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Original Research Article

Associations among Qualitative Morphological Traits in Indigenous Camels of Ethiopia: A Multiple Correspondence Analysis

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Abstract

Camels play a crucial role in Ethiopia's livestock production and livelihoods, yet research on their phenotypic diversity is limited. This hinders the development of breeding programs and conservation strategies. This study aimed to address this gap by analyzing qualitative morphological traits in Ethiopian camel populations using multiple correspondence analysis (MCA), and to identify significant traits for potential use in breeding and conservation programs. Data on seven qualitative morphological traits were collected from 300 mature camels (150 from each district). Significant differences were found between districts for facial traits, specifically nose shape ($p = 0.0153$) and face profile ($p = 0.0133$). Other traits, including coat colour, hair type, ear orientation, and lip shape, did not show significant differences. MCA identified two main dimensions, explaining 26% of the total variance. The first dimension was associated with facial traits, while the second dimension was associated with coat colour and hair type. This study provides valuable insights into the morphological diversity of Ethiopian camel populations. The findings suggest that facial traits may be useful for differentiating camel populations and could be considered in breeding and conservation programs. Further research is needed to explore the genetic basis of these morphological differences.

Keywords: Camel; characterization; multivariate analysis; principal inertia; qualitative traits.

INTRODUCTION

World Camel population is estimated to be around 35.5 million; where Somalia has the highest population of 7.2 million followed by Sudan 4.9 million and Ethiopia 1.3 million (FAOSTAT, 2018). The camel ecotypes in Ethiopia serve numerous functions (e.g., milk, meat, riding, packing) and thereby contribute significantly to the livelihood of the pastoralists and agro-pastoralists living in fragile environments (Abbas *et al.*, 2000; Tura *et al.*, 2010). In addition to this, pastoralists have kept and bred camels owing to exploit their extraordinary power to withstand thirst and hunger for long duration in the most inhospitable ecological conditions (Al-Dahash & Sassi, 2009).

Despite the high population of camel and its extremely considerable importance in Ethiopia, it has not received adequate attention from research and development institutions as well as policymakers. Studies on camel production system, phenotypic and genetic characterization are scanty (Yohannes *et al.*, 2007) and show a serious lack of information (Gifford-Gonzalez & Hanotte, 2011). This hindered the design of an appropriate strategy for optimal utilization of the existing potential of camel genetic resources and the establishment of breeding programs. Taking into consideration of the current importance of camels in contributing to the livelihoods of pastoralists in marginal areas, and the role it plays towards resilience to the present climate change, it is thus imperative to identify and differentiate the phenotypic characteristics of camel populations in Ethiopia based on FAO (2012) guidelines.

So far, in many studies investigating the analysis of qualitative morphological traits, contingency table analysis (Pearson's chi-square) was used to analyse the data. Contingency tables are easy to set up and 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 the correlation between two traits and traits with many categories requiring 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 analyse 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 by 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 programmes and conservation.

MATERIALS AND METHODS

Location of the Study Area

The study was conducted in two districts namely, Yabello and Melka Soda in the Southern Oromia regional state. Yabello district is one of the districts of the Borena zone. The district is situated in Latitude/Longitude: N 4° 52' 59.99" E 38° 4' 59.99". Melka Soda district is located in the northeastern part of the West Guji zone. The location of Melka Soda Woreda is between 35^0 East and 30^0 West (Figure 1).

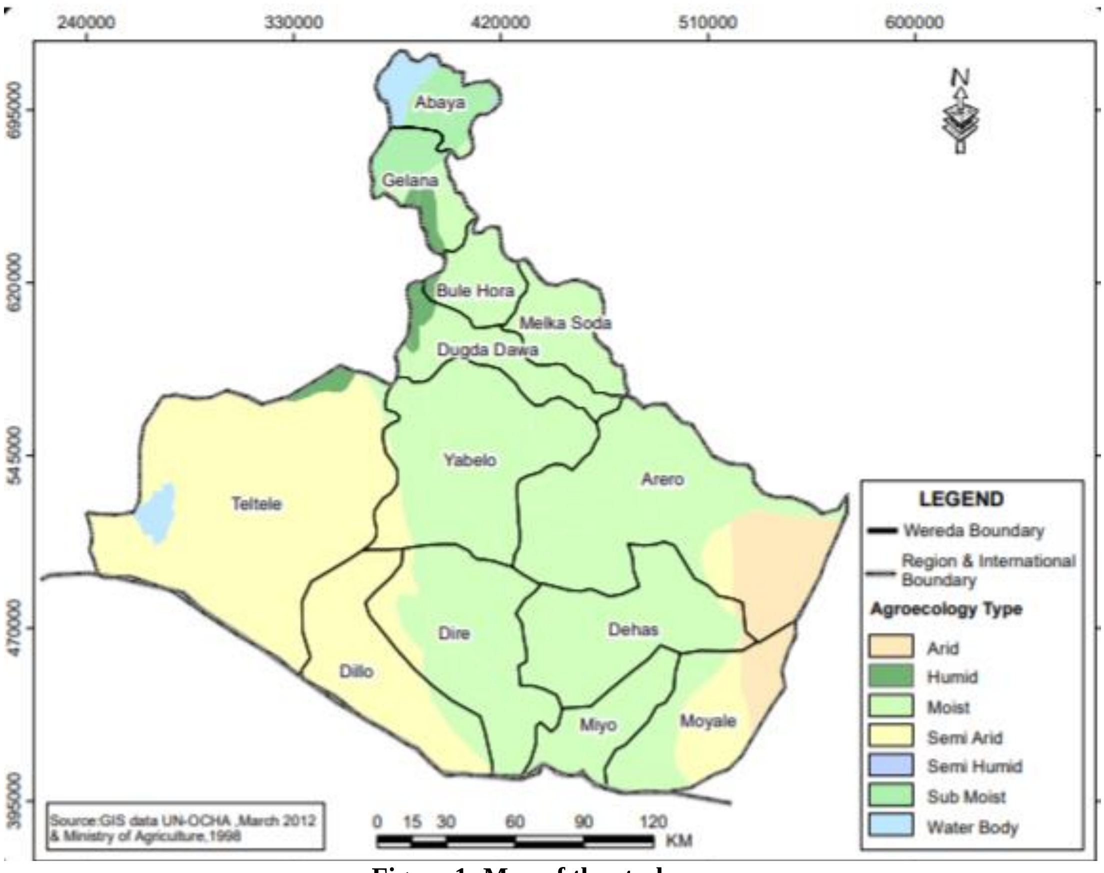

Figure 1: Map of the study area

Sampling Techniques for Data Collection

Discussions were held with the experts in the zonal and district pastoral development offices and representative pastoral community on the present production system and present condition and concentration of the Borena camels. A total of 300 mature camels (150 camels from the Yabello district and 150 camels from the Melka Soda district) were randomly selected. Seven qualitative morphological traits namely coat colour pattern (CCP), coat colour type (CCT), hair type, (HT), ear orientation (EO), face profile (FP); nose shape (NS); and lip shape (LS) were recorded following the recommended FAO descriptors for camel genetic resources (FAO, 2012).

Figure 2: Photos of Camels from Melka Soda (a – c) and Yabello (d - f) districts in the field

Statistical Data Analysis

SAS-program version 9.4 (SAS, 2019) was used for all statistical analyses in this study.

Exploratory data analysis

To analyze the data, descriptive statistics and chi-square tests were performed on qualitative morphological traits using SAS procedures (SAS, 2019). Contingency tables were created and Pearson's chi-square tests were used to determine associations between pairs of traits. If cell counts in the contingency tables were below five, Fisher's exact test was used instead of Pearson's to ensure accuracy with small samples.

Multiple Correspondence Analysis

In order to look into possible correlations between more than two categorical traits, multiple correspondence analysis (MCA) was used. MCA is a multivariate technique that evaluates the proximity and distance (Chou, 1994; Greenacre, 1998; Baspinar & Mendes, 2002) between categorical variables to examine relationships and associations among them. MCA specifically aims to visually represent changes across the rows and columns of categorical data organized in a contingency table in a lower dimensional space (Ozdamar, 2002). MCA has advantages over competing methods such as chi-square, G-test, Z-test, Fisher's exact test, or log-linear models in that it is simpler to use, offers more detailed information, and displays results visually (Gifi, 1990; Kaciak & Louviere, 1990; Greenacre, 1998).

Each trait level in MCA is represented as a point in a multidimensional space. The regions into which the points fall make those that appear closer together related, while those that appear farther apart are more distinct. Overall, MCA made it easier to explore correlations among different categorical traits by arranging their relationships into a more straightforward dimensional solution (Dunteman, 1989).

RESULTS AND DISCUSSIONS

Exploratory data analysis:

The outcomes of statistical analysis, including descriptive statistics and chi-square tests, are shown in Table 1 along with the statistical significance of each trait. According to the data's frequencies and percentages, all of the traits exhibit some degree of variation across the various districts.

Table 1: Descriptive statistics and chi-squares test results of the qualitative morphological traits

Traits & attributes		District			
		Yabelo	Melka Soda	ChiSquare	p-value
CCP	1: plain	141 (47.00)	144 (48.00)		
	2: patchy	8 (2.67)	6 (2.00)	0.093	0.5978
	3: Spotted	1 (0.33)	0 (0.00)		
CCT	1: dark brown	83 (27.67)	68 (22.67)		
	2: golden	16 (5.33)	20 (6.67)	3.005	0.2225
	3: whitish	51 (17.00)	62 (20.67)		
HT	1: smooth	47 (15.67)	52 (17.33)	0.377	0.5393
	2: rough	103 (34.33)	98 (32.67)		
EO	1: erect	122 (40.67)	124 (41.67)		
	2: semi-pendulous	7 (2.33)	5 (1.67)	0.350	0.8396
	3: horizontal	21 (7.00)	21 (7.00)		
FP	1: straight	92 (30.67)	112 (37.33)		
	2: concave	-	-	6.127	0.0133
	3: convex	58 (19.33)	38 (12.67)		
NS	1: flat	64 (21.33)	85 (28.33)		
	2: concave	86 (28.67)	65 (21.67)	5.880	0.0153
LS	1: pendulous	125 (41.67)	119 (39.67)	0.790	0.3740
	2: tight	25 (8.33)	31 (10.33)		

*Values before brackets are frequencies while those in brackets are percentages; X^2 = chi-square; *Significant at $p<0.05$; ns (not significant); CCP = coat colour pattern, CCT = coat colour type; HT = hair type, horn, EO = ear orientation, FP = face profile; NS = nose shape; LS = lip shape.*

The results of the study (Table 1) show that there are significant differences in the distribution of some qualitative morphological traits between the Yabelo and Melka Soda districts while others do not show significant differences.

Comparisons of coat colour pattern (CCP) between the Yabelo and Melka Soda districts showed that the plain pattern was most common in both areas, with 47% in Yabelo and 48% in Melka Soda. The patchy and spotted patterns occurred at low frequencies (<3%) in both districts. Chi-square analysis revealed no significant difference between districts for CCP (p=0.5978). A study by Gebremedhin *et al.,* (2017) found that coat colour patterns were similar between camels from different regions of Ethiopia. The most common coat colour pattern in both regions was plain, accounting for 63.7% of individuals in one region and 57.7% in the other. On the contrary, a study by Habtemichael *et al.,* (2010) found that coat colour patterns differed between camels from different regions of Ethiopia. The most common coat colour pattern in one region was plain, accounting for 66.0%, while the most common coat colour pattern in another region was patchy, accounting for 60.0%.

For coat colour type (CCT), dark brown was the most frequent type in both populations, with 28% of individuals in Yabelo and 23% in Melka Soda. Whitish was most common in Melka Soda (21%). Golden CCT only accounted for 5-7% in both districts. The CCT distribution did not differ significantly between districts based on the chi-square test (p=0.2225). In line with this study, Habtu *et al.,* (2014) found no significant difference in coat colour type distribution between indigenous camel populations in different regions of Eritrea. In disagreement to the current study, El-Ashmawy *et al.,* (2020) reported significant differences in coat colour type distributions between male and female dromedary camels in Egypt.

Hair type (HT) was predominantly rough in both Yabelo (34%) and Melka Soda (33%), while the smooth type accounted for 15-17%. The HT proportions were not significantly different between the two districts (p=0.5393). In a study done by Buijtels *et al.,* (2009) no significant difference in hair type was found between male and female camels. On the other hand, Aboul-Ela *et al.,* (2012) found no significant difference in hair type between male and female camels.

Ear orientation (EO) was largely erect in both districts, with 41% erect in Yabelo and 42% erect in Melka Soda. Semi-pendulous and horizontal EO were uncommon (≤7%) in both districts, and no significant difference was seen between areas (p=0.8396). In line with this study, Khalafalla and Osman (2013) also found no significant difference in ear orientation between male and female camels in eastern Sudan. On the contrary, Ali *et al.,* (2019) found ear orientation to significantly differ between male and female Saudi dromedary camels, presenting different results.

For face profile (FP), Yabelo had a higher frequency of convex shapes (19%) compared to Melka Soda (13%), while straight FPs were more common in Melka Soda (37%) than in Yabelo (31%). These FP differences were statistically significant based on the chi-square test (p=0.0133). In line with this study Buijtels *et al.,* (2009) found a significant difference in face profile distribution between male and female camels; while Khalafalla *et al.,* (2010) found a significant difference in face profile distribution between male and female camels.

Nose shape (NS) also differed between the two districts, with concave NS more frequent in Yabelo (29%) versus Melka Soda (22%), while Melka Soda had a higher proportion of flat NS (28%) compared to Yabelo (21%). The NS distribution was significantly different between the districts (p=0.0153). A study by Aboul-Ela *et al.,* (2012) also found a significant difference in nose shape distribution between male and female Egyptian dromedaries. In contrast to the current finding, Mohamed *et al.,* (2011) found a significant difference in nose shape distribution between male and female Egyptian dromedaries.

No major differences were observed in lip shape (LS) between Yabelo and Melka Soda. Pendulous lip shape was the most common in both populations, with 41.67% of individuals in Yabelo and 39.67% in Melka Soda. The chi-square test revealed no significant LS variation between districts (p=0.3740). A study by Habtu *et al.,* (2014) also found no significant difference in lip shape distribution between indigenous camel populations in different regions of Eritrea; while El-Ashmawy *et al.,* (2020) reported significant differences in lip shape distributions between male and female dromedary camels in Egypt, presenting different results than observed in Ethiopia.

Most other morphological traits examined, including coat colour, hair type, ear orientation and lip shape do not exhibit significant differentiation between the two areas. This suggests these camel populations are relatively homogeneous for these traits. The lack of variation for these traits may be due to high gene flow between the districts.

This study revealed morphological differences between camel populations from the Yabelo and Melka Soda districts, specifically for facial traits relating to nose shape and face profile. The significant variation in nose shape and face profiles between the two districts may reflect underlying genetic differences between the populations. Environmental and husbandry factors could also contribute to these distinctions in facial morphology. Further genomic analysis is required to determine if genetic differentiation underlies the divergent facial traits between districts.

Overall, this study provides baseline information on the morphological diversity and population structure of indigenous Ethiopian camels across different districts.

Multivariate Analysis:

Table 2 displays the results of multiple correspondence analysis (MCA), including the eigenvalues and the percentage of variance explained by each dimension. The data shows that the eigenvalues decrease steadily, with the first principal axis accounting for 14% of the principal inertia and the second principal axis accounting for 12%. Together, the first two principal axes explain 26% of the principal inertia. Eigenvalues measure the amount of variance in the data that is captured by each dimension, with higher eigenvalues indicating that more variance is explained by that dimension.

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

Singular Value	Inertia	ChiSquare	Per cent	Cumulative Percent
0.44310	0.19633	431.46	13.74	13.74
0.42144	0.17761	390.32	12.43	26.18
0.41790	0.17464	383.79	12.23	38.40
0.39425	0.15543	341.58	10.88	49.28
0.37922	0.14381	316.03	10.07	59.35
0.36745	0.13502	296.71	9.45	68.80
0.35092	0.12315	270.62	8.62	77.42
0.33374	0.11138	244.76	7.80	85.22
0.33066	0.10934	240.28	7.65	92.87
0.31915	0.10186	223.84	7.13	100.00

The MCA plot (Figure 2) was created using a stepwise process. MCA was applied to each group of traits, and the squared cosine test was used to select traits. Only traits with a cos2 value greater than 0.2 in at least one of the first three MCA dimensions were included. Figure 2 is a two-dimensional graph that shows the relationships between the categories of the traits analyzed. The district variable was added to the analysis as a supplementary variable to investigate the association between districts and qualitative traits.

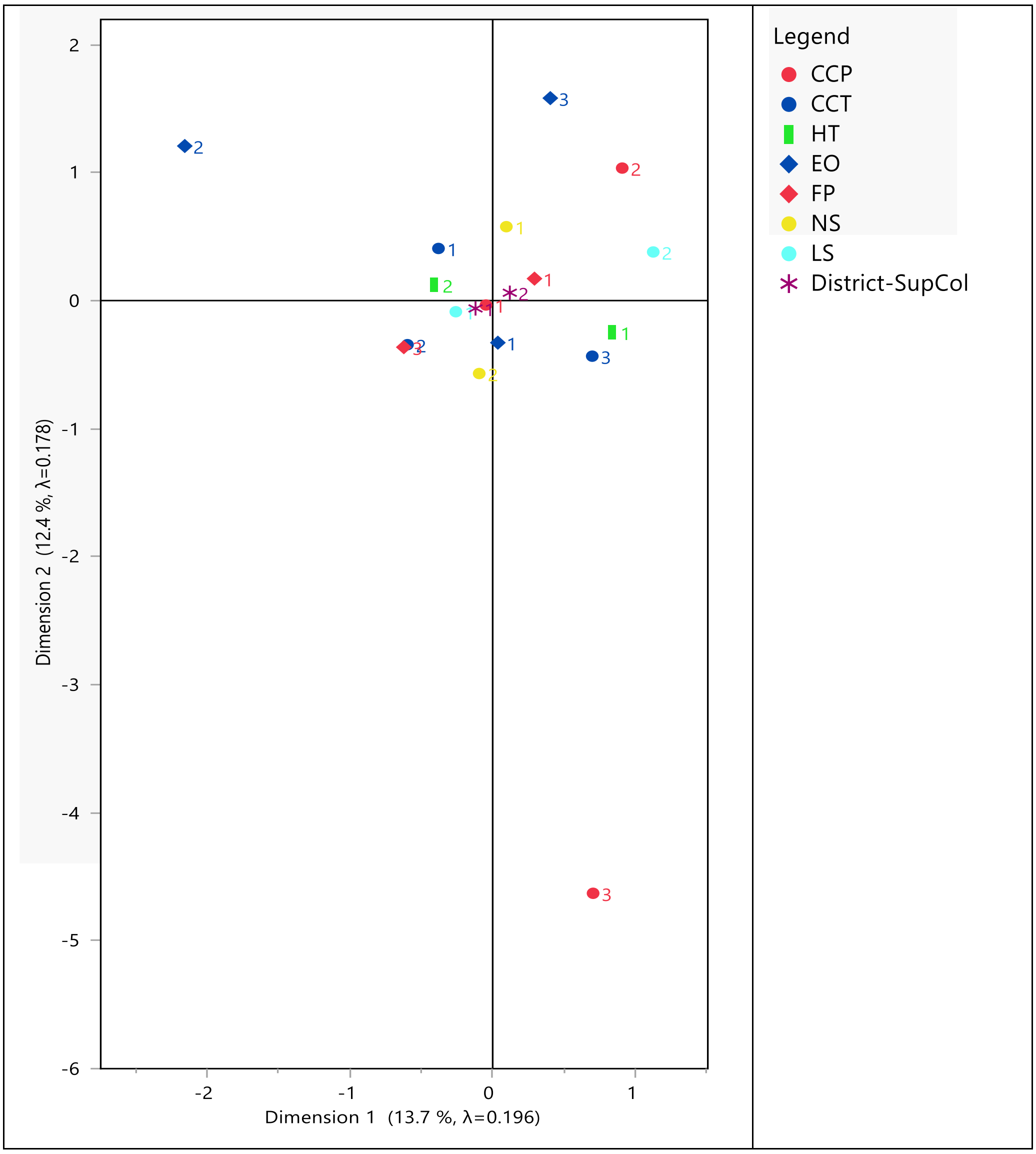

Figure 3: Two-dimensional biplot illustrating the association among qualitative morphological traits

CCP = coat colour pattern, 1 = plain, 2 = patchy, 3 = spotted; CCT = coat colour type, 1 = dark brown, 2 = golden, 3 = whitish; HT = hair type, 1 = smooth, 2 = rough; EO = ear orientation, 1 = erect, 2 = semi-pendulous, 3 = carried *horizontally; FP = face profile, 1 = straight, 2 = concave, 3 = convex; NS = nose shape, 1 = flat, 2 = concave, 3 =convex ; LS = lip shape, 1 = pendulous, 2 = tight.*

MCA is a graphical technique that produces a solution in which highly correlated categories are plotted close together, while uncorrelated categories are plotted further apart. Categories that are close to the mean value are plotted near the origin of the MCA plot, while those that are more distant are plotted farther away. The dimensions of the plot can be interpreted by examining the positions of the points on the map and their loadings on the dimensions.

On the dimensions identified (Fig 3), the sample camel population of Melka Soda district clustered together with patch CCP, horizontal EO, straight FP, flat NS, and tight LS; while the corresponding values for the camel population of Yabelo district clustered together with plain CCP, golden CCT, convex FP, concave NS, and tight LS.

CONCLUSIONS

This study employed multiple correspondence analysis to examine qualitative morphological traits in Ethiopian camel populations. Camel populations from Yabelo and Melka Soda districts exhibited significant differences in nose shape and face profile, suggesting potential underlying genetic variations. Coat coloUr, hair type, ear orientation, and lip shape did not show significant differences between districts, indicating relative homogeneity for these traits. The MCA revealed associations between specific trait categories and district origin, providing valuable insights into population structure.

Overall, this study highlights the value of MCA in analyzing camel morphological diversity and lays the groundwork for further research on genetic differentiation, environmental influences, and breeding program development for improved camel productivity and conservation.

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