NATIONAL AGRICULTURAL AND FOOD CENTRE
RESEARCH INSTITUTE FOR ANIMAL PRODUCTION NITRA

Slovak J. Anim. Sci., 51, 2018 (2): 45–51

ISSN 1337-9984

MULTIFACTORIAL DISCRIMINANT ANALYSIS OF CEPHALIC MORPHOLOGY OF INDIGENOUS BREEDS OF SHEEP IN NIGERIA

M. A. POPOOLA[1]*, S. O. OSENI[2]

[1]Federal College of Animal Health and Production Technology, Ibadan, Nigeria
[2]Department of Animal Sciences, Obafemi Awolowo University, Ile-Ife, Nigeria

ABSTRACT

The study aimed at classifying Nigerian indigenous breeds of sheep on the basis of their head conformation using multivariate analyses. Twelve cephalic traits of 1,200 sheep belonging to four breeds (Balami, Yankasa, Uda and WAD) were measured. The traits were subjected to principal component (PC) analysis to reduce data dimensionality. A discriminant canonical analysis was also applied to differentiate between the breeds. The cephalic index revealed that the sheep breeds are brachycephalic (short-headed) except Uda which was mesocephalic (medium-headed). The first PC reflected variables related to length and diameter amplitudes and explained 37.5 percent of the total variance. The second PC gave major relevance to skull, face and neck lengths of the sheep and contributed to 21.30 percent of the total variance, while the third PC loaded highly for skull length, head depth and neck length and contributed 17.35 percent of the total variance. The stepwise discriminant analysis revealed that skull width, head width, head length and head depth were the most discriminating variables to separate the four breeds of sheep.

Key words: sheep breeds; cephalic; discriminant analysis; multivariate; traits

INTRODUCTION

In Nigeria, breeds of sheep are meat producing animals adapted to specific ecological zones of the country. They play agricultural, economic, cultural and religious roles. There are generally considered to be four breeds of sheep native to Nigeria. These are Balami, Uda, Yankasa and West African Dwarf (Ngere *et al*., 1979). Indigenous sheep breeds are an important storehouse of genetic material because of their ability to acclimatize to local, sometimes harsh environmental conditions, nutritional fluctuations across seasons and resistance to diseases and parasites (Kosgey and Okeyo, 2007). The Global Plan of Action for Animal Genetic Resources recognizes that a better understanding of the characteristics of indigenous livestock breeds is necessary for guiding decision making in the development of breeding programmes (FAO, 2007).

Sheep biodiversity has been described using morphological measurements or characterized using molecular data (Paiva *et al.*, 2011). According to Solomon *et al.* (2007), morphological description is an essential component of breed characterization that can be used to physically identify, describe and recognize a breed, and also to classify livestock breeds into broad categories. Historically, morphological studies, especially of the skull, were the major source of data used to characterize breeds (Kidd and Pirchner, 1971). Given their biometric nature, cephalic measurements and indices allow comparisons between breeds from very distant geographical areas, and permit research into

***Correspondence:** Email: herbyolar@gmail.com
Moshood Abiola Popoola, Federal College of Animal Health and Production Technology, Ibadan, Nigeria

Received: September 7, 2017
Accepted: December 11, 2017

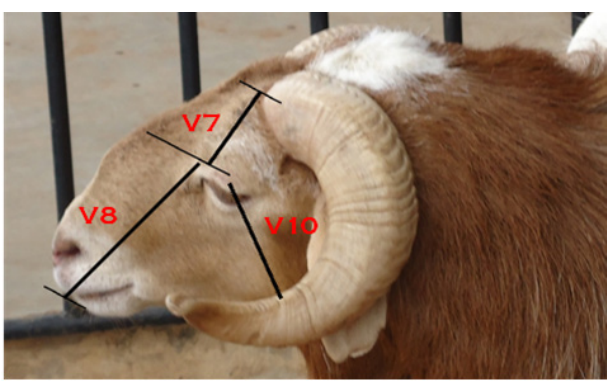
the distinctiveness of breeds based on cephalic evaluation (Pares and Jordan, 2008). According to Yunusa *et al.* (2013) incorporating more cephalic measurements in principal component analysis (PCA) models combined with biometry of cephalic anatomy will shed more light on the suitability of head measurements for breed classification. Skull morphometric studies within and across sheep breeds based on a relatively large number of specimens and employing multivariate analysis techniques are limited. Thus, this study sought to examine skull differences among indigenous breeds of sheep in Nigeria using their intraspecific variability by means of multivariate analyses via principal component and discriminant analyses.

MATERIALS AND METHODS

The study was conducted in Ibadan, Oyo State, Nigeria. The city is the largest metropolitan geographical area in the country. In 2006, the total population of Ibadan was 2,550,593 while the average population density was 828 persons per km^2 (NPC, 2006). Due to its large population, Ibadan is a strategic location and hub for transactions in large number of livestock such as cattle, sheep, goats and chickens. Thus, all the breeds of sheep are found in Ibadan as representation of sampling frame for the study. A total of 1,200 sheep consisting of 300 animals from each breed were sampled from major small ruminant markets in Ibadan and households where sheep are raised. The sampling was conducted from November 2014 to June 2016.

Data collection

Twelve basic morpho-structural traits were taken with a flexible tape rule. Cephalic traits measured were skull width, head width, face width, skull length, head length, face length, head depth, neck length, neck width, horn length, horn width and horn space. All measurements were taken with calibrated tape rule. The measurements were taken following standard procedures and anatomical reference points as described by Parés *et al.* (2012), as shown in Figure 1. Cephalic index was estimated from the measured traits as the ratio of maximum



V1 – horn space, V2 – skull width, V3 – head width, V4 – face width, V5 – horn length, V6 – horn width, V7 – skull length, V8 – face length, V9 – head length (V4+V7), V10 – head depth, V11 – neck length, V12 – neck width

Figure 1. Cephalic morphology of sheep

width of the head multiplied by 100 and divided by maximum head length (Edilberto *et al.*, 2011). The cephalic index was used to categorize individuals as: dolicocephalic (long-headed) if the cephalic index value was less than 75.9; mesocephalic (medium-headed) if the cephalic index value ranged between 76 and 81 and brachycephalic (short-headed) if the cephalic index value was greater than 81.1 (Schlueter *et al.*, 2009).

Statistical analyses

Data were subjected to multivariate analyses, the data were submitted to preliminary univariate analyses using UNIVARIATE and FREQ of SAS (SAS INSTITUTE® 9.13, 2004). Data were analysed using simple descriptive statistics before it was submitted for principal component analysis (PCA). Stepwise discriminant procedure was applied using PROC STEPDISC. The CANDISC procedure was used to enable differentiation between the breeds, to estimate Mahalanobis distances and derive canonical functions. Differences among sheep breeds for cephalic traits were analysed using the following linear model:

$Y_{ij} = \mu + \alpha_i + e_{ij}$ where;

Y_{ij} is the j^{th} morphological variable for the i^{th} breed of sheep,

μ the overall mean for each morphological variable for all sheep breeds,

α_i the effect of the i^{th} sheep breed (i^{th} = 4, for Yankasa, Uda, Balami, WAD)

e_{ij} the residual error of null average and a constant variance.

RESULTS AND DISCUSSION

Results of summary statistics of cephalic traits of the indigenous sheep are presented in Table 1. The results revealed a relatively moderate to high variability for the traits (Coefficient of variation (CV)). The highest CVs were obtained for horn space (52.71 %) and the lowest was recorded in head depth (15.77 %). The CV ranges between 16 % and 45.13 % were obtained for skull width, skull length, head width, face width, head length, face length, head depth, neck length, neck width and horn width.

Table 2 shows the effect of breeds on the cephalic traits of the sheep. Breeds of sheep differed significantly in the cephalic traits considered ($P < 0.05$). Results revealed significant differences between breeds in all variables. Uda and Balami had significantly ($p < 0.05$) higher mean values of the cephalic traits than Yankasa and WAD, with exception in skull length and horn space, which were significantly higher in WAD. Highest cephalic index was obtained in Balami (82.66 ± 11.98 %) followed by Yankasa (82.28 ± 11.65 %), WAD (82.16 ± 13.02 %) and Uda (78.35 ± 9.41 %). On average, the cephalic index reveals that Balami, WAD and Yankasa are brachycephalic (short-headed) breeds having cephalic

Table 1. Summary statistics of cephalic traits of indigenous sheep breeds in Nigeria

Traits (cm)	Mean	Variance	Standard deviation	Coefficient of variation (%)	Range
Skull width	20.92	2.52	1.50	16.00	9.00
Head width	32.24	9.87	3.14	19.35	27.90
Face width	27.73	8.63	2.94	21.40	16.50
Skull length	13.00	3.27	1.81	45.13	20.70
Head length	30.94	10.76	3.28	16.45	26.00
Cephalic index (%)	87.57	112.41	8.96	17.68	74.89
Face length	30.73	11.21	3.35	18.89	27.20
Head depth	29.51	5.98	2.45	15.77	21.00
Neck length	33.69	34.97	5.91	24.97	33.00
Neck width	50.37	82.12	9.06	24.91	62.40
Horn length	40.10	120.28	10.97	42.02	56.00
Horn width	26.21	15.34	3.92	27.56	28.50
Horn space	9.44	3.29	1.81	52.71	20.70

Table 2. Effect of breeds on cephalic traits of indigenous sheep breeds in Nigeria

Traits (cm)	Balami	Uda	WAD	Yankasa
Skull width	10.05 ± 1.37[b]	10.74 ± 1.42[a]	9.02 ± 1.62[c]	9.97 ± 1.52[b]
Head width	17.60 ± 3.10[a]	17.53 ± 2.76[a]	13.53 ±2.78[c]	16.39 ± 2.55[b]
Face width	14.65 ± 2.15[b]	15.53 ± 3.21[a]	10.98 ± 2.44[c]	13.89 ± 2.32[b]
Skull length	3.63 ± 0.65[b]	4.17 ± 1.89[ab]	4.29 ± 1.99[a]	3.96 ± 2.06[ab]
Head length	21.35 ± 2.11[b]	22.41 ± 2.77[a]	16.27 ± 2.76[d]	20.03 ± 2.45[c]
Cephalic index (%)	82.66 ± 11.98[a]	78.35 ± 9.41[b]	82.16 ± 13.02[ab]	82.28 ± 11.65[ab]
Face length	18.27 ± 2.51[b]	19.70 ± 3.32[a]	15.27 ± 2.65[c]	17.86 ± 3.34[b]
Head depth	16.38 ± 2.49[a]	16.27 ±2.32[a]	13.91 ± 1.84[c]	15.55 ± 2.37[b]
Neck length	25.36 ± 5.49[ab]	26.86 ± 5.50[a]	18.96 ± 5.01[c]	23.90 ± 5.20[b]
Neck width	39.29 ± 8.85[a]	39.71 ± 9.34[a]	30.22 ± 8.15[c]	36.62 ± 7.80[b]
Horn length	32.59 ± 9.19[a]	30.20 ± 10.90[a]	13.93 ± 6.42[c]	8.41 ± 14.68[b]
Horn width	15.78 ± 3.47[a]	16.11 ± 3.62[a]	10.21 ± 2.60[c]	14.68 ± 3.31[b]
Horn space	3.51 ± 2.54[ab]	3.34 ± 1.55[ab]	3.92 ± 1.65[a]	3.18 ± 1.46[b]

[abc]Means within the same row having different superscripts differ significantly ($p < 0.05$)

index values of circa 82 %. A sheep is said to be brachycephalic or brachycranial when its cephalic index is greater than 81.1 %. A brachycephalic individual is characterized with short and broad skull, flattened and widened occiput (Marchant *et al*., 2017). Uda sheep are mesocephalic (medium-headed) with cephalic index of 78 %, implying that the breed possess narrow or nearly oval skull. In previous studies on cephalic index, Sarma (2006) reported cephalic index of 41.95 for goats; 58.45 for puppies and 51.73 for lambs (Onar, 1999) and Karimi *et al.* (2011) reported cephalic index of 53.57 for Mehraban sheep.

Phenotypic correlation coefficients among cephalic traits of the sheep are presented in Table 3. Some traits were highly and positively correlated, while few traits were negatively correlated. High, positive and significant correlations were found between face length and face width (0.84), horn length and horn width (0.83), head length and face width (0.72), horn length and head length (0.70), horn length and neck width (0.70), horn

Table 3. Phenotypic correlations among cephalic traits of indigenous sheep breeds in Nigeria

Traits (cm)	Skull width	Head width	Face width	Skull length	Head length	Face length	Head depth	Neck length	Neck width	Horn length	Horn width	Horn space
Skull width	1.00											
Head width	0.39	1.00										
Face width	0.44	0.59	1.00									
Skull length	0.10	0.06	0.03	1.00								
Head length	0.41	0.66	0.72	-0.04	1.00							
Face length	0.44	0.55	0.84	0.48	0.61	1.00						
Head depth	0.38	0.50	0.35	0.04	0.46	0.33	1.00					
Neck length	0.32	0.03	0.31	0.02	0.40	0.22	0.19	1.00				
Neck width	0.40	0.48	0.53	0.07	0.57	0.50	0.57	0.28	1.00			
Horn length	0.39	0.53	0.61	0.03	0.70	0.55	0.56	0.45	0.70	1.00		
Horn width	0.38	0.53	0.61	0.03	0.69	0.55	0.51	0.45	0.70	0.83	1.00	
Horn space	0.02	-0.25	-0.35	-0.03	-0.31	-0.32	-0.10	-0.03	-0.28	-0.36	-0.43	1.00

width and neck width (0.70). Result also revealed that horn space was the least correlated with all other traits. This implies that increase in any of the correlated traits will lead to corresponding increase in the other traits. There was no significant correlation between skull length and face width ($p > 0.05$). The correlation between skull length and neck length was not significant ($p > 0.05$), this implies that there is significant no relationship between these traits. However, horn space was negatively correlated with all other traits except skull width with no significant correlation ($p > 0.05$). Similarly, Karimi *et al.* (2011) reported a strong negative correlation between the cephalic index and the length and width of the skull in Mehraban sheep.

The percentage of total variance that best explained the data was summarized in the first three components. The three PCAs jointly explained 76.2 percent of the total variance formed by the traits. PC 1 axis could be linked to variables related to length and diameter amplitudes; PC2 gave a major relevance to skull, face and neck lengths of the sheep; whereas PC 3 axis gave a major relevance to skull length, head depth and neck length. Yunusa *et al*. (2013) reported that measurements that were associated with cranial development (head length and head width) tend to load on first component for Uda and Balami, which suggested them as classification traits for these sheep. Similar results were reported by Salako (2006) on immature Uda sheep, where all parameters considered but skull width, rump length and rump width loaded on the first component. The PC plot of scores for the sheep breeds is presented in Figure 2. Some breeds (Balami, Yankasa and Uda) overlapped, although the cephalic classification suggested different groupings.

The stepwise discriminant analysis indicated that four (skull width, head width, head length and head depth) out of twelve cephalic traits were effective at detecting the differences among the four breeds of sheep (Table 4). Head length was the most discriminating variable followed by head width, head depth and skull width. These variables were included in the final model as they were more informative.

The canonical (CAN) discriminant analysis identified three statistically significant ($p < 0.001$) canonical variables that accounted for 83.04, 13.54 and 3.42 percent of the total variation (Table 5). CAN 1 was dominated by head width and skull width. Skull width, head length and head width were highly correlated with CAN 2. Skull width and head width were highly correlated with CAN 3. In a study, conducted on Pyrean cattle by Parés *et al*. (2012), it was reported that variables that mostly contributed to the discrimination between breeds were face width and head depth.

The Mahalanobis test established significant differences among the breeds of sheep. The distance between Balami and WAD was the longest while the shortest distance was

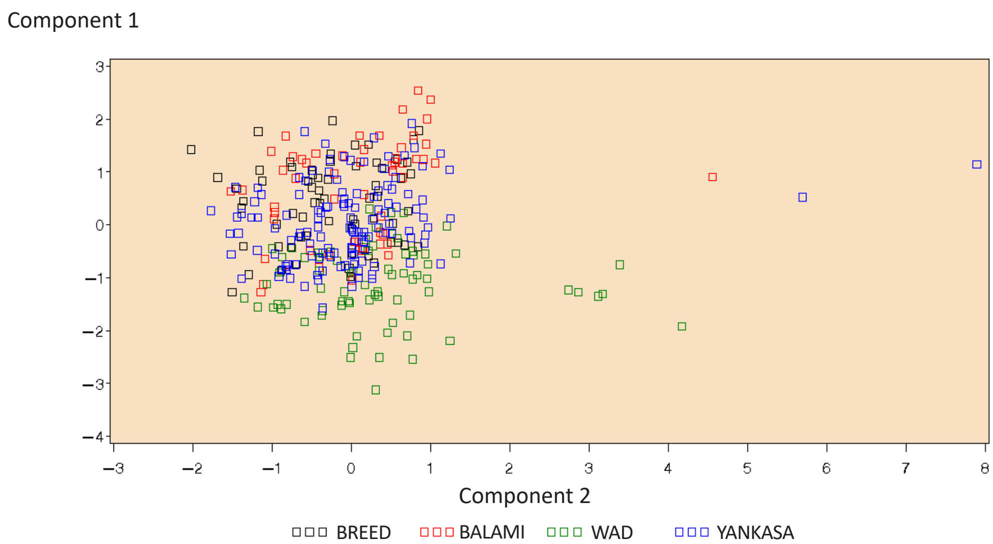


Figure 2. Principal component plot of scores for morphometric data of four breeds of sheep

Table 4. Summary of stepwise selection of traits

Variables entered	Partial R^2	F – value	Pr > F	Wilks' Lambda	Pr < Lambda	Average squared canonical correlation	Pr < ASCC
Skull width	0.520	24.87	<0.0001	0.730	<0.0001	0.270	<0.0001
Head width	0.717	71.00	<0.0001	0.486	<0.0001	0.513	<0.0001
Head length	0.784	107.25	<0.0001	0.385	<0.0001	0.615	<0.0001
Head depth	0.560	30.70	<0.0001	0.686	<0.0001	0.314	<0.0001

Table 5. Canonical correspondence analysis of breeds of sheep

Traits (cm)	Discriminant variates		
	CAN 1	CAN 2	CAN 3
Skull width	0.630	1.000	1.000
Head width	1.000	0.717	1.000
Head length	0.305	0.784	0.046
Head depth	0.408	0.360	0.033
Adjusted canonical correlation	0.512	0.713	0.782
Eigenvalue	0.370	1.057	1.596
Variance accounted for (%)	83.04	13.54	3.42
Cumulative variance (%)	83.04	86.46	100

Table 6. Mahalanobis distances between breeds of sheep

Breeds	Balami	Yankasa	Uda	WAD
Balami	0			
Yankasa	1.19	0		
Uda	0.91	0.50	0	
WAD	1.69	1.61	0.91	0

recorded between Uda and Yankasa. The distance between Uda and Balami was also close. There was a clear separation among the breeds of sheep. The significant differences in the distance indicated that differences among sheep breed populations are important for classification (Yakubu *et al*., 2012). Separate grouping is an indication that different breeds of these sheep possess different cephalic qualities and characteristics. These differences might be attributed mainly to geographical origin of breeds. According to Mulyono *et al*. (2009), differences of origin distinguish phenotypic response based on potential for additive genes controlling body measurements.

CONCLUSION

There are differences in the cephalic traits of Nigerian indigenous breeds of sheep. On the basis of the cephalic index, the sheep breeds are brachycephalic (short-headed), except Uda, which is mesocephalic (medium-headed). Traits such as head width, skull width, head length and head depth mostly contributed to the discriminating variables among the breeds of sheep.

ACKNOWLEDGEMENTS

The authors hereby express their profound gratitude to EU for providing the funds for this research through iLINOVA (www.iLINOVA.org) project. Appreciation also goes to members of Sheep Lovers Association of Nigeria and households, who granted the permission to take measurements of their animals.

REFERENCES

FAO 2012. Phenotypic characterization of animal genetic resources. *FAO Animal Production and Health Guidelines No. 11*. Rome. Available at http://www.fao.org/dorcep/012/i2686e/i2686e00.pdf

FAO 2007 Global Plan of Action for Animal Genetic Resources and the Interlaken Declaration. Available at http://www.fao.org/docrep/010/a1404e/a1404e00.HTM.

KARIMI, I. – ONAR, V. – PAZVANT, G. – HADIPOUR, M. – MAZAHERI, Y. 2011. The Cranial Morphometric and Morphologic Characteristics of Mehraban Sheep in Western Iran. *Global Veterinarian*, vol. 6 (2), 2011, p. 111–117.

KIDD, K.K. – PIRCHNER, F. 1971. Genetic relationships of Austrian cattle breed. *Animal Genetics*, vol. 2 (3) 1971, p. 145–158.

KOSGEY, I.S. – OKEYO, A.M. 2007. Genetic improvement of small ruminants in low input, smallholder production systems: technical and infrastructural issues. *Small Ruminant Research*, vol. 70, 2007, p. 76–88.

MARCHANT, T.W. – JOHNSON, E.J. – McTEIR, L. – JOHNSON, C.I. – GOW, A. – LIUTI, T. – KUEHN, D. – SVENSON, K. – BERMINGHAM, M.L. – DRÖGEMÜLLER, M. – NUSSBAUMER, M. – DAVEY, M.G. – ARGYLE, D.J. – POWELL, R.M. – GUILHERME, S. – LANG, J. – TER HAAR, G. – LEEB, T. – SCHWARZ, T. – MELLANBY, R.J. – CLEMENTS, D.N. – SCHOENEBECK, J.J. 2017. Canine Brachycephaly is Associated with a Retrotransposon-Mediated Missplicing of SMOC2. *Current Biology*, 27 (11), 2017, p. 1573–1584.

MULYONO, R.H. – SARTIKA, T. – NUGRAHA, R.D. 2009. A study of morphometric-phenotypic characteristic of Indonesian chicken: Kampong, Sentul and Wareng-Tangerang, based on discriminant analysis, Wald-Anderson criteria and Mahalanobis minimum distance. In: *1st Int. Seminar on Animal Husbandry*. Faculty of Animal Science, Bangor Agricultural University, 2009, p. 278–288.

NGERE, L.O. – ADU, I.F. – MANI, I. 1979. *Report of sub-committee on small ruminants: Ad-hoc committee on national livestock breeding policy.* National Animal Production Research Institute, Shika, Nigeria.

National Population Commission, (NPC) Nigeria 2006. Census Report.

ONAR, V. 1999. A morphometric study on the skull of the German shepherd dog (Alsatian). *Anatomia, histologia, embryologia*, vol. 28, 1999, p. 253–256.

PAIVA, S.R. – FACÓ, O. – FARIA, D.A. – LACERDA, T. – BARRETO, G.B. – CAMEIRO, P.L. – LOBO, R.N. – McMANUS, C. 2011. Molecular and pedigree analysis applied to conservation of animal genetic resources: the case of Brazilian Somali hair sheep. *Tropical animal health and production*, vol. 43, 2011, p. 1449–1457.

PARÉS, P.M. – CASANOVA, I. – SINFREU, I. – VILLALBA, D. 2012. Principal component analysis of cephalic morphology to classify some Pyrenean cattle. *Animal Genetic Resources*, vol. 50, 2012, p. 59–64.

PARÉS, P.M. – JORDANA, J. 2008. Zoometric measurements of cephalic conformation in adult bovine males and females (*Bos Taurus*). *Veterinarija ir Zootechnika*, vol. 43 (65), 2008, p. 73–76.

SALAKO, A.E. 2006. Principal component factor analysis of the morphostructure of immature Uda sheep. *International Journal of Morphology*, vol. 24, 2006, p. 571–574.

SOLOMON, G. – VAN ARENDONK, J.A.M – KOMEN, H. – WINDIG, J.J – HANOTTE, O. 2007. Population structure, genetic variation and morphological diversity in indigenous sheep of Ethiopia. *Animal Genetics*, vol. 38, 2007, p. 621–628.

SARMA, K. 2006. Morphological and Craniometrical Studies on the Skull of Kagani Goat (*Capra hircus*) of Jammu Region. *International Journal of Morphology*, vol. 24, 2006, p. 449–455.

SAS (2004). SAS/STAT. User's Guide (release 8.03). SAS Institute, Cary North Carolina, USA.

YUNUSA, J.A – SALAKO, A.E. – OLADEJO, O.A. 2013. Morphometric characterization of Nigerian indigenous sheep using multifactorial discriminant analysis. *International Journal of Biodiversity and Conservation*, vol. 5 (10), 2013, p. 661–665.

YAKUBU, A. – PETERS, S.O. – ILORI, B.M. – IMUMORIN, I.G. – ADELEKE, M.A. – TAKEET, M.I – OZOJE, M.O. – IKEOBI, C.O.N. – ADEBAMBO, O.A. 2012. Multifactorial discriminant analysis of morphological and heat-tolerant traits in indigenous, exotic and cross-bred turkeys in Nigeria. *Animal Genetic Resources*, vol. 50, 2012, p. 21–27.