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The Use of Multiple Correspondence Analysis to Explore Associations between Categories of Qualitative Morphological Traits in Indigenous Chickens in Ethiopia

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Abstract

Characterization of poultry breeds based on morphological traits variations is essential for planning breed improvement programs and conservation strategies. This study aimed to use multiple correspondence analysis to evaluate qualitative morphological traits and identify significant traits. The study found variations in shank color, neck feather distribution, earlobe color, comb type, skin color, and head shape among indigenous chicken populations in two agro-ecologies in Ethiopia. These findings provide valuable information for the characterization and conservation of indigenous chicken ecotypes in Ethiopia. The first two dimensions of the multiple correspondence analysis explained 22% of the total variance among the traits. The bi-dimensional graph showed that the sample chicken population of lowland agro-ecology clustered together with certain trait values, while the corresponding values of midland agro-ecology clustered together with different trait values.

Keywords: Chicken; Multivariate Analysis, Qualitative Traits

Abbreviations: MCA: Multiple Correspondence Analysis; DDA: Dire Dawa Administration

Introduction

Poultry production is one of the integral parts of livestock farming activities in Ethiopia. Smallholder farmers own indigenous chickens that are widespread almost in every rural area of the country to supply eggs and meat [1,2]. The rural poultry production system is dominated by indigenous chickens and has made a significant contribution to poverty alleviation and household food security in many developing countries [3]. The provision of animal protein, the generation of extra cash income, and religious / cultural considerations are among the major reasons for keeping village chickens in rural communities [3]. According to [4], small farming families, landless laborer's, and people with incomes below the poverty line were able to raise village poultry with low inputs and harvest the benefits of eggs and meat via scavenging feed resources. However, most rural communities lack the required husbandry skills, training, and opportunity to effectively improve their poultry production. Studies on the characterization of poultry are essential for planning breed improvement programmers, sustainable utilization, and conservation strategies of a breed [5]. In the absence of baseline characterization information, some breed populations and unique characteristics possessed by them may decline significantly, or be lost, before their value is recognized and measures are taken to conserve them [5]. The wide-ranging agroecology of Ethiopia has contributed to the existence of a large diversity of farm animal genetic resources. Characterization of poultry breeds based on their morphological (qualitative and quantitative) traits variation is the first step towards the use of the available animal genetic resources. Morphometric measurements have been used to evaluate the characteristics of various breeds of animals and could provide information on the suitability of animals for selection. However, only limited efforts were made to characterize the existing chicken ecotype of the country on a comprehensive standard. In general, indigenous chickens are non-descriptive, with a variety of morphological appearances [6].

Different genetic improvement programs have been initiated in Ethiopia for increasing the productivity of indigenous chickens through selective breeding, as a means both to improve the livelihoods of poor people as well as conserve the existing genetic diversity through utilization [7,8]. Developing appropriate animal breeding programs for village conditions requires defining the production environments, and identifying the breeding practices, production objectives, trait choices of rural farmers, and unique characteristics of indigenous chicken ecotypes [9]. So far, in many studies investigating the analysis of qualitative morphological traits, contingency table analysis (Pearson's chi-square) was used to analyses the data. Contingency tables are easy to set up, easy to understand are useful because little of the statistical concepts is necessary for interpretation and one can easily observe patterns of correlation. However, they have drawbacks including not precisely measuring the nature of correlation between two traits and traits with many categories requires large tables that are difficult to manage. Again, categories with few observations obfuscate the bivariate correlation and the Chi-square test cannot provide predicted values. Above all contingency tables can only be used to analyses the effect of a single categorical variable on the response. Therefore, the current study was intended to overcome the above limitations by using multiple correspondence analysis (MCA) to evaluate qualitative morphological traits and identify significant traits compared to contingency table analysis. The study will thereby increase and promote the adoption of MCA to researchers in the field and help find the relative closeness of the key correlation factors so that necessary actions can be taken to the development of suitable policies for designing breeding programmers and conservation.

Materials and Methods

Study Area Location

The study was conducted in rural kebele around Dire Dawa Administration (DDA) which is geographically located between 9°27` to 9°49` N and 41°38`to 42°19' E longitude. DDA is found in the eastern part of Ethiopia at about 515 km away from the capital Addis Ababa and 330 km to the west of the Republic of Djibouti. The altitude of DDA ranges from 960-2450 meters above sea level (masl). The rainfall pattern of the area is characterized by a small rainy season from February to May and a relatively long rainy season from July to September with the mean annual rainfall ranging from 550 to 850 mm and monthly mean minimum and maximum temperature of 14.5°C to 34.6°C. Sampling Techniques for Data Collection. The study was done in purposively selected rural kebeles of DDA. Areas, where production is practiced and representing two farming systems (mixed crop-livestock and agro-pastoral production system), were selected in consultation with experts of the Agricultural Office of the Administration and through rapid field visits made in the area. For qualitative morphological traits, a total of 480 indigenous chickens, approximately six months of age or older were selected and then the traits were recorded following the recommended descriptors for chicken genetic resources [5]. For the sample chicken population of the lowland and midland agroecology, nine qualitative morphological traits (i.e., feather distribution, hen spurs, head shape, earlobe color, comb type, shank color, skin colour, shank feather, and plumage colour) were recorded (Figure 1).

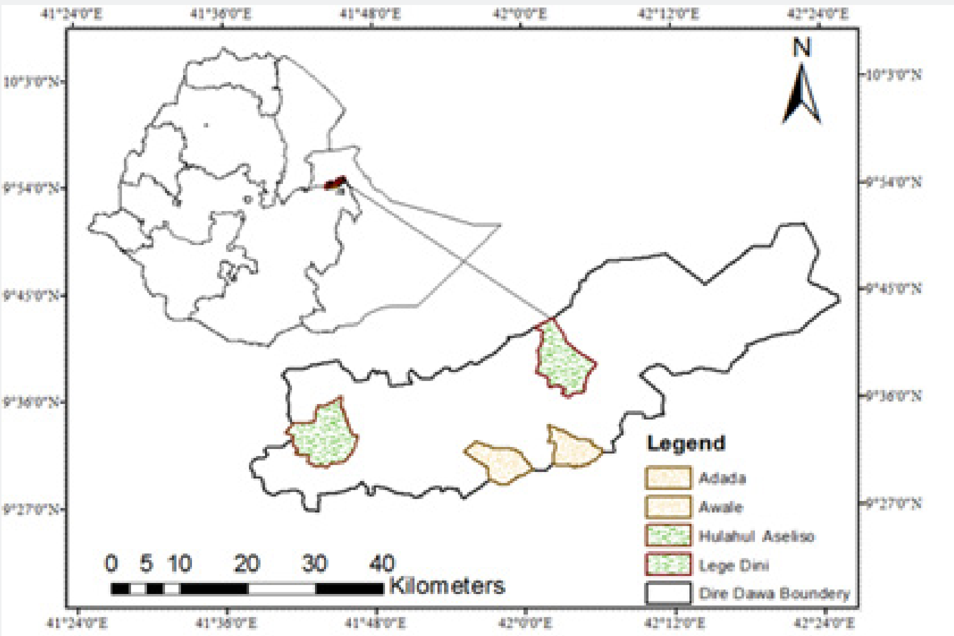

Figure 1: Map of the study area.

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Statistical Data Analysis

SAS-program version 9.4 [10] was used for all statistical analyses in this study.

Exploratory data analysis

To get descriptive statistics and chi-squares tests, qualitative morphological traits were subjected to exploratory data analysis using the PROC FREQ procedures of SAS [10]. The data was analysed by contingency tables (Pearson's Chi-square) and when the cell counts were below five, they were analysed by Fisher's Exact Test method in establishing a correlation between any two traits.

Multiple Correspondence Analysis

In trying to establish if there could be any correlation for more than two categorical traits, MCA was applied. MCA is a multivariate technique designed to discover both inter-relations and intra-relations of two or more categorical variables by reviewing the closeness and remoteness between them [11-13]. The MCA technique is aiming to show the group changes to rows and columns of categorical data arranged in the form of a contingency table in graphical form in a less-dimensional space [14]. This technique is very advantageous because it is easier to apply than such other alternatives as Chi-square analysis, G-test, Z test, Fisher Exact test or Log-linear models, because it provides more detailed information to the researcher, and it is able to present the results in visual form [15,16,12]. Each of the trait levels reviewed by means of MCA is represented with a dot in a multi-dimensional space. Dots being close to each other are similar to or related to each other depending on the areas they fall into. Similarly, dots being far from each other are unrelated [17].

Results and Discussions

Exploratory data analysis: Descriptive statistics and chi-squares tests results of the qualitative morphological traits with their statistical significance are presented in Table 1. All the traits showed a wide range of variability (frequencies and percents) between the agro-ecologies. According to the current study, four shank colours were identified namely yellow, grey, white, and red in two agro-ecologies. The proportion of chickens having yellow shanks was dominant in midland (60%) and lowland (38%) and followed by grey colour (30.42% in midland), (32% in low land) and white colour (6% in mid land), (30% in low land) respectively. Red colour (4%) was only observed in midland agro-ecology. The results of the shank colour in the present study are in line with the findings of [18] who reported 53% of the chicken population in southern Ethiopia had a yellow shank colour. Yellow is due to dietary carotenoid pigments in the epidermis when the melanic pigment is absent varying shades of black are the result of melanic pigment in the dermis and epidermis. When there is black pigment in the dermis and yellow in the epidermis, the shanks have a greenish appearance. In the complete absence of both of these pigments, the shanks are white. The studied chicken populations had normal necked neck feather distribution. The normal feather distribution was observed dominantly in both agro-ecologies with 92% in midland and 94% in low land. Shank feather was dominantly present in both agro-ecologies with values of 89% in low land and 92% in mid land respectively. The current results are also in agreement with those of [19] who reported a higher frequency (98.48%) of featherless chickens in Ethiopia.

Table 1: Total frequency (and percentage in brackets) for each level of the qualitative morphological traits scored in indigenous chickens within agroecology.

Agroecology				
Traits & levels	**Low land**	**Midland**	**X2**	**Prob>ChiSq**
Feather distribution			0.506	0.4767^ns^
Normal	221 (92.08)	225 (93.75)		
Necked neck	19 (7.92)	15 (6.25)		
Hen spurs			0.613	0.4337^ns^
Absent	220 (91.67)	215 (89.58)		
Present	20 (8.33)	25 (10.42)		
Head shape			0.751	0.3861^ns^
Crest	30 (6.25)	24 (5.00)		
Plain	210 (43.75)	216 (45.00)		
Earlobe colour			12.887	0.0049*
Red	52 (21.67)	38 (15.83)		
Red and white	73 (30.42)	107 (44.58)		
White	68 (28.33)	46 (19.17)		
Yellow	47 (19.58)	49 (20.42)		
Comb type			1.374	0.7116^ns^

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Single	187 (38.96)	184 (38.33)		
Rose	20 (8.33)	27 (11.25)		
Double	18 (3.75)	15 (3.13)		
Buttery	15 (3.13)	14 (2.92)		
Shank colour			57.473	0.001*
Grey	76 (31.67)	73 (30.42)		
Red	0 (0.00)	9 (3.75)		
White	72 (30.00)	15 (6.25)		
Yellow	92 (38.33)	143 (59.58)		
Skin colour			4.229	0.1207ns
Pink	37 (15.42)	35 (14.58)		
White	184 (76.67)	172 (71.67)		
Yellow	19 (7.92)	33 (13.75)		
Shank feather			0.613	0.43ns
Absent	215 (88.58)	220 (91.67)		
Present	25 (10.42)	20 (8.33)		
Plumage colour			49.182	0.001*
Black	39 (8.12)	37 (7.71)		
Brown	0 (0.00)	17 (3.54)		
Gebsima	17 (3.54)	36 (7.50)		
Grey	0 (0.00)	4 (0.83)		
Kokima	53 (11.04)	27 (5.63)		
Red	83 (17.29)	91 (18.96)		
Teteruma	26 (5.42)	6 (1.25)		
White	22 (4.58)	22 (4.58)		

Values before brackets are frequencies while those in brackets are percentage; X2 = chi-square; *Significant at p<0.05; ns (not significant).

Five earlobe colours were observed where red and white earlobe showed the highest proportions with values of 30% for low land and 45% for mid land respectively. While 28% of the chicken in the lowland and 19% in the midland showed a white earlobe colour. These frequencies are close to the findings of [7], where the proportions of indigenous chickens showing white, and red earlobe was 40%, and 52% respectively. Four comb types, single, rose, double, and buttery was observed to occur in the order of 39%, 8%, 4%, and 3% for low land and 38%, 11%, 3% and 2% for midland. The current study revealed that the single comb type was predominant accounting for 39%, and 38%, in lowland and midland agro-ecologies respectively. The current finding agrees with [18] who reported similar results for single comb types in Sheka indigenous chicken. In contrast to our findings, [19] found pea comb type as dominant for Aseel chicken in India. Comb size is linked to gonadal development and light intensity, although comb type is a result of gene interaction [19]. Most of the local chickens observed in low land ecotypes had white (77 %) skin colour followed by pink (15%) and yellow (8%). Similarly in the midland white was the predominant skin colour (72%), followed by yellow (14%), and pink (15%). This finding was similar to that of [20] who reported that most of the local chickens observed in the Horro district had white (77%) skin colour followed by yellow (22%) and bluish-black (0.9%).

[18] also found that skin colour variations of white, pink, and yellow were observed in indigenous chicken populations, and that white skin colour was the most prominent among them. The finding disagrees with [21] who reported that the skin colour was 100% yellow for Aseel male chickens in India. According to [22], the presence or absence of carotenoid pigments results in yellow or white skin. Domestic hens with yellow skin are homozygous for a recessive gene that inhibits the synthesis of an enzyme called BCDO2 (beta-carotene dioxygenase 2) in comparison to white chickens with the dominant allele. This recessive gene may have been introduced from Grey Jungle fowl (Gallus sonnerati). Head shape is one of the vital morphological features that can be used to separate variations between breeds or strains of indigenous chickens. Plain (44%) and crest (45%) head shapes were found in the study area. These findings were similar to that of [23], who

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found that 49% and 51% for plain and crested head shape types, respectively.

Multivariate Analysis

The eigen values measure indicates how much of the categorical information is accounted for by each dimension. The higher the eigen value, the larger the amount of the total variance among the traits on that dimension. Usually, the first two or three dimensions contain higher eigen values than others. In Table 2, eigen values and percentages of variance of the dimensions are revealed. It can also be seen that there is a steady decrease in eigen values. The first principal axis explained 11.96% of the principal inertia, the second principal axis explained 10.18 %, and cumulatively the first two principal axes explained 22.14% of the principal inertia. In a similar study undertaken by [23,24], 29% of the total variations are explained by the first two dimensions. The MCA map was constructed step wisely. For each of the groups of traits, the MCA was applied and traits were selected using the squared cosine test. All traits with cos2 > 0.2 in at least one of the three first MCA dimensions were maintained. Figure 2 shows a bi-dimensional graph representing the associations among the categories of the analysed traits. To examine the association between the agro-ecologies and qualitative traits, agroecology was included in the analysis as a supplementary variable. MCA can be explained as a graphical representation by producing a solution in which most correlated categories are plotted close together and un-correlated ones are plotted far apart. Points (categories) that are close to the mean value are plotted near the MCA plot's origin and those that are more distant are plotted farther away. Hence, the dimensions are interpreted by the positions of the points on the map, using their loading over the dimensions as crucial indicators. On the dimensions identified (Figure 2), the sample chicken population of lowland agro-ecology clustered together with grey SC, red ELC, white SkC, single CT and absence of HsP; while the corresponding values of midland agro-ecology clustered together with red SC, yellow SkC; rose CT; and presence of HSp.

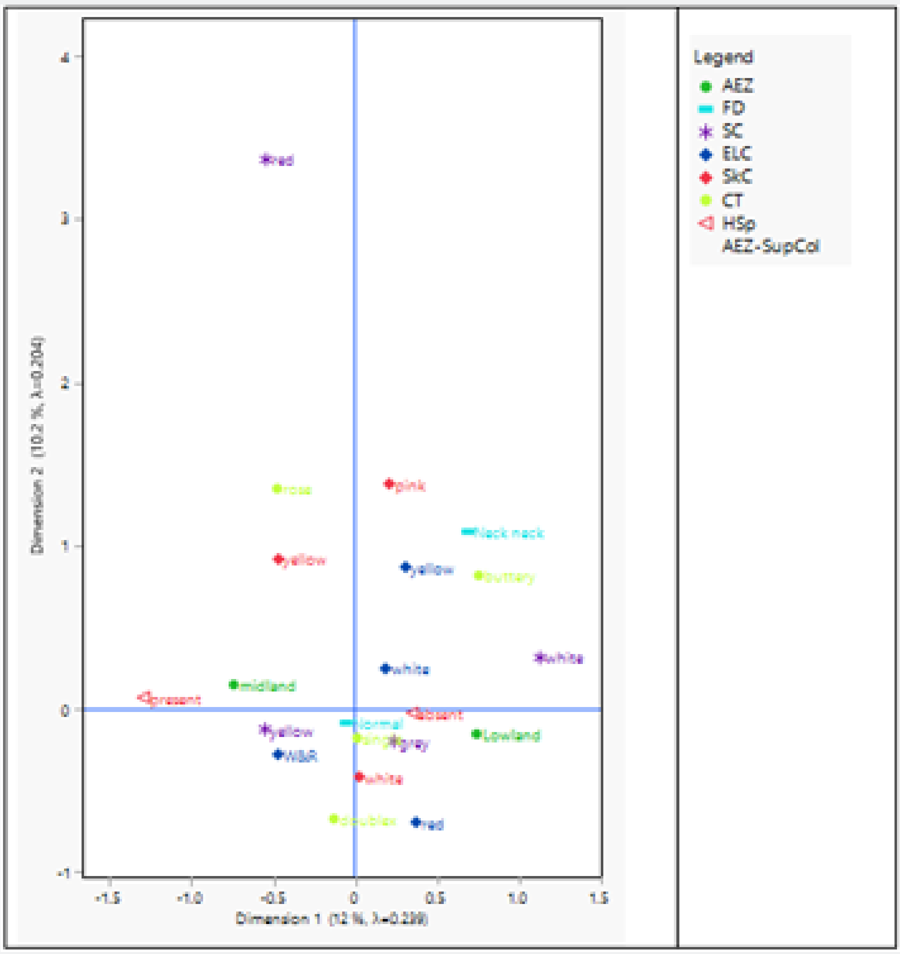

Figure 2: Two dimensional biplot illustrating the association among qualitative morphological traits.
FD = feather distribution; SC =shank colour; ELC = Ear lobe colour; SkC = Skin colour; CT = comb type; HSp = Hens spurs; W&R = white and red.

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Table 2: Principal inertias (eigenvalues), the percentages and cumulative percentages for all dimensions of the data matrix.

Singular Value	Inertia	ChiSquare	Percent	Cumulative Percent
0.48912	0.23924	873.53	11.96	11.96
0.45126	0.20363	743.52	10.18	22.14
0.41161	0.16943	618.61	8.47	30.62
0.40286	0.1623	592.58	8.11	38.73
0.3972	0.15777	576.05	7.89	46.62
0.38808	0.1506	549.89	7.53	54.15
0.38648	0.14936	545.37	7.47	61.62
0.37062	0.13736	501.52	6.87	68.48
0.35836	0.12842	468.9	6.42	74.91
0.34391	0.11827	431.83	5.91	80.82
0.33612	0.11297	412.49	5.65	86.47
0.31467	0.09902	361.54	4.95	91.42
0.30973	0.09593	350.27	4.8	96.22
0.27511	0.07569	276.35	3.78	100

Conclusions

The MCA method identified systematic relationships among traits and trait categories. Moreover, it uniquely simplified interpretation of large complex data. In particular the ability of MCA to deal with multidimensional data makes it particularly useful for exploring the factors influencing qualitative morphological traits. The findings from this research shed light on the pattern recognition of these traits and also point to potential future research considering more traits and large datasets.

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