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Phenotypic Characterization of Indigenous Chicken Population in Ethiopia

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Abstract

Phenotypic characterization of indigenous chicken ecotypes in two districts of Ethiopia was done using multivariate analyses. Chickens were managed under traditional scavenging system. Qualitative and quantitative morphological traits were analyzed. Out of nineteen distinct plumage colors, brown mottled and red were the predominant ones. Among ecotypes all qualitative traits were significant ($P<0.05$). Multiple correspondence analysis showed 18.96% of the total variation explained by the first two dimensions. Long legs, large combs and wattle could be indicative of better heat dissipation of birds in tropical hot environment. Discriminant analysis identified shank length, body length, comb width, body weight, wingspan and comb height to have more discriminating power causing morphological variation between chicken ecotypes. The correlation between the first canonical variable and the two chicken ecotypes is moderate (0.55), canonical variables being highly significant based on the Wilks lambda test. Hundred nineteen chickens (86.2%) that belonged to Horro ecotype were correctly classified with 13.8% rate of error while 123 chickens (80.4%) that belonged to Jarso ecotype were correctly classified leaving 19.6% error rate.

Key Words: Discriminant analysis; indigenous chicken; morphological traits; multiple correspondence analysis

Introduction

Indigenous breed is a general terminology to describe those birds kept in the extensive system, scavenging in the free-range, have no identified description, multi-purpose and unimproved [13, 17]. Indigenous chickens are reported to have variable morphological identity carrying genes that have adaptive values to their environment and diseases. According to Horst [13], indigenous chickens can be considered as gene reservoir, particularly, for those genes that have adaptive values in the tropical conditions. In Ethiopia chickens are the most widespread where almost every rural family owns chickens, which contribute greatly to supply of eggs and meat [3, 21, 2]. The total chicken population in the country is estimated to be about 44.9 million [6], most of the chicken types being local ones, which show a large variation in body conformation, plumage color, comb type and productivity [22, 20, 11]. A number of studies have been carried out on the performance characteristics of various ecotypes of Ethiopian chickens [3, 21, 8, 11, 1, 14]. Some of these chicken ecotypes viz., Tilili, Horro, Chefe, Jarso, Tepi, Gelila, Debre-Elias, Melo-Hamusit, Farta, Guangua, Mecha appear to be very useful and required to be maintained as per the studies. However, there is little information available on the diversity of different chicken ecotypes. Moreover, no real efforts have been made to conserve these chicken genetic resources. The present and future improvement and sustainable utilization of indigenous chickens are dependent upon the availability of these genetic variations [4].

Presently, studies on characterization (some phenotypic and very few genetic characterization) in Ethiopia are being taken up to generate useful information towards conservation of animal genetic resources, but these works are mostly on small ruminants and cattle rather than on chickens. Genetic characterization based on molecular assessment is reported to be most common and used method to evaluate genetic diversity among and within livestock breeds, but it needs high technology and cost [23, 18, 12].Researchers have used a characterization method based on morphological traits that are easy to measure, low cost and provide valuable information [8, 11]. Hence, the study was undertaken to phenotypically characterize local chicken populations in Horro and Jarso districts of Oromia regional state of Ethiopia by taking qualitative and quantitative morphological traits.

Materials and Method

Location of study area: The study was conducted in two districts, i.e. Horro and Jarso, of Oromia regional state of Ethiopia representing two different indigenous chicken ecotypes. Horro district is located in east Wellega zone having 9°43´60´´N latitude and 37˚4´0´´E longitudes and an area of 998.7 km^2. It is located at an elevation of 2,460 m above sea level. Jarso district is located in east Hararghe zone having 9°7´60´´N latitude 37˚28´0´´E longitude and an area of 504.54 km^2. Altitude ranges from 1050 to 3030 m above sea level.

Measurement of qualitative and quantitative morphological traits: A total of 448 indigenous chickens of both sexes: 224 chickens (86 male and 138 female) from Horro and 224 chickens (68 male and 156 female) from Jarso, managed through traditional scavenging system, were selected randomly for this study. The chicken used were approximately six months or older in age as per information provided by the owners, and also verified by the researchers using wing plumage. Qualitative morphological traits (i.e., plumage color, skin color, shank color, comb type, earlobe color, eye color, head shape) and quantitative morphological traits (i.e., shank length, comb height, comb width, body length, breast circumference, back length, keel length, wattle length, wingspan and body weight) were recorded following the recommended descriptors for chicken genetic resources [10].

Measuring tapes and a spring balance were used to measure the respective quantitative traits and body weight of sampled chickens. A 5-kg measuring scale was used for the weight measurement. The length and circumference measurements were effected using a measuring tape calibrated in centimeter (cm). All measurements were taken by the same individual early in the morning before the birds were fed.

Data analysis : SAS-program version 9.2 [19] was used for all statistical analysis in this study.

Qualitative Morphological Traits

Univariate Analysis: Qualitative morphological traits were subjected to the frequency procedure of SAS (PROC FREQ) [19].

Multivariate Analysis: The associations among qualitative morphological traits were assessed via a multiple correspondence analysis of SAS (PROC CORRESP) [19].

Quantitative Morphological Traits

Univariate Analysis: Quantitative morphological traits were subjected to analysis of variance using the general linear model procedure (PROC GLM) of SAS [19] to determine the effects of district (Horo and Jarso), sex and their interaction. Significant means were separated using the Duncan's New Multiple Range Test.

Multivariate analysis: The stepwise discriminant analysis procedure (PROC STEPDISC) [19] was run to rank the quantitative morphological traits by their discriminating power. Selected significant traits from PROC STEPDISC [19] were then subjected to canonical discriminant analysis (PROC CANDISC) [19] and discriminant function analysis (PROC DISCRIM) [19] to ascertain the existence of population level phenotypic differences between the districts. The analysis was performed taking individual birds as a unit. In order to avoid potential sampling bias due to low number of males in the study, only female birds were considered in discriminant analysis.

Results and Discussion

Qualitative Morphological Traits

Univariate Analysis: The number (N) and percentage of each level of the qualitative morphological traits (i.e. plumage color, comb type, head shape, shank color, eye color, shank color, and skin color) that were subjected to the frequency procedure of SAS, are given in Table 1 and 2 for the two districts studied. Since some birds have missing values, the sample size (N) of valid records is different from that mentioned under the material and methods part.

A total of nineteen distinct plumage colors were identified in both districts in which brown mottled and red were the predominant ones. Chickens predominantly have brown mottled plumage color, 20.27% and 21.10% in Horro and Jarso districts respectively. A complete body red plumage is typical of 17.12% and 15.60% of chickens from Horro and Jarso districts respectively (Table 1). Excluding these two main phenotypes, plumage diversity was higher in both studied districts. This is in agreement with previous studies which found similar results for the indigenous chickens in Horro, Tepi and Jarso [8] and Northwest Ethiopia [11]. Maintenance of this plumage color diversity is indicative of many genes governing the trait and random mating with respect to plumage color.

Most of the local chickens observed in Horro district had white (77.03%) skin color followed by yellow (22.07%) and bluish black (0.9%). Similarly in Jarso, white was the predominant skin color (68.81%), followed by yellow (28.44%) and bluish black (2.75%) (Table 2). According to Eriksson [9] yellow or white skin is the result of the presence or absence of carotenoid pigments respectively. Domestic chickens with yellow skin are homozygous for a recessive allele, which caused the inhibition of the expression of an enzyme BCDO2 (beta-carotene dioxygenase 2) in yellow skin birds with white birds carrying the dominant allele. This recessive allele might have been introgressed from Grey Jungle fowl (Gallus sonnerati) [9].

The orange eye color (wild-type color) was found in higher frequency in Horro than Jarso district (87.84% vs 72.48%) and it was followed by the red, largely more represented in Jarso (24.31%) than in Horro (9.01%). The pearl and brown eye colors were rare in both districts. Variation in eye color to a large extent depends on the pigmentation (carotenoid pigments) and blood supply to a number of structures within the eye [7]. Four earlobe colors were observed. The red and white earlobe was 41.63% and 49.54% in Horro and Jarso districts respectively. These frequencies are close to the ones (46%) reported by Bogale [5] for earlobe color of Fogera chicken. The red earlobe was the commonest, 44.8% in Horro and second common, 28.44% in Jarso districts. While19.27% of the chicken in Jarso and 12.67% in Horro showed a white earlobe, the yellow earlobe was only observed with a very low proportion of 2.75% and 0.90% in Jarso and Horro districts respectively. Four comb types were observed in both districts. Rose comb type (48.42%) was predominant in Horro followed by pea, single and cushion while single comb type (33.49%) was found to be most represented in Jarso and closely followed by pea and rose comb type. However, Halima [11] and Nigussie [16] observed 50.72% and 53% of chicken in North West Ethiopia and other parts of Ethiopia to be of pea comb type, respectively. The difference could be attributed to the sample of study with differences in gene frequency of the trait. Of the investigated chicken ecotypes, 71.17% in Horro and 95.41% in Jarso had plain head type. The corresponding values for crest head type were 28.83% in Horro and 4.59% in Jarso. Six shank colors were observed. The yellow and white shank colors were the most frequent ones with 79.28% and 16.67% in Horro and 60.09% and 25.23% in Jarso districts respectively. The other shank colors were not highly represented in both districts.

Multivariate Analysis: For the two chicken ecotypes, the chi-square test of independence for all the six qualitative morphological traits were found significant ($P<0.05$, Table 2). A multiple correspondence analysis of SAS (PROC CORRESP) was thus carried out on these traits. To examine the association between district and the qualitative traits, the respective districts were included in the analysis as a supplementary variable. Figure 2 shows a bi-dimensional graph representing the associations among the categories of the analyzed traits. This association is based on points found in approximately the same direction from the origin in approximately the same region of the space. From the figure, it can be seen that 18.96% of the total variations are explained by the first two dimensions (10.01% by the first and 8.95% by the second dimensions). On the dimensions identified chickens from Horro district clustered together with rose comb type, red ear lobe color, brown eye color, yellow and bluish black shank color. On the other hand chickens from Jarso district were closely associated with birds that have cushion comb type, white and yellow ear lobe color, pearl eye color, black and white shank color. The significant differences of the qualitative morphological traits among districts are also indicative of the ecotypes to be different in the two districts. This shows that the populations in the two districts are probably closed type with no or little inter mixing.

Quantitative Morphological Traits:

Univariate Analysis: The table 3 shows the effects of sex and district on the quantitative morphological traits (ANOVA result of PROC GLM). Different superscripts ([a, b, c, d]) in the same column for a given trait show differences are significant ($P < 0.05$).

The average body weight of local adult hens in Horro and Jarso were 1.29 kg and 1.12 kg respectively (Table 3) which is higher than the reported values for the central highlands of Ethiopia (1.04 kg) by Alemu and Tadelle [3] and that reported (847.77 g) by Halima [11] in north-west Ethiopia. The corresponding values for mature cock were 1.69 kg and 1.41 kg which were closer to the values reported for central highlands of Ethiopian chicken (1.5 kg) [3] and lower than the average weight of indigenous chicken in north-west Ethiopia (2.05 kg),[11]. The body weight variation in the present study compared to the literature could be attributed to the ecotype differences among various indigenous chicken populations of Ethiopia. Shank length of males from Horro and Jarso district were11.32 cm and 9.99 cm, respectively which are comparable with the reported value (9.8 cm) by Bogale [7] and with that of (10.31 cm) reported by Halima [11] in other parts of Ethiopia. Among the local hens, chickens from Horro had longer shank length (9.22 cm) than their Jarso counterpart (8.51 cm). These values are higher than that of (7.25 cm) reported by Bogale [5]. As to comb width, comb height and wattle length, they did not differ significantly between the two districts for the two sexes except wattle length which showed significant difference among males of the two districts. The mean values of comb width (5.88 cm and 2.37 cm vs. 5.64 cm and 2.53 cm) for Horro male and female vs. Jarso male and female respectively, were higher than 5.3 cm and 2.3 cm reported by Bogale [5] for the male and female chicken respectively. In this study long legs, large combs and wattle were observed, which could be important morphological traits that allow better heat dissipation in the tropical hot environment. The comb and wattles play important role in sensible heat losses. This specialized structure accounts for about 40% of the major heat losses, by radiation, convection and conduction of heat produced from body surfaces at environmental temperature above 26.7^0C [15]. Multivariate Analysis: Stepwise discriminant analysis was carried out with ten quantitative morphological traits (i.e. comb width, comb height, wattle length, keel length, wingspan, body length, shank length, breast circumference, back length and body weight) to assess the significance of these explanatory variables in discriminating the chicken populations sampled from the two districts in a stepwise fashion. At each step, the significance of already entered explanatory variables is evaluated based on the significance for staying (P-value: 0.15) criterion, and the significance of newly entering variables is evaluated based on the significance for entering (P-value: 0.15) criterion. When no variables can be removed or entered, the stepwise selection procedure stops. The summary results of the stepwise selection method are presented in Table 4. The stepwise discriminant analysis identified six of the ten quantitative traits (Table 4) to have more discriminating power in assessing morphological variation between the chicken populations sampled from the two districts. These six traits were thus used in further analysis of canonical discriminant analysis and discriminant function analysis.

Canonical Discriminant Analysis: The univariate ANOVA results indicate that highly significant district effect exist for all the explanatory variables except 'comb height' (Table 5). By comparing the F-value and the P-value statistics for each significant explanatory variable, we can conclude that 'shank length' has the highest amount of significant discriminative potential, while 'comb width' has the least significant discriminative power in differentiating the chicken populations sampled from the two districts**.** The relatively large significant P-values obtained for the five explanatory variables (Table 5) indicate the fact that these predictors have high discriminatory power in classifying the two chicken populations sampled. Table 6 presents the total-sample standardized canonical coefficients of variables contributing to the first canonical variable (CAN 1). The total-sample standardized canonical coefficients indicate the partial contribution of each variable to the discriminant function, controlling for other attributes entered in the equation. Accordingly, the total-sample standardized canonical coefficients given in the table indicate that the explanatory variables, shank length, body length, body weight and wingspan contributed significantly in that order to the first canonical variable (CAN1). The correlation between CAN1 and the chicken populations sampled from the two districts was moderate (0.55), with the canonical variables being statistically highly significant based on the Wilks lambda test (P-value <0.0001). The standardized means of the two chicken ecotypes are presented in Table 7. The mean values of comb width and comb height for the Horro chicken ecotype are relatively lower than that of the Jarso chicken, while the mean values of wingspan, body length, shank length and body weight for the Horro chicken are relatively higher than their Jarso counterparts**.** Thus, in general, these canonical variables successfully discriminate the two chicken ecotypes.

Discriminant function analysis: This is commonly used for classifying observations to predefined groups based on the knowledge of their quantitative attributes. The discriminant function is estimated by measuring the generalized squared distance. The Mahalanobis distance between Horro and Jarso chicken was 1.7641 and it was highly significant (P-value: <0.0001). The performance of a discriminant function analysis in classification is evaluated by estimating the probabilities of misclassification. Table 8 lists the misclassified observations based on the posterior probability estimates computed by the quadratic discriminant function via cross-validation. Nineteen cases that belong to the Horro district were classified into the Jarso district while thirty cases that belong to the Jarso district were classified into the Horro district.

Conclusion

In this study significant morphological variations between the two chicken ecotypes were detected. The high diversity in indigenous chicken phenotypes is major evidence for the existence of high genetic variability in indigenous chickens of Ethiopia. However, there is an urgent need to preserve this genetic variability of the indigenous chickens of Ethiopia because of continuous pressure of their adulteration. Therefore, further work on indigenous chicken of Ethiopia need to be carried out to assess and to prevent such adulteration through promoting their utilization and undergoing advanced characterization at molecular level to assert their advantage of maintaining genetic diversity and adaptability.

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Table 1 Plumage color variation of indigenous chicken ecotypes

	District	
	Horro	**Jarso**
Plumage color	**N (%)**	**N (%)**
Black	2 (0.90)	16 (7.34)
Black mottled	8 (3.60)	16 (7.34)
Black-laced white	-	5 (2.29)
Brown	29 (13.06)	13 (5.96)
Brown mottled	45 (20.27)	46 (21.10)
Dark brown	15 (6.76)	3 (1.38)
Dark Brown mottled	6 (2.70)	10 (4.59)
Greyish mixture	4 (1.80)	6 (2.75)
Golden yellow mottled	-	3 (1.38)
Grey mottled	1 (0.45)	3 (1.38)
Red	38 (17.12)	34 (15.60)
Multi color	-	5 (2.29)
White with reddish brown	7 (3.15)	-
Reddish brown	22 (9.91)	5 (2.29)
Wheaten	17 (7.66)	19 (8.72)
Wheaten mottled	7 (3.15)	26 (11.93)
White	19 (8.56)	5 (2.29)
White mottled	2 (0.90)	1 (0.46)
White-laced black	-	2 (0.92)

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Table 2 Qualitative morphological traits of indigenous chicken ecotypes

Trait, level and description	District	
	Horro	Jarso
	N (%)	N (%)
Comb type (A)		
A1. Cushion	5 (2.26)	19 (8.72)
A2. Pea	62(28.05)	65(29.82)
A3. Rose	107(48.42)	61(27.98)
A4. Single	47 (21.27)	73(33.49)
	X^2 and P value:26.45 and <0.0001	
Head type (B)		
B1. Crest	64(28.83)	10(4.59)
B2. Plain	158(71.17)	208(95.41)
	X^2 and P value:46.20 and <0.0001	
Earlobe color (C)		
C1. Red	99 (44.80)	62(28.44)
C2. Red and white	92 (41.63)	108(49.54)
C3. White	28 (12.67)	42(19.27)
C4. Yellow	2 (0.90)	6(2.75)
	X^2 and P value: 14.56 and <0.0018	
Eye color (D)		
D1.Pearl	6 (2.70)	6(2.75)
D2.Brown	1 (0.45)	1(0.46)
D3.Orange	195(87.84)	158(72.48)
D4.Red	20 (9.01)	53(24.31)
	X^2 and P value:18.76 and <0.0001	
Shank color (E)		
E1.Black	1 (0.45)	14(6.42)
E2.Bluish black	6 (2.70)	1(0.46)
E3.Green	1 (0.45)	12(5.50)
E4.Green blue	1 (0.45)	5(2.29)
E5.White	37 (16.67)	55(25.23)
E6.Yellow	176(79.28)	131(60.09)
	X^2 and P value:36.90 and <0.0001	
Skin color (F)		
F1.Bluish black	2 (0.90)	6(2.75)
F2.White	171(77.03)	150(68.81)
F3.Yellow	49 (22.07)	62(28.44)
	X^2 and P value:4.86 and <0.0023	

- *Whenever cell frequencies were less than 5, Fisher's exact test was used.*

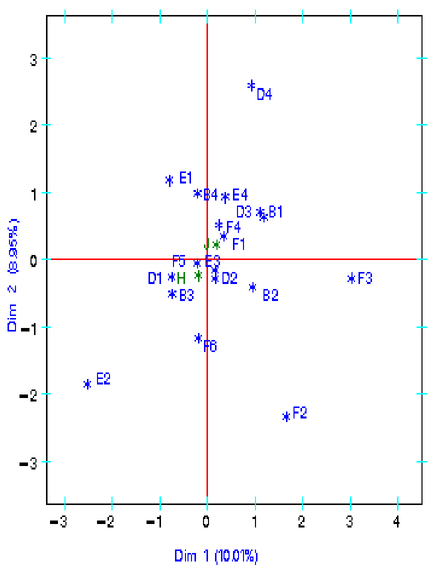

Figure 2 Bi-dimensional plot illustrating the association among qualitative traits (the description of the different letters and their level, i.e. A1, A2, A3, A4, ..., F1, F2, and F3 are as per table 2)

Table 3 Effect of sex and district on the quantitative morphological traits of indigenous chicken ecotypes

Trait	District	Sex	LSMean±SE
Comb Width (cm)	Horro	Male	5.88±0.12[a]
	Jarso	Male	5.64±0.14[a]
	Horro	Female	2.37±0.10[b]
	Jarso	Female	2.53±0.09[b]
Comb Height (cm)	Horro	Male	2.16±0.09[a]
	Jarso	Male	2.31±0.08[a]
	Horro	Female	0.77 ±0.06[b]
	Jarso	Female	0.84±0.06[b]
Wattle Length (cm)	Horro	Male	3.51±0.08[a]
	Jarso	Male	2.95±0.09[b]
	Horro	Female	0.81±0.06[c]
	Jarso	Female	0.74±0.06[c]
Keel Length (cm)	Horro	Male	16.55±0.23[a]
	Jarso	Male	14.92±0.25[b]
	Horro	Female	13.44±0.18[c]
	Jarso	Female	12.72±0.17[d]
Wingspan (cm)	Horro	Male	77.87±0.65[a]
	Jarso	Male	70.96±0.73[b]
	Horro	Female	69.96±0.51[c]
	Jarso	Female	62.58±0.49[d]
Body Length (cm)	Horro	Male	39.97±0.35[a]
	Jarso	Male	36.13±0.39[b]
	Horro	Female	35.16 ±0.27[c]
	Jarso	Female	32.66±0.26[d]
Shank Length (cm)	Horro	Male	11.32±0.10[a]
	Jarso	Male	9.99±0.12[b]
	Horro	Female	9.22±0.08[c]
	Jarso	Female	8.51±0.08[d]
Breast Circumference (cm)	Horro	Male	30.47±0.32[a]
	Jarso	Male	28.85±0.36[b]
	Horro	Female	27.83±0.25[c]
	Jarso	Female	27.22±0.24[c]
Back Length (cm)	Horro	Male	21.84±0.27[a]
	Jarso	Male	20.96±0.30[b]
	Horro	Female	19.26 ±0.21[c]
	Jarso	Female	18.62±0.20[d]
Body Weight (kg)	Horro	Male	1.69±0.03[a]
	Jarso	Male	1.41±0.04[b]
	Horro	Female	1.29 ±0.02[c]
	Jarso	Female	1.12±0.02[d]

Table 4 Significant traits that discriminated chicken ecotypes

Step	Variable entered	Partial R^2	F Value	P-value	Wilks' Lambda	ASCC
1	Shank Length	0.1724	60.20	<0.0001	0.8276	0.1724
2	Body Length	0.0973	31.06	<0.0001	0.7470	0.2530
3	Comb Width	0.0363	10.82	0.0011	0.7199	0.2801
4	Body Weight	0.0207	6.04	0.0146	0.7050	0.2950
5	Wingspan	0.0090	2.58	0.1092	0.6987	0.3013
6	Comb Height	0.0081	2.31	0.1293	0.6930	0.3070

The P-*values for both Wilks' lambda a*nd ASCC (Average Squared Canonical Correlation) were highly significant ($P<0.0001$)

Table 5 Univariate Test Statistics

Nr.	Variable	Pooled STD	Between STD	F Value	P-value
1	Comb Width	0.9957	0.1552	3.54	0.0611
2	Comb Height	0.9988	0.1071	1.67	0.1969
3	Wingspan	0.9363	0.5018	41.78	<0.0001
4	Body Length	0.9294	0.5267	46.74	<0.0001
5	Shank Length	0.9113	0.5862	60.20	<0.0001
6	Body Weight	0.9316	0.5189	45.14	<0.0001

Table 6 Total-sample standardized canonical coefficients

Variable	CAN1
Comb Width	-0.3045
Comb Height	-0.2061
Wingspan	0.2270
Body Length	0.4591
Shank Length	0.5406
Body Weight	0.3777

Table 7 Total-Sample Standardized Class Means

Variable	Comb Width	Comb Height	Wingspan	Body Length	Shank Length	Body Weight
Horro	-0.1156	-0.0797	0.3736	0.3922	0.4364	0.3863
Jarso	0.1042	0.0719	-0.3370	-0.3537	-0.3936	-0.3485

Table 8 Classification result

From District	Horro	Jarso	Total
Horro	119 (86.23%)	19 (13.77%)	138 (100%)
Jarso	30 (19.61%)	123 (80.39)	153 (100%)
Total	149 (51.20%)	142 (48.80%)	291 (100%)
Priors	0.4742	0.5258	