AFRICA ENVIRONMENTAL REVIEW Journal
ISSN: 1727-8341

AER Journal Volume 4, Issue 2, pp. 139-147, Aug, 2021

RESEARCH ARTICLE
Available Online at *http://www.aer-journal.info*

Assessment of Morphological Characteristics of Indigenous Chicken Ecotypes of Kenya

*B. K. Chesoo, J. O. Wanga and A. Nandwa
Department of Biological Science, University of Eldoret, P. O. Box 1125-3100 Eldoret, Kenya
**Corresponding Author's E-mail: chesooben@yahoo.com*

Abstract

Poultry mainly consist chicken (Gallus gallus domesticus) with varied morphological appearances. The amplified global use of highly prolific breeds leads to a loss of inherent genetic diversity in indigenous chicken (IC) ecotypes. Description of ecotypes provides data on present and impending future uses of IC ecotypes populations. The study was conducted at University of Eldoret, commercial Farm using six IC ecotypes of Kenya based on selected phenotypic characters. The study was conducted using eggs sourced for hatching from agro ecological zones and the chicks were reared under deep litter production system for 14 weeks. sample size totalled 87 birds distributed as follows: Nandi (ND,10), Elgeyo Marakwet (EM,17), Turkana (TR,20), Lamu (LM,10), Homa Bay (HB,10), Meru (MR, 10) and KARI improved (KR,10). Data on morphological body parameters was collected at week 14 of age. Chi square test (χ^2) in SPSS (Version 20) was used to test for any significant difference in percentages (α=5%). Plumage colour, majority (60%) of KR ecotype chickens were either blue with red (20%), blue and red (20.0%) and either blue mixed with white or brown (20%) (χ^2= 12.00, d.f. =6, P = 0.0620). For the EM ecotype, majority of chicken plumage was blue with brown (47.1%) (P< 0.05). In TR ecotypes, a significant percentage (χ^2= 296.28, d.f.=7, P = 0.0000) had black with white coloured plumage. HB ecotype, a higher significant proportion (χ^2= 26.0, d.f.=6, P=0.0002) had black with white and brown coloured plumage (30.0%). A large proportion of chicken had yellow coloured shank. These were from KR (100%), TR (61.9%), HB (80.0%), MR (80.0%) and ND (50.0%). As far as comb type was of concern, all KR and HB ecotypes had single comb type (100%). All KR, TR, LM and MR IC ecotypes had normal head type while in EM ecotype, a lower significant proportion (χ^2= 77.44, d.f.=1, P= 0.0000) had crested head type (5.88%). In conclusion, the study indicated presence of a substantial variety in morphological characteristics between and among the Kenya chicken ecotypes. More phenotypic and genetic facts that involves all qualities and all ecotypes of Kenya together with the role of the traits and the principal genes on socio-economic factors should be evaluated to abundantly characterize them in order to use in advancement of their use, preservation of genetic variability and regulate further gene dilution.

Keywords: Agro Ecological Zone, Chicken Production, Indigenous Chicken Ecotypes, Morphological Characteristics

INTRODUCTION

Poultry consists mainly chickens, ducks and turkeys and is the largest group of livestock estimated to at about 25.9 billion in the world (Shahbandeh, 2021) Socio economically, chicken rearing in particular plays general vital role for people living in developing low-income countries especially in Africa where it contributes to over 70% and 20% of poultry products and animal protein intake respectively (Asresie *et al*., 2015).

Different researchers (Fitsum, 2015; Getu *et al.*, 2014, 2015; Addis & Alemayehu, 2017; Mwambene *et al*., 2019; Habimana *et al.*, 2021) have done some attempts to characterize local chicken ecotypes in east Africa. Previous research works by Fitsum (2015); indicated that local indigenous chickens are non-descriptive, with a variety of morphological and morphometric appearances. In some selected areas of Ethiopia (Asresie *et al.*, 2015) and Kenya, phenotypic and genetic characterization of local indigenous chicken ecotypes has been carried out (Getu, 2015).

In Kenya, poultry more so chicken are the most widespread and almost every countryside family owns them providing source of cheap protein and income from sale of eggs and meat. They are of heterogeneous population exhibiting vast phenotypic variability (Ngeno *et al.*, 2014). The variations in morphological characters such as plume, shank colour, and comb as well as head type are common among indigenous chicken populations (Banerjee, 2012). Variations in phenotypic characteristics among indigenous chicken ecotypes in east Africa has been documented by various scholars (Mwambene *et al.*, 2019; Habimana *et al.*, 2021). Fleming *et al*. (2016) reported wide phenotypic variability among IC population found several districts of Uganda and Rwanda. Similarly, Ngeno *et al.* (2014) reported morphological variations in Kenyan IC population.

The increased global use of highly and imported productive breeds leads to a dilution and loss of genetic diversity in indigenous chicken ecotypes as well as in other livestock (Sinoya, 2017). This leads to dilution of genetic merits with exotic breeds (Melesse & Negesse, 2011). Conservation of local gene pool is a vital step, as it is a way for conserving the standing local chicken populations that have been suited to the local environment. Major challenge in the upgrading of indigenous chicken is lack of sufficient information on the genetic capacities of the available IC populations in Kenya. Morphological characterization of Kenyan IC studies have not been based on agro ecological zones predicted to host chicken demonstrating different characteristics (Ngeno *et al.*, 2014). Therefore, this calls for a research study to specifically characterize IC populations in each agro-ecological zone using morphological traits. Information on IC production system in Kenya and unique characteristics are crucial in designing and implementation of IC based development programs, important for poultry farmers (Melesse & Negesse, 2011).

MATERIALS AND METHODS

Study Sites

This study was conducted at University of Eldoret (UoE) Commercial farm Poultry Section. University is located at latitude: 0° 31' 13.30" N, longitude: 35° 16' 11.75" E**.** with an elevation of about 2154 m above sea level (Figure 1). An average uni-modal rainfall pattern of 1000 mm to 1520 mm per annum has been recorded over the last ten years. The rains span from February to August and the temperatures range from 23.6ºC day to 9.6ºC night (Chesoo *et al.*, 2014).

Origin of the Study Animals

Indigenous chicken (IC) ecotypes were sourced from six agro-ecological zones of Kenya. Selection was based on agro ecological zones, geographical distances and coverage of the past IC improvement programmes (by Kenya Agricultural and Livestock Research Institute) (Ngeno e*t al.*, 2014). The agro-ecological zones considered and associated IC ecotypes were; The Western Highland (Elgeyo Marakwet-EM and Nandi-ND), North Western Arid and Semi-Arid lands (Turkana- TR), Lake Shore (Homa Bay- HB), Central Highland (Meru-MR) and Coastal Lowlands and Midlands (Lamu- LM) as portrayed in Figure 1. Naming of IC ecotypes was according to the county of origin as per Aklilu *et al.* (2013).

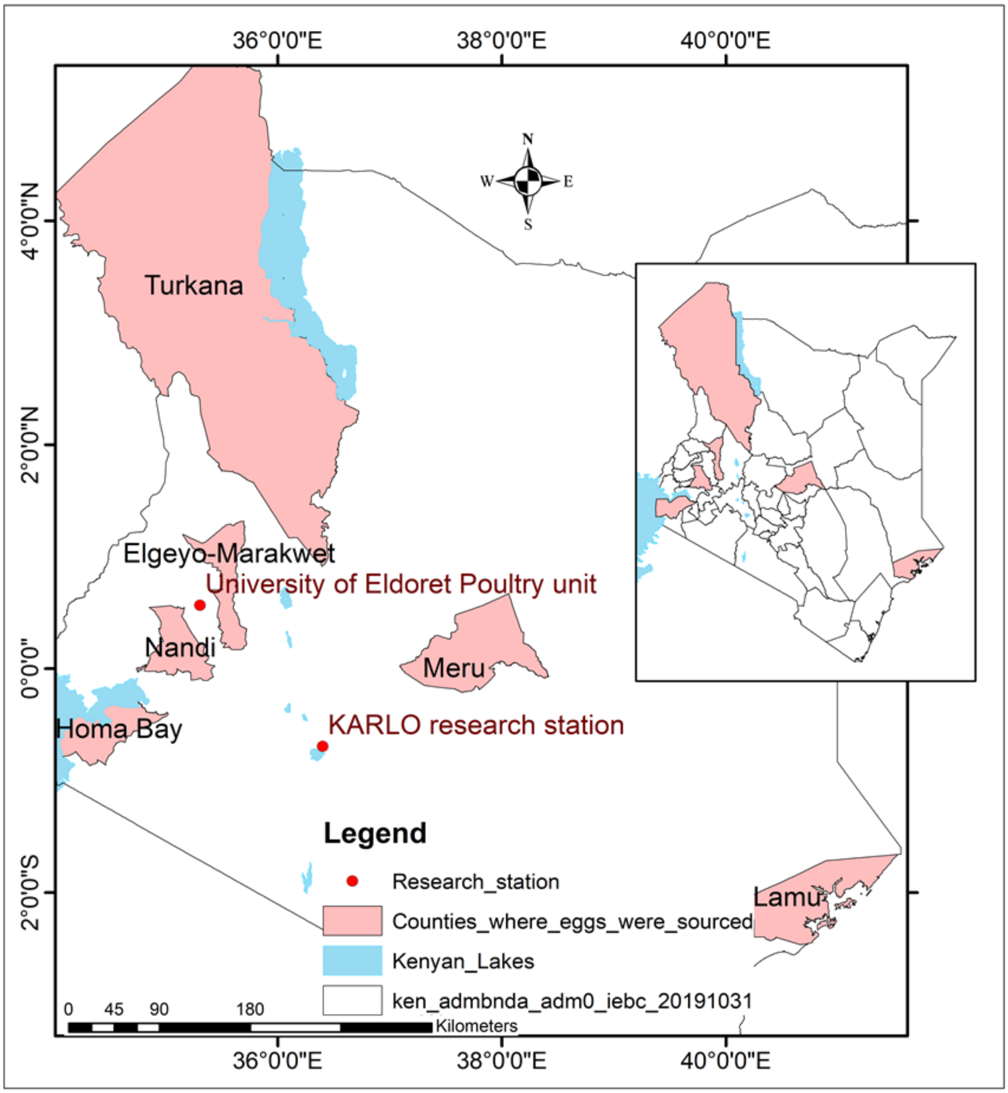

Figure 1: A map of Kenya enlarged to show locations of original indigenous chicken egg ecotypes and the sourced birds and the study site for the project.

Management of the Initial Source Population of Chicken

The IC were primarily managed traditionally where they were left to scavenging freely feeding on what nature offered as well as household wastes and grain supplements provided by the farmers in respective agro ecological zones. Only KR ecotype was initially managed intensively.

Management of Study Animals

Eggs of each IC ecotype were sourced from the agro ecological zone (AEZ) of the respective chicken ecotype and made to hatch artificially at UoE Commercial Farm. The hatchery room was prepared by cleaning followed by disinfecting with 1% formalin spray 24 hours before the arrival of the eggs. Before incubation, eggs were fumigated for hygiene using 17 g potassium permanganate + 100 mL of 20% formalin used to. 1% formalin was again used to disinfect eggs against ovo infections. Egg candling was then undertaken at 7 and 18 days of setting in the hatcher.

All hatched chickens were vaccinated against common poultry diseases such as Newcastle from day 1 to week fourteen in accordance with the producer's recommendation. A 2% formalin was used to disinfect brooder and grower houses with all poultry equipment and deep litter beddings 1 day before the introduction of the chicken. The house was bedded with straw and heated with infrared bulbs. Chicks were supplied and fed with a local formulated starter ration (Table 1) and clean potable *ad libitium* water for six weeks and weaned with formulated grower ration (Table 1) in grower house for another eight weeks.

Table 1: Formulated Chick Starter and Growers Mash (100 kg)

	Qty (kg)	**MEKcal**	**CP (%)**	**Lys**	**Meth**	**C F**	**Ca++**
Chick Starter Mash (100 kg):	100.0	2825	19.67	0.9235	0.9235	4.1935	0.9489
Growers Mash (100 kg):	100.0	2915.5	17.15	0.8605	0.3937	9.18	0.8098

Study Design

Six indigenous ecotypes (EM, TR, LM, HB, MR and ND) and one improved ecotype (KR) for a total of seven were used in the study. Data collection was made on a total of eighty seven (n=87) birds distributed as follows among the ecotypes 10 KR, 17 EM, 20 TR, 10 LM, 10 HB, 10 MR and 10 ND.

Data Collection

Data on body parameters (Ngeno *et al.*, 2014) including Plumage colour, Shank colour, Comb type and Head type was collected by physically restraining the birds and observing the morphological traits. This was done at week 14 of age.

Data Analysis

Percentages of birds in an ecotype with a trait was calculated by dividing the number of birds (n) having the trait by the total number of animals examined (N) and multiplied with hundred (100). Chi square goodness of fit test (χ^2) in SPSS (IBM SPSS Inc., Chicago, Ill, USA, Version 20) was used to test for significant difference in simple descriptive statistics at 95 % confidence interval (α=5%).

RESULTS

Plumage Colour

For the plumage colour, majority (60%) of KR ecotype chickens were either blue with red (20%) and either blue mixed with white or brown (20%) as portrayed in figure 1 with no significant difference (χ^2= 12.00, d.f.=6, P = 0.0620). For the EM ecotype, majority of chicken plumage was blue with brown (47.1%) and significantly different from those which had other colours types (χ^2= 112.16, d.f.=7, P = 0.0000). In TR ecotypes, a significant percentage (χ^2= 296.28, d.f.=7, P = 0.0000) of chicken had black with white coloured plumage (35.0%) followed by those which had blue with brown (20.0%) with a lower percentage having green and blue plumage. A significant proportion of LM ecotypes had white plumage (40.0%) followed closely with those which had black and white coloured plumage (30.0%) significantly different from those which had other types of coloured plumage (χ^2= 40.00, d.f.=4, P = 0.0000) as portrayed in Table 2. For the HB ecotype chicken, a higher significant proportion (χ^2= 26.0, d.f.=6, P = 0.0002) had black with white and brown coloured plumage (30.0%). The MR ecotypes had different plumage colour with a significant proportion having blue and brown plumage (χ^2= 20.0, d.f.=5, P = 0.0012) likewise with ND ecotype chickens, whose majority (60%) had blue and brown plumage significantly different (χ^2= 71.67, d.f.=4, P = 0.0000) with those with other coloured plumage as portrayed in Table 2.

Table 2: Plumage Color Characteristics of IC Ecotypes of Kenya (%)

Plumage color	KR (n=10)	EM (n=17)	TR (n=20)	LM (n=10)	HB (n=10)	MR (n=10)	ND (n=10)
Bl	10.0	5.9	10.0	10.0	-	-	-
Bl/Br	-	47.1	20.0	10.0	10.0	30.0	60.0
Bl/Br/Gr	10.0	5.9	-	-	-	10.0	20.0
Bl/Gr	-	5.9	5.0	-	10.0	-	-
Bl/Gr/Y	10.0	-	-	-	-	-	-
Bl/Red	20.0	-	-	-	-	-	-
Bl/Red/Y	20.0	-	-	-	-	-	-
Bl/Wh	20.0	-	35.0	30.0	-	20.0	10.0
Bl/Wh/Br	-	5.9	-	-	30.0	-	-
Br	-	11.8	10.0	-	10.0	20.0	-
Br/Wh	-	-	-	-	20.0	-	10.0
Gr/Bl	-	-	5.0	10.0	10.0	-	-
Gr	10.0	-	10.0	-	-	10.0	-
Wh	-	11.8	0-	40.0	-	-	-
Wh/Bl/Gr	-	5.9	5.0	-	-	10.0	-
Total (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Footnote: Bl= Blue, Br=Brown, Gr=Green, R= Red, Blac= Black, Y= Yellow, Wh= White, EM= Elgeyo Marakwet, ND= Nandi, TR Turkana, HB= Homa Bay, MR= Meru, LM= Lamu

Shank Colour

A large proportion of chicken had yellow coloured shank. These were from KR (100%), TR (62%), HB (80%), MR (80%) and ND (50%). Majority of LM ecotype had white coloured shanks as portrayed in Table 3. There was a significant difference in colour shanks in EM ecotype (χ^2= 56.0441, d.f.=4, P = 0.0000), TR ecotype (Chi-Square = 77.04 with 3 d.f. P-Value = 0.0000), LM ecotype (χ^2= 36.0, d.f.=1, P= 0.0000), HB ecotype (χ^2= 98.0, d.f.=2, P = 0.0000), MR ecotype (Chi-Square = 36.0, d.f.=1, P= 0.0000) as well as in ND ecotype (χ^2 = 14.0, d.f.=2, P = 0.0009) as presented in Table 3.

Table 3: Shank Colour Characteristics of IC Ecotypes of Kenya (%)

Shank color	KR (n=10)	EM (n=17)	TR (n=21)	LM (n=10)	HB (n=10)	MR (n=10)	ND (n=10)
Yellow	100.0	35.3	62	20	80	80	50
Black	-	11.8	14	-	10	-	-
White	-	41.2	19	8	10	20	30
Grey	-	5.9	4.8	-	-	-	20
White/def	-	5.9	-	-	-	-	-
Total (%)	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Comb Type

In terms of comb type, all KR and HB chicken ecotypes had single comb type

(100%). For the EM, TR, MR and ND ecotypes, majority of the chicken had single comb type followed by rose type (5.88%, 9.52%, 40.0% and 10.0%, respectively) while in LM ecotype, a large proportion of chicken had strawberry type of comb. There was a significant difference in comb type in EM ecotype (χ^2= 134.48, d.f.=2, P= 0.0000), TR ecotype (χ^2= 123.63, d.f.=2, P= 0.0000), LM ecotype (χ^2= 36.0 with 1 d.f. P-Value = 0.0000), MR ecotype (χ^2= 4.0, d.f.=1, P= 0.0455) and ND ecotype (χ^2= 64.0, d.f.=1, P= 0.0000) as portrayed in table 4.

Table 4: Comb Type Characteristics of IC Ecotypes of Kenya (%)

Comb type	KR (n=10)	EM (n=17)	TR (n=20)	LM (n=10)	HB (n=10)	MR (n=10)	ND (n=10)
Single	100.0	88.2	85.7	20.0	100.0	60.0	90.0
Rose	-	5.8	9.5	-	-	40.0	10.0
Walnut	-	5.8	-	-	-	-	-
Strawberry	-	-	4.7	80.0	-	-	-
Total (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Head Type

All KR, TR, LM and MR ecotypes had normal head type. For the EM ecotype, a lower significant proportion (χ^2= 77.44, d.f.=1, P= 0.0000) had crested head type (6%) similarly with HB ecotype (10%) significantly lower while ND had normal (80%) significantly higher than others (χ^2= 98.0, d.f.=2, P = 0.0000) as portrayed in Table 5.

Table 5: Head Type Characteristics of IC Ecotypes of Kenya (%)

Head type	**KR (n=10)**	**EM (n=17)**	**TR (n=21)**	**LM (n=10)**	**HB (n=10)**	**MR (n=10)**	**ND (n=10)**
Normal	100.	94	100	100	90	100	80
crest	-	6	-	-	10	-	10
Necked/neck	-	-	-	-	-	-	10
Total (%)	100	100	100	100	100	100	100

DISCUSSION

Body Plumage Colours

Among the body plumage colour, majority of KR ecotype chickens were either blue with red, blue and red and either blue mixed with white or brown with no significant (P= 0.0620). This could be attributed to the fact that KR ecotypes are improved indigenous chicken ecotypes collected from all over Kenya. According to Ngeno *et al.* (2014), farmers have colour preferences in local chicken they rear which influence plumage colour frequencies observed among ecotypes. For EM ecotype, plumage was significantly dominated by blue with brown (P< 0.05). Differences could be attributed to camouflaging ability and reaction response to predator attack such as birds of prey thus leading to diverse body plumage colouration. Where else TR ecotypes, had majority of chicken having black with white coloured plumage as well blue with brown which can be attributed to camouflage against predators. The findings are in line with Ngeno *et al.* (2014) that indigenous chicken vulnerability levels to predators depend on the camouflaging capacity to their abundant local habitats. A significant proportion of LM as well as HB ecotypes had white plumage and black with white and brown coloured plumage, respectively (P <0.05).

This could have been attributed to the high temperatures of the ecological zone thus white colour is good for heat reflection and dissipation. MR ecotypes had significant proportion of birds with blue and brown likewise with ND ecotype chickens. These ecotypes are found in highland where temperatures are low and thus dull colours can be as an adaptation to heat absorption. The findings concur with those of Romano *et al*. (2019) that in tropical conditions, different plumage colour in a cosmopolitan bird arise as a result of adaptive significance in thermoregulation.

Comb Type

All KR and HB chicken ecotypes had single comb type while majority of EM, TR, MR and ND ecotypes, had single comb type followed by rose type while in LM ecotype, a large proportion of chicken had strawberry type of comb ($p < 0.05$). This is in agreement with the reports by Rogelio *et al*. (2013) and Apuno *et al*. (2011) on Nigerian indigenous chicken and in Ethiopia by Dana *et al*. (2010). Studies by Faruque *et al*. (2010) and Ige *et al.* (2012) indicated that single comb dominant over any other type. Presence of a single comb type is associated to high efficiency in heat dissipation in prevailing climatic conditions in the respective ecological zones as well as the effect of comb genes within the ecotypes. This is in agreement with findings of *Ige et al.* (2012) and Chesoo *et al.* (2016) that single comb in indigenous chicken especially the scavenging ones help in losing excessive body heat under prevailing environmental temperature since chicken do not sweat (Aklilu *et al*., 2013; Chesoo *et al.*, 2016).

Shank Colour

Yellow coloured shank contributed more than half of the population of majority of IC ecotypes with LM ecotype having white coloured shanks. There was a significant difference in colour shanks in EM ecotype ($P < 0.05$). Bright coloured shanks of ecotypes is associated with temperature regulation, nutrition levels as well as varied type of diet freely and readily found in the local IC habitat, maturity stage as well as sex. The same findings are in line with those of Rajput *et al*. (2012) that body skin and shank colours are an indicator of immune status, foraging efficiency, chicken nutritional and sexual attractiveness. Dominant yellow coloured shank observed in different IC ecotypes were similar to those reported by Habimana *et al.* (2021) in Rwanda and Ngeno *et al*. (2014) in Kenya as well as those reported in Ethiopia IC ecotypes as reported by Dana *et al.* (2010). In addition, Siwek *et al.* (2013) pointed out that shank colour is controlled by three genes namely; dermal melanin (id+), inhibition of dermal melanin (Id), black extension factor (E) and autosomal white (W+) genes situated in the Z sex chromosome. Fallahshahroudi *et al*. (2019) also added that White skin alleles are presumed to originate from red jungle fowl (*Gallus gallus*), whereas yellow skin is from hybridization of Ceylon jungle fowl (*Gallus lafayettii*), grey jungle fowl (*Gallus sonneratii*), and red jungle fowl.

Head Type

All KR, TR, LM and MR ecotypes had normal head type. For the EM ecotype had crested head type similarly with HB ecotype while ND had normal head type. Presence of a crest is associated with HOXC8 ectopic expression in Cranial Skin causing a tuft of elongated feathers to sprout from the head (Li *et al*., 2021) an autosomal incompletely dominant mutation that causes. In the findings, it was not well ascertained the reasons for difference in presence or absence of crest.

CONCLUSION AND RECOMENDATION

In conclusion the study shows a considerable difference in Body plumage colours, Comb type, Shank colour and Head type between the studied Kenyan IC ecotypes. More morphological information that involves other traits such as earlobe, eye, beak, body skin colour of studied ecotypes of Kenya should be collected to abundantly characterize them. Studies on zoometric characterization of Kenyan IC ecotypes populations should be well and abundantly emphasized. Further studies on the effects of characters and the causal genes on social economic factors of the farmers should be undertaken for future breeding programs and to preserve genetic variability and reduce dilution thus conservation for future use.

Acknowledgment
This study was funded by the Annual Research Grant (ARG) of University of Eldoret (UoE) and the National Research Fund (NRF) of National Commission for Science, Technology and Innovation (NACOSTI).

References

Addis. A.and Alemayehu, K. (2017). *Review on the Status, Characterization and Conservation Methods of Local Chicken Ecotypes, Ethiopia* (Doctoral dissertation).

Aklilu, E., Kebede, K., Dessie, T. and Banerjee, A. K. (2013). Phenotypic characterization of indigenous chicken population in Ethiopia. *International Journal of Interdisciplinary and Multidisciplinary Studies*, *1*(1), 24-32.

Apuno, A. A., Mbap, S. T. and Ibrahim, T. (2011). Characterization of local chickens (Gallus gallus domesticus) in Shelleng and Song local Government areas of Adamawa State, Nigeria. *Agriculture and Biology Journal of North America*, *2*(1), 6-14.

Asresie, A., Eshetu, M. and Adigrat, E. (2015). Traditional chicken production system and marketing in Ethiopia: a review. *J Mark Consum Res*, *8*, 27-34.

Banerjee, S. (2012). Morphological characterization of indigenous chickens of Sikkim and West Bengal, India. *Anim. Genet. Resour*, *51*, 57-71.

Chesoo, B. K., Oduho, G. W., Kios, D. K., Rachuonyo, H. A. and Kitilit, J. K. (2016). Assessment of Morphological Characteristics of Kuchi Indigenous Chicken Ecotype of Kenya. *African Journal of Education, Science and Technology*, *3*(1), 39.

Chesoo, B., Oduho, G. W., Kios, D. K. and Rachuonyo, H. A. (2014). Evaluation of three management systems on growth performance of Kuchi indigenous chicken ecotype of Kenya. *African Journal of Education, Science and Technology*, *1*(4), 170-174.

Dana, N., Van der Waaij, L. H., Dessie, T. and van Arendonk, J. A. (2010). Production objectives and trait preferences of village poultry producers of Ethiopia: implications for designing breeding schemes utilizing indigenous chicken genetic resources. *Tropical animal health and production*, *42*(7), 1519-1529.

Fallahshahroudi, A., Sorato, E., Altimiras, J. andJensen, P. (2019). The domestic BCO2 Allele buffers low-carotenoid diets in chickens: possible fitness increase through species hybridization. *Genetics*, *212*(4), 1445-1452.

Faruque, S., Siddiquee, N. U., Afroz, M. A. and Islam, M. S. (2010). Phenotypic characterization of Native Chicken reared under intensive management system. *Journal of the Bangladesh Agricultural University*, *8*(1), 79-82.

Fitsum, M. (2015). *Phenotypic characterization of local chicken ecotypes in the central zone of Tigray in Northern Ethiopia* (Doctoral dissertation).

Fleming, D. S., Koltes, J. E., Markey, A. D., Schmidt, C. J., Ashwell, C. M., Rothschild, M. F., Persia, M. E., Reecy, J. M. and Lamont, S. J., (2016). Genomic analysis of Ugandan and Rwandan chicken ecotypes using a 600 k genotyping array. *BMC genomics*, *17*(1), pp.1-16.

Getu, A., Alemayehu, K. and Alebie, A. (2015). Status, Characterization and Conservation Practices of Local Chicken Ecotypes, International Journal of Scientific Research in Science and Technology. ISSN : 2395-6011Ethiopia.

Habimana, R., Ngeno, K., Mahoro, J., Ntawubizi, M., Shumbusho, F., Manzi, M. and Okeno, T. O. (2021). Morphobiometrical characteristics of indigenous chicken ecotype populations in Rwanda. *Tropical Animal Health and Production*, *53*(1), 1-11.

Ige, A. O., Salako, A. E., Yakubu, A. and Adeyemi, S. A. (2012). Qualitative traits characterization of Yoruba and Fulani ecotype indigenous chickens in Derived Savannah Zone of Nigeria. *International Journal of Poultry Science*, *11*(10), 616-620.

Li, J., Lee, M. O., Davis, B. W., Wu, P., Hsieh-Li, S. M., Chuong, C. M. and Andersson, L.

(2021). The crest phenotype in domestic chicken is caused by a 197 bp duplication in the intron of HOXC10. *G3 Genes| Genomes| Genetics*.

Melesse, A. and Negesse, T. (2011). Phenotypic and morphological characterization of indigenous chicken populations in southern region of Ethiopia. *Animal Genetic Resources/Resources génétiques animales/Recursos genéticos animales*, *49*, 19-31.

Mwambene, P. L., Kyallo, M., Machuka, E., Githae, D. and Pelle, R. (2019). Genetic diversity of 10 indigenous chicken ecotypes from Southern Highlands of Tanzania based on Major Histocompatibility Complex-linked microsatellite LEI0258 marker typing. *Poultry science*, *98*(7), 2734-2746.

Ngeno, K., van der Waaij, E. H., Kahi, A. K. and van Arendonk, J. A. M. (2014). Morphological features of indigenous chicken ecotype populations of Kenya. *Animal Genetic Resources/Resources génétiques animales/Recursos genéticos animales*, *55*, 115-124.

Rajput, N., Naeem, M., Ali, S., Rui, Y. and Tian, W. (2012). Effect of dietary supplementation of marigold pigment on immunity, skin and meat color, and growth performance of broiler chickens. *Brazilian Journal of Poultry Science*, *14*(4), 291-295.

Rogelio Jr, V. L., Lambio, A. L., Vega, R. S. and De Guia, A. P. O. (2013). Phenotypic characterization of native chicken in Palawan, Philippines. *Philippine Journal of Veterinary and Animal Sciences*, *39*(2).

Romano, A., Séchaud, R., Hirzel, A. H. and Roulin, A. (2019). Climate-driven convergent evolution of plumage colour in a cosmopolitan bird. *Global Ecology and Biogeography*, *28*(4), 496-507.

Shahbandeh, M. (2021). Global number of chickens,1990-2019.https://www.statista.com/aboutus/our-research-commitment/1239/m-shahbandeh

Sinoya, K. S. (2017). *Genetic diversity of indigenous chicken (gallus domesticus) population in Kenya* (Doctoral **Siwek, M.,** Wragg, D., Sławińska, A., Malek, M., Hanotte, O. and Mwacharo, J. M. (2013). Insights into the genetic history of G reen-legged P artridgelike fowl: mt DNA and genome-wide SNP analysis. *Animal genetics*, *44*(5), dissertation, University of Nairobi).522-532.