Veterinary Integrative Sciences 2022; 20(3): 775 - 791 DOI; 10.12982/VIS.2022.060

Vet Integr Sci

Veterinary Integrative Sciences

ISSN; 2629-9968 (online)

Website; www.vet.cmu.ac.th/cmvj

Research article

Multivariate analysis of morphometric traits to differentiate the indigenous chicken reared under different Agro-ecologies of Ethiopia

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Abstract

This is to differentiate indigenous chickens at different agro-ecologies based on morphometric traits using multivariate analysis. Morphometric data were collected from a total of 520 (130 male and 390 female) adult indigenous chickens. Traits scored were body weight, body length, breast circumference, wingspan, shank length, shank circumference, comb length, wattle length, earlobe length and beak length. Ten quantitative traits for both sexes were subjected to the stepwise discriminant analysis, of which four (wingspan, live body weight, shank circumference, and body length) in females and two of them (shank length, and wingspan) in males were identified as the best discriminating variables. CAN1 and CAN2 were extracted with 61.5% and 38.6% of the total variation in females, respectively and CAN1 (89.3%) and CAN2 (10.7%) of the total variation in parameters of male chicken populations. The higher classification rates were obtained in highland agroecology for female (64.7%) and midland for male (89.8%) chickens. Cross-validation with split–sample indicated that 62.7% (highland), 39% (lowland) and 59.3% (midland) success rate. The longest pairwise Mahalanobis distance was observed between midland and highland in male chickens and between lowland and highland in females, whereas the shortest distance was observed between lowland and highland in male and female chicken populations. The variations obtained in chickens of different agro-ecologies and sexes considered as opportunities for genetic improvement of indigenous chicken genetic resources, because significantly related parameters could be used as selection criterion for improving body weight of Ethiopian indigenous chickens under small scale farmers.

Keywords: Agro-ecology, Ethiopia, Indigenous chicken, Morphometric traits

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Funding; This research was funded by grants from the African Chickens Genetic Gain project (ACGG), ILRI

Article history; *received manuscript: 12 September 2022,*
revised manuscript: 15 October 2022,
accepted manuscript: 25 September 2022,
published online:31 October 2022

Academic editor; *Korakot Nganvongpanit*

INTRODUCTION

In the rural areas of Ethiopia, chicken is the most widespread and almost every rural family owns few to large number of chickens. Moreover, recent socio-economic studies have indicated that chicken rearing has potential to improve household nutrition security by increasing animal source of food production and consumption of meat and eggs (Wodajo et al., 2020). Native chickens play a vital role in rural households as a source of high-quality protein. The important characters are the ability to tolerate harsh environmental conditions and poor husbandry practices (Doungnapa and Khanitta, 2021).

Indigenous domestic chicken is often reared under the traditional farming system by small-holder farmers in developing countries (Magothe et al., 2012; Desta et al., 2013). The indigenous chicken is popular in Ethiopia because of their tolerance to common poultry diseases and fluctuations in both feed quality and quantity, hence requiring minimum or no input (Desta and Wakeyo, 2012).

According to CSA (2021), there are about 48,955,675 chickens in Ethiopia, of which 81.7% indigenous, 10.9% crossbred and 7.4% exotic chicken. The dominance and widespread distribution of indigenous chicken in contrasting production systems and agro-ecological zones indicates their diverse adaptive potential to the prevailing harsh environments, diseases, and other stresses as they possess genes and special adaptation attributes not to be found in other improved modern breeds (Melesse et al., 2011; Al-Qamashoui et al., 2014; Habimana et al., 2020). Thus, they broadly represent a highly diverse genetic reservoir with high level of heterozygosity that could provide the biological base for the development of genetic stocks with improved adaptability and productivity in a wide range of production environments (Dana et al., 2010; Melesse and Negesse, 2011; Melesse, 2014; Getachew et al., 2016). However, the uncontrolled introduction of exotic chicken breeds to the local community without a systematic genetic improvement strategy has led to the dilution of their genetic makeup resulting in a dramatic loss of genetic diversity in the indigenous chicken (Woelders et al., 2006; Melesse and Negesse, 2011; Negassa et al., 2014).

Documenting the information of the body weight and linear body parameters through phenotypic characterization is important for further improvement and sustainability of chicken production following their genetic variability (Benitez, 2002), which can be ascertained through characterization studies. Since morphological traits constitute major components of phenotypes in animal genetic resources, knowing the variations of morphological traits is fundamental to characterization of local genetic resources. Morphological traits are very important in describing the uniqueness of animal genetic resources and providing data for use, conservation, and utilization of poultry genetic resources (Ayalew et al., 2004; Tixier-Boichard et al., 2009). Many statistical tools are available for assessing the morphological profiles of indigenous chicken populations. Among others, cluster and canonical discriminant analysis has been reported to be the most suitable statistical tool to describe the relationship between two or more variables through linear combinations (Daikwo et al., 2015; Dahloum et al., 2016; Al-Atiyat et al., 2017). It can be applied to discriminate various livestock types when all measured morphological variables are considered simultaneously and thus helpful in exploring the morphological diversity study of local animal genetic resources.

Though work on the multivariate analysis of morphometric traits of local chicken in Ethiopia has been carried out by researchers covering some parts of Ethiopia; till documenting such information through this kind of activity across agro-ecological zones of the study sites is scanty. Given the high potential for poultry production and the presence of diverse ecotypes, it is imperative to conduct comprehensive studies that can cover the agro-ecology based morphometric trait evaluation of the indigenous chicken using multivariate analysis in study sites. Hence this study was undertaken with the aim of differentiation of indigenous chicken populations reared in different agro-ecologies by applying multivariate statistical tools.

MATERIALS AND METHODS

Description of the study area

Hadiya zone is located at western margin of the Great Ethiopian Rift Valley and at the fringe of the Gurage Mountains in the northern part of the Southern Regional State.

The area receives seasonal rainfall amount ranging between 470 and 1567 mm annually. The respective maximum and minimum mean annual temperature is 22.54^{0}C and 10.35^{0}C.

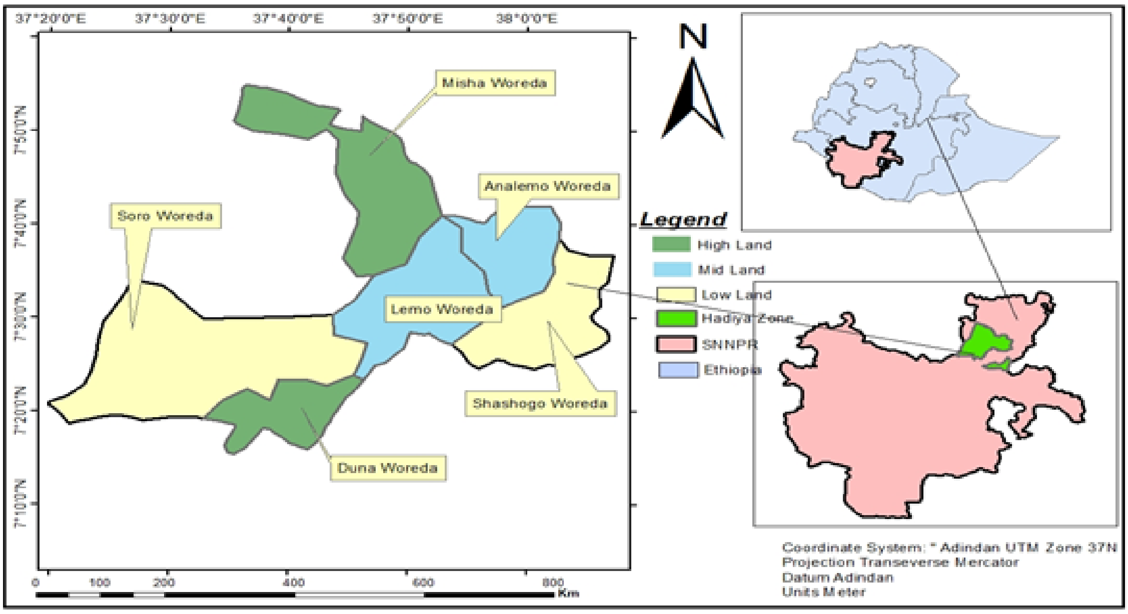

Figure 1 Map of the study area.

Table 1 Description of agro-ecological zones of the study sites

Agro-ecology	Features
Lowland	Hot semi-arid, 800-1100 m.a.s.l, low vegetation, rain fall (400-500mm), agro-pastoral, poor infrastructure
Midland	Hot sub humid, 1501-2500 m.a.s.l, high vegetable, rain fall (1001-1200 mm/year), temperature (16-20°C), mixed farming system, moderate infrastructure
Highland	Humid and sub humid, 2500-3348 m.a.s.l, high vegetable, rainfall (>1300mm/year), temperature (7-12°C), mixed crop farming, poor to moderate infrastructure Gizaw et al. 2007; Bekele et al. 2020

m.a.s.l = meter above sea level, **°C** = degree Celsius

Data collection

A total of 520 live adult chicken were randomly selected from which 30 males and 90 females from lowland, 50 males and 150 females from midland and 50 males and 150 females from highland agro-ecologies. The study sites were identified purposively based on availability of adult indigenous chicken population, distribution of exotic chicken and agro-ecological variation.

Data on ten morphometric traits were recorded following the descriptor list of (FAO, 2012) for phenotypic characterizations of chicken. Accordingly, the following traits were measured: live body weight (LBW), body length (BL), breast circumference (BC), wingspan (WS), shank length (SL), shank circumference (SC), comb length (CL), wattle length (WL), earlobe length (ELL) and beak length (BkL).

Spring balance was used to measure LBW of individual adult bird. All other linear measurements were measured using textile measuring tape meter to the nearest unit centimeter. Measurements were taken from males aged 24 weeks and above, and females that have already started laying eggs based on information obtained from the owner of each chicken.

Data analysis

Data were subjected to general linear model procedures of Statistical Analysis System (SAS 2012, ver. 9.4) by fitting agro-ecology and sex as independent variables. When F-test declared significance at 0.05 level, Duncan multiple range test was used to separate the fixed effect means.

The degree of morphological similarity or divergence among the indigenous chicken populations was determined using the multivariate analysis. Different procedures (STEPDISC, CANDISC, Cluster, TEMPLATE and SGREDER) of SAS (2012, ver. 9.4) were used to analyze morphometric traits accordingly. The procedure of the Cluster Analysis was performed and Dendrogram was constructed using the average linkage distance option between the chicken populations of the three agro-ecological zones to group them into their morphological traits' similarity. Moreover, the stepwise discriminant analysis procedure (STEPDISC) was conducted to rank the morphometric traits according to their discriminating power. Selected traits were then subjected to canonical discriminant analysis using the CANDISC procedure to determine the existence of population level phenotypic differences between the studied populations of the three agro-ecologies. The TEMPLATE and SGRENDER procedures were further applied to create a plot of the first two canonical variables in a scatter graph for visual interpretation. The discriminant analysis of the DISCRIM procedure was also conducted to determine the percentage classification of chicken into their source populations using quadratic discriminant function for unequal covariance matrices within classes after conducting the Bartlett's homogeneity test. The cross-validation option was finally applied to evaluate the accuracy of the classification with a minimum bias. All multivariate analyses were performed using the Statistical Software of SAS (2012, Ver. 9.4). The following model was used for body weight and nine linear body measurements per individual chicken.

$$Y_{ij} = \mu + S_i + A_j + S_i{*}A_j + e_{ij}$$

Where: Y_{ij}= individual observation; μ= fixed overall mean; S_i = effect of sex (i = male, female); Aj = effect of agro-ecology (j = lowland, midland, highland); $S_i{*}A_j$ = interaction effect of i^{th} sex and j^{th} agroecology; e_{ij}= random residual error.

Statement of animal rights

All applicable international, national, and institutional guidelines for the care and use of animals were followed. Study was reviewed and approved by the Livestock Department of Hadiya Zone under Ministry of Agriculture in Ethiopia.

RESULTS

Quantitative traits

Mean values for live body weight and linear body measurements of cocks and hens are presented in Table 2. Agro-ecology had significant effect (p<0.05) on body length, live body weight, breast circumference, shank circumference, shank length and wingspan. However, it had no effect (p>0.05) on beak length, comb length, ear lobe length and wattle length. Sex was the main cause of variation of measurable traits of indigenous chicken of Ethiopia.

Agro-ecology had a significant effect (p<0.05) on LBW, BL, BC, WS, SL, and BkL in male chicken and on LBW, BL, BC, WS, SL, SC, and CL in female chicken. Male chicken in midland agro-ecology possessed significantly higher BL, WS, and SL than the remaining two agro-ecologies. LBW, BL, BC, and SL were significantly higher in female chicken of midland agro-ecology; unlike to SC which was significantly higher in female chicken of lowland (Table 2).

Table 2 Mean values of live body weight (kg) and linear body measurements (cm) in indigenous chicken populations as affected by agro-ecology and sex (N = 520)

Parameters		LBW	BL	BC	WS	SL	SC	CL	WL	ELL	BkL
Average		1.15	24.2	24.88	37.4	6.95	2.58	2.44	2.26	1.55	2.32
R^2		0.15	0.15	0.52	0.19	0.16	0.18	0.70	0.63	0.01	0.03
CV (%)		23.3	13.4	15.27	8.91	17.2	22.6	30.45	24.7	98	14.7
Highland		1.09^{a}	23.7^{a}	24.2^{a}	36.2^{a}	6.70^{a}	2.58ab	2.38	2.20	1.47	2.30
Midland		1.23^{b}	24.8^{b}	25.7^{b}	38.6^{c}	7.32^{b}	2.64b	2.42	2.29	1.66	2.35
		1.11^{a}	23.8^{a}	24.7^{a}	37.6^{b}	6.75^{a}	2.47^{a}	2.58	2.29	1.50	2.31
Male	Highland	1.23^{a}	25.6^{a}	25.5^{a}	37.7^{a}	7.37^{a}	2.98	4.40	3.44	1.78	2.31^{a}
	Midland	1.39^{b}	27.1^{b}	27.6^{b}	41.2^{b}	8.12^{b}	3.12	4.38	3.46	2.35	2.49^{b}
	Lowland	1.26^{ab}	25.1^{a}	25.8^{ab}	39.3^{a}	7.24^{a}	2.96	4.34	3.67	2.69	2.39^{ab}
Female	Highland	1.03^{a}	23.1^{a}	23.7^{a}	35.6^{a}	6.48^{a}	2.44^{ab}	1.71^{a}	1.79	1.37	2.29
	Midland	1.18^{b}	24.0^{b}	25.0^{b}	37.7^{b}	7.03^{b}	2.48^{b}	1.77^{a}	1.90	1.43	2.31
		1.05^{a}	23.4^{ab}	24.3^{ab}	37.0^{b}	6.59^{a}	2.30^{a}	1.99^{b}	1.83	1.43	2.29
Sources of variations											
A		<.0001	0.0007	<.0001	<.0001	<.0001	0.0351	0.0571	0.2060	0.125	0.2437
Sex (S)		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.001	0.0023
A*S		0.9867	0.1943	0.500	0.1286	0.2551	0.7167	0.2197	0.1674	0.1790	0.1167

LBW = live body weight; BL = body length; BC = breast circumference; WS = wingspan; SL = shank length; SC = shank circumference; CL = comb length; WL = wattle length; ELL = ear lobe length; BkL = beak length; A = agro-ecology; A*S = interaction effect of agroecology and sex

Stepwise Discriminant analysis

Ten quantitative variables with complete data were subjected to the STEPDISC procedure using parametric discriminant analysis and four of them were identified as the best discriminating variables for female chicken while only two variables for males (Table 3). Wilk's lambda test confirmed that all the selected variables had highly significant ($p<0.0001$) contribution to discriminate the total population into separate groups.

The variables with the highest discriminating power for females were wingspan, live body weight, shank circumference and body length (Table 3). For male chicken, only two variables (shank length and wingspan) identified with higher discriminating power. The remaining variables had poor discriminating power and were thus removed during the stepwise analysis.

Table 3 Summary of stepwise discriminant analysis for selection of traits with the highest discriminating power for female and male chicken populations

Step	Variables entered	Partial R2	F-value	Pr > F	Wilks' Lambda	Pr < Lambda	ASCC	Pr > ASCC
Females								
1	Wingspan	0.079	16.5	<.0001	0.921	<.0001	0.040	<.0001
2	Live weight	0.040	8.03	0.0004	0.884	<.0001	0.059	<.0001
3	Shank circumference	0.025	4.85	0.0083	0.827	<.0001	0.091	<.0001
4	Body length	0.019	3.61	0.0279	0.811	<.0001	0.099	<.0001
Males								
1	Shank length	0.150	11.1	<.0001	0.851	<.0001	0.075	<.0001
2	Wingspan	0.086	5.91	0.0035	0.778	<.0001	0.114	<.0001

ASCC = average squared canonical coefficient (exploring the relationship between two multivariate sets of variables), R2 = coefficient of determinant, Wilks' Lambda is a measure of how well each trait separates populations into groups. Smaller values of Wilks' lambda indicate greater discriminatory ability of the traits.

Canonical discriminant analysis

The identified variables with the highest discriminating power were then subjected to canonical discriminant analysis for male and female populations separately, which performed the multivariate analysis, the Mahalanobis distances, eigen-values of extracted canonical variables, standardized canonical coefficients and canonical structures.

As shown in Table 4, all pairwise Mahalanobis distances were significant ($p<0.001$) except Mahalanobis distance between midland and highland for male chicken. Accordingly, the shortest Mahalanobis distance of the female chickens was observed between lowland and highland agro-ecologies (0.626) followed by lowland and midland agro-ecologies (0.666) and the furthest Mahalanobis distances between those of midland and highland (0.693). In male chickens, the shortest pairwise Mahalanobis distance was observed between chickens of lowland and highland (0.306), whereas the longest between those of the midland and highland agroecology chicken populations (1.43). Moreover, a dendrogram (Figure 2), which was generated by using a cluster analysis, provided complementary information in which chickens reared in the highland and lowland agro-ecologies were clustered under one sub-cluster while chickens of midland agroecology clustered independently under a separate cluster

Table 4 Mahalanobis distances between female and male chicken populations of the three agro-ecologies based on morphometric traits.

Sex group	Female chicken			Male chicken		
Agro-ecologies	Highland	Midland	Lowland	Highland	Midland	Lowland
Highland	0 1.0000			0 1.0000		
Midland	0.693 <.0001	0 1.0000		1.43 0.136	0 1.0000	
Lowland	0.626 <.0001	0.666 <.0001	0 1.0000	0.306 <.0001	0.985 0.0007	0 1.0000

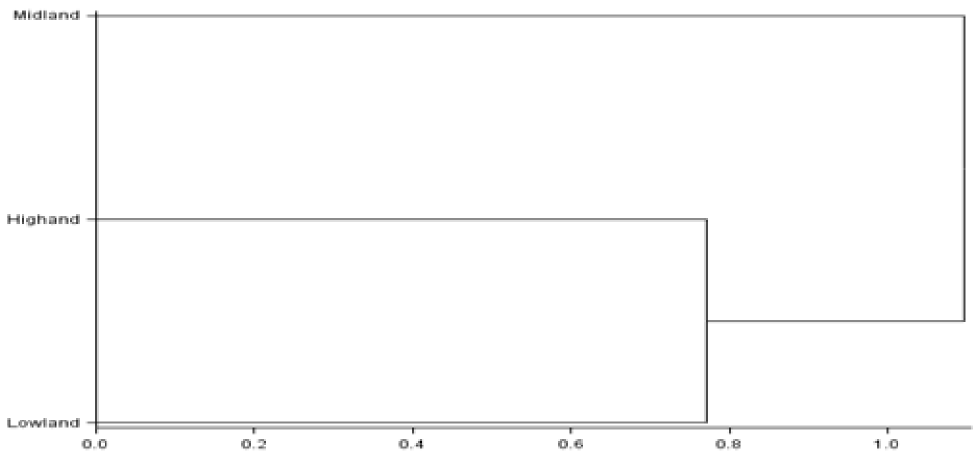

Figure 2 Dendrogram based on morphometric traits of indigenous female chicken populations using the minimum distance method.

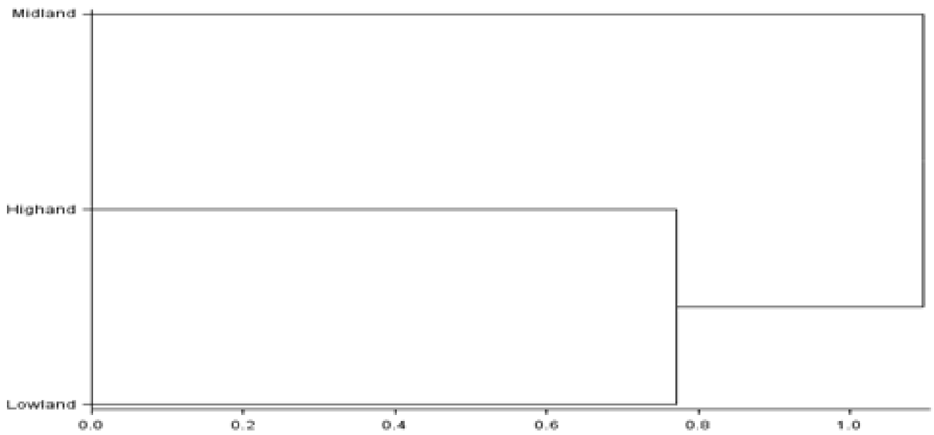

Figure 3 Dendrogram based on average linkage distances between indigenous male chicken populations of the three agro-ecologies using morphometric traits.

Summary of canonical correlation and eigen-values of male and female chicken were presented in Table 5. The canonical discriminant analysis derived a linear combination of the variables that has the highest possible multiple correlation with the groups called the first canonical correlation. The variable that is defined by the linear combination is the first canonical variable (CAN1). The process of extracting the rest canonical variables that is needed for the separation purposes would be repeated until the number of variables equals the number of classes/groups minus one. In the present study, since there were three agro-ecologies, the maximum number of CANs to be extracted for the separation purposes would be $3 - 1 = 2$ possible CANs (CAN1 and CAN2) needed for separation purposes. Accordingly, two canonical variables namely CAN1 and CAN2 were extracted, which accounted for 61.5% and 38.6% of the total variation in female chicken, respectively being highly significant ($p<0.0001$). In male chicken, however, CAN1 and CAN2 accounted for 89.3% and 10.7% of the total variation, respectively, the latter being insignificant ($p = 0.1118$; Table 5).

Table 5 Summary of canonical correlations and eigen-values in female and male chicken

Functions	Canonical correlations	Eigenvalues			Likelihood Ratio	F-value	Pr>F
		Eigen value	Proportion	Cumulative			
Females							
CAN1	0.344	0.135	0.615	0.615	0.813	8.36	<.0001
CAN2	0.279	0.084	0.386	1.000	0.922	8.10	<.0001
Males							
CAN1	0.479	0.298	0.893	0.893	0.744	6.58	<.0001
CAN2	0.186	0.036	0.107	1.000	0.966	2.23	0.1118

CAN = canonical variables

Table 5 further displays the likelihood ratio test rejecting the hypothesis that the current canonical correlation and all smaller ones are zero, except CAN2 in male chicken. Figure 3 shows a plot built with the two canonical variables illustrating the relationships between the female chicken populations belonging to different agro-ecologies. The plot displayed that the female chicken of the midland agro-ecology was mainly distributed to the right side of x-axis (CAN1) while those of the highland scatters to the left of the x-axis being closer to CAN2. Chicken of the lowland agro-ecology were distributed within both agro-ecologies being much closer to CAN2.

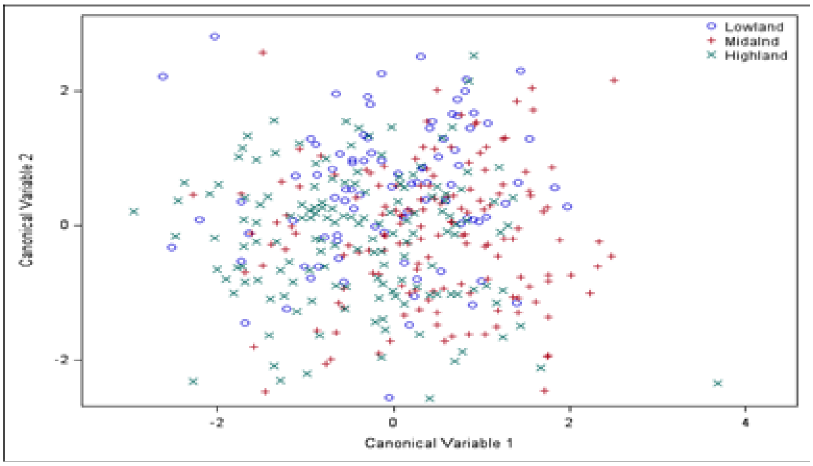

Figure 4 Canonical representations of indigenous female chicken populations across the three agro-ecological zones.

Figure 5 shows a plot built with the two canonical variables illustrating the relationships between the male chicken populations belonging to different agro-ecologies. According to the plot, the male chicken of the midland agro-ecology was scattered to the far-right side of the positive x-axis (CAN1) while those of the lowland distributed to the center of the x-axis being closer to both canonical variables (CAN1 and CAN2). On the other hand, chicken of the highland scattered all over the plane being more skewed towards the positive side of y-axis being closer to CAN12. In general, it can be observed in the figure that there is a visible overlapping among the chicken populations of the three agro-ecologies indicating the existence of homogeneity.

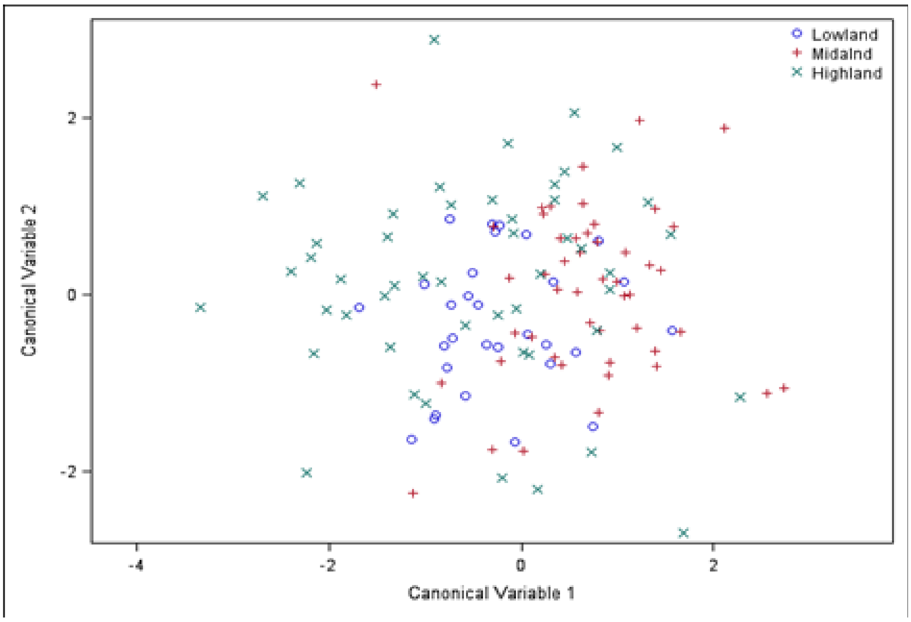

Figure 5 Canonical representations of indigenous male chicken populations across the three agro-ecological zones.

The standardized canonical coefficients and canonical structures help in weighing each original trait contribution to each of the canonical variables (Table 6). In female chicken the first canonical variable CAN1 highly loaded for live body weight and wingspan. Similar trends have been also observed in the canonical structures for both canonical variables. In male chicken, CAN1 highly loaded for wingspan, while CAN2 highly loaded for shank length. Morphometric traits that loaded the highest in canonical coefficients have also showed similar effect in the canonical structures. The traits that loaded high in both canonical variables suggest their relevance in discriminating indigenous chicken across different agro-ecologies.

Table 6 Standardized total canonical coefficients based on morphometric variables of both female and male indigenous chicken.

	Standardized canonical coefficients		Canonical structures	
Females				
Variables	CAN1	CAN2	CAN1	CAN2
Wingspan	0.732	0.414	0.798	0.228
Live body weight	0.977	-0.651	0.743	-0.254
Shank circumference	-0.177	-0.578	0.122	-0.409
Body length	-0.573	0.372	0.392	-0.034
Males				
Shank length	0.6642	0.874	0.768	0.639
Wingspan	0.719	-0.788	0.765	-0.390

CAN1 = canonical variable one; CAN2 = canonical variable two

Discriminant analysis

For female chickens, the discriminant function correctly classified 64.7%, 43.3%, and 63.3% of individual female chicken into their respective source population of highland, lowland, and midland, respectively. The correct classification rate for male chicken was 54.0% in highland, 50.0% in lowland and 89.8% in midland (Table 7).

The highest classification rates were obtained in highland agro-ecology for female (64.7%) and in midland agro-ecology for male (89.8%) chickens. Unlike wise, highland and in lowland for female (5.33%) and midland in lowland female (6.12%) chicken populations have a lower classification rate. These indicate that discriminate multivariate classification shows the existence of variation in traits between sexes across the study agro-ecologies.

Cross-validation with the split–sample method indicated that 62.7%, 39% and 59.3% success rate in highland, lowland, and midland, respectively. The classification results of this study could directly be used to identify the indigenous chicken populations; the four discriminating variables extracted in females and two in males were sufficiently strong to be used in the field to separate them in to three agro-ecologies.

Table 7 Percent of individual chicken classified into their respective agro-ecologies and cross-validation of classification based on morphometric variables (values in brackets are number of chicken)

Sex groups	Female chicken				Male chicken			
Agro-ecologies	Highland	Lowland	Midland	Total	Highland	Lowland	Midland	Total
Re-substitution								
Highland	64.7 (97)	5.33 (8)	30.0 (45)	100 (150)	54.0 (27)	12.0 (6)	34.0 (17)	100 (50)
Lowland	24.4 (22)	43.3 (39)	32.2 (29)	100 (90)	20.0 (6)	50.0 (15)	30.0 (9)	100 (30)
Midland	24.0 (36)	12.7 (19)	63.3 (95)	100 (150)	4.08 (2)	6.12 (3)	89.8 (44)	100 (49)
Error count estimates	0.353	0.567	0.367	0.408	0.460	0.500	0.102	0.333
Cross-validation								
Highland	62.7 (94)	5.33 (8)	32.0 (48)	100 (150)	52.0 (26)	12.0 (6)	36.0 (18)	100 (50)
Lowland	25.6 (23)	38.9 (35)	35.6 (32)	100 (90)	26.7 (8)	40.0 (12)	33.3 (10)	100 (30)
Midland	26.0 (39)	14.7 (22)	59.3 (89)	100 (150)	12.2 (6)	10.2 (5)	77.6 (38)	100 (49)
Error count estimates	0.3733	0.6111	0.4067	0.4410	0.4800	0.6000	0.2245	0.4109

DISCUSSION

Quantitative parameters

Variation in production environment was reported as a source of variation for LBW, BL, BC, WL, SL, and SC like earlier studies by Melesse and Negesse (2011) and Wolde et al. (2019) who stated that variation of the chickens may arise due to environmental effect, breed's specific traits, adaptation fattiness to their environment. The average body lengths observed in the present study (24.8 in midland and 23.7 cm in highland) were much higher than those reported by Fitsum (2016) in Northern Ethiopian midland and highland which were 26.3 and 26.6 cm, respectively, and the chickens in midland was relatively higher for breast circumference (29.2) and shank length (28.5) like to the current study that revealed significantly higher for breast circumference and shank length than highland agroecology (Table 2).

Multivariate analysis

In this study, the units of analysis were mature male and female local chicken populations at each site characterized by the mean of the continuous variables. The selected variables to describe the mature chicken populations were live body weight, body length, breast circumference, wingspan, shank length, shank circumference, comb length, wattle length, earlobe length and beak length. Multivariate analysis technique is used to study the factors influencing dissimilarity within a population, and eventually alter a heterogeneous set of observation units into relatively more homogenous groups from the total population. This is in line with the reports of (Minitab, 1998; Fitsum, 2016).

Multivariate analysis was conducted using quantitative variables for mature female and male indigenous chickens separately across three agro ecologies. Among the multivariate analysis, discriminant, canonical discriminant, and stepwise discriminant analyses were conducted.

The stepwise discriminate analysis is the most important technique to discriminate the studied chicken populations and is used to detect the best discriminator variables to use in differentiating groups (Wario et al., 2021).

Stepwise discriminant characterization traits of indigenous chicken sample populations were sorted out the traits in the order of their contribution to separation. Stepwise selection indicates that except body length and shank circumference, all the traits in the data set were found to have highly significant ($p<0.0001$) discriminatory power in female and male chicken populations (Table 3). This indicates that, traits in the model were significant at level ($p<0.05$) to discriminate the chicken populations into the study agro-ecologies. In this study, wingspan in females, and shank length in males were the most important traits to cluster the sampled indigenous chicken populations similarly with the report of Tareke et al. (2018) and Ogah et al. (2011) who revealed that wingspan and shank length were among the most important traits to cluster Ethiopian and Nigerian indigenous chicken populations, respectively. Moreover, Al-Atiyat (2009) and Rosario et al. (2008) reported that body length as discriminating traits for chicken populations which agree the current study for female chickens where body length was among the traits with high discriminating power in females.

As reported in the study conducted by Gwaza et al. (2013), the higher percentage of shared variance (eigen-value) and total variability in the groupings of discriminant CAN1 indicated that the model in CAN1 was more efficient in explaining the variation existing in the grouping variable than the models of next CAN. The efficiency of the higher canonical correlation that measures the strength of the model to explain the variation existing in the grouping variables further confirms this observation.

Eigen-value of CAN1 and CAN2 were accounted 13.5% and 8.4% in female chickens, respectively and 29.8% and 3.6% in male, respectively, and 34.4% (CAN1) and 27.9% (CAN2) canonical correlation in female and 47.9% (CAN1) and 18.6% (CAN2) canonical correlation in male indigenous chickens which is higher in CAN1 than CAN2 like the eigen-value This is in line with the studies conducted by Gwaza et al. (2013), Tareke et al. (2018), and Dahloum et al. (2016) who revealed that, the percentage of shared variance CAN1 was higher than CAN2 and the canonical correlation of CAN1 was also higher than CAN2. The high percentage of shared variance (Eigen value) in CAN1 indicated that more efficiency of model in CAN1 for explaining the variation existing in the grouping variable than the models of CAN2. The efficiency of the higher canonical correlation which measures the strength of the model to explain the variation existing in the grouping variables was also indicated. Hence, the higher value indicates the higher strength of canonical correlation.

Multivariate analysis was used to consider the variability of chickens simultaneously; as revealed by (Buttigieg and Ramette, 2014); univariate statistical techniques may not sufficiently explain how populations differ when all measured variables are considered jointly; however, in canonical discriminant analysis a multivariate statistical technique, all variables are considered simultaneously in the differentiation of population. This approach results in a more powerful comparison of the population that cannot be achieved with univariate analysis, provided the variables are correlated.

Canonical discriminate analysis could explain the strength of the relationship between the linear synthesis of the interpreter set of variables (Minitab, 1998). In this analysis the predictor is the canonical variants, and the criterion is the agroecology. Canonical discriminant analysis evaluated group means to discriminant distributions and graphic representations of the homogeneity of the three chicken populations.

Table 4 indicated that shortest Mahalanobis distances of the female chickens were observed between lowland and highland agro-ecologies (0.63) followed by lowland and midland agro-ecologies (0.67) and the furthest Mahalanobis distances between those of midland and highland agro-ecologies (0.69). In male chickens, the shortest pairwise Mahalanobis distances were observed between chickens of lowland and highland agro-ecologies (0.306), whereas the longest between those of the midland and highland agroecology chicken populations (1.43). In general, Mahalanobis distance in female indigenous chickens was shorter than of males. This agrees with the report of Wario et al. (2021) who revealed that female chicken ecotypes had a shorter genetic distance in comparison with those of male ecotypes. The long distance among male ecotypes reflected small numbers of male chicken's population across three agro-ecologies and the number of samples for the male is small. As sample size decreases variation might increase. This revealed to the male population from each agroecology has its measurable differences from other male populations. Similarly, the study of Al-Atiyat et al. (2017) also reported the long distances among the male ecotypes in Saud Arabia. In reverse of the report of Getachew et al. (2016) who stated that the pair-wise squared Mahalanobis distances for females were considerably higher than for males; for the current study, males have higher than females for their pair-wise squared Mahalanobis distances. This might be due to sampling methods and number of samples. However, congruent for the distances among sites for female sample populations were highly significant ($p<0.0001$) and the longest distance implying male sample populations from all agro-ecologies were much different in quantitative features under consideration.

CONCLUSIONS

The use of canonical discriminant analysis in evaluating morphometric traits of indigenous chicken populations across the three agro-ecologies help in understanding the chicken across agro-ecologies. Most of traits showed significant variations across agro-ecologies and between sexes. These variations considered as opportunities for genetic improvement of indigenous chicken genetic resources. In the study sites, there is introduction of exotics chicken whose sources is not well known. This situation leads to dilution of indigenous chicken genotype. So, the information raised at this study could provide the direction for developing breeding plan for conservation of indigenous chicken genetic resources, management, and improvement of indigenous chicken populations by based on the variations of their body measurements.

ACKNOWLEDGEMENTS

We are grateful to ILRI (International Livestock Research Institute), ACGG (African Chicken Genetic Gain) project to its provision of fund to accomplish this work.

AUTHOR CONTRIBUTIONS

Berhanu Bekele: conceptualization; designing methodology; data collection; formal analysis; writing original draft.
Aberra Melesse: conceptualization; modifying the manuscript.
Wondmeneh Esatu: conceptualization; modifying the manuscript.
Tadelle Dessie: conceptualization; modifying the manuscript and provision of fund. All authors have read and approved the final manuscript.

REFERENCES

Al-Atiyat, R.M., 2009. Diversity of chicken populations in Jordan determined using discriminate analysis of performance traits. Int. J. Agri. Biol. 11(4), 374–380.

Al-Atiyat, R.M., Aljumaah, R.S., Abudabos, A.M., Alotybi, M.N., Harron, R.M., Algawaan, A.S., Aljooan, H.S., 2017. Differentiation of free ranging chicken using discriminant analysis of phenotypic traits. Revi. Brasi. Zoot. 46(10), 791-799.

Al-Qamashoui, B., Mahgoub, O., Kadim, I., Schlecht, E., 2014. Towards conservation of omani local chicken: phenotypic characteristics, management practices and performance traits. Asia-Austral. J. Anim. Sci. 27(6), 767-777.

Ayalew, W., Getahun, E., Tibbo, M., Mamo, Y., Rege, J., 2004. Current state of knowledge on characterisation of farm animal genetic resources in Ethiopia. In Proceedings of the 11th annual conference of Ethio, Addis Ababa, Ethio, 28-30 August 2003.

Bekele, B., Melesse, A., Banerjee, S., Esatu, W., Dessie, T., 2020. Farmers' preferences towards breeding objective for indigenous chicken in different agro-ecologies of Ethiopia. Afri. J. Agri. res. 16(12), 1681-1690.

Benitez, F., 2002. Reasons for the use and conservation of some local genetic resources in poultry. In Proceeding of 7th World congress on genetics applied to livestock production, Montpellier, France, 19-23 August 2002.

Buttigieg, P.L., Ramette, A., 2014. A guide to statistical analysis in microbial ecology: a community-focused, living review of multivariate data analyses. Fed. Euro. Microbiol. Soc. 90(3), 543-550.

Central Statistical Agency, 2021. Agricultural sample survey. Volume II report on livestock and livestock characteristics. Available online: https://www.statsethiopia.gov. et/our-survey-reports/.

Dahloum, L., Moula, N., Halbouche, M., MignonGrasteau, S., 2016. Phenotypic characterization of the indigenous chicken (Gallus gallus) in the northwest of Algeria. Archi. Anim. Breed. 59, 79-90.

Daikwo, S.I., Dike, U.A., Dim, N.I., 2015. Discriminant analysis of morphometric differences in the normal feathered and frizzles feathered chicken of North Central Nigeria. J. Trop. Agri. Fo. Envi. Exte. 14(3), 12-15.

Dana, N., Vander, W.E., Johan, A.M., 2010. Genetic and phenotypic parameter estimates for body weights and egg production in Horro chicken of Ethiopia. Trop. Anim. Health. Prod. 43, 21-28.

Desta, T.T., Wakeyo, O., 2012. Uses and flock management practices of scavenging chickens in Wolaita Zone of Southern Ethiopia. Trop. Anim. Health Prod. 44(3), 537-544.

Desta, T.T., Dessie, T., Bettridge, J., Lynch, S.E., Melese, K., Collins, M., Christley, R.M., Wigley, P., Kaiser, P., Terfa, Z., Mwacharo, J.M., Hanotte, O., 2013. Signature of artificial selection and ecological landscape on morphological structures of Ethiopian village chicken. Anim. Genet. Res. 52, 17-29.

Doungnapa, P., Khanitta, R., 2021. The comparative of growth and carcass performance of Thai native chickens between economic selection (Chee KKU12) and natural selection (Chee N). Vet. Integ. Sci. 19(2), 247-257.

Fitsum, M., 2016. Phenotypic characterization of local chicken ecotypes in the central zone of Tigray in northern Ethiopia [Master's thesis]. Jimma University. Available online: https://cgspace.cgiar.org/handle/10568/77362.

Food and Agriculture Organization, 2012. Phenotypic characterization of animal genetic resource. Available online: http://www.fao.org/3/a-i2686e.pdf.

Getachew, F., Abegaz, S., Abraham, A., Manaye, M., Emishaw, Y., 2016. Multivariate analyses of morphological traits in indigenous chicken populations of Metekel Zone, Northwestern Ethiopia. J. Anim. Genet. Res. 59, 15-25.

Gizaw, S., Van Arendonk, J.A., Komen, H., Windig, J.J., Hanotte, O., 2007. Population structure, genetic variation and morphological diversity in indigenous sheep of Ethiopia. Anim. Genet. 38(6), 621-628.

Gwaza, D.S., Noah, E., Wamagi, T.I., 2013. Discriminant analysis of morphological traits in selected population of the Tiv local chicken ecotype in the derived Guinea Savanah of Nigeria. IOSR J. Agri. Vet. Sci. 3(6), 60-64.

Habimana, R., Okeno, T.O., Ngeno, K., Mboumba, S., Assami, P., Gbotto, A.A., Keambou, C.T., Nishimwe, K., Mahoro, J., Yao, N., 2020. Correction: Genetic diversity and population structure of indigenous chicken in Rwanda using microsatellite markers. PLoS One. 15(9), e0238966.

Magothe, T.M., Okeno, T.O., Muhuyi, W.B., Kahi, A.K., 2012. Indigenous chicken production in Kenya: I. Current status. Worl. Poult. Sci. J. 68(1), 119-132.

Melesse, A., Negesse, T., 2011. Phenotypic and morphological characterization of indigenous chicken population in southern region of Ethiopia. Anim. Genet. Res. 49, 19-31.

Melesse, A., Maak, S., von Lengerken, G., 2011. Effects of genetic group × ambient temperature interactions on performance and physiological responses of Naked-neck chicken and their F1 crosses with Lohmann White and New Hampshire laying hens. J. Anim. Fe. Sci. 20(4), 599-612.

Melesse, A., 2014. Significance of scavenging chicken production in the rural community of Africa for enhanced food security. Worl. Poult. Sci. J. 70(3), 593-606.

Minitab, 1998. Minitab for Windows Release 12.21. Available online: https://www.amazon.com/Minitab-Statistical-Software-Student-Paperback/dp/B011YU46WC.

Negassa, D., Melesse, A., Banerjee, S., 2014. Phenotypic characterization of indigenous chicken populations in Southeastern Oromia Regional State of Ethiopia. Anim. Genet. Res. 55, 101-113.

Ogah, D.M., Momoh, M.O., Dim, N.I., 2011. Application of canonical discriminant analysis for assessment of genetic variation in Muscovy duck ecotypes in Nigeria. Egy. Poult. Sci. 31(2), 429-436.

Rosario, M.F., Silva, M.A., Coelho, A.A., Savino, V.J., Dias, C.T., 2008. Canonical discriminant analysis applied to broiler chicken performance. Animal. 2(3), 419-424.

Tareke, M., Assefa, B., Abate, T., Tekletsadik, E., 2018. Evaluation of morphometric differences among indigenous chicken populations in Bale Zone, Oromia Regional State, Ethiopia. Poult. Sci. J. 6(2), 181-190.

Tixier-Boichard, M., Bordas, A., Rognon, X., 2009. Characterization and monitoring of poultry genetic resources. Worlds Poult. Sci. J. 65(2), 272-285.

Wario, D., Tadesse, Y., Yadav, S., 2021. On-farm phenotypic characterization of indigenous chicken, in Dire and Yabello Districts, Borena Zone, Oromia Regional State, Ethiopia. J. Genet. Res. 7(1), 36-48.

Wodajo, H., Gemede, B., Wole, K., Annet, A., Anouka, V., Barbara, W., 2020. Contribution of small ruminants to food security for Ethiopian smallholder farmers. J. Smal. Rumi. Res. 184, 1-10.

Woelders, H., Zuidberg, C.A., Hiemstra, S.J., 2006. Animal genetic resources conservation in the Netherlands and Europe: Poultry perspective. J. Poult. Sci. 85(2), 216-222.

Wolde, B., Tadesse, Y., Ameha, N., 2019. On farm phenotypic characterization of indigenous chicken ecotypes in west Hararghe zone, Oromia region, Ethiopia. J. Vet. Med. Anim. Sci. 2(1), 1-7.

How to cite this article;

Berhanu Bekele, Aberra Melesse, Wondmeneh Esatu and Tadelle Dessie. Multivariate analysis of morphometric traits to differentiate the indigenous chicken reared under different Agro-ecologies of Ethiopia. Veterinary Integrative Sciences. 2022; 20(3): 775- 791.