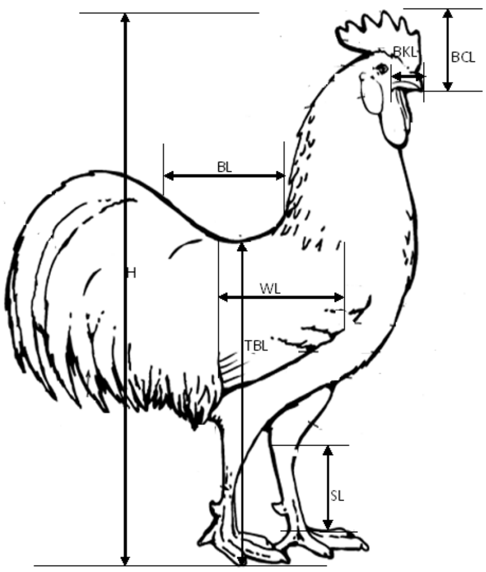

Fig. 2: Location of measurements. WL , Wing length; BL, Back length; H, Height (Toe to comb); BCL, beak to comb Length; SL, Shank length; BKL, Beak length; TBL, Toe to back length. The jaw width which is not shown was measured approximately as the distance between the wattles.

Statistical Analysis

Mean and standard deviation of each measurement were computed. Morphological measurements were submitted to a principal component analysis (PCA) and a canonical variate analysis (CVA), with the type of chicken as a separation criterion, using PASW Statistics 18 and graphs were generated using the same software. Population centroids with 95% confidence ellipses derived from the CVA were used to visualize relationships among populations. Birds were assigned to the samples using the canonical functions, and the percentage of correctly assigned birds was an additional measure of differentiation among samples. This output shows the number of cases correctly and incorrectly assigned to each type based on discriminant analysis. The percentage of correctly classified birds gives a measure of the morphological distinctness of the samples. The number of misclassified individuals indicates the degree of intermingling between the types. The Single Linkage method (Nearest Neighbour technique) was used to construct dendograms for the identification of the morphologically homogenous groups (clusters) using the same software. The measure of selection was based on the squared Euclidean distance between the types.

RESULTS

Testing the interaction between variables and sexes from 101 sex-recorded birds revealed that sex was only a significant source of variation for 3 out of 8 morphometric measurements. Only back length, shank length and beak to comb length showed significant differences between the sexes ($P<0.05$). Table 2 shows the results of the morphological measurements for all sampled birds. The F-ratios (i.e., the between-groups mean square relative to the within-groups mean square) and their significance revealed statistically significant differences between means of the five types for 5 of the morphometric measurements ($P<0.05$). The variable that presents the highest variable is body weight ($F=30.445$).

Table 3 shows the discriminant function coefficients (standardized and unstandardized). Table 4 presents the first three canonical discriminant function coefficients at group centroids for each type. Fig. 3 shows the scatterplot of the discriminant analysis computed for the birds of the different types. The first canonical function accounted for the largest amount of between-group variability (72.7%), second, third, and fourth accounted for 20.4%, 5.5% and 1.4% respectively (table 5). The Fisher's linear discriminant functions are shown in table 6.

Discriminant analysis results based on the type of chicken as a separation criterion are given in table 7. The overall percentage of correctly classified cases is 56.0%. The proportion of individuals correctly classified into their original group was highest in the wild type (78.6%) and high in the naked neck (63.6%) and featherless wing (60.0%), indicating that the wild type is divergent from the other types. The proximity matrix for the different chicken types is given in table 8. The shortest distance is 6.010, which is between frizzle feather and naked neck chickens. The longest distance is 147.940, which is between wild type and featherless wing. In order to illustrate which morphometric characters differentiate chicken types, the contribution of variables to the principal components (PC) were examined. The first principal component (PC), accounted for 36.264%, the second accounted for 16.949% and the third accounted 14.988% (fig. 3). Examination of the distance of the variables from the origin revealed that the observed differences were mainly from the beak length, toe to back length, back length, shank length, body weight, and beak to comb length. In addition, examination of the Fischer's linear discriminant functions (table 6) revealed that beak length was highest in frizzle feather and lowest in rose comb. Toe to back length was highest in wild type and lowest in rose comb.

The canonical function 1 (CF1) and canonical function 2 (CF2) were plotted to allow visual examination of the distribution of each sample along the CF axis that showed a clear between-type differentiation (Fig. 4). In the discriminate space, the rose comb and the wild type were mostly isolated from each other and from all other types. There seems to be a little overlap in the considered morphological characters between the featherless wing and naked neck as well as between frizzle feather and naked neck. This overlap seems to be greater between the naked necks and frizzle feathered. From the dendogram (Fig. 5), wild type is discriminated from the other four types, suggesting that there are morphological differences between this type and the other types. Among the other types, frizzle feather is very close to naked neck and these two are close to featherless wing. Rose comb is also discriminated from frizzle feather, naked neck and featherless wing as presented in the dendrogram analysis.

Table 2: Mean values (standard deviation in parentheses) of morphological characters of the chicken types; n, number of animals analysed; A, Wing length (cm); B, body weight (kg); C, back length (cm); D, shank length (cm); E, toe to back length (cm); F, jaw width (cm); G, beak to comb length (cm); H, beak length (cm)

	Frizzle feather (n = 44)	Naked neck (n = 22)	Rose comb (n = 16)	Wild type (n = 14)	Featherless wing (n = 5)	F-ratio	Sig.
A	17.027 (4.089)	15.791 (2.074)	18.388 (3.148)	16.036 (2.214)	15.720 (2.796)	1.793	0.137
B	0.904 (0.327)	0.905 (0.259)	1.144 (0.372)	2.079 (0.575)	0.950 (0.245)	30.445	0.000
C	20.031 (2.946)	19.441 (2.583)	21.994 (4.250)	23.879 (2.057)	21.300 (2.900)	6.005	0.000
D	6.870 (1.846)	6.964 (2.349)	8.731 (3.017)	8.036 (0.975)	6.760 (0.896)	2.907	0.026
E	27.393 (7.900)	29.227 (11.194)	25.125 (3.631)	35.364 (7.513)	24.000 (4.301)	3.762	0.007
F	2.016 (0.859)	2.018 (0.385)	2.329 (0.683)	1.771 (0.524)	1.960 (0.894)	1.252	0.294
G	3.950 (1.706)	4.932 (1.736)	6.069 (2.083)	6.886 (2.267)	3.880 (1.359)	8.813	0.000
H	2.766 (0.499)	2.700 (0.563)	2.431 (0.372)	2.771 (0.305)	2.500 (0.354)	1.993	0.102

Table 3: Discriminant function coefficients of discriminant analysis for the chicken types, abbreviations of variables as in table 2

Variables	Unstandardized canonical discriminant function coefficients				Standard canonical discriminant function coefficients			
	1	2	3	4	1	2	3	4
A	-0.002	0.010	0.176	0.219	-0.007	0.033	0.586	0.730
B	3.035	-0.718	1.285	0.206	1.101	-0.261	0.466	0.075
C	-0.082	0.159	0.114	-0.186	-0.248	0.482	0.345	-0.564
D	-0.084	0.283	-0.047	0.146	-0.174	0.589	-0.097	0.304
E	0.064	-0.056	-0.077	0.011	0.521	-0.455	-0.624	0.088
F	-0.808	0.364	0.122	-0.295	-0.559	0.252	0.0840	-0.204
G	-0.032	0.305	-0.436	0.102	-0.059	0.567	-0.811	0.188
H	-0.261	-1.186	0.503	0.999	-0.121	-0.551	0.234	0.464
Constant	-0-318	-2.235	-3.698	-3.994				

Table 4: Canonical discriminant function coefficients at group centroids

	Frizzle feathered	Naked neck	Rose comb	Wild type	Featherless wing
1	-0.569	-0.410	-0.526	3.209	-0.609
2	-0.452	-0.251	1.518	-0.002	0.141
3	0.256	-0.647	0.047	0.044	0.372
4	0.079	-0.035	0.077	-0.002	-0.763

Table 5: Summary of Canonical Discriminant Functions

Function	Eigen value	% of Variance	Cumulative %	Canonical Correlation
1	1.769	72.7	72.7	0.799
2	0.496	20.4	93.0	0.576
3	0.135	5.5	98.6	0.345
4	0.035	1.4	100.0	0.183

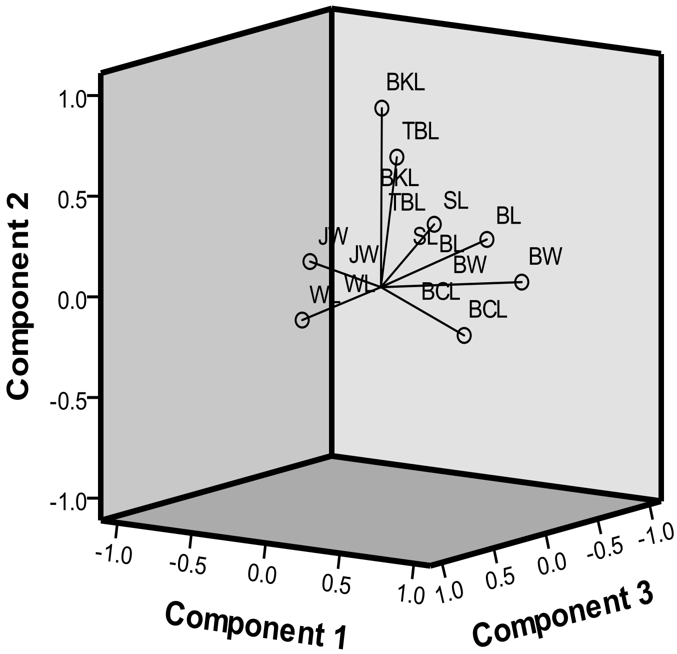

Fig. 3: Scatterplot of the first three canonical discriminant functions (group centroids) resulting from the discriminant analysis when using the type of chicken as a separation factor. BKL, Beak length; TBL, Toe to back length; SL, Shank length; BL, Back length; BW, Body weight; BCL, Beak to comb length; WL, Wing length; JW, Jaw width.

Table 6: Fisher's linear discriminant functions

	frizzle feather	naked neck	rose comb	wild type	Featherless wing
Back Length	2.156	2.093	2.443	1.908	2.424
Shank Length	.261	.331	.826	.072	.304
Toe to Back Length	-.229	-.162	-.320	.003	-.283
Beak to Comb Length	.745	1.184	1.436	.846	.791
Winglength	1.409	1.226	1.391	1.350	1.250
Body Weight	-7.544	-8.391	-9.100	3.308	-8.116
Jaw Width	-.985	-1.117	-.327	-3.877	-.474
Beak Length	10.848	10.001	8.394	9.142	9.373
(Constant)	-45.190	-41.920	-49.821	-51.141	-43.824

Table 7: Classification results of discriminant analysis

		Type	Predicted Group Membership					
			frizzle feather	naked neck	rose comb	Wild type	featherless wing	Total
Original	Count	frizzle feathered	21	8	5	2	7	43
		naked neck	3	14	2	0	3	22
		rose comb	1	3	7	0	5	16
		wild type	1	1	0	11	1	14
		featherless wing	1	0	1	0	3	5
	%	frizzle feathered	48.8	18.6	11.6	4.7	16.3	100.0
		naked neck	13.6	63.6	9.1	.0	13.6	100.0
		rose comb	6.3	18.8	43.8	.0	31.3	100.0
		wild type	7.1	7.1	.0	78.6	7.1	100.0
		featherless wing	20.0	.0	20.0	.0	60.0	100.0

56.0% of original grouped cases correctly classified.

Table 8: Proximity matrix for the chicken types

	Frizzle feather	Naked neck	Rose comb	Wild type	Featherless wing
Frizzle feather		6.010	18.174	88.468	14.468
Naked neck	6.010		34.731	63.827	31.979
Rose comb	18.174	34.731		116.378	17.717
Wild type	88.468	63.827	116.378		147.940
Featherless wing	14.468	31.979	17.717	147.940	

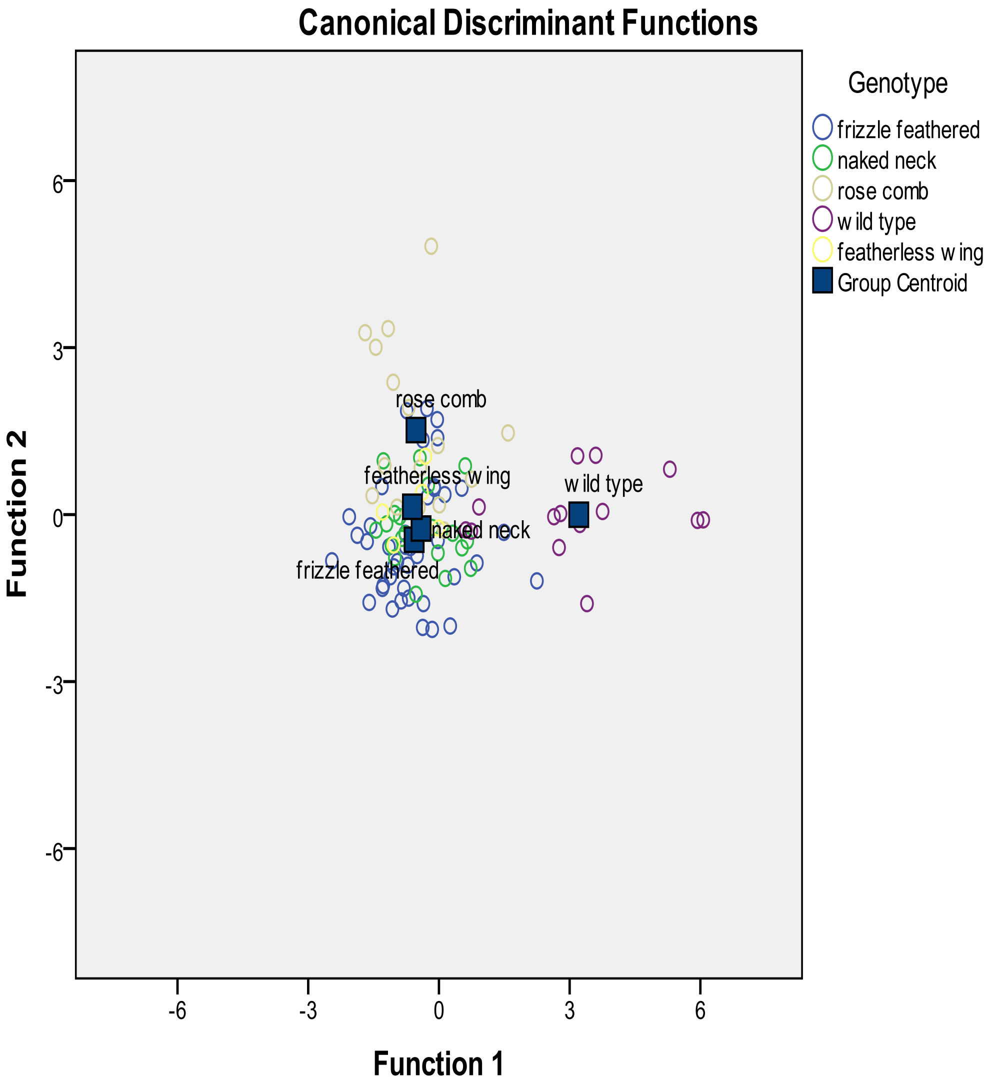

Fig. 4: 95% confidence ellipses of CFA scores of morphological characters.

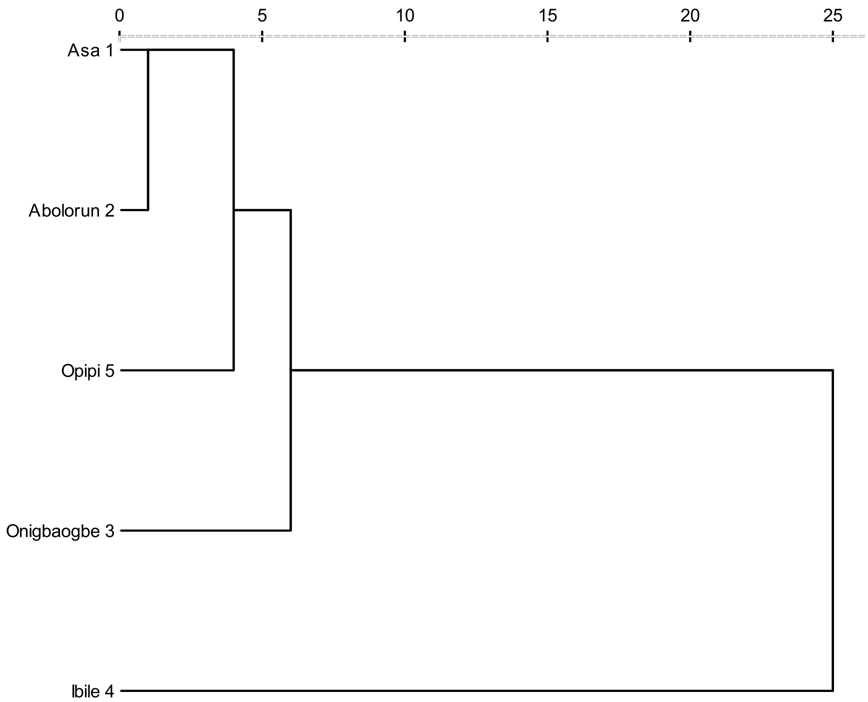

Fig. 5: Dendogram of hierarchical cluster analysis for the chicken types. *Asa*, Frizzle feather; *Abolorun*, Rose comb; *Opipi*, Featherless wing; *Onigbaogbe*, Rose comb; *Ibile*, Wild type.

DISCUSSION

The present morphological analysis of chicken types in Nigeria revealed some divergence among the types. Wild type was the most divergent from the others followed by rose comb. Wild type had the highest body weight, back length, toe to back length, beak to comb length and beak length. Rose comb had the highest shank length and higher body weight and back length, when compared to frizzle feather, naked neck and featherless wing. Frizzle feather and naked neck had very similar values for body weight, back length, shank length, toe to back length and beak length. Featherless wing also had similar values with frizzle feather and naked neck for body weight, back length and shank length. This report is contrary to the general belief that naked neck chickens have improved body weight and body dimensions because of their upper limits of critical body temperatures in hot climates which positively affects appetite (Islam and Nishibori, 2009). The higher body weight and general body size of wild type and rose comb, which are normally feathered, reported in this study is in agreement with the report of Norris *et al.* (2007), de Almeida and Zuber (2010) and Magothe *et al.* (2010). Norris *et al.* (2007) observed a lighter mature weight of indigenous Venda naked neck chickens when compared to their normally feathered counterparts. Magothe *et al.* (2010) presented a negative effect of frizzle genotype and naked neck on body weight from their study. de Almeida and Zuber (2010) also observed poorer growth rate of naked neck chickens when compared with the normally feathered chickens in their study on the effect of the naked neck genotype on growth characteristics of free range broilers in a hot climate. Yahav *et al.* (1998) and Yakubu *et al.* (2009), however, reported no genotype advantage of naked neck under diurnal cyclic temperature conditions. Garcês *et al.* (2001) observed no significant productive advantage of feather reduced birds (frizzle feather and naked neck) over the normally feathered birds. Norris *et al.* (2007) proposed that the Venda indigenous naked neck showed a higher growth rate, reaching maturity earlier but attaining a lighter mature weight than the normally feathered birds. The high negative correlation observed between mature weight and growth rate indicates that chickens that grow faster do not attain a large mature weight compared to those that mature slowly in early life (Norris *et al.,* 2007).

The similar values of morphological characters recorded for frizzle feather, naked neck and featherless wing can be explained by their similarity in reduction in feather coverage, *vis-à-vis* feather morphology and feather distribution, which provides relative heat tolerance. This also explains the overlap of frizzle feather with naked neck and featherless wing with naked as presented in this study. The greater overlap between the naked neck and frizzle feather, as compared to that between naked neck and featherless wing, maybe because the reduction in feather coverage is on the body for both naked neck and frizzle feather which should allow greater internal heat loss compared to the feather loss on the wings for the featherless wing.

Our result on the higher weight of chickens of the single comb type relative to the rose comb is consistent with the report of Collins *et al.* (1963) who found consistently higher weights in broilers with single comb than in their siblings carrying pea comb. Merat and Bordas (1978) also found a slight but significantly lower body weight of pea comb chickens compared to their single comb counterparts. They found a more depressed appetite, and therefore lower food consumption, of pea comb chickens at high ambient temperature. Crobas and Hawes (1965), however, found no consistent effects of comb type on mean body weight in their studies on single, rose, walnut and pea comb type Canadian chickens. Merat also found no significant effect of rose comb on growth rate (Crober and Hawes) and Hartmann (1972) found no association between comb type and broiler growth. According to Collins *et al*. (1963) the comb and environment interactions may be a source of error in predicting performance at a particular location (Crober and Hawes, 1966).

The dendogram shows that the rose comb is intermediate in morphology between the frizzle feather, naked neck and featherless wing on one hand, and the wild type on the other. This is in accordance with the superiority of the normal feather to a reduction in feather coverage and the superiority of the single comb to the rose comb.

PCA revealed that morphometric differentiation between types was largely from the beak length, toe to back length, back length, shank length, body weight, and beak to comb length. The normally feathered chickens had longer beak, toe to back, back, shank, and beak to comb lengths as well as higher body weight. Such differences between the types maybe related to environmental adaptation and growth rate. The longer shanks, beak to comb (which relates to the head and comb size), beak, and toe to back (which accounts for both the shank length and back length) lengths in normally feathered birds should give room for dissipation of heat. Those areas, that is, the beak, comb, face and shank, are not normally covered with feather and therefore allow heat loss. Thermal stress is reduced in naked neck, frizzle feather and featherless wing chicken types as a result of a reduction in feather coverage (Islam and Nishibori, 2009; Magothe *et al.*, 2010). Chickens with reduced feather have a higher growth rate but lower body weight and dimensions at maturity (Norris *et al.* 2007).

The proportion of individuals correctly classified into their original group was highest in the wild type (78.6%) and high in the naked neck (63.6%) and featherless wing (60.0%). This means that the wild type chickens can be more easily distinguished from others, followed by naked neck and featherless wing. The overall percentage of correctly classified cases is 56.0%. According to Turan *et al*. (2005), although a high prediction can be obtained for a particular type or population of animals, it is difficult to obtain 100% prediction of group membership in samples belonging to the same species. Application of molecular genetics technique will be useful in confirming the detected phenotypic differentiation.

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REFERENCES

Collins, W.M., B.J. Lang, H.A. Stone, N.F. Zervas and H.K. Seedah. 1963. Performance of single and heterozygous pea-combed broiler chickens in different brooding environments. *Poultry Science.* 42: 1260.

Crober, D.C. and R.O. Hawes. 1966. The influence of comb type on growth rate in the domestic fowl. *British Poultry Science.* 7(4): 241-247.

de Almeida, A.M. and U. Zuber. 2010. The effect of the naked neck genotype (Nana), feeding and outdoor rearing on growth and carcass characteristics of free range broilers in a hot climate. *Tropical Animal Health Production.* 42: 99-107.

de vicente, M.C., F.A. Guzmán, J. Engels and V. Ramanatha-Rao. 2005. *Genetic characterization and its use in decision making for the conservation of crop germplasm*. In: J. Ruane and A. Sonnino (ed.) The Role of Biotechnology in Exploring and Protecting Agricultural Genetic Resources. Food and Agriculture Organization of the United Nations, Rome. Pp121-128.

Food and Agricultural Organization (FAO). 2007. The global plan of action for animal genetic resources and the Interlaken declaration on animal genetic resources. International Conference on animal genetic resources for food and Agriculture. Interlaken, Switzerland, 3-7 September 2007. 33pp.

Garcês, A., N.H. Casey and P. Horst. 2001. Productive performance of naked neck, frizzle and dwarf laying hens under various natural climates and two nutritional treatments. *South African Journal of Animal Science.* 31(3): 174-180.

Hanotte, O. and H. Jianlin. 2005. Genetic characterization of livestock populations and its use in conservation decision-making. *The Role of Biotechnology.* FAO International Congress Villa Gualino, Turin, Italy, 5-7 March, 2005. Pp131-136.

Hartmann. W. 1972. Relationship between genes at the pea and single comb locus and economic traits in broiler chicken. *British Poultry Science.* 13(3): 305-309.

International Livestock Research Institute (ILRI). 2006. 'Safeguarding livestock diversity: the time is now' *ILRI Annual Report.* Pp22-39.

Islam, A.M. and M. Nishibori. 2009. Indigenous naked neck chicken: a valuable genetic resource for Bangladesh. *World's Poultry Science Journal.* 65: 125-138.

Magothe, T.M., W.B. Muhuyi and A.K. Kahi. 2010. Influence of major genes for crested-head, frizzle feather and naked-neck on body weights and growth patterns of indigenous chickens reared intensively in Kenya. *Tropical Animal Health Production.* 42: 173-183.

Merat, P. and A. Bordas. 1978. Effects associated with the pea-comb gene on chick weight, and body weight and food efficiency of adult hens. *British Poultry Science.* 20(5): 463-472.

Norris, D., J.W. Ngambi, K. Benyi, M.L. Makgahlela, H.A. Shimelis and E.A. Nesamvuni. 2007. Analysis of growth curves of indigenous male Venda and Naked Neck chickens. South African *Journal of Animal Science*. 37(1): 21-26.

Padmakumar, V. 2008. Livestock and climate change adaptation. *Knowledge Management Platform.* 4pp.

Salako, A.E and Ige, A.O. 2006. Haemoglobin polymorphism in the Nigerian indigenous chickens. *Journal of Animal Veterinary Advance*. **5**:897 – 900.

Turan, C., S. Yalcin, F. Turan, E. Okur and I. Akyurt. 2005. Morphometric comparisons of African catfish, *Clarias gariepinus,* populations in Turkey. *Folia Zoology.* 54(1-2): 165-172.

Yahav, S., D. Luger, A. Cahaner, M. Dotan, M. Rusal and S. Hurwitz. 1998. Thermoregulation in naked neck chickens subjected to different ambient temperatures. *British Poultry Science.* 39: 133-138.

Yakubu, A. D. Kuje and M. Okpeku. 2009. Principal components as measures of size and shape in Nigerian indigenous chickens. *Thai Journal of Agricultural Science.* 42(3): 167-176.