Ethiop. J. Agric. Sci. 34(1) 36-59 (2024)

Morphological characterization of indigenous sheep types in Anfillo and Sibu Sire Districts, Western Oromia, Ethiopia

Dinka Hora, Hasan Yusuf[2], Ayantu Mekonnen[2], Diriba Diba[2], and Gemeda Duguma[2*]
[1]*Anfillo Agricultural Office, West Wallaga zone, Dambi Dollo, Ethiopia;*
[2]*Wallaga University, Po Box 395, Nekemte, Ethiopia*
[*]*Corresponding author: gdjaallataa@yahoo.com*

Abstract

This study was conducted with the objective of morphological characterization of indigenous sheep populations found in Anfillo and Sibu Sire districts of Oromia, Ethiopia. The study districts were selected purposively based on sheep population potential. Four peasant associations were selected from each district purposively based on sheep population. A total of 450 head of sheep (333 females and 117 male) from all age groups were involved in the study. Linear body measurements and field observations were used to capture data. Both quantitative and qualitative data were collected and analyzed. Plain brown coat color, smooth hair type, long-fat tails were the dominant features of sheep populations of the study areas. Location, sex, age and interaction of sex by age had significant effect (at least at $p<0.05$) on live body weight and linear body measurements considered in the current study. Highest positive correlations were observed between body weight and heart girth for both sexes. The analyzed structural indices revealed that sheep populations of the study areas had poor thoracic capacity and classified as meat type. Finally, a comprehensive phenotypic characterization study using more data from wider areas and covering all seasons is warranted.

Keywords: Anfillo; Indigenous sheep; phenotypic characterization; Sibu Sire

Introduction

Ethiopia has estimated sheep population of 42.9 million, out of which about 71% are females and 29% are males. Of the total sheep population, the country owns about 99.52% are indigenous types while only about 0.40% and 0.08% were crossbreds and exotic types, respectively (CSA, 2021). According to this same source, Oromia region possess about 23%. The country is rich in sheep population as well genetic diversity, which is developed by natural selection and potential genetic resources of sheep breeds (Gizaw *et al.* 2007). The existence of this genetic variation between and within breeds provides the raw materials for genetic improvement (Gizaw *et al.* 2010). Focus on this large numbers and diversity of sheep resources in the country might be a way of increasing the livelihood of the sheep producers.

Phenotypic characterization is the first step for identification of qualitative and quantitative traits of the livestock resources in general and indigenous sheep population in particular. The first phase of characterization is surveying to identify populations based on morphological, geographical distribution, uses and husbandry and production environments (Traore *et al*. 2008). Assessment of qualitative traits is subjective as opposed to the quantitative traits that are measured. Quantitative characters are influenced by environmental factors as opposed to the qualitative characters for which the influence of environment is absent or nil (FAO, 2012). Characterization of indigenous sheep breeds using morphological characters has significant importance for planning improvement and conservation strategies (Belay *et al*. 2021). In Ethiopia, there are high morphological variability (Gizaw *et al.* 2008) and variations on phenotypic performances and appearance (Weldeyesus, 2020) among the major sheep breeds/types. Measuring within population diversity is important since it is one of the major criterions to set improvement and conservation priorities (Gizaw *et al.* 2011).

Many sheep characterization studies were conducted in Ethiopia. However, such studies were limited only on few specific sheep types located at specific places. No characterization was done on indigenous sheep breeds/populations in Qellam Wallaga zone as a whole and Sibu Sire district of East Wallaga zone. Nevertheless, an accurate description of sheep population/breed kept under extensive management conditions would enable accurate comparisons of the breed/population with other sheep breeds in the country and elsewhere. In addition, characterization would enable devising improvement programs using information generated from the characterization works.

Materials and Methods

Study areas

The study was conducted at Anfillo district of Qellam Wallaga zone and Sibu Sire district of East Wallaga zone, Oromia. Anfillo district is located at about 694 km from Addis Ababa, capital city of the country, on the west direction. Anfillo district is situated at $8^{0}29'$N latitude and $34^{0}39'$ E longitude. The altitude of the district ranges from 500 to 3470 m.a.s.l. The mean maximum and minimum annual temperature of the district is 33^{0} C and 14 ^{0}C, respectively. The district experiences a uni-modal type of rainfall with annual rainfall ranging from 1453 mm to 2074 mm. The major crops grown in Anfillo district is coffee (Anfillo district Agricultural office, 2023 unpublished data).

Sibu Sire is situated at about 278 km from Addis Ababa to the west direction on the main road to Nekemte. The district is located between altitudes ranging from 800 to 2750 m.a.s.l. Sibu Sire district is situated at $9^{0}4'$N latitude and $36^{0}49'$ E longitude. The mean annual maximum and minimum temperatures recorded for Sibu Sire were 26^0C and 20^0C, respectively. Sibu Sire district experiences a uni-modal type of rainfall ranging from 1000 mm to 1200 mm. The major crops grown in Sibu Sire district are cereal crops mainly maize and sorghum (Sibu Sire district Agricultural office, 2023, unpublished data). Some of the major livestock species produced in both districts are cattle, sheep, goats and equines.

Sampling techniques

Anfillo district of Qellam Wallaga zone and Sibu Sire district of East Wallaga zone, Oromia were purposively targeted for the current study. From each district four peasant associations (PAs) were identified for the study based on sheep population potential. A total of 450 head of sheep (333 females and 117 males) were randomly selected from the two districts and their corresponding PAs for linear body measurements and qualitative traits descriptions. Each sampled sheep was identified by district, sex and age to evaluate influences these categories may exert on body weight and linear body measurements. The qualitative variables recorded were: coat color type, coat color pattern, coat hair type, head profile, ear orientation, presence or absence of wattles, horn shape, horn orientation, presence or absence of horn, presence or absence of ruff, back profile, rump profile, tail type and tail shape. Quantitative traits measured included live body weight, body length, heart girth, wither height, rump height, pelvic width, ear length, tail length, rump width, head width, head length, rump length, tail width and horn length. In addition, scrotum circumference and scrotum length were measured for males. Scrotal circumference is measured by pulling down the testicles and measuring across the widest part of the scrotum. The sampled sheep were classified into five age groups: no pair of permanent incisor (0PPI), one pair of permanent incisor (1PPI), two pairs of permanent incisor (2PPI), three pairs of permanent incisor (3PPI) and four pairs of permanent incisor (4PPI) based on dentition. The average estimated age of the sampled sheep were taken according to Wilson and Durkin (1984) for African sheep breed. According to the authors, age of sheep with zero permanent incisors (0PPI) ranges from 6 to 12 months, those with one pair of permanent incisors (1PPI) are about 15.5 months old, those with two pairs of permanent incisors (2PPI) are about 22.5 months old, those with three pairs of permanent incisors (3PPI) are about 28 months old and those with four pairs of permanent incisors (4PPI) are about 39 months old and above. In the current study due to fewer number of animals above 2PPI, age groups used were 0PPI, 1PPI and ≥ 2PPI.

Data collection methods

Both the linear body measurements and body weight were recorded on 450 head of sheep (333 females and 117 males) maintained under on-farm conditions by smallholder sheep producers. All linear body measurements were taken by ensuring that each animal was in a standing position and weight of an animal was proportionally on all four feet. Physical restraint was sometimes applied, particularly for those which had wild behavior, to limit their movement. Pregnant females were excluded from sampling to remove the effect of pregnancy on some of body parameters. Similarly, castrates were excluded from the sampling. Fourteen qualitative traits were observed and recorded on the breed morphological characteristics descriptor list of FAO (2012). The linear body measurements were measured using measuring tape whereas live body weight was taken by using a hanging spring scale having 50 kg capacity with 200 g (0.2 kg) precision. Vertical measurements such as wither height and rump height were measured by using wooden meter.

Data analysis

Districts, sex, age and sex by age interaction were fitted as fixed effects while live body weight and other linear body measurements were considered as dependent variables. The General Linear Model (GLM) Procedure of the Statistical Analysis System (SAS, release 9.4, 2012) was employed to analyze quantitative variables to determine effects of class variables. The Statistical Package for Social Sciences (SPSS) was employed to analyze qualitative variables; where a chi-square (X^2) was fitted test significance. Pearson correlation was carried out to evaluate the relationship among live body weight the different linear measurements for each sex. This is to know whether the attributes are positively or negatively associated and to know the magnitude of their associations. Stepwise multiple linear regression analysis was carried out to obtain the best fit model to predict body weight of both sexes from the linear body measurements.

The following model was fitted to analyze the linear body measurements and live body weight, except scrotal circumstances and scrotal length:

$$Y_{ijkl} = \mu + A_i + S_j + D_k + (AS)_{ij} + e_{ijkl}$$

Where:

Y_{ijkl} = the observed mean live body weight or linear body measurements in the i^{th} age group, j^{th}sex and k^{th} district**,**

μ= overall mean,

A_i= the i^{th} effect of age group (0PPI, 1PPI and ≥ 2PPI),

S_j= the j^{th} effect of sex (1=male, 2= female),

D_k= the k^{th} effect of district (1 =Anfillo district, 2= Sibu Sire district),

$(AS)_{ij}$= the interaction effect of i^{th} age group and j^{th} sex, and

e_{ijkl}= random residual error

The model fitted to analyze the scrotal circumference (SC) and scrotal length (SL) was:

$$Y_{ikl} = \mu + A_i + D_k + e_{ikl}$$

Where:

Y_{ikl} = the observed or measured mean scrotal circumference (SC) or scrotal length (SL) in the i^{th} age group and k^{th} district,
μ= overall mean,
A_i= the i^{th} effect of age group (0PPI, 1PPI and ≥ 2PPI),
D_k= the k^{th} effect of district (1 =Anfillo district, 2= Sibu Sire district),
e_{ikl}= random residual error

The statistical models used for the analysis of multiple linear regressions are indicated for females and males as indicated below.

1) For females:

$$Yj = \beta0 + \beta1X1 + \beta2X2 + \beta3X3 + \beta4X4 + \beta5X5 + \beta6 X6 + \beta7X7 + Ej$$

Where, Yj= the dependent variable live body weight, β0 = the intercept, X1, X2, X3, X4, X5, X6 and X7 are the independent variables; heart girths, body length, wither height, rump height, tail length, rump width, pelvic width, respectively, β1, β2, β3, β4, β5, β6 and β7are the regression coefficients of the variables X1, X2, X3, X4, X5, X6 and X7 respectively, Ej = the residual random error

2) For males:

$$Yj = \beta0 + \beta1X1 + \beta2X2 + \beta3X3 + \beta4X4 + \beta5X5 + \beta6 X6 + \beta7X7 + Ej$$

Where: Yj= the dependent variable body weight, β0= the intercept, Ej = the residual random error,
X1, X2, X3, X4, X5, X6 and X7 are the independent variables; heart girths, body length, wither height, rump height, scrotal circumstances, scrotal length and tail length respectively, β1, β2, β3, β4, β5, β6, and β7 are the regression coefficients of the variables X1, X2, X3, X4, X5, X6 and X7, respectively.

Eleven structural indices (Body index (BI), Body frame index (BFI), Pelvic index (PI), Area index (AI), Body ratio index (BRI), Compact index (CI), Height slope index (HIS), Proportionality index (PrI), Thoracic development index (TdI), Conformational index (ConI) and Cephalic index (Cel)) were calculated from the morphometric measurements of traits based on Salako (2006), Banerjee. (2015) and Chiemela *et al*. (2016) to assess the types and functions of the indigenous sheep types in the study areas.

Results and Discussions

Characterization of qualitative traits

Detailed qualitative characters of the studied sheep population are presented in Tables 1 and 2. The overall major dominant coat color patterns observed were plain (79.10%) followed by patchy (20.90%) in both districts. Plain coat color pattern was more dominant at Sibu Sire than it was at Anfillo district. About 90.2% and 68% head of sheep observed had plain coat color at Sibu Sire and Anfillo districts, respectively. Patchy coat color pattern (32%) was observed at

Anfillo district which was 9.8% at Sibu Sire district. The likely explanation for the coat color variation at Anfillo district may indicate the absence of selection intervention compared to sheep flocks at Sibu Sire district. Smallholder sheep producers at Sibu Sire district may have better exposure to agricultural extension services due to the presence of Bako Agricultural Research Center nearby/at its vicinity.

Majority of the studied sheep population (70.2%) were characterized by having short and smooth coat hair type in both districts, which might be one of the indictors for evaluating the adaptability of the sheep population in these particular study areas. About 68.4% and 72% of sheep observed in the current study had short and smooth hair type, respectively. With regard to head profile, about 93.1% of the sheep (about 94.7% at Sibu Sire district and 91.6% at Anfillo district) had straight head profile. The result is paralleled with the report of Birhanu and Oli (2020). All of the sampled sheep in both districts were polled. Duguma *et al.* (2011) also characterized Horro sheep as polled and a breed having a long fat tail. About 94.6% and 64.5% of sheep flocks had either semi-pendulous or pendulous ear orientation at Sibu Sire and Anfillo districts, respectively. The qualitative characteristics obtained in the current study are in general agreement with the report of Edea *et al*. (2009) for Horro sheep. The observed tail shape was similar with the result of Edea (2008) and Hizkel (2017) for Horro sheep breed and Bonga sheep breed (indigenous sheep types in southern Ethiopia), respectively. In the present study, the frequently observed back profile was straight (65.8%) followed by slopes up towards the rump (27.1%) and slopes down from withers (5.3%). The majority of rump profile recorded was sloppy (52.7%) followed by flat type of ramp (26.2%). Sheep flocks at both districts had neither ruff nor wattles. All sheep flocks monitored had long straight fatty tail which is slightly twisted at its tip below the hock. The qualitative characters reported in the current study are in general agreement with literature reports (Galal, 1983; Edea, 2008; Duguma et al., 2011).

Table 1: Summary of coat color types of sheep population of the study areas

Traits	Descriptors	Districts													
		Anfillo						Sibu Sire						Overall	
		Male		Female		Total		Male		Female		Total			
		№	%	№	%	№	%	№	%	№	%	№	%	№	%
Coat color pattern	Plain	51	76.1	102	64.5	153	68	47	94	156	89.1	203	90.2	356	79.1
	Patchy	16	23.9	56	35.4	72	32	3	6	19	10.9	22	9.8	94	20.9
	Total	67	100	158	100	225	100	50	100	175	100	225	100	450	100
	X^2 between population	33.7**													
Coat color type	White	10	14.9	9	5.7	19	8.4	1	2.0	19	10.9	20	8.9	39	8.7
	Red	4	5.97	13	8.2	17	7.6	3	6.0	17	9.7	20	8.9	37	8.2
	Black	3	4.50	8	5.1	11	4.9	2	4.0	24	13.7	26	11.5	37	8.2
	Brown	31	46.3	67	42.4	98	43.6	23	46.0	62	35.4	85	37.8	183	40.6
	Light brown	3	4.5	5	3.2	8	3.6	18	36	34	21.1	52	23.1	60	13.3
	Red and White with red dominant	1	1.5	13	8.2	14	6.2			3	1.7	3	1.3	17	3.80
	Black + White with black dominant	4	6.0	11	7.0	15	6.7							15	3.3
	White + black with white dominant	3	4.5	8	5.1	11	5.9							11	2.4
	Brown & white with brown dominant	6	9.0	18	11.4	24	10.7	2	4.0	9	5.1	11	4.9	35	7.8
	White + brown with white dominant	1	1.5	4	2.5	5	2.2			5	2.9	5	2.2	10	2.2
	Brown & black with brown dominant	1	1.5	2	1.3	3	1.3	1	2.0	2	1.1	3	1.3	6	1.3
	Total	67	100	158	100	225	100	50	100	175	100	225	100	450	100
	X^2 between population	77.5**													
Coat hair type	Short and smooth	45	67.2	117	74.1	162	72	31	62	123	70.3	154	68.40	316	70.2
	Short and course	22	32.8	41	25.9	63	28	19	38	52	29.7	71	31.60	134	29.8
	Total	67	100	158	100	225	100	50	100	175	100	225	100	450	100
	X^2 between population	10.7**													

Table 2. Summary of some of qualitative traits of sheep population of the study areas

Head profile	Straight	57	85.10	149	94.3	206	91.6	38	76	175	100	213	94.67	419	93.1
	Slightly concave			3	1.9	3	1.3							3	0.7
	Slightly convex	10	14.9	6	3.8	16	7.1	12	24			12	5.33	28	6.2
	Total	67	100	158	100	225	100	50	100	175	100	225	100	450	100
	X^2 between population	3.7NS													
Horn	Absent	67	100	158	100	225	100	50	100	175	100	225	100	450	100
Ear orientation	Pendulous	23	34.3	57	36.1	80	35.6	4	8	46	26.3	50	22.2	130	28.9
	Semi-pendulous	34	49.3	67	42.4	101	44.9	41	82	122	69.7	163	72.4	264	58.9
	Horizontal	10	14.9	34	21.5	44	19.6	5	10	7	4	12	5.3	56	12.4
	Total	67	100	158	100	225	100	50	100	175	100	225	100	450	100
	X^2 between population	39.8**													
Back profile	Straight	43	64.20	104	65.80	147	65.3	37	74	112	64	149	66.20	296	65.8
	Slopes up towards the rump	15	22.40	34	21.50	49	21.8	13	26	60	34.30	73	32.40	122	27.1
	Slopes down from withers	9	13.40	12	7.60	21	9.3			3	1.70	3	1.3	24	5.3
	Curved			8	5.10	8	3.6							8	1.80
	Total	67	100	158	100	225	100	50	100	175	100	225	100	450	100
	X^2 between population	26.3**													
Rump profile	Flat	28	41.80	52	32.90	80	35.6	13	26	25	14.30	38	16.90	118	26.2
	Sloppy	36	53.7	95	60.1	131	58.2	30	60	76	43.4	106	47.1	237	52.7
	Roofy	3	4.5	11	7.0	14	6.2	7	14	74	42.3	81	36	95	21.1
	Total	67	100	158	100	225	100	50	100	175	100	225	100	450	100
	X^2 between values	64.8**													
Wattles	Absent	59	88.1	142	89.9	201	89.3	48	96	166	94.9	214	95.1	415	92.2
	Present	8	11.9	16	10.1	24	10.7	2	4	9	5.1	11	4.9	35	7.8
	Total	67	100	158	100	225	100	50	100	175	100	225	100	450	100
	X^2 between population	5.2*													
Ruff	Absent	54	80.6	154	97.5	208	92.4	10	20	174	99.4	184	81.8	392	87.1
	Present	13	19.4	4	2.50	17	7.6	40	80	1	0.60	41	18.2	58	12.9
	Total	67	100	158	100	225	100	50	100	175	100	225	100	450	100
	X^2 between population	11.4**													
Tail type	Long fat tailed	67	100	158	100	225	100	50	100	175	100	225	100	450	100
Tail shape	Straight tip	36	53.7	109	68.9	145	64.4	21	42	87	49.7	108	48	253	56.2
	Twisted up at the tip	31	46.3	49	31	80	35.6	29	58	88	50.3	117	52	197	43.8
	Total	67	100	158	100	225	100	50	100	175	100	225	100	450	100
	X^2 between population	12.4**													

Live Body Weight and Linear body measurements

The least squares means (±SE) for the effect of district, sex, age and the interaction of sex and age on live body weight and linear body measurements of sheep population in the study areas are presented in Table 3. District had significant effect ($p<0.01$) on live body weight and most of the linear body measurements, except rump height (RH), wither height (WH), head width (HW) and head length (HL). Sheep flocks at Sibu Sire district had significantly heavier body weight and higher body length (BL) and heart girth (HG) than sheep flocks at Anfillo district. On the other hand, sheep flocks at Anfillo district had higher rump length (RL), rump width (RW), wider pelvic width (PW), tail length (TL), tail width (TW) and ear length. Intact males from Sibu Sire had significantly ($p<0.05$) larger scrotum circumference (SC) than those at Anfillo district. They had, however, shorter scrotal length (SL) than males at Anfillo district. The likely explanation for the higher body weight and larger scrotum circumference may be due to the fact that testicular development in rams is positively associated with body weight (Motos and Thomas, 1992). The difference in body weight may be due to agro-ecology difference and differences in production environments. Wagari *et al.* (2020) also reported that location/agro-ecology had significant effect on live body weight and most of the linear body measurements. Contrary to the present result, Michael *et al* (2016) reported that location had no effect ($p>0.05$) on live body weight of sheep in Northern Ethiopia.

Sex had significant ($p<0.01$) effect on mean live body weight and most of the linear body measurements, except ear length (EL), head width (HW) and head length (HL) (Table 2). Higher values were recorded for male sheep for both live body weight and all linear body measurements including ear length (EL), head width (HW) and head length (HL) those traits for which both sexes did not vary significantly. The least squares mean live body weight of rams and ewes obtained in the current study were 26.2±0.50 kg and 23.1±0.60 kg, respectively. On average, males were heavier than females by about 3.1 kg. The higher performance of males compared to their female counterparts reported in the current study is in close agreement with results reported in the literatures (Kassahun, 2000; Tibbo *et al.* 2004; Hizkel *et al*. 2017; Wagari *et al.* 2020). According to Sowande and Sobola (2007), female sheep have slower growth rate and reach maturity at smaller size compared to males due to the effect of estrogen that restricts the growth of the long bones of the body. Therefore, it might be due to this effect that male sheep were heavier than female sheep in most variables considered, except ear length, head width and head length.

Age had significant (at least at $p<0.05$) on live body weight and the linear body measurements evaluated in the current study (Table 2). Both live body weight and linear body measurements have showed significant ($p<0.01$) increasing trend with advance in age. The live body weight of the sampled sheep increased by 4.6kg and

6.08kg as sheep age advances from milk tooth (0PPI) to 1PPI dentition class and from 1PPI to ≥ 2PPI dentition class, respectively. The age effect obtained in the current study is in general agreement with the findings reported in the literatures (Edea *et al*. 2009; Weldeyesus and Yayneshet, 2016; Nurlign *et al*. 2017; Zemenu, 2020).

Sex by age interaction effect significantly ($p<0.01$) influenced both the live body weight and most of the linear body measurements, except ear length (EL), head width (HW) and head length (HL) (Table 2**.** Males with 0PPI, 1PPI and ≥ 2PPI age groups weighed 22.0±0.20 kg, 25.7±1.00 kg and 30.9±0.40 kg, respectively. The corresponding female age groups weighed 18.2±0.90kg, 23.2±0.90 kg and 28.1±0.70 kg, respectively. The differences of about 3.8 kg, 2.5 kg and 2.8 kg were observed among the different male and female age groups in live body weight. Similar trends were also obtained for the linear body measurements in both sexes of different age groups. In line with the current study, Kerga (2021) reported that male sheep are larger than female sheep with quantitative traits in Gurage zone of Southern Ethiopia.

Table 3. Least square means and standard error (LSM ± SE) of live body weight and least square means of sampled sheep

Effect	N	BW(Kg)	BL(cm)	HG(cm)	RL(cm)	RH(cm)	RW(cm)	PW(cm)	SC(cm)
Overall	450	24.7±0.65	58.1±0.39	65.2±0.53	17.4±1.70	61.1±0.40	15.9±1.70	14.5±1.50	26.0±2.65
CV	450	12.7	6.4	5.3	9.9	4.7	10.5	10.2	12.3
R^2	450	0.71	0.62	0.60	0.5	0.6	0.50	0.50	0.60
Districts		**	*	**	*	**NS**	**	**	*
Anfillo	225	23.4±0.80^{b}	57.1±0.40^{b}	63.6±0.75^{b}	17.8±1.90^{a}	60.9±0.20^{b}	16.6±1.70^{a}	15.3±1.60^{a}	25.5±3.60^{b}
Sibu Sire	225	25.9±0.30^{a}	59.2±0.35^{a}	66.7±0.31^{a}	17.0±1.40^{b}	61.2±0.60^{b}	15.2±1.65^{b}	13.7±1.40^{b}	26.5±1.70^{a}
Sex		**	**	**	**	**	**	**	
Male	117	26.2±0.50^{a}	59.4±0.38^{a}	66.5±0.80^{a}	18.0±1.50^{a}	62.3±0.10^{a}	16.6±1.60^{a}	15.3±1.40^{a}	25.9±3.20
Female	333	23.1±0.73^{b}	56.8±0.40^{b}	63.8±0.33^{b}	16.8±1.80^{b}	60.0±0.72^{b}	15.2±1.70^{b}	13.8±1.50^{b}	
Age		**	**	**	**	**	**	**	**
0PPI	160	19.1±0.40^{c}	53.5±0.51^{c}	61.7±0.31^{c}	15.8±1.40^{c}	57.5±0.30^{c}	14.4±1.40^{c}	13.1±1.60^{c}	22.4±4.00^{c}
1PPI	92	23.7±0.60^{b}	57.8±0.26^{b}	64.9±0.72^{b}	17.5±1.80^{b}	60.8±0.65^{b}	15.6±1.40^{b}	14.5±1.20^{b}	25.7±1.70^{b}
≥2PPI	198	29.8±0.80^{a}	62.9±0.40^{a}	68.8±0.52^{a}	18.9±2.00^{a}	65.0±0.34^{a}	17.8±2.10^{a}	16.1±1.80^{a}	29.9±2.70^{a}
Sex by age		**	**	**	**	**	**	*	
0Female	113	18.2±0.90^{e}	52.1±0.35^{f}	59.7±0.33^{e}	15.6±1.40^{cd}	56.3±0.90^{f}	14.0±1.40^{d}	12.6±1.30^{e}	
1Female	71	23.2±0.90^{d}	56.7±0.37^{d}	64.3±0.29^{c}	16.5±1.80^{c}	59.8±0.90^{d}	15.0±1.40^{c}	13.5±1.20^{d}	
≥2Female	149	28.1±0.70^{b}	61.6±0.43^{b}	68.2±0.40^{b}	18.5±2.00^{b}	64.0±0.32^{b}	16.6±2.50^{b}	15.2±1.80^{b}	
0Male	47	22.0±0.20^{d}	54.9±0.48^{e}	63.2±0.64^{d}	16.0±1.40^{dc}	58.7±0.05^{e}	14.9±1.20^{c}	13.6±1.10^{d}	22.4±4.00^{c}
1Male	21	25.7±0.10^{c}	58.5±0.24^{c}	65.5±0.80^{c}	18.0±1.70^{b}	61.5±0.08^{c}	16.6±1.50^{b}	15.0±1.40^{c}	25.7±1.70^{b}
≥2Male	49	30.9±0.40^{a}	64.9±0.40^{a}	70.3±0.97^{a}	19.9±1.50^{a}	66.8±0.27^{a}	18.5±1.90^{a}	17.0±1.70^{a}	29.9±2.70^{a}

Means with different superscripts within the same column and class are statistically different (at least *P*<0.05). NS = non-significant; NA = not applicable. * Significant at 0.05 **significant at 0.01 0PPI = 0Pair of permanent incisor, 1PPI = 1Pairs of permanent incisors and ≥2PPI=2 or more pairs of permanent incisors=number, CV=coefficient of variation, R^2 =coefficient of determination, BW=body weight, BL=body length, HG=heart girth, RL=rump length, RH=rump height, RW=rump width, PW=Pelvic width, SC=scrotal circumstances,

Table 3. Continued

Effect	N	SL(cm)	TL(cm)	TW(cm)	EL(cm)	WH(cm)	HW(cm)	HL(cm)
Overall	450	11.8±1.20	28.0±0.50	12.2±1.50	9.8±0.80	60.2±0.93	9.6±0.90	16.2±1.73
CV	450	10.5	12.4	12.9	9.3	5	9.30	10.7
R^2	450	0.50	0.30	0.50	0.20	0.60	0.30	0.24
Districts		**	**	**	**	**NS**	**NS**	**NS**
Anfillo	225	12.6±1.30^{a}	29.6±0.40^{a}	13.1±1.50^{a}	10.4±0.80^{a}	59.8±0.89	9.6±0.90	16.0±2.30
Sibu Sire	225	11.0±1.00^{b}	26.3±0.60^{b}	11.4±1.30^{b}	9.1±0.80^{b}	60.5±0.96	9.5±0.76	16.3±0.63
Sex			**	**	**NS**	**	**NS**	**NS**
Male	117	11.9±1.30	29.0±0.40^{a}	13.3±1.40^{a}	9.9±0.80	61.10±.84^{a}	9.6±0.80	16.40±1.60
Female	333		26.9±0.50^{b}	11.2±1.60^{b}	9.7±0.90	59.20±.93^{b}	9.5±0.90	15.90±1.80
Age		**	**	**	*	**	**	**
0PPI	160	10.4±1.30^{c}	25.6±0.55^{c}	10.2±1.50^{c}	8.5±0.80^{c}	56.0±0.88^{c}	8.2±0.80^{c}	14.5±1.70^{c}
1PPI	92	11.9±1.20^{b}	27.5±0.35^{b}	12.1±1.30^{b}	9.7±0.80^{b}	60.3±0.85^{b}	9.4±1.00^{b}	15.9±1.30^{b}
≥2PPI	198	13.2±1.20^{a}	30.8±0.64^{a}	13.9±1.80^{a}	10.6±0.90^{a}	63.9±1.00^{a}	10.6±0.90^{a}	17.3±2.00^{a}
Sex by age		*	**	*	**NS**	*	**NS**	**NS**
0Female	113		24.8±0.34^{d}	10.4±1.00^{d}	9.8±0.90	55.5±0.98^{e}	8.8±0.80	15.5±1.80
1Female	71		26.7±0.45^{c}	10.7±1.30^{d}	9.9±0.80	58.8±0.90^{d}	9.4±1.10	15.9±1.40
≥2Female	149		29.2±0.70^{b}	12.5±1.90^{c}	10.2±0.90	62.8±0.95^{b}	10±0.90	16.3±2.00
0Male	47	10.4±1.30^{c}	26.5±0.38^{c}	11.7±1.60^{c}	9.9±0.80	57.1±0.80e	9±0.80	16.0±1.50
1Male	21	11.9±1.20^{b}	28.3±0.26^{b}	13.4±1.40^{b}	9.9±0.90	60.5±0.69^{c}	9.3±1.00	16.3±1.00
≥2Male	49	13.2±1.20^{a}	32.2±0.60^{a}	15.0±1.20^{a}	10.3±1.10	65.9±0.95^{a}	10.3±0.80	16.7±1.90

Means with different superscripts within the same column and class are statistically different (at least P<0.05). NS = non-significant; NA = not applicable. * Significant at 0.05 **significant at 0.01, 0PPI = 0Pair of permanent incisor, 1PPI = 1Pairs of permanent incisors and ≥2PPI=2 or more pairs of permanent incisors, CV=Coefficient variation, R^2 =Coefficient of determination, SL=Scrotal length, TL=tail length, TW=tail width, EL=ear length, WH=withers height, HW=head width, HL=head length

Correlation between live body weight and linear body measurements

The Pearson's correlation coefficients (r) between the live body weight and linear body measurements are presented in Tables 4 and 5 for sheep flocks of Anfillo and Sibu Sire districts, respectively. Live body weight was significantly ($p<0.01$) correlated with all linear body measurements considered in the present study, except ear length in both districts. Ear length was positively and significantly (at least at $p<0.05$) associated with linear body measurements, except body weight at Anfillo district for both male and female sheep. It was however, only significantly ($p<0.01$) and positively associated with head width (HW) and head length (HL) for female sheep at Sibu Sire district. In the current study, the highest correlation coefficient values of 0.94 and 0.91 were obtained between heart girth (HG) and body weight (BW) for male and female sheep at Sibu Sire district, respectively (Table 5). The corresponding correlation coefficient values for male and female sheep of Anfillo district were 0.91 and 0.89, respectively. Similar trends were reported by Karga (2021). Highest correlation coefficient value of 0.91 was recorded between heart girth (HG) and body weight (BW) and between body length (BL) and rump height (RH) for males at Anfillo district (Table 4). Among the linear body measurements evaluated, heart girth had the highest positive association with live body weight for both sexes at Sibu Sire district. The current finding is in general agreement with findings reported in the literatures (Bosenu *et al*. 2014; Mohammed *et al*. 2015**;** Abbaya and Dauda, 2018; Guadie, 2021; Sintayehu, 2021). The current findings confirmed that heart girth is the best variable for the prediction of live body weight than other measurements. This is particularly important in rural settings where weighing balance is not available.

Multiple linear regression analysis

The multiple linear regression analysis of live body weight on different body measurements for Anfillo and Sibu Sire district is presented in Tables 6 and 7, respectively. Seven linear body measurements were included for both sexes to estimate live body weight from them. Stepwise regression analysis was employed for each district for each sex by entering all the seven linear body measurements at a time. The R^2 (coefficient of determination) was the criterion used to select the model that best predict the live body weight of sheep. That means, the higher the R^2 value indicates that the statistical model well predicts an outcome. The result of the stepwise multiple regression analyses in the present study showed that adding of other linear body measurement's to heart girth did not result in a significant improvements in accuracy of live body weight prediction. Hence, the present study suggested that live weight estimation using sole heart girth would be preferable under field conditions. Similar trends were also reported by Asefa *et al*. (2017), Hizkel (2017), Abebe and Korato (2020). Heart girth consists of bones, muscles and viscera that share larger contribution to the body weight

(Thiruvenkadan, 2005). Based on the current study findings the following regression equations are suggested for the flocks of the two districts for each sex group.

I. Anfillo district:
   a. Male sheep: Y= -38.787+0.980X
   b. Female sheep: Y= -38.062+ 0.971X

II. Sibu Sire district:
   a. Male sheep: Y = -40.900+ 0.997X
   b. Female sheep: Y=-56.154+1.217X

where: Y and X are live body weight) BW) and heart girth (HG), respectively.

Table 4. The coefficient of correlation between body weight and linear body measurements of sheep population in Anfillo district (above diagonal for males and below diagonal for females N= 67 males and N=158 females)

Traits	BW	BL	HG	RL	RH	RW	PW	SC	SL	TL	TW	EL	WH	HW	HL
BW	**1**	.87**	.91**	.75**	.86**	.77**	.71**	.65**	.62**	.63**	.74**	.55ns	.86**	.52**	.51**
BL	.86**	**1**	.88**	.69**	.91**	.73**	.68**	.63**	.69**	.64**	.73**	.57**	.89**	.60**	.45**
HG	.89**	.87**	**1**	.71**	.90**	.79**	.68**	.62**	.59**	.61**	.67**	.54**	.87**	.50**	.40**
RL	.75**	.73**	.77**	**1**	.74**	.88**	.72**	.56**	.50**	.52**	.60**	.47**	.75**	.37**	.60**
RH	.86**	.87**	.92**	.77**	**1**	.80**	.74**	.68**	.67**	.67**	.76**	.60**	.96**	.60**	.49**
RW	.72**	.69**	.70**	.84**	.73**	**1**	.84**	.64**	.61**	.60**	.64**	.52**	.77**	.48**	.58**
PW	.65**	.63**	.61**	.72**	65**	.87**	**1**	.63**	.69**	.62**	.66**	.62**	.74**	.58**	.59**
SC								**1**	.69**	.60**	.63**	.66**	.65**	.55**	.35**
SL									**1**	.66**	.69**	.63**	.66**	.76**	.32**
TL	.64**	.55**	.52**	.41**	.58**	.46**	.53**			**1**	.60**	.52**	.69**	.55**	.26*
TW	.69**	.70**	.61**	.61**	.67**	.64**	.62**			.51**	**1**	.68**	.75**	.63**	.53**
EL	.51ns	.50**	.38**	.39**	.48**	.48**	.51**			.49**	.48**	**1**	.60**	.61**	.44**
WH	.85**	.85**	.88**	.72**	.94**	.72**	.66**			.57**	.68**	.50**	**1**	.62**	.47**
HW	.54**	.54**	.45**	.32**	.51**	.41**	.43**			.55**	.48**	.53**	.53**	**1**	34**
HL	.49**	.51**	.55**	.56**	.51**	.46**	.39**			.20*	.40**	.19*	.46**	.25**	**1**

BW=body weight, BL=body length, HG=heart girth, RL=rump length, RH=rump height, RW=rump width, PW=pelvic width, SC=scrotal circumstances, SL=scrotal length, TL=tail length, TW=tail width, EL=ear length, WH=withers height, HW=head width, HL=head length, NA=not applicable, ns=non-significances=non significance, * significant at 0.05, **significant at 0.01

Table 5. The coefficient of correlations between body weight and linear body measurements of sheep population in Sibu Sire district (above diagonal for males and below diagonal for females) (N= 50 males and N=175 females)

Traits	BW	BL	HG	RL	RH	RW	PW	SC	SL	TL	TW	EL	WH	HW	HL
BW	**1**	.89**	.94**	.83**	.89**	.80**	.77**	.87**	.80**	.67**	.71**	0.05ns	.91**	.58**	.67**
BL	.87**	**1**	.89**	.85**	.89**	.84**	.83**	.84**	.72**	.62**	.69**	0.03ns	.88**	.63**	.58**
HG	.91**	.85**	**1**	.74**	.91**	.76**	.76**	.79**	.76**	.59**	.65**	0.10ns	.88**	.55**	.59**
RL	.64**	.65**	.47**	**1**	.80**	.81**	.78**	.76**	.66**	.65**	.62**	-0.13ns	.83**	.63**	.45**
RH	.87**	.87**	.84**	.68**	**1**	.79**	.77**	.80**	.81**	.65**	.72**	0.01ns	.97**	.54**	.60**
RW	.74**	.72**	.64**	.69**	.74**	**1**	.90**	.72**	.67**	.64**	.61**	0.04ns	.81**	.73**	.49**
PW	.73**	.67**	.71**	.51**	.72**	.80**	**1**	.69**	.65**	.66**	.69**	0.12ns	.75**	.72**	.57**
SC								**1**	.85**	.60**	.63**	0.06ns	.79**	.59**	.59**
SL									**1**	.58**	.59**	0.04ns	.81**	.43**	.50**
TL	.60**	.54**	.45**	.62**	.60**	.65**	.58**			**1**	.68**	0.01ns	.64**	.49**	.45**
TW	.44**	.41**	.34**	.64**	.52**	.48**	.41**			.55**	**1**	0.14ns	.70**	.47**	.54**
EL	.31ns	.27**	.40**	-.17*	.17*	.22**	.37**			0.06ns	-.25**	**1**	0.03ns	0.22ns	.37**
WH	.62**	.63**	.47**	.59**	.68**	.61**	.55**			.69**	.48**	0.04ns	**1**	.54**	.58**
HW	.43**	.39**	.47**	.22**	.40**	.40**	.43**			0.11ns	0.12ns	.27**	0.09ns	**1**	.43**
HL	.75**	.63**	.70**	.36**	.63**	.60**	.63**			.60**	.24**	.45**	.49**	.35**	**1**

Acronym as indicated under Table 3

Table 6. Multiple regression analysis of live body weight on different linear body measurements for sheep population at Anfillo district of all age group

Sex	Model	Intercept	β_1	β_2	β_3	β_4	β_5	B_6	B_7	R^2	Adj.R^2	MSE
Female (N=158)	HG	-38.062	0.971							0.77	0.74	8.59
	HG+BL	-36.143	0.530	0.455						0.80	0.80	7.74
	HG+BL+WH	-39.488	0.351	0.354	0.346					0.81	0.81	7.18
	HG+BL+WH+RH	-39.238	0.370	0.359	0.38	-0.062				0.81	0.81	7.22
	HG+BL+WH+RH+ TL	-38.852	0.419	0.311	0.347	-0.174	0.274			0.84	0.83	6.26
	HG+BL+WH+RH+ TL+RW	-36.812	0.403	0.293	0.312	-0.207	0.267	0.259		0.85	0.84	6.06
	HG+BL+WH+RH+ TL+RW+PW	-36.680	0.393	0.297	0.322	-0.213	0.280	0.370	-0.145	0.86	0.84	6.07
Male (N=67)	HG	-38.787	0.980							0.80	0.78	8.67
	HG+BL	-34.840	0.575	0.375						0.83	0.82	7.22
	HG+BL+WH	-36.805	0.495	0.275	0.215					0.83	0.82	7.07
	HG+BL+WH+RH	-36.163	0.517	0.285	0.285	-0.112				0.83	0.82	7.16
	HG+BL+WH+RH+SC	-33.810	0.520	0.275	0.302	-0.203	0.109			0.84	0.83	7.02
	HG+BL+WH+RH+SC+SL	-33.740	0.517	0.278	0.302	-0.201	0.112	-0.026		0.85	0.82	7.14
	HG+BL+WH+RH+SC+SL+TL	-33.941	0.514	0.282	0.273	-0.191	0.105	-0.072	0.065	0.86	0.84	7.23

HG=Heart girth, BL=Body length, WH=Wither height, RH=Rump height, TL=Tail length, RW=Rump width, PW=Pelvic width, MSE=Mean square error, R^2 =coefficient of determination

Table 7: Multiple regression analysis of live weight on different linear body measurements for sheep population in Sibu Sire district

Sex	Model	Intercept	β1	β2	β3	β4	β5	B6	B7	R^2	Adj.R^2	MSE
Female(N=175)	HG	-40.900	0.997							0.83	0.82	4.09
	HG+BL	-37.909	0.655	0.336						0.86	0.86	3.21
	HG+BL+WH	-41.782	0.700	0.202	0.146					0.88	0.88	2.80
	HG+BL+WH+RH	-42.865	0.642	0.161	0.119	0.145				0.88	0.88	2.76
	HG+BL+WH+RH+ TL	-42.568	0.643	0.164	0.057	0.101	0.225			0.89	0.89	2.54
	HG+BL+WH+RH+ TL+RW	-43.414	0.639	0.114	0.055	0.740	0.182	0.351		0.90	0.89	2.49
	HG+BL+WH+RH+ TL+RW+PW	-43.263	0.651	0.138	0.056	0.075	0.185	0.405	-0.122	0.91	0.89	2.50
Male(N=50)	HG	-56.154	1.217							0.87	0.84	4.72
	HG+BL	-45.317	0.586	0.535						0.90	0.90	3.08
	HG+BL+WH	-45.306	0.407	0.390	0.335					0.92	0.91	2.62
	HG+BL+WH+RH	-45.632	0.465	0.402	0.488	-0.218				0.92	0.91	2.62
	HG+BL+WH+RH+SC	-42.611	0.455	0.257	0.477	-0.284	0.418			0.94	0.93	2.08
	HG+BL+WH+RH+SC+SL	-42.982	0.464	0.238	0.491	-0.275	0.459	-0.139		0.94	0.93	2.12
	HG+BL+WH+RH+SC+SL+TL	-43.050	0.472	0.230	0.483	-0.307	0.435	0.154	0.123	0.96	0.94	2.04

HG=Heart girth, BL=Body length, WH=Wither height, RH=Rump height, TL=Tail length, RW=Rump width, PW=Pelvic width, MSE=Mean square error, R^2= coefficient of determination

Structural indices of sheep population of the study areas

Indices calculated from body measurements are presented in Table 8. The overall mean body index value of 89 was obtained in the current study. The mean body index value (90) obtained from sheep flocks at Anfillo district was significantly different ($p<0.05$) from the mean body index value (88.6) obtained from sheep flocks of Sibu Sire district. The overall mean value obtained in the present study areas are higher than the 78.6 and 88.4 body index values reported for the local and crossbred sheep, respectively (Mohammed *et al*., 2018). According to Dauda (2018) and Silva-Jarquin *et al.* (2019), when index of proportionality or body index value is ≥ 0.90 the animals have longiline profile, body index value between 0.86-0.89 indicate that animals have medigline profile and body index value ≤ 0.85 indicate that animals have brevigline profile. Thus, sheep population at Anfillo district has longiline profile while those sheep population at Sibu Sire district has medigline profile. In the current study, there were significant differences ($p<0.05$) between sheep populations at Anfillo and Sibu Sire districts pelvic index, area index, height slope index, conformational index and cephalic index values (Table 7). However, significant differences ($p>0.05$) were not observed between the two sheep population in body frame index, body ratio index, compact index, proportionality index and thoracic development index values computed.

The area index values obtained from sheep population at Sibu Sire district was significantly ($p<0.05$) higher than the area index value recorded for sheep population at Anfillo district (Table 8). This indicates that Sibu Sire sheep have larger body surface than those of Anfillo district. According to Dereje *et al*. (2019), animals with larger body surface area relative to their body mass have a better ability to tolerate heat stress effectively by dissipating the excess heat load from their body surface by means of sensible and insensible heat dissipation mechanisms. The difference between the two sheep populations in area index value may be due to agro-ecological differences. For instance, the minimum altitude for Sibu Sire district is as low as 1300m.a.s.l. and that of Anfillo district is 1845 m.s.a.l. Conformational index value of sheep population at Sibu sire district was also significantly higher ($p<0.05$) than the value of conformational value obtained for sheep population of Anfillo district. Conformational index indicates the overall body shapes of an animal and the greater the conformational index is the more vigorous the sheep population is (Dereje *et al*. 2019). The overall conformational index value obtained in the current study was 70.50, which is lower than the 119.40 reported for Nigerian sheep (Olaniyi *et al.*, 2018). Accordingly, Nigerian sheep are expected to be much vigorous with healthier physical appearance than sheep population in the present study area. Compact index shows how compact the animal is. Meat type animals have values above 3.15 and value close to 2.75 or 3.14 to 2.75 indicates that the animals are dual purpose and those with compact index values closer to 2.60 and below shows that the animals are more suitable for milk purpose (Dauda, 2018). The overall mean compact index value of sheep populations in the study areas was 4.05. Therefore, sheep populations considered in the current study can be classified as meat type animals. Similarly, Mohammed *et al*. (2018) classified pure Dorper and crossbred sheep in Ethiopia as meat type animals.

Table 8: Calculated structural and functional indices from morphometric traits of sheep types

Indices	Districts			CV	SEM
	Anfillo	Sibu Sire	Overall		
Body index (BI)	90.00[a]	88.60[b]	89.00	5.20	4.60
Body frame index (BFI)	0.97	0.97	0.97	5.10	0.05
Pelvic index (PI)	111.20[a]	108.60[b]	109.90	6.90	7.70
Area index (AI)	3459[b]	3610[a]	3534.50	17.90	630.70
Body ratio index (BRI)	0.98	0.98	0.98	2.40	0.02
Compact index (CI)	3.90	4.20	4.05	16.70	0.60
Height slope index (HIS)	1.30[a]	1.10[b]	1.20	13.03	1.40
Proportionality index (PrI)	98.8	98.8	98.8	5.10	5.30
Thoracic development index (TdI)	1.06	1.10	1.08	4.23	0.04
Conformational index (ConI)	68[b]	73[a]	70.50	9.50	6.70
Cephalic index (CeI)	65[a]	58[b]	60.15	17.50	10.50

a, b means different superscripts along the same row are significantly different($p<0.05$). SEM-Standard Error of Mean

Thoracic development is another essential indicator of good fitness and good respiratory system particularly for animal breeds that adapt to the higher altitudes (Khargharia *et al*. 2015; Dereje *et al*. 2019). Animals with thoracic development index values above 1.2 indicate animals that adapt to the higher altitudes (Dauda, 2018; Guadie, 2021). However, the overall mean thoracic development index value obtained in the current study was 1.08, which fall short of the 1.2. The mean thoracic value (1.08) obtained in the present study implies that indigenous sheep in the study districts had poor thoracic capacity and may not be efficiently survived in the highland areas. This is general agreement with the detailed genetic diversity study results reported by Edea *et al*. (2017). According to the authors, Horro sheep breed is best suited to areas with altitude ranges of 1400 to 2000 m.a.s.l.

Conclusions and Recommendations

In the current study, 450 sheep of different age groups were used for qualitative trait observation and quantities variables measurements. Phonotypic variations were observed within and among sampling districts. Plain coat color pattern was the most dominant qualitative trait observed with brown coat color type. District, sex, age and interaction of sex with age had significant effects (at least at $p<0.05$) on linear body measurements and live body weight of sheep. Based on the live body weight, the linear body measurements and other qualitative traits observed, sheep populations of both districts are classified under same breed. In addition, when one look at the dominant plain brown coat color, smooth hair type, the long-fat tails and the uniform polled population reported in the current study, the sheep population used in the current study are categorized under Horro sheep breed. That means, the current study confirmed characterization conducted four decades back by Galal (1983). Heart girth was the most important trait identified for the prediction of body weight. The structural indices revealed that sheep population considered in current study are medigline with poor thoracic capacity and they are categorized as meat type. The findings of the current study serves as baseline for sheep breed improvement program in the study areas. For further characterization and identification, genetic characterization of sheep types in the study areas is necessary.

Acknowledgements

Anfillo Agricultural Office, West Wallaga zone, Oromia, Ethiopia is acknowledged for granting study leave for the major author.

Contribution of Authors

- This article is extracted from the MSc thesis of the major author, Dinka Hora.
- Hasan Yusuf, Ayantu Mekonnen and Diriba Diba have contributed in the analysis and interpretation of data in the preparation of the article.
- The Senior Author, Gemeda Duguma is the advisor of the MSc thesis work and involved in the conception, design, analysis and interpretation of data

Conflicts of Interest

- We declare that there is no conflict of interest.

References

Abbaya, H. and Dauda, A. 2018. Morphometric Differentiation of Yankasa Sheep in Maiduguri, Northeastern Nigeria, Journal of Genetics and Genetic Engineering. **2(3): 1 - 6.**

Abebe, T. and Korato, M. 2020. Phenotypic characterization of Indigenous Goats in East Arsi Zone, Oromia Regional State, Global Journal of Animal scientific Research. **8(1): 75 – 92.**

Asefa, B. Abate, T. and Adugna, E. 2017. Phenotypic Characterization of Indigenous Sheep Types in Bale Zone, Oromia Regional State, Ethiopia, J Vet Sci Technol. **8: 452.**

Banerjee, S. 2015. Body Indices of Garole Sheep Reared in West Bengal India. Zoological Society, Kolkata, India, ISSN 0373-5893.

Belay, D, Dereje, B. Kifle, D. Tesfaye, G. Solomon, G. and Ayele, A. 2021. Morphological diversity of Northeastern fat-tailed and Northwestern thin-tailed indigenous sheep breeds of Ethiopia. www.cell.com/heliyon

Birhanu, M. and Oli, W. 2020. Morphological Characterization of Indigenous Arsi-Bale Sheep in the Oromia Regional State, Ethiopia, Agric. J. **15(4): 71-77.**

Bosenu, A, Kefelegn, K. Solomon, G. and Teka, F. 2014. On-Farm Phenotypic Characterization of Indigenous Sheep Types in Selale Area, Central Ethiopia, Veterinary Sci Technol. **5:180**.

Central Statistical Agency of Ethiopia (CSA). 2021. Agricultural Sample Survey 2020/21. Volume II report on livestock and livestock characteristics (private peasant holdings). Statistical bulletin 589. Addis Ababa, Ethiopia

Chiemela, P.N., Seung-Hwan, L., Egbu, C.F., Prabuddha, M. and Jun Heon, L. 2016. Review on challenges, opportunities and genetic improvement of sheep and goat productivity in Ethiopia, J. of Anim. Breeding and Genomics**. 2(1): 001-008**

Dauda, A. 2018. Morphological Indices and Stepwise Regression of Koroji Sheep. Wayamba Journal of Animal Science. 1669-1674.

Dereje, D. Aberra, M. and Yoseph, M. 2019. Application of Morphometric Traits and Body Indices in Assessing the Type and Function of Local Goats Reared in Two Districts of Gamogofa Zone, South Ethiopia. Eth. J. Anim. Prod. **19(1): 73-90.**

Duguma, G. Mirkena, T. Haile, A. Iñiguez, L. Okeyo, A.M. and Markos, M. 2011. Identification of smallholder farmers' and pastoralists' preferences for sheep breeding traits: choice model approach, Animal**. 5: 1984–1992**.

Edea, Z. 2008. Characterization of Bonga and Horro Indigenous Sheep Breeds of Smallholders for Designing Community Based Breeding Strategies in Ethiopia. MSc Thesis, Haramaya University, Dire Dawa, Ethiopia.

Edea, Z. Dessie, T. Dadi, H. Do, Kyoung-Tag and Kim, Kwan-Sok. 2017. Genetic diversity and population structure of Ethiopian sheep populations revealed by high-density SNP markers. Front Genet. **22(8): 1-14.**

Edea, Z. Haile, A. Tibbo, M. Sharma, A.K. Assefa, D. Sölkner, J. and Wurzinger, M. 2009. Morphological Characterization of Bonga and Horro Indigenous Sheep Breeds under Smallholder conditions in Ethiopia,Eth. J. Anim. Prod. **9(1): 117-123**.

FAO. 2012. Phenotypic characterization of animal genetic resources. Animal Production and Health Guidelines. No.11.Rome.

Galal, E.S.E. 1983. Sheep germplasm in Ethiopia. Animal Genetic Resources Information Bulletin. **1(83):4-12.**

Gizaw, S. Van Arendonk, J.A.M. Komen, H. Windig, J.J. Hanotte, O. 2007. Population structure, genetic variation and morphological diversity in indigenous sheep of Ethiopia. Animal Genet. **38: 621-628.**

Gizaw, S. Komen, H. Hanotte, O. and van Arendonk, J.A.M. 2008. Indigenous sheep resources of Ethiopia: types, production systems and farmers preferences, Animal Genetic Resources Information.**43: 25-39**

Gizaw, S. Komen, H. Hanotte, O. van Arendonk, J.A.M. Kemp, S. Haile, A. Mwai, O. and Dessie, T. 2011. Characterization and conservation of indigenous sheep genetic resources: A practical framework for developing countries. ILRI Research Report No. 27. Nairobi, Kenya, ILRI.

Gizaw, S. Tegegne, A. Gebremedhin, B. and Hoekstra, D. 2010. Sheep and goat production and marketing systems in Ethiopia: Characteristics and strategies for improvement. IPMS (Improving productivity and market success) of Ethiopian farmer's project working paper 23.ILRI, Nairobi, Kenya 58.

Guadie, G. 2021. Phenotypic characterization of indigenous sheep populations and defining breeding objectives in selected districts of central and west Gondar zone, Amhara regional state, Ethiopia. MSc Thesis, Bahir Dar University, Bahir Dar, Ethiopia

Hizkel, K. Yoseph, M. and Yosef, T. 2017. On Farm Phenotypic Characterization of Indigenous Sheep type in Bensa district, Southern Ethiopia. Developing Country Studies. **7(11): 1-9.**

Hizkel, K. 2017. On-Farm Phenotypic Characterization and Consumer Preference Traits of Indigenous Sheep Type as an Input for Designing Community Based Breeding Program in Bensa District, Southern Ethiopia. Msc Thesis. Haramaya University, Haramaya, Ethiopia

Kassahun, A. 2000. Comparative performance evaluation of Horro and Menz sheep of Ethiopia under grazing and intensive feeding condition. A PhD Dissertation Humboldt-University. 129p.

Kerga, T. 2021. Husbandry practices and phenotypic characterization of indigenous sheep types in Gurage Zone,Southern Ethiopia, Int. J. Livest. Prod**. 12(4):154-167**.

Khargharia, G. Kadirvel, G. Kumar, S. Doley, S. Bharti, P.K. Das, M. 2015. Principal component analysis of morphological traits of Assam Hill goat in Eastern Himalayan India, J. Anim. Plant Sci**. 25:1251–1258.**

Michael, A, Kefelegn, K, Yoseph, M. 2016. Phenotypic Characterization of Indigenous Sheep Types in Northern Ethiopia,Journal of Natural Sciences Research**. 6(15): 16-27.**

Mohammed, J. Abegaz, S, Lakew, M, Tarekegn, GM. 2018. Evaluation on the Structural Indices Unveil Performance Variation among Dorper, Local and their F1 Crossbred Sheep Population in Ethiopia Genome**. 1(2): 1-9.**

Mohammed, T. Kefelegn, K. Yoseph, M. and Bosenu, A. 2015. On-farm phenotypic characterization of native sheep types in North Wollo zone, Northern Ethiopia, Direct Res. J. Agric. Food. Sci**. 3(3):48-56.**

Motos, C.A.P. and Thomas, O.L. 1992. Physiology and genetics of testicular size in sheep: a review. Livestock production Science. **12(1):1-30.**

Nurlign, M. Kefyalew, A. and Tesfaye, G. 2017. On-farm phenotypic characterization of indigenous sheep population and its cross with Awassi in selected Districts of South Wollo, Amhara, Ethiopia,Tropical drylands**. 1(1):1 -11.**

Olaniyi, T. Popoola, M. Olaniyi, O. Faniyi, T. and Inioboneg, U. 2018. Relationship between morphological traits, body indices and body condition score as a welfare indicators of Nigerian sheep. Journal of animal science and veterinary medicine. **3(1): 1-5.**

Salako, A.E. 2006. Application of morphological indices in the assessment of type and function in sheep, Int J Morphol. **24: 13-18.**

SAS. 2012. Statistical Analysis System, SAS for Windows, Release 9.1. SAS Institute Inc., Cary, NC, USA.

Silva, J. Roman, P. Duran, A. Vera, A. Cambron, S. and Andrade, M. 2019. Morphostructural characterization of the Black Creole Goat raised in Central Mexico, a currently threatened Zoogenetic resource. Animal. **9(459):1-12.**

Sintayehu, S. 2021. On-Farm Phenotypic Characterization of Indigenous Sheep in Simada and Lay Gayint Districts, South Gonder Zone Of Amhara Region, Ethiopia, Global Journal of Animal Scientific Research**. 9(2):42-64.**

Sowande, O. S. and Sobola, O.S.. 2007. Body measurements of West African dwarf sheep as parameters for estimation of live weight, Tropical Animal Health and Production. **40(6): 433–439.**

Thiruvenkadan, A. K. 2005. Determination of best-fitted regression model for estimation of body weight in Kanni Adu Kids under farmer's management system. Livestock research for rural development. **17(7): 1-7.**

Tibbo, M. Ayalew, W. Awgichew, K. Ermias, E. and Rege, J.E.O. 2004. On-station characterization of indigenous Menz and Horro sheep breeds in the central highlands of Ethiopia. FAO/UNEP Animal Genetic Resources Information. **35:61-74.**

Wagari, G. Getachew, T. Bayou, E. 2020. Multivariate analysis of phenotypic traits of indigenous sheep revealed new population in western part of Ethiopia, Int J Agric Sci Food Technol. **6(1):050-057.**

Weldeyesus, G. 2020. Review on Phenotypic variations of indigenous sheep breed ecotypes of Ethiopia, Journal of Cell and Animal Biology. **14(1):6-20.**

Weldeyesus, G. and Yayneshet, T. 2016. Morphological Characterization of Indigenous Highland Sheep Population of Tigray, Northern Ethiopia, J. of Nat. Sc. Res. **6(1):96-104.**

Wilson, R. T. and Durkin, J. W. 1984. Age at permanent incisor eruption in indigenous goats and sheep in semi-arid Africa. Livestock Production. Sciences. **11(4):451-455.**

Traore, A., Tamboura, H.H., Kaboré, A., Royo, L.J., Fernandez, I., Alvaréz, I., Sangaré, M., Bouchel, D., Poivey, J.P., Francais, D., Toguyeni, A., Sawadogo, L. and Goyache, F. 2008. Multivariate characterization of morphological traits in Burkina Faso sheep. Small Rumin. Res. **80(1): 62-67.**

Zemenu, G. 2020. On-Farm Phenotypic Characterization of Indigenous Sheep Populations in Dangila and Banja Districts of Awi Zone, Amhara Region, Ethiopia. MSc Thesis. Bahir Dar University. Bahir Dar, Ethiopia.