Heliyon 9 (2023) e18662

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Phenotypic characterization of donkey population in South Omo Zone, Southern Ethiopia

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A R T I C L E I N F O

Keywords:
Characterization
Donkey
Ethiopia
Multivariate
Morphometric

A B S T R A C T

The study conducted in South Omo Zone, Southern Ethiopia with the aim of investigation within population diversification and characterization morphologically that helps to fill the gap of molecular characterization on this population. The data was collected from 500 adult donkeys from both sexes. Quantitative data was subjected to SAS GLM procedures by fitting districts and sex as the main effects. Qualitative data was subjected to a chi-square test with the district as the main effect. Color graph of donkey was done using Microsoft Excel, 2010. For both qualitative and quantitative data, the significance test was conducted at 5% of the level of error, and Tukey multiple range tests were used to separate the significance levels for the two types of data. CANDISC was used to calculate Mahalanobis distances, DISCRIM was used to cluster observations into predetermined groups, and STEPDISC was used to determine the quantitative characteristics that better differentiate populations. Roan coat color cover highest number compare with other coat color of donkey population. Quantitative traits of donkey has variation ($P < 0.05$) both in study areas and sex of donkeys. Overtly, except height at wither and height at the back Hammer donkey has mostly better metric value than the rest districts of the study areas. Moreover, CANDISC show variation on Hammer and Dasenech districts of donkey population. Furthermore, the longest (6.32) Mahalanobis distance observed in between Hammer and Dasenech donkey population. The Hammer and Dasenech donkey population is where the study fills in population variation the most. This can be because to management or genetics. Therefore, additional research might be required. Furthermore, morphometric measures show that donkey sex is similar, with the exception of heart girth circumference. This can be the result of poor selection, where superior male donkeys are sold for a higher price. Therefore, sound breeding programs should be used to reverse it.

1. Introduction

Donkey is an equine animal of the order odd-toed ungulates. Among common livestock animals, it occupies an important place in the history of human transportation. It is often used as a pack animal for long-distance transportation due to its good pack ability, durability, and traction, thereby greatly facilitating commerce among regions. With the advancement of modern technology,

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https://doi.org/10.1016/j.heliyon.2023.e18662
Received 25 January 2023; Received in revised form 11 July 2023; Accepted 24 July 2023
Available online 28 July 2023
2405-8440/

mechanization of agriculture, and rapid development of transportation, the service value of donkeys has decreased [1]. By and large there are no records to indicate the spread of the donkey in the pre-contact era. However, evidence from mitochondrial DNA studies has confirmed that the present day domestic donkey originated in Africa rather than in Asia [2]. It is therefore believed that donkey is the only domestic animal of African origin. In Ethiopia, donkey domesticated before 1200 years ago [3]. In the worldwide there are 194 donkey/ass breed distributed in different agro ecology. Likewise, in Ethiopia there are six donkey breeds namely Abyssinian, Afar, Hararghe, Ogaden Omo and Sinnar [4]. In number the country has more than 8 million donkey population and higher number distributed in the highland part of the country [5]. Overall, donkeys in Ethiopia use for transporting, pulling cart and plowing purpose [6]. Similar to other donkey breed of Ethiopia, the Omo donkey used transporting, pulling cart and plowing purpose and it distributed in the lowland pastoral area of Omo zone and adjacent areas [7].

[8] Insights the extent of within and between matrilineal genetic diversities and evolutionary relationships among the morphologically identified six native Ethiopian donkey populations. Furthermore, the study traces their matrilineal genetic origin. However, it lacks phenotypic characterization data (both qualitative and morphometric). Yet, describing their external body and production characteristics within a given environment and management by considering social and economic factors that affect its production is important [9]. Moreover, this morphometric characterization helps to identify within breed variation. Additionally the finding helps to fill the gap of qualitative and morphometric data regarding to the breed of Omo donkey on domestic animal diversity information system (DADIS) data base of FAO in Ethiopia. Ethiopian Biodiversity Institute is the focal organization regarding to this data base. Therefore, the study conducted to fill the gap of phenotypic information on this population of donkey. Furthermore, the study aimed to investigate within population variation.

2. Material and method

2.1. Study area description

The study was conducted in Dasenech, Hamer and Benna-Tsemay districts of south omo zone found in the Southern Nations, Nationalities, and People's Regional State of Ethiopia as presented in Fig. 1. The study area is selected on the base of earlier molecular characterization [8] by consider as the breeding track area of Omo donkey. Site selection also considered zonal expert information regarding rod accessibility, population distribution of the breed etc. The study areas are characterized by semiarid and arid climatic conditions, with mean annual rainfall ranging from 350 mm to 838 mm. The rainfall is bimodal, with the long rain season from March to June. The study areas located at 4°27-6°26′ N and 34°57′-37°49′ E. The districts reigning in the altitude range of 353–2084 m.a.s.l. The average annual temperature ranges between 18 °C and 32 °C [10]. In the study areas major income of livelihood is livestock rearing mainly and agro-pastoral farming [11]. Pastoralists in the study area keep a diverse composite of livestock species as part of a coping mechanism for uncertainties and risks. Livestock population in south Omo zone is estimated to 1, 068, 120 cattle; 471, 449 sheep; 1, 230, 399 goats; 90,630 donkeys and 495 camels [5]. Based on the 2007 Census conducted by the central statistics agency (CSA), this zone has a total population of 573,435, of whom 286,607 are men and 286,828 women; with an area of 21,055.92 square kilometers [12].

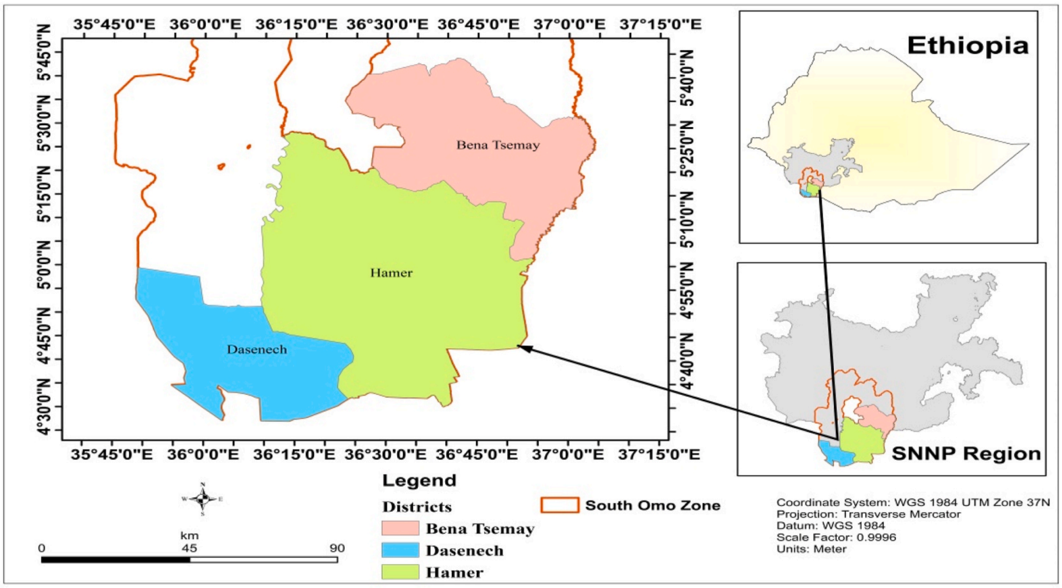

Fig. 1. Map of the study areas.

2.2. Data collection

The data was collected from 500 adult (>4 years) donkeys from both sexes according to FAO guideline [9,13] that does not need ethics approval regarding to the welfare of donkeys. Qualitative characters were recorded through observation whereas morphometric traits measured using measuring tape. Qualitative characters collected on coat description, pattern, dorsal body color, abdominal color, head color, ear tips, tail switch, hoof color, muzzle color, ear size, ear shape, back cross, leg strips, shoulder strips, face profile, back profile, rump profile, length of tail, thickness at the base. Metric value were collected from heart girth circumference (HGC), height at wither (HW), height at the back (HB), height at rump (HR), body length (BOL), back length (BAL), neck length (NL), head length (HL), forelimb length of cannone bone (LCBf), length of for leg (LFL), width of hip (WH), chest width (CW), chest depth (CW), canon bone circumference (CBC) and ear length (EL). The donkey was tethered and maintained in a stable environment to prevent errors in linear body measurements. All measurements were taken in the morning before eating in order to avoid the impact of feed on linear body measurement and to access the donkey in its natural setting.

2.3. Data management and analysis

Data that was both qualitative and morphometric was entered into Excel and subjected to various statistical procedures. The impact of agro-ecology was not investigated because the study places had a similar agro-ecology (low altitude); the effect of agro-ecology was not tested. Therefore, management and/or genetic variation may be correlated to the population disparity. To find outliers and test for data normality, quantitative data was exposed to the UNIVARIATE SAS 9.0 (SAS Institute, 2002) process. The data was then fitted with districts and sex as the major factors and subjected to the SAS GLM procedures. The effect of age was not tested due to the sample is taken from adult donkeys (considered to be similar age class). Districts and sex interactions had an insignificant impact; as a result, they were excluded from the model. A chi-square test was performed on qualitative data, with the district acting as the main effect. Microsoft Excel was used to create a donkey color graph. For both qualitative and quantitative data, the significance test was conducted at 5% of the level of error, and Tukey multiple range tests were used to separate the significance levels for the two types of data. The following model was used in order to analysis quantitative data.

$$Y_{ij} = \mu + \text{districts } (L_i) + \text{sex } (A_j) + e_{ij}$$

Y_{ij} = the observed k (linear body measurements) in the ith districts jth sex, μ = overall mean, L_i = the effect of districts (i = Hammer, Dasenech, Benatsemay), A_j = the effect of ith sex (j = female, male), e_{ij} = random residual error.

Multivariate analytic approaches based on quantitative features were carried out to determine the degree of convergence or divergence across the donkey population. In order to identify the quantitative characteristics that better differentiate populations from different districts, the stepwise discriminant function analysis (STEPDISC) forward selection technique was carried out. Canonical discriminant analysis (CANDISC) was used to obtain Mahalanobis distances between donkey populations and to visualize the spatial distribution of donkey populations on canonical variables using a figure. Discriminant analysis (DISCRIM) was used to cluster observations into known categories.

Table 1
Qualitative characteristics of donkey population frequency (%).

Attributes		Districts					
		Hammer	Benatsemay	Dasenech	Total	X^2	P.value
Coat description	(short)	250 (100)	100 (100)	150 (100)	500 (100)		
Pattern	(plain)	250 (100)	100 (100)	150 (1000	500 (100)		
Abdominal color	white	250 (100)	96 (96)	150 (100)	496 (99.2)	16.13	**
	Black	0 (0)	4 (4)	0 (0)	4 (0.8)		
Ear tips	Black	250 (100)	100 (100)	150 (100)	500 (100)		
Tail switch	Black	250 (100)	94 (94)	150 (100)	494 (98.8)	24.29	**
	White	0 (0)	6 (6)	0 (0)	6 (1.2)		
Hoof color	Black	250 (100)	100 (100)	150 (1000)	500 (100)		
Muzzle color	White	250 (100)	100 (100)	150 (1000)	500 (100)		
Ear size	Large	250 (100)	100 (100)	150 (1000)	500 (100)		
Ear shape	Straight edged	250 (100)	100 (100)	150 (1000)	500 (100)		
Back cross	present	250 (100)	90 (90)	150 (100)	490 (98)	40.82	**
	Absent	0 (0)	10 (10)	0 (0)	10 (2)		
Leg strips	present	33 (13.2)	7 (7)	17 (11.3)	57 (11.4)	0.26	NS
	Absent	217 (86.8)	93 (93)	133 (88.7)	443 (88.6)		
Shoulder strips	present	250 (100)	94 (94)	150 (100)	494 (98.8)	24.29	**
	Absent	0 (0)	6 (6)	0 (0)	6 (1.2)		
Face profile	straight	250 (100)	100 (100)	150 (1000)	500 (100)		
Back profile	straight	250 (100)	100 (100)	150 (1000)	500 (100)		
Rump profile	Flat	250 (100)	100 (100)	150 (1000)	500 (100)		
Length of tail	Medium	250 (100)	100 (100)	150 (1000)	500 (100)		
Tail thickness at the base	wide	250 (100)	100 (100)	150 (1000)	500 (100)		

3. Results and discussion

3.1. Qualitative characteristics of Omo donkey

Qualitative characteristics of donkey are presented in Table 1 and some of population picture taken during data collection presented in Fig. 2 (see Fig. 1). Accordingly, abdominal color, tail switch, back cross, shoulder strips has diversification in the study area. The variation of this character may be caused by the fact that these qualitative traits have not yet reached the point of fixation in natural selection, providing a good opportunity for selection with regard to the qualitative character of this population of donkeys [14], whereas other characteristics are uniform among the donkey population. Similar traits can be a sign that a population has evolved through natural selection or adaptation to become a real breed [14,15].

Hoof color and leg strips are similar with Tuscan donkey population [16] and this related to breed peculiar character [17]. The face profile is straight (100%) and coat description of donkey is short (100%). The short coat description helps for adaption in tropical environments by losing heat through convection with hot environment and the face profile relate to breed character as [18] reported in the study of Nigerian donkey. Most of the donkey population has back cross (98%) and shoulder strips (98.8%) similar with Tuscany donkey of Italy and these character indicate the domestic donkey ancestor of the African wild ass (Equusasinus atlanticus) which indicate sign low of selection pressure [16,18,19]. Tail thickness at the base is wide (100%) that indicate donkey population is in a good body condition or indicator for the of presence better management [20]. The tail thickness of donkey was wider than Sinnar donkey of Ethiopia [21]. Muzzle color was white (100%) similar with donkey population in Kenya [22]. Generally, coat color description, body coat pattern, ear shape, leg strips, shoulder strips, face profile, ramp profile and tail length of Omo donkey has similarity with local donkey in Benshangul Gumuz regional state. Moreover, the dorsal strip of this donkey population has similarity with Sinar donkey of Ethiopia. However, the back profile of Omo donkey has dissimilarity from both local and Sinar donkey in Benshangul Gumuz regional state [21].

4. Coat color description of South Omo donkey

Coat color of the donkey presented in Fig. 3. According to this, coat color variation observed more in Benatsemay district i.e. color that observed in this district doesn't observe to other district like white, spotted-dark-brown. The observation of varied coat color may be a sign of within-population diversity or interbreeding with nearby populations [14]. Generally, Roan coat color cover highest number compare with other coat color. For example in Hammer district more than 82% donkeys from totally measured donkey had roan coat color. Similarly in Dasenech district more than 68% donkeys had roan coat color and more than 70% donkeys has this coat color in Benatsemay district. The observation of roan color may relate to the presence dominant Dun allele causing strong dilution of the pigmentation in the population of donkey [23]. Furthermore, long term artificial and natural selection may facilitate to shift the color of donkey from the base of color (black or red) of donkeys during domestication and the population goes to true breed this mainly

Fig. 2. Some figure captured during sample collection of donkey population.

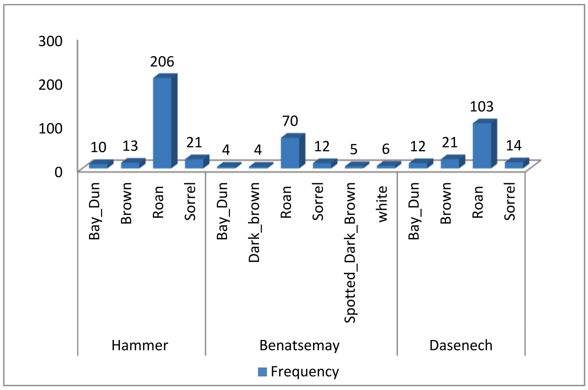

Fig. 3. Coat color description of South omo donkey in hammer, Benatsemay and Dasenech districts. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

observed in Hammer districts [24,25]. The coat color of Omo donkey is has resemblance with Kenya Masai donkey breed [26]. Moreover, the population has similarity with donkey population of Turkey [27] and the donkey population of India in which 70% coat color is gray/roan [28]. However, the body coat color is unlike with donkey population of donkey in Algeria and Bulgaria [29,30] in which brown coat color is the most observed.

4.1. Quantitative characteristics of donkey

The quantitative characteristics of donkey presented in Table 2 based on districts and sex of donkey. According to this, quantitative traits of donkey has variation at $P < 0.05$ both in the study areas and sex of donkeys. Height at the back (HB) of Dasenech district donkey population was higher than the rest study areas donkey population. HB indicates the lengths of the phalanges, tarsus, metatarsus, femur, and tibia. The higher HB can indicate the vital organs are high from the ground and less exposed to radiation from the earth, and that make donkeys easier to travel long distances and adapt to hot environmental circumstances [31]. Overall, except height at the wither (HW) and HB Hammer donkey has mostly better matric value than the rest districts of the study areas. The greater metric value of the Hammer donkey population may suggest management factors, such as the availability of nutrition and/or genetic variation, and the Hammer district may benefit from these factors [32]. Heart girth circumference (HGC), HW, back length, (BAL), neck length (NL) and ear length (EL) is better than Nigerian donkey of [33] report. Moreover, HW, HGC, CW chest width (CW) and head length (HL) of study areas donkeys has better metric value than Algeria donkey population [34]. Furthermore, BL, HW, HGC and EL of Omo donkey has better metric value than donkey of Indian [28].

Donkeys' heart girth circumference (HGC) varies depending on their sex, with males having a superior metric value ($P < 0.05$). The ability to accommodate the heart, liver, and other essential organs may be greater if the HGC is higher. As a result, male donkeys may have more capacity in their organs of vitality [35]. The HGC of female donkeys is comparable to that of the donkey population in Turkey, but it differs from that of male donkeys in the same population [27]. However, the rest quantitative characters has no variation

Table 2
Morphometric characteristics of donkey in the study areas.

	Districts (LSM±S.E)			Sex (LSM±S.E)		
Character	Benatsemay	Dasenech	Hammer	Female	Male	P. value
HGC	122.43 ± 0.91b	120.37 ± 0.85b	131.76 ± 0.77a	123.24 ± 0.45	126.47 ± 1.14	0.009
HW	108.78 ± 0.62 ab	109.63 ± 0.58a	107.20 ± 0.52b	108.42 ± 0.30	108.65 ± 0.77	0.79
HB	109.62 ± 0.40b	111.50 ± 0.37a	108.42 ± 0.33b	109.79 ± 0.20	109.90 ± 0.50	0.84
HR	112.51 ± 0.56a	113.59 ± 0.52a	114.22 ± 0.47a	113.64 ± 0.27	113.24 ± 0.70	0.60
BOL	114.27 ± 0.61b	111.86 ± 0.57c	118.03 ± 0.51a	115.25 ± 0.30	114.19 ± 0.76	0.20
BAL	74.36 ± 0.63b	77.25 ± 0.59a	77.35 ± 0.53a	75.96 ± 0.31	76.68 ± 0.78	0.40
NL	53.93 ± 0.61b	53.39 ± 0.57b	59.07 ± 0.51a	56.10 ± 0.30	54.82 ± 0.76	0.10
HL	48.57 ± 048a	48.48 ± 0.45a	48.42 ± 0.40a	48.68 ± 0.23	48.30 ± 0.60	0.60
LCBF	26.29 ± 0.50 ab	26.04 ± 0.47b	27.77 ± 0.42a	27.01 ± 0.24	26.39 ± 0.62	0.40
LFL	71.44 ± 3.21b	71.51 ± 3.00b	77.12 ± 2.70a	73.16 ± 1.58	73.55 ± 4.00	0.93
WH	48.34 ± 0.53b	48.73 ± 0.49b	51.36 ± 0.44a	49.74 ± 0.26	49.21 ± 0.65	0.45
CW	28.82 ± 0.45a	30.00 ± 0.42a	28.92 ± 0.38a	29.27 ± 0.22	29.23 ± 0.57	0.95
CD	49.92 ± 0.58b	50.91 ± 0.54b	53.18 ± 0.49a	51.24 ± 0.29	51.43 ± 0.72	0.81
CBC	17.11 ± 0.16a	16.57 ± 0.15 ab	16.50 ± 0.14b	16.73 ± 0.08	16.72 ± 0.20	0.95
EL	27.33 ± 0.29b	27.68 ± 0.27b	29.56 ± 0.24a	28.21 ± 0.14	28.18 ± 0.36	0.94

Heart girth circumference, HGC; height at wither, HW; height at the back, HB; height at rump, HR; body length, BOL; back length, BAL; neck length, NL; head length, HL; forelimb length of cannone bone LCBF, length of for leg, LFL; width of hip, WH; chest width, CW; chest depth, CW; cannon bone circumference, CBC; and ear length EL. P < 0.05.

($P > 0.05$) among the sex of donkey in the study areas and the finding is line with donkeys in south–western Zimbabwe that male and female has no significance variation [36]. Biologically male may has better metric value than female in the same age, breed, health condition and management factor etc. Yet, the measured donkeys are in mature (adult) stage in this study it doesn't show the trend of nature. The reason may be male which has better body size may sold to get better price and it need intervention to reverse this problem by considering male to female ration [37]. Furthermore [38], indicate that the reason may relate to lack of sexual dimorphism.

4.2. Multivariate analysis

The results of stepwise discriminant analysis, which were used to identify the donkey population from fifteen (15) traits to twelve (12) traits, were utilized to demonstrate within-breed variation [39]. The trait contained the following measurements: the heart girth circumference (HGC), the height at the back (HB), the body length (BOL), the cannon bone circumference (CBC), the ear length (EL), the chest width (CW), the neck length (NL), the back length (BAL), the head length (HL), the forelimb length of the cannon bone (LCBF), the length of the fore leg (LFL), and the wither height (WH). At 5% of the level of significance, traits that potentially distinguish goat populations were chosen chronologically as presented in Table 3.

4.3. Eigen value proportion cumulative and adjusted canonical correlation of multivariate analysis

Table 4 displays the multivariate analysis's canonical analysis outcome. The CAN1, CAN2, and CAN3 canonical approaches were developed. However, 94.6% of the donkey population was explained by the first two canonical techniques, CAN1 and CAN2. The third canonical technique (CAN3) was thus abandoned because it had little effect on dividing donkey populations. On the other hand, CAN2 has a lower eigenvalue, which renders it inefficient for separating goat populations. As a result, CAN1 is more effective (94%) than CAN2 and CAN 3 at separating the donkey population. By putting in a negative X-axis and a positive X-axis, respectively, CAN1 displays variance in the number of donkeys in the Hammer and Dasenech areas. This population of donkeys may vary due to management (environmental) or breed-specific differences [20]. However, Benenatesmay donkey population has similarity within both populations of the rest districts of study areas as presented in Table 2. Moreover, CAN-DISC figure indicated similarity and dissimilarity of donkey population as presented in Fig. 4.

4.4. Pairwise mahalanobis distance of donkey population

Table 5 displays the pairwise mahalanobis distance for the donkey. The study area's Hammer and Dasenech donkey population had the longest Mahalanobis distance (6.32) measured. According to Table 2, the cause might be either a management factor or breed-level diversification. The distance between Dasenech and Benatsemay's donkey population is the shortest (1.13). This suggests that the population is more unified [40].

4.5. Percent of classified in to its original area and error rate of classification

As shown in Table 6, DISCRIM multivariate analysis was used to group observations into recognized sample districts within the study area. According to this, the districts of Benatsemay, Dasenech, and Hammer, respectively, classified 55.5%, 68%, and 84.68% of the donkey population as belonging to its sampling area. Hammer district has a higher categorization rate (84.68%). On the other hand, the classification of the remaining districts into its sampling region is lower, which may be because the populations of donkey in those districts are more comparable. Additionally, the high error rate of the classification in general (0.31) indicates that the sampled population of donkeys, primarily from the Benatsemay and Dasenech districts, is similar in population.

Table 3
Stepwise discriminant analysis outputs of multivariate analysis.

Steps	Entered character	R-square	F. value	Pr > f	Wilks' lambda	Pr < lambda
1	HGC	0.26	89.51	<0.0001	0.74	<0.0001
2	HB	0.12	34.21	<0.0001	0.64	<0.0001
3	BOL	0.14	38.87	<0.0001	0.56	<0.0001
4	CAC	0.05	14.04	<0.0001	0.53	<0.0001
5	EL	0.05	13.24	<0.0001	0.50	<0.0001
6	CW	0.05	14.06	<0.0001	0.47	<0.0001
7	NL	0.03	14.25	<0.0001	0.45	<0.0001
8	BAL	0.03	8.43	0.0003	0.43	<0.0001
9	HL	0.02	7.88	0.0004	0.42	<0.0001
10	LCB1	0.02	5.31	0.0052	0.41	<0.0001
11	L1L	0.02	4.91	0.001	0.40	<0.0001
12	HW	0.02	3.76	0.024	0.40	<0.0001

Heart girth circumference (HGC), height at back (HB), body length (BOL), canon bone circumference (CBC), ear length (EL), chest width (CW), neck length (NL), back length (BAL), head length (HL), forelimb length of cannone bone (LCBF), length of for leg (LFL) and wither height (WH).

Table 4
Summary of eigen value, proportion cumulative and adjusted canonical correlation.

Attribute	Eigen value	proportion cumulative	Adjusted Canonical correlation
CAN1	1.31	0.94	0.75
CAN2	0.09	0.06	0.25

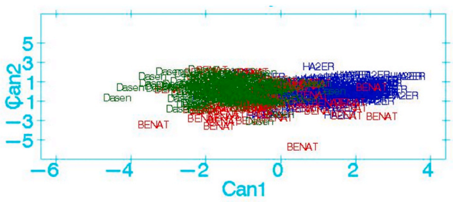

Fig. 4. Canonical Representation of Donkey Population in three districts of the study areas.
Green colors indicate; Dasenech, Red; Benatsemay, Blue; Hammer districts.

Table 5
Pairwise mahalanobis distance of donkey.

	Benatsemay	Dasenech	Hammer
Benatsemay	0	1.13	3.81
Dasenech	1.13	0	6.32
Hammer	3.81	6.32	0

Table 6
Percent Classified in to its Original Area and Error Rate.

	Benatsemay	Dasenech	Hammer	Total
Benatsemay	56 (55.45)	35 (34.65)	10 (9.00)	101 (100)
Dasenech	40 (26.67)	102 (68.00)	8 (5.33)	150 (100)
Hammer	27 (10.89)	11 (4.44)	210 (84.68)	248 (100)
Total	123 (24.65)	148 (29.66)	228 (45.69)	499 (100)
Error rate	0.45	0.32	0.33	0.31

5. Conclusion

Roan coat color is observed mainly in study area. The observation of roan color may relate to the presence dominant Dun allele causing strong dilution of the pigmentation in the population of donkey. Moreover, long term artificial and natural selection may facilitate to shift the color from the base of color (black or red). The population of hammer donkeys has a higher metric value, which may be due to management factors or within-population variation. Other than the heart girth, there is no difference in other body dimensions between the sexes of the donkey population. The cause could be that superior jacks are being sold to pay for family expenses, which resulted into negative selection. Therefore, a sound breeding program may be required to turn this scenario reverse. Additionally, this morphological variation suggests population diversity within the research locations, particularly in the Dasenech and Hammer populations. Therefore, additional research may need to exploit the genetic diversity of the Omo donkey population.

Contribution statement

Teklewold Belayhun Getachew: participate in Conceived and designed the experiments, Performed the experiments, Analyzed and interpreted the data, Contributed reagents, materials, analysis tools or data and Wrote the paper.

Abebe Hailu Kassa: participate to Conceived and designed the experiments, Performed the experiments, Contributed reagents, materials, analysis tools or data.

Ashenafi Getachew Megersa: Conceived and designed the experiments, Performed the experiments.

Data availability statement

Data will be made available on request.

Funding details

Funding information is not available.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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