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Morphological Characterization of Indigenous Goat Types in Anfillo and Sibu Sire Districts, Western Ethiopia

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Abstract

A morphological characterization study was conducted on native goat types in the Anfillo and Sibu Sire districts. Data were collected from a total of 450 goats of both sexes and analyzed using appropriate software. The most frequently observed coat color patterns were plain (59.1%), patchy (40%), and spotted (0.9%). The dominant coat color types were white (28%), followed by white-dominated black (26.9%) and brown (10.4%). The majority (72%) of the goat population had short and smooth-coated hair. The goat head profiles in the Anfillo and Sibu sire districts were concave (63.1%) and straight (82.1%), respectively. Goats were horned, with straight (71.8%), backward (50%), and lateral (38.2%) horn orientations. About 72.9% and 62.9% of the goats had straight backs and sloppy rump profiles, respectively. The overall body weight, body length, and heart girth were 25.7±3.02 kg, 59.6±3.5 cm, and 67.08±3.2 cm, respectively. Heart girth had significant (p<0.001) positive correlations with body weight. The correlations between heart girth and body weight were 0.91 and 0.84 for males and 0.88 and 0.87 for female goats in the Anfillo and Sibu Sire districts, respectively. Based on the body index (BI) value (>3.15), the goat populations of the study areas are classified as meat types.

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INTRODUCTION

The first step in identifying local genetic resources is phenotypic characterization, which relies on an understanding of the diversity in morphological traits. Knowing the morphological character and their variations among and within goat populations is an alternative option and important input to designing effective breeding programs (Birhanie et al., 2019).

Referring to the Ethiopia Sheep and Goat Productivity Improvement Program, Jembere (2016) and Jembere et al. (2019) reported that Ethiopia owns about 12 Indigenous goat breeds where eight of which are reared for their milk production in addition to meat, manure, and skin products.

The varying perspectives mentioned above would suggest that the nation's goat populations are not fully described. In order to create genetic improvement plans for the sustainable use and protection of native animal genetic resources, it is crucial to evaluate the phenotypic traits of populations raised in various production conditions (Birara et al., 2021). In order to design genetic improvement initiatives, it is necessary to thoroughly characterize the variations that exist both within and between populations. In several regions of Ethiopia, most native goats were identified by both qualitative and quantitative characteristics. Nevertheless, there are only a few studies conducted on goat phenotypic characterization in western Oromia (Seid, 2016). That means, the characterization efforts accomplished thus far were not comprehensive nor did they cover all of the large territories of Western Oromia. One way to identify different breeds or populations in a particular production area is to characterize the genetic potential of animals by defining their physical and productive capabilities (FAO, 2012).

Therefore, the purpose of this study was to characterize the goat populations in western Oromia in terms of their morphological traits and structural indices with the objective of future genetic improvement purposes.

MATERIALS AND METHODS

Two districts in western Oromia were used for this study: the Sibu Sire district in East Wallaga Zone and the Anfillo district in Qellem Wallaga Zone. Anfillo district is located in the Qellem Wallaga zone about 694 km from Addis Ababa to the west direction. Geographically, it is located at 8°30′ to 8°48′N and 34°40′ to 34°59’E. The minimum and maximum annual temperatures of the district are 15°C and 29°C, respectively. The mean annual rainfall of the Anfillo district ranges from 1453 to 2074 mm (ALFDO, 2023, unpublished data). Sibu Sire district is in the East Wallaga zone and situated about 278 km from Addis Ababa in the west direction. Geographically, it is located between 8°16' to 10°16'N and 36°47' to 37°0’E. The minimum and maximum annual temperatures of the district are 20°C and 26°C, respectively (SSDAO, 2023, unpublished data).

Sampling techniques and sample size determination

Two districts (Anfillo and Sibu Sire) were purposively selected for this study. From each district, four rural *kebeles* were selected. Body weight and linear body measurements were taken from a total of 450 (328 female and 122 male) heads of goats measured from flocks of 135 households. Measurements were conducted randomly on animals of all age groups. Wilson and Durkin's (1984) dentition classification system was used in the current age determination. Accordingly, the animals were categorized into 0PPI, 1PPI, 2PPI, 3PPI, and 4PPI. Animals with 0PPI dentition included those goats between 6 to 12 months old and their ages were determined both by the dentition method and the recall method of the owners. However, dentition was solely used for age determination for those animals above yearling age. In selecting sampled goats from each district, kids less than six months old, castrated goats, pregnant does, and sick animals were excluded.

Data collection

Using the standard format adapted from the FAO (2012) breed descriptor list, thirteen qualitative traits were observed and recorded, including coat color pattern, coat color, hair type, presence or absence of horn, horn shape, horn orientation, ear shape, ear orientation, facial (head) profile, wattles, beard, ruff, and back profile. In addition, each goat was measured early in the morning before being released for grazing for thirteen different morphometric measurements, including body weight (BW), body length (BL), heart girth (HG), height at withers (HeW), pelvic width (PW), rump length (RL), rump width (RW), rump height (RH), horn length (HoL), ear length (EL), head width (HW), head length (HL), and scrotum circumference (SC). Body weight (kg) measurements were recorded using a suspended spring balance with a precision of 0.2 kg. Linear body measurements were obtained by using a measuring tape calibrated in centimeters (cm) after restraining and holding the animals in an unforced position.

Data management and statistical analysis

All information gathered was coded and entered into the Microsoft Excel spreadsheet. To compare study districts based on categorical variables (qualitative qualities), a chi-square (X^2) test was employed. Quantitative factors were analyzed using the General Linear Model (GLM) techniques of the Statistical Analysis System (SAS, version 9.4, released in 2012). For every physical characteristic sex, age, and district effects, and least squares means were determined along with the accompanying standard errors. The coefficient of determination (R^2) and mean square error were used to determine the models that fit the data the best. For quantitative features, district/location, sex, and age group were fitted as independent variables; however, the scrotal circumference was not fitted for females. For every trait, the least squares mean (LSM) and associated standard errors were determined.

The model fitted for quantitative traits was:

$$Y_{ijk} = \mu + A_i + S_j + D_k + e_{ijk}$$

Where: Y_{ijkl} was the observation of body weight and linear body measurements (excluding scrotal circumference for females) in the i^{th} age group j^{th} sex and k^{th} district

μ is the overall mean, A_i was the i^{th} effect of age group (i = 0PPI, 1PPI, 2PPI, 3PPI, and 4PPI), S_j was the j^{th} effect of sex (j =male, female), D_k was the k^{th} effect of the district (1 = Anfillo, 2= Sibu Sire) and e_{ijkl} was the random residual error.

The model used to analyze the scrotal circumference (SC) was:

$$Y_{ij}=\mu + Ai +Dj+ eij$$

Where: Y_{ijk} was the observed value of the scrotal circumference, μ was the overall mean, A_i was the i^{th} effect of age class (i=0PPI, 1PPI, 2PPI, 3PPI, and 4PPI), D_j was the j^{th} effect of the district (1 = Anfillo, 2= SibuSire), e_{ijk} was a random residual error

Multiple linear regression analysis

The prediction of live body weight from linear body measurements was done using multiple linear regression analyses. The prediction model that best suited the data was chosen based on its higher coefficient of determination (R^2) values, minimum mean square error (MSE), and modified R^2 value. These metrics indicate the proportion of total variability explained by the model. Excluding the scrotum circumference for females, all the independent variables were added to the model, and the least MSE and maximum adjusted R^2 were determined for each sex. Following that, the variables were simultaneously fitted into the model to get the best-fit regression equation. These variables were chosen based on the maximum adjusted R^2 value and the minimum MSE.

The following models were employed for the estimation of body weight from the linear body measurements for males and females.

I. For Males

$$Y_j = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + ej$$

Where: Yj was the dependent variable body weight, β0 was the intercept,

X1, X2…X4, and X5= are the independent variables, Heart girth, Body length, Rump height, height at wither, and Scrotum circumference, respectively. β1, β2 ... β4 and β5 were the regression coefficients of the variables X_1, X_2…X_4 and X_5 respectively, and ej was the residual error.

II. For Females

$$Y_j = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + ej$$

Where: - Y_j was the dependent variable body weight

β0= the intercept,

X1…X5 were the independent variables, Heart girth, Body length, Rump height, height at wither, and pelvic width, respectively.

β_1, β_2 ... β_4 and β_5 were the regression coefficients of the variables X_1, X_2…X_4 and X_5 eij were the residual error. Structural indices were calculated from morphometric measurements based on the formulas of (Chacón et al., 2011; Chiemela et al., 2016).

RESULTS AND DISCUSSIONS

Qualitative characteristics

Table 1 displays the frequency proportions of qualitative traits seen in both male and female goats from the two groups. The results of the chi-square test (χ2) showed that there were significant differences (p<0.001) in most qualitative features, such as coat color pattern, coat color type, horn presence, horn form, horn orientation, ear orientation, head profile, and back profile, between the goat populations in the two districts. The goat populations in the two districts did not differ significantly (p > 0.05) in terms of coat hair type, rump profile, wattles, beard, or ruff.

The two goat populations that were sampled showed plain, patchy, and dotted coat color patterns. The evaluated native goat populations had plain coats with patches and spots in about 59.1%, 40%, and 0.9% of the cases. About 23.1% of the native Anfillo female goat population had white coats with black predominating, while almost 32.3% of the males had brown coats with black stripes down their backs and legs (Figure 1 and Table 1). On the other hand, about 29.8% and 36.9%, respectively, white coat color was the most common coat color type among the sampled male and female goat population from the Sibu Sire district (Figure 2 and Table 1). The above finding is consistent with the findings of Sheriff et al. (2021), who found that Oromo goats had a light brown coat color while Arab goats had a white coat color. The current study found that in both research regions, around 72% of the goats had short, smooth hair, about 27.6% had short, coarse hair, and approximately 0.4% had long, coarse hair. Approximately 36.9% of the goats in the Anfillo district had a straight head, and the remaining 63.1% had a concave head profile.

Table 1

Morphological characteristics of goat population in the study areas

Attributes	Anfillo			SibuSire			
	Male	Female	Total	Male	Female	Total	Overall
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	
Coat color pattern							
Plain	28(43.1)	87(54.4)	115(51.1)	41(71.9)	110(65.5)	151(67.1)	266(59.1)
Patchy	36(55.4)	73(45.6)	109(48.4)	15(26.3)	56(33.3)	71(31.6)	180(40)
Spotted	1(1.5)	-	1(0.4)	1(1.8)	2(1.2)	3(1.3)	4(0.9)
χ^2 value							*13.89******
Coat color type							
White	12(18.5)	35(21.9)	47(20.9)	17(29.8)	62(36.9)	79(35.1)	126(28)
Red	2(3.1)	4(2.5)	6(2.7)	-	5(3)	5(2.2)	11(2.4)
Dark red/brown	9(13.8)	11(6.9)	20(8.9)	4(7)	23(13.7)	27(12)	47(10.4)
Black	-	10(6.3)	10(4.4)	6(10.5)	9(5.4)	15(6.7)	25(5.6)
Light red	1(1.5)	4(2.5)	5(2.2)	-	4(2.4)	4(1.8)	9(2)
Fawn	2(3.1)	15(9.4)	17(7.6)	2(3.5)	-	2(0.9)	19(4.2)
Grey	3(4.6)	8(5)	11(4.9)	12(21.1)	7(4.2)	19(8.4)	30(6.7)
White + light brown with white dominant	-	8(5)	8(3.6)	2(3.5)	30(17.9)	32(14.2)	40(8.9)
White + black with white dominant	11(16.9)	43(26.9)	54(24)	4(7)	10(6)	14(6.2)	68(15.1)
Black and white with black dominant	4(6.2)	18(11.3)	22(9.8)	5(8.8)	6(3.6)	11(4.9)	33(7.3)
Grey+ white with grey dominant	-	-	-	-	2(1.2)	2(0.9)	2(0.4)
Black +white black spotted	-	-	-	1(1.8)	2(1.2)	3(1.3)	3(0.7)
Brownback stripes along the back + leg	21(32.3)	4(2.5)	25(11.1)	4(7)	8(4.8)	12(5.3)	37(8.2)
χ^2 value							*75.51****
Coat hair type							
Short and Smooth	55(84.6)	113(70.6)	168(74.7)	49(86)	107(63.7)	156(69.3)	324(72)
Short and Coarse	10(15.4)	47(29.4)	57(25.3)	6(10.5)	61(36.3)	67(29.8)	124(27.6)
Long and coarse	-	-	-	2(3.5)	-	2(0.8)	2(0.4)

Table 1 continues

χ2 value							*3.25*^{NS}
Head profile							
Straight	28(43.1)	55(34.4)	83(36.9)	33(57.9)	138(82.1)	171(76)	254(56.4)
Concave	37(56.9)	105(65.6)	142(63.1)	24(42.1)	30(17.9)	54(24)	196(43.6)
χ2 value							*69.99****
Horn presence							
Present	44(67.7)	77(48.1)	121(53.8)	39(68.4)	123(73.2)	162(72)	283(62.9)
Absent	21(32.3)	83(51.9)	104(46.2)	18(31.6)	45(26.8)	63(28)	167(37.1)
χ2 value							*16.00******
Horn shape							
Straight	16(36.4)	33(42.9)	49(40.5)	36(92.3)	119(96)	154(95.6)	203(71.8)
Curved	28(63.6)	41(53.2)	69(57.3)	3(7.7)	4(3.2)	7(4.5)	76(26.8)
Spiral	-	3(3.9)	3(2.5)	-	1(0.8)	1(0.6)	4(1.4)
χ2 value							*102.69******
Horn orientation							
Backward	28(63.6)	45(58.4)	73(60.3)	14(35.9)	54(43.8)	68(42.2)	141(50)
Upward	9(20.5)	8(10.4)	17(14)	25(64.1)	53(43.)	78(48.1)	95(33.7)
Forward	-	-	-	-	15(13)	15(6.7)	15(5.3)
Lateral	7(15.9)	24(31.2)	31(25.6)	-	2(1.6)	2(1.2)	32(11.3)
χ2 value							*111.93******
Ear orientation							
Horizontal/lateral	22(33.8)	63(39.4)	85(37.8)	23(40.4)	64(38.1)	87(38.7)	172(38.2)
Forward	5(7.7)	15(9.4)	20(8.9)	16(28.1)	38(22.6)	54(24)	74(16.4)
Pendulous	18(27.7)	27(16.9)	45(20)	8(14)	15(8.9)	23(10.2)	68(15.1)
Semi-pendulous	14(21.5)	36(22.5)	50(22.2)	10(17.5)	50(29.8)	60(26.7)	110(24.4)
Erect	6(9.2)	19(11.9)	25(11.1)	-	1(0.6)	1(0.4)	26(5.8)
χ2 value							*51.08******
Back profile							
Straight	41(63.1)	113(70.6)	154(68.4)	47(82.5)	127(75.6)	174(77.3)	328(72.9)
Sloppy toward rump	13(20)	16(10)	29(12.9)	8(14)	37(22)	45(20)	74(16.4)
Sloppy toward withers	9(13.8)	21(13.1)	30(13.3)	2(3.5)	4(2.4)	6(2.7)	36(8)

Table 1 Continues

Dipped	2(3.1)	10(6.3)	12(5.3)	-	-		12(2.7)
χ2 value							*32.67****
Rump profile							
Flat	21(32.3)	42(26.3)	63(28)	27(47.4)	36(21.4)	63(28)	126(28)
Sloppy	40(61.5)	99(61.9)	139(61.8)	28(49.1)	116(69)	144(64)	283(62.9)
Roofy	4(6.2)	19(11.9)	23(10.2)	2(3.5)	16(9.5)	18(8)	41(9.1)
χ2 value							0.69^{NS}
Wattles							
Present	29(44.6)	77(48.1)	106(47.1)	10(17.5)	79(47)	89(39.6)	195(43.3)
Absent	36(55.4)	83(51.9)	119(52.9)	47(82.5)	89(53)	136(60.4)	255(56.7)
χ2 value							2.615^{NS}
Beard							
Present	40(61.5)	82(51.2)	122(54.2)	52(91.2)	47(28)	99(44)	221(49.1)
Absent	25(58.5)	78(48.8)	103(45.8)	5(8.8)	121(72)	126(56)	229(59.9)
χ2 value							0.89^{NS}
Ruff							
Present	34(52.3)	21(13.1)	55(24.4)	51(89.5)	7(4.2)	58(25.8)	113(25.1)
Absent	31(47.7)	139(86.9)	170(75.6)	6(10.5)	161(95.8)	167(74.2)	337(74.9)
χ2 value							0.10^{NS}

The present study's results are in line with those of Mekonnen et al. (2023), where the majority of goats (60.185) exhibited concave head profiles. In the Sibu Sire district, the proportions of goats with concave and straight head profiles were 82.1% and 17.9%, respectively.

Roughly 72% of goats in the Sibu Sire district and 53.8% of goats in the Anfillo district had horns. According to Seid et al. (2016), the proportions of horned goats in the Guduru, Amuru, and Horro districts were around 91.67%, 86.76%, and 74.02%. In the current study, the percentages of goat populations with horizontal or lateral ear orientation were around 37.8% and 38.7%, respectively, in the districts of Anfillo and Sibu Sire. Seid et al. (2016) found that approximately 45.59% and 32.84% of the native goat populations in the Horro Guduru Wallaga zone exhibited lateral and droopy ear orientations, which is consistent with the current findings. The rump profiles of the majority of the native goat populations in the current study districts were sloppy (62.9%), followed by flat (28%).

According to Abebe and Korato's (2020) assessment, around 79.5% of the indigenous goat population in the East Arsi Zone exhibited a sloppy rump profile. The majority of goat populations in the studied locations (56.7%) in the current study lacked wattle. This result is consistent with that of Sheriff et al. (2021), who found that 87.93% of the Oromo and Arab goats in northwest Ethiopia were wattle-free. In the present study, males (bucks) exhibited more beards and ruffs than females. The reason behind this could be that sex had an impact on the ruff and beard. Figures 1 and 2, respectively, show images of adult male and female goats from the districts of Anfillo and Sibu Sire.

Figure 1. *Adult Indigenous breeding doe (left) and buck (right) in Anfillo district*

Figure 2. *Adult Indigenous breeding doe (left) and buck (right) in SibuSire district*

Body weight and linear body measurements

Table 2 displays the body weight and linear body measurements of the native goat populations in the study districts. With the exception of head and ear length, sex significantly ($p<0.05$) affected body weight and all other linear body dimensions. Ambel and Bayou (2022) similarly reported that there was no sex influence on ear length. The authors also reported that, with the exception of ear length, sex significantly ($p<0.05$) affected live body weight and all other body measurements. In the current study, the average body weight of the male and female goats was 27.12±3.20 kg and 25.24±3.13 kg, respectively. In terms of body weight and linear body measures, male goats consistently weighed more than female goats. Hormonal influences could be the cause for the difference between male and female goats. The body weight recorded in this study was marginally less than the reported values for the Horro Guduru Wallaga zone, which were 33.0 ±0.6 kg for male goats and 26.8 ±0.20 kg for female goats (Seid et al., 2016). This could be a result of management variations and the inclusion of 6- to 12-month-old goats (0PPI) in the current investigation.

Districts, with the exception of head length, had a significant ($p<0.05$) impact on body weight and linear body dimensions, as shown in Table 2. The average body weight of goats in the districts of Anfillo and Sibu Sire was 26.60±5.80 kg and 24.90±4.51 kg, respectively. Additionally, according to Seid et al. (2016), locations had a substantial impact on body weight and the majority of linear body measurements ($p<0.05$). The two districts' goat populations' likely differences in body weight and linear body measurements could be attributed to variations in agroecology and feed availability.

Each body measurement, including body weight, was significantly ($P<0.05$) influenced by age group. The animal's linear body measurements grew from 0PPI to ≥2PPI, as predicted. This result is consistent with that of Yaekob et al. (2015), who examined Woyto-Guji goats and found that as goats aged from the youngest (0PPI) to the oldest (4PPI), body weight and linear body measurements increased.

A substantial ($p<0.05$) effect was seen in the interaction of sex by age group on body weight, heart girth, body length, height at wither, rump height, and head length. Male goats are substantially larger than female goats ($p<0.05$) in all age categories. Mature males (≥2PPI) had a considerably ($p<0.05$) larger scrotum circumference than males with 0PPI and 1PPI. According to Ambel and Bayou (2022), male goats in the 4PPI age group in West Omo and Bench-Sheko Zone had considerably ($p<0.05$) larger SC than males in the 1PPI, 2PPI, and 3PPI age groups. This finding is consistent with the current findings.

Correlation between body weight and linear body measurements

All quantitative traits of male and female goats in the current study showed a positive, strong, and significant association with body weight (Table 3). For male goats in the Anfillo district, body weight showed a high significant association ($r = 0.88$) with heart girth, and a positive and strong correlation ($r = 0.91$) with body length ($r = 0.90$). This result is consistent with a large body of research showing strong positive associations ($r = 0.81–0.96$) between linear body measurements and body weight (Seid et al., 2016).

Table 2

Least squares mean and standard error for body quantitative traits for Anfillo and Sibu Sire goat population by sex, age, and location

Effects and level	**N**	BW(kg)	HG(cm)	BL(cm)	HeW(cm)	RH(cm)	RL(cm)	RW(cm)
		LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE
Overall	450	25.7±3.02	67.08±3.2	59.6±3.5	61.7±3.2	63.3±3.3	15.6±1.6	13.73±1.17
CV %	450	11.73	4.86	5.88	5.26	5.31	10.03	8.56
R^2	450	0.68	0.65	0.61	0.63	0.63	0.39	0.40
Sex		*	*	*	*	*	*	*
Male	122	27.12±3.20	68.85±3.00	60.70±3.46	63.11±3.41	64.78±3.54	16.23±1.64	14.21±1.23
Female	328	25.24±3.13	66.43±3.16	59.19±3.84	61.23±3.51	62.96±3.57	15.48±1.59	13.55±1.21
Age		*	*	*	*	*	*	*
0PPI	166	21.74±3.89^{a}	62.84±3.31^{b}	56.30±4.24^{a}	58.10±3.52^{c}	59.56±3.63^{a}	14.61±1.56^{a}	12.83±1.49^{a}
1PPI	86	24.41±2.79^{b}	66.19±2.47^{c}	57.32±3.34^{b}	60.58±3.66^{b}	61.95±3.27^{c}	15.36±1.37^{c}	13.68±0.94^{b}
≥2PPI	198	29.70±3.91^{c}	71.03±4.72^{a}	63.45±4.68^{a}	65.29±4.44^{a}	66.92±4.87^{b}	16.72±1.95^{b}	14.51±1.19^{c}
Districts		*	*	*	*	*	*	*
Anfillo	225	26.60±5.80	67.35±6.79	61.12±5.77	63.12±5.73	64.70±6.11	15.22±2.43	13.28±1.83
SibuSire	225	24.90±4.51	66.82±3.62	58.09±4.86	60.36±4.28	61.81±4.21	16.15±1.19	14.19±0.76
Sex by age		*	*	*	*	*	NS	NS
Female,0PPI	111	20.93±3.52^{a}	61.81±3.15^{a}	55.58±3.84^{a}	57.45±3.29^{b}	58.79±3.32^{a}	14.28±1.30^{c}	12.48±1.23^{b}
Female,1PPI	66	24.04±2.49^{b}	65.75±2.31^{b}	57.10±2.95^{b}	60.42±3.03^{c}	61.77±2.64^{b}	15.16±1.32^{b}	13.68±0.81^{a}
Female,≥2PPI	151	28.94±3.65^{c}	70.11±4.18^{c}	62.76±4.29^{c}	64.35±3.60^{a}	65.96±3.96^{c}	16.49±1.95^{a}	14.32±1.18^{c}
Male,0PPI	55	23.36±4.18^{a}	64.90±3.60^{a}	57.20±4.36^{b}	59.41±3.51^{b}	61.10±3.90^{b}	15.27±1.76^{b}	13.54±1.56^{b}
Male,1PPI	20	25.65±2.98^{b}	67.65±3.07^{b}	57.74±3.42^{b}	61.10±3.95^{b}	62.55±3.12^{c}	16.00±1.18^{b}	13.95±1.16^{b}
Male,≥2PPI	47	32.14±3.46^{c}	73.97±4.12^{c}	65.65±3.42^{a}	68.29±3.78^{c}	70.04±4.26^{a}	17.46±1.93^{c}	15.10±1.15^{a}

Effects and level	**N**	PW(cm)	HW(cm)	HL(cm)	EL(cm)	HoL(cm)	N	SC(cm)
		LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	122	LSM±SE
Overall	450	12.66±1.15	10.04±0.86	16.16±1.17	12.42±1.19	11.15±2.87		23.86±2.60

Table 2 ***continues.***

CV %	450	9.09	8.60	7.23	9.63	25.79		10.92
R^2	450	0.49	0.58	0.51	0.40	0.01		0.64
Sex		*	*	NS	NS	*		
Male	122	13.12±1.01	10.31±0.72	16.36±1.22	12.45±1.05	11.59±3.27		23.86±2.60
Female	328	12.49±1.28	9.94±1.06	16.09±1.15	12.42±1.24	10.94±2.69		
Age		*	*	*	*	*		*
0PPI	166	11.55±1.55[b]	9.46±0.97[b]	15.11±1.17[a]	11.43±1.24	9.03±2.59[a]	55	20.67±2.98[a]
1PPI	86	12.70±1.06[a]	9.62±1.06[b]	15.70±1.01[b]	12.22±1.26	9.75±1.92[a]	20	23.35±1.36[b]
≥2PPI	198	13.58±1.05[c]	10.71±1.34[bc]	17.25±1.56[c]	13.37±1.27	12.71±2.21[ac]	47	27.80±2.16[c]
Districts		*	*	NS	*	*		*
Anfillo	225	12.08±1.88	10.65±1.51	16.07±2.15	12.16±1.92	12.28±2.75	65	22.70±3.08
SibuSire	225	13.24±0.82	9.44±0.69	16.26±0.95	12.69±0.95	10.31±2.63	57	25.17±1.52

*a, b, c means with different superscripts within the same column and significantly different at (P<0.05); Ns = Non-significant (P>0.05); *significant at 0.05; NA=Not applicable; BW=Body weight; BL=body length; HG=heart girth; RL=rump length; RH=rump height; RW=rump width; PW=pelvic width; EL=ear length; HeW=Height at wither, HW=head width; HL=head length; HoL=horn length, SC=scrotum Circumference*

Multiple linear regression analysis

Tables 4 and 5 exhibit linear regression models employed for estimating does' and bucks' body weights based on linear body measurements. For the selection of independent variables, stepwise regression was performed for each district and each sex, with males inputting the entire traits one at a time and females excluding SC. Because heart girth contributed more to the model than the other variables, it was chosen for both sexes (male and female) in both districts and thus added to the model in the first step of the stepwise regression process. Then two independent variables were chosen to be included in the model at the second step of stepwise regression, and so on. For each district and sex, the number of variables included in each step, parameter estimations, and their contributions in terms of mean square error (MSE), adjusted R^2, and coefficient of determination (R^2) were described. The percentage of the overall variability described by the model is shown by the coefficient of determination (R^2). Heart girth was selected first, which explains 77.0% in the Anfillo district and 76% in the Sibu Sire district, respectively in female goats. On the other hand, heart girth accounts for between 71.6% and 83% of the variation in Bucks. This is consistent with findings by Seid et al. (2016), and Sheriff et al. (2021), which showed that heart girth is the best predictor of body weight of goats.

Table 3

Coefficient of correlations among live body weight and linear body measurements for each district within sex; above (male) and below (female) the diagonal.

District	Traits	BW	BL	HG	RL	RH	RW	PW	EL	HeW	HW	HL	HoL	SC
Anfillo	BW	1	0.90**	0.91**	0.46**	0.86**	0.47**	0.58**	0.70**	0.86**	0.75**	0.76**	0.43**	0.73**
	BL	0.85**	1	0.87**	0.43**	0.83**	0.48**	0.59**	0.66**	0.84**	0.71**	0.73**	0.38**	0.78**
	HG	0.88**	0.85**	1	0.59**	0.90**	0.50**	0.63**	0.74**	0.88**	0.78**	0.84**	0.48**	0.82**
	RL	0.38**	0.46**	0.58**	1	0.63**	0.46**	0.50**	0.32**	0.56**	0.45**	0.69**	0.25*	0.56**
	RH	0.81**	0.84**	0.89**	0.62**	1	0.53**	0.58**	0.64**	0.93**	0.77**	0.78**	0.48**	0.75**
	RW	0.43**	0.47**	0.54**	0.50**	0.54**	1	0.80**	0.34**	0.49**	0.47**	0.58**	0.17^{NS}	0.54**
	PW	0.57**	0.48**	0.59**	0.56**	0.59**	0.76**	1	0.40**	0.61**	0.48**	0.67**	0.26*	0.66**
	EL	0.58**	0.56**	0.57**	0.22**	0.58**	0.32**	0.44**	1	0.68**	0.65**	0.65**	0.36*	0.56**
	HeW	0.81**	0.81**	0.86**	0.53**	0.94**	0.47**	0.54**	0.55**	1	0.75**	0.75**	0.46**	0.76**
	HW	0.55**	0.53**	0.54**	0.27**	0.57**	0.43**	0.47**	0.53**	0.58**	1	0.76**	0.44**	0.63**
	HL	0.59**	0.56**	0.67**	0.45**	0.63**	0.51**	0.54**	0.42**	0.59**	0.58**	1	0.41*	0.69**
	HoL	0.32**	0.31**	0.45**	0.35**	0.39**	0.26**	0.34**	0.19^{NS}	0.41**	0.20**	0.34**	1	0.48**
Sibu Sire	BW	1	0.83**	0.84**	0.48**	0.80**	0.70**	0.56**	0.50**	0.80**	0.75**	0.57**	0.48**	0.84**
	BL	0.86**	1	0.77**	0.55**	0.86**	0.66**	0.57**	0.38**	0.84**	0.56**	0.52**	0.42**	0.69**
	HG	0.87**	0.86**	1	0.48**	0.82**	0.61**	0.57**	0.38**	0.80**	0.62**	0.42**	0.38**	0.67**
	RL	0.68**	0.68**	0.76**	1	0.61**	0.44**	0.48**	0.24^{NS}	0.57**	0.39**	0.60**	0.13^{NS}	0.37**
	RH	0.81**	0.82**	0.83**	0.63**	1	0.70**	0.53**	0.38**	0.97**	0.58**	0.44**	0.47**	0.66**
	RW	0.61**	0.65**	0.66**	0.58**	0.69**	1	0.62**	0.35**	0.70**	0.51**	0.30*	0.57**	0.62**
	PW	0.71**	0.68**	0.71**	0.66**	0.64**	0.69**	1	0.29*	0.50**	0.44**	0.50**	0.29*	0.45**
	EL	0.61**	0.58**	0.65**	0.64**	0.47**	0.49**	0.56**	1	0.34**	0.62**	0.45**	0.18^{NS}	0.70**
	HeW	0.79**	0.78**	0.78**	0.59**	0.97**	0.68**	0.58**	0.43**	1	0.56**	0.39**	0.47**	0.64**
	HW	0.67**	0.61**	0.62**	0.57**	0.49**	0.51**	0.53**	0.63**	0.48**	1	0.61**	0.44**	0.70**
	HL	0.64**	0.59**	0.67**	0.72**	0.52**	0.47**	0.62**	0.63**	0.46**	0.69**	1	0.08^{NS}	0.48**
	HoL	0.44**	0.44**	0.41**	0.34**	0.38**	0.46**	0.38**	0.43**	0.38**	0.40**	0.36**	1	0.46**

NS= Non-significant at ($p<0.05$); *=significant at ($p<0.05$); **=highly significant at ($p<0.01$)

Table 4

Regression of live body weight on different body measurements for Does and Bucks in all age groups at Anfillo district

Sex	Equation	Intercept	Regression coefficients							
Does		β0	β1	β2	β3	β4	β5	R^2	Adj R^2	MSE
	HG	24.78	0.76					0.77	0.75	7.88
	HG+BL	-29.15	0.45	0.41				0.80	0.80	6.38
	HG+BL+HeW	-30.81	0.37	0.37	0.14			0.81	0.80	6.29
	HG+BL+HeW+RH	-30.89	0.42	0.39	0.28	0.20		0.81	0.80	6.21
	HG+BL+HeW+RH+PW	-30.94	0.44	0.39	0.27	0.18	0.14	0.81	0.81	6.20
Bucks	HG	-23.48	0.74					0.83	0.83	6.14
	HG+BL	-29.62	0.45	0.42				0.87	0.86	4.79
	HG+BL+HeW	-30.32	0.39	0.38	0.11			0.87	0.87	4.76
	HG+BL+HeW+RH	-30.42	0.36	0.38	0.07	0.06		0.87	0.86	4.83
	HG+BL+HeW+RH+SC	-33.61	0.43	0.41	0.09	0.04	0.16	0.88	0.87	4.68

Table 5

Regression of live body weight on different body measurements for Does and Bucks in all age groups at Sibu Sire district

Sex	Equation	Intercept	Regression coefficients								
		β0	β1	β2	β3	β4	β5	β6	R^2	Adj R^2	MSE
Does	HG	-44.29	1.03						0.763	0.76	4.66
	HG+BL	-38.62	0.58	0.42					0.81	0.81	3.60
	HG+BL+HeW	-40.87	0.51	0.38	1.01				0.83	0.83	3.33
	HG+BL+HeW+RH	-42.19	0.38	0.31	1.11	0.20			0.84	0.83	3.16
	HG+BL+HeW+RH+PW	-43.36	0.33	0.30	1.03	0.19	0.51		0.84	0.84	3.08
Bucks	HG	-56.97	1.21						0.71	0.71	6.58
	HG+BL	-48.70	0.71	0.44					0.79	0.79	4.73
	HG+BL+HeW	-48.17	0.66	0.39	0.09				0.80	0.79	4.77
	HG+BL+HeW+RH	-48.31	0.70	0.45	0.4	0.43			0.80	0.79	4.70
	HG+BL+HeW+RH+SC	-41.68	0.51	0.28	0.41	0.42	0.67		0.88	0.87	2.85

HG=Heart girth; BL=Body length; HeW=Height at Wither; RH=Rump Length; SC=Scrotum Length

The values of R^2, or the percentage of the variance in the response variable that is predictable from the explanatory variable, increased from 0.77 to 0.80 for female goats in Anfillo and from 0.83 to 0.87 for male goats when additional linear body measurements were added to heart girth. In the Sibu Sire district, the improvement for female goats went from 0.77 to 0.81, while the improvement for male goats was from 0.71 to 0.79.

In the regression models used to predict the body weight of male and female goats based on the linear body measurements; Y is the response variable (body weight), and X is the explanatory variable (heart girth)

In the Anfillo district, the figures for females and males are, respectively, indicated as follows:

Y = 24.785 + 0.76 HG + 0.41 BL + 0.14 HEW + 0.20 RH + 0.14 PW, and Y = 23.481 + 0.74 HG + 0.42 BL + 0.11 HEW + 0.06 RH + 0.16 SC.

In the Sibu sire district, Y=-44.29 6+1.03HG+0.42BL+1.01HeW+0.20RH+0.51 PW for females, and Y=-56.977 +1.21HG + 0.44BL+0.09HeW+0.43RH+0.67SC for males.

For example, in female Anfillo goats, the heart girth increased by 1 cm for every 0.76 kg rise in body weight.

Zoometric indices

Ten structural and functional indices are computed for each of the districts using various linear measurements and body weight (Table 6). Goat populations in the Anfillo district (90.91) and Sibu Sire district (86.87) may be classified as longiline and medigline, respectively, based on body index (BI) values. The current study's body index values are comparable to those of Chiemela et al. (2016) for Boer does which were 89.44±1.81. These changes could be brought about by age, breed, or variations in the conditions in which goats are managed in various locations.

The proportionality of the hindquarters (rump width and rump length) determines the pelvic index (PI), which is correlated with the reproductive potential of female goats (Chacon et al., 2011). In the research areas, the average pelvic index (PI) value for goat populations was 88.14. The values obtained in the current study were within the range of 80.1 to 84.3 that Birara et al. (2021) reported for goat populations in Farta and Fogera, Amhara region, Ethiopia. For the animals to be fit and have a healthy respiratory system, particularly at higher altitudes, the compact index (CI) and thoracic development index (TDI) are crucial (Chacon et al., 2011; Kumar et al., 2021). Animals classified as meat-types include breeds or populations whose compact index or body conformation index values above 3.15 (Chiemela et al., 2016).

Compact index values of 4.17 and 4.10 we re obtained for goat populations in the Anfillo and Sibu Sire districts, respectively. Many academics, who reported compact index values for diverse goat populations in various locations, such as Birara et al. (2021), and Chiemela et al. (2016) concurred with this finding. Goat populations under consideration in this study are categorized as meat-type goats based on the current compact index values.

Thoracic development is an essential indicator of good fitness and the respiratory system. Particularly for breeds that adapt to higher elevations, thoracic growth is a crucial sign of respiratory health and fitness (Kumar et al., 2021). Animals with good thoracic development have thoracic development index values greater than 1.2 (Chiemela et al., 2016). Goat populations in the study districts had limited thoracic capacity, which is indicative of tall, thin animals that might not be able to survive at the highland altitude, according to the thoracic development index values found for these groups (Table 6). This result is consistent with that of Getaneh et al. (2022), who found that goat populations in the East Gojjam zone had thoracic development values ranging from 1.03±0.05 to 1.08±0.06.

Table 6

The least-square means of body indices of Anfillo and Sibu sire goat populations

Body Indices	Anfillo district	Sibu Sire district	Overall mean	CV (%)
Cephalic index (CeI)	66.64[a]	58.10[b]	62.37±6.03	6.04
Body index (BI)	90.91[a]	86.87[b]	88.89±4.46	4.8
Body frame index (BFI)	0.96	0.96	0.966±0.05	5.3
Body ratio index (BRI)	0.97	0.98	0.97±0.024	2.55
Pelvic index (PI)	88.14	88.14	88.24±9.94	11.27
Conformation/Baron index (ConI)	72.04[a]	74.11[b]	73.08±7.716	10.48
Compact index (CI)	4.17	4.10	4.14±0.601	14.42
Height slope index (HSI)	1.58	1.44	1.51±1.631	107.39
Area index (AI)	3885.80[a]	3523.44[b]	3704.61±617.763	17.19
Thoracic development index (TDI)	1.06[a]	1.10[b]	1.08±0.051	5.10

a b, means that different superscript letters across the row within a group are significant. SEM = standard error of the mean; CV=Coefficient of Variation

CONCLUSIONS

The present morphological characterization investigation's results show that the two districts are mostly characterized by a plain coat color pattern, solid white color, and a combination of other colors. Different coat color patterns and types may be signs of variances that warrant (mass selection) in order to improve genetics. Excluding head and ear length, body weight and all other linear body dimensions were significantly ($p<0.05$) impacted by sex. District had an impact on body weight and linear measurements that were statistically significant ($p<0.05$), except for head length. Linear body measurements, including weight, showed a significant ($p<0.05$) influence from the age group. An interaction between sex and age group on body weight, heart girth, body length, and other variables was shown to be significant ($p<0.05$). The most important variable for predicting body weight was heart girth in both sexes. The regression coefficient values of HG were 77.1% and 83% for female and male goats in the Anfillo district, respectively. The corresponding values for female and male goats of the Sibu Sire district were 76.3% and 71%.

Recommendations

Based on structural indices calculated from linear measurements, goat populations in two districts are classified as meat-type goats. Despite being classified as belonging to the same breed based on prior phenotypic characterization, the goat populations involved in the current morphological characterization displayed morphological differences. This may indicate that phenotypic characterization alone is not enough to satisfy this observed variation, so molecular characterization should be done to identify the goats' unique traits and the variation of goats' populations between the two districts.

CRediT authorship contribution statement

Ayela Abera: Conceptualization, Methodology, Validation **Ayantu Mekonnen:** Formal analysis, Investigation, Resources, Diriba **Diba:** Data Curation, Visualization **Gemeda Duguma:** Writing - Original Draft, Writing - Review & Editing, Supervision.

Declaration of Competing Interest

The authors declare that there is no conflict of interest

Data availability

Data will be made available on request

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