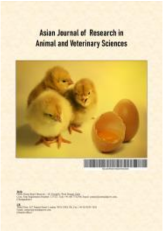

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Exterior Body Characteristics of Indigenous Sheep Populations in Western Zone of Tigray Region, Ethiopia

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Authors' contributions

This work was carried out in collaboration among all authors. Author TM did the conceptualization, methodology data curation and project administration. Authors TM, ST and MA did the investigation. Authors TM and ST writing-original draft preparation. Authors TM, ST and MA writing-review and editing. All authors read and approved the final manuscript.

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ABSTRACT

The field data collection was conducted before the ignition of the war (before October 2020) in Tigray Regional State, Ethiopia. Characterization of farm animal genetic resources (FAGRs) and their production systems are essential prerequisites for the sustainable utilization, conservation and improvement of FAGRs. The objective of the characterization work was to describe the exterior body characteristics and body indices of the indigenous sheep populations. A total of 488 (Begait-173, Rutanna-151 and Arado-164) sample animals with one permanent pair of incisor (1PPI) up to four permanent pair of incisors (4PPI) were randomly involved in the field data collection. Measurement of the quantitative traits and observation of qualitative traits were the techniques of

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data collection. Statistical Package for Social Sciences software was used to analyze the data. The indigenous sheep were kept at extensive production system. The indigenous sheep have marked sexual dimorphisms in almost all the linear body traits. The index of conformation (86.7±0.86) and index of body weight (61.8±0.98) of Rutanna sheep indicated that Rutanna sheep is more preferred for mutton production than the Begait and Arado sheep. Begait (93.1% plain, 99.4% white), Rutanna (90.6% plain, 69.8% brown red) and Arado sheep (86.6% plain, 51.8% brown red), respectively were the dominant coat color patterns and coat color types. Arado sheep can be used for wool production. Arado sheep were short-fat-tailed whilst Begait and Rutanna sheep were long-thin-tailed. Begait (100%) and Rutanna (99.3%) sheep were polled whereas 30.5% of Arado sheep were horned. Pendulous ear orientation was in Begait (98.3%) and Rutanna sheep whilst Arado sheep were with small ear. Concave face profile was in Begait (98.8%) and Rutanna sheep. Wattle and ruff were absent in Begait (98.3%, 91.9%), Rutanna (80.8%, 100%) and Arado (76.2%, 98.8%) sheep, respectively. Roofy rump profile was exhibited in Begait (86.7%), Rutanna (63.1%) and Arado (87.8%) sheep. Overall, Rutanna sheep is large framed whilst Begait sheep is medium framed and Arado sheep is small framed breed. Conservation and improvement of the valuable indigenous sheep of the study area should be the first task of breeders and stakeholders. Genetic characterizations of the indigenous sheep populations should be conducted to identify the most economical candidate genes and diversity within breed.

Keywords: Characterization; indigenous sheep; morphostructural traits; traits; body indices; sheep; body traits; sheep populations.

1. INTRODUCTION

The estimated total sheep population of entire rural, sedentary and pastoral areas of Ethiopia was about 38.0 million, and about 99.62% of the population were indigenous [1]. Ethiopia has 14 sheep types which are diverse sheep populations and grouped in to four main groups which comprised of highland long fat-tailed, sub-alpine short fat-tailed, lowland fat-rumped and lowland thin-tailed [2]. The indigenous sheep classification factors were geographic distribution and tail phenotypes [3,4]. World sheep breeds tail phenotypes are classified in to thin-tailed, short fat-tailed, long fat-tailed and fat-rumped sheep breeds [4,5]. The indigenous sheep of Ethiopia are adapted to diverse agro-ecological environments with the presences of the four tail morphotype groups (thin-tail, short fat- tail, long fat-tail and fat-rump) [6].

Morphological characterization involves the description of the physical traits of a breed [7]. Sexual dimorphism is a fundamental morphological component of angulates and has a bearing on population dynamics, ecology, behavior and evolution [8]. There is inadequate breed level characterization information in Ethiopia although the country possessed a large and enormous diversity of sheep population [9]. Phenotypic characterization is a prerequisite for sustainable utilization, conservation and improvement of a breed through designing appropriate sheep breeding programs [10]. Moreover, Budisatria *et al*. [11] and Ibrahim *et al*. [12] reported that characterization and inventory of genetic resources is the first step in implementing livestock genetic improvement strategies.

The indigenous sheep (Begait, Rutanna and Arado) were kept at low input extensive production system in the lowland part of the Western Zone of Tigray Region, Ethiopia. The agro-climatic condition of the breeding track of Begait and Rutanna sheep was arid lowland of Western Zone of Tigray Region, Ethiopia whilst Arado sheep breeding tracts are in the highland and lowland parts of the Western Zone of Tigray Region, Ethiopia. The indigenous sheep populations of the current study area were not included in the comprehensive study of sheep breeds of Ethiopia by Gizaw *et al*. [13] which comprised of Simien, *Short fat tailed*, Washera, Gumz, Horro, Arsi, Bonga, Afar and Blackhead Somali sheep. Some Kebelles in Kafta Humera (May Kadra and Bereket) shifted from Begait sheep production to Rutanna sheep (introduced from Sudan) production, hence, the quantitative and qualitative advantages of both breeds need to be scientifically evaluated. Moreover, the characterization information of the indigenous sheep will be helpful for the genetic improvement of the indigenous sheep. Therefore, the objective of the characterization work was to describe the exterior body characteristics and body indices of the indigenous sheep populations.

2. MATERIALS AND METHODS

2.1 Description of the Study Areas

The field data collection was carried out in Kafta Humera, Tsegede and Welkait districts. Kafta Humera district is the lowland part of Western Zone of Tigray Region, Ethiopia whereas Welkait and Tsegede districts are the highland areas of Western Zone of Tigray Regional State. The Western Zone of Tigray is located at 570 and 991 kilometers (km) far from Mekelle and Addis Ababa, respectively [14]. The Zone also lies at 13°42′ to 14°28′ North latitudes and 36°23′ to 37°31′ East longitudes [15].

The altitude, rainfall, temperature and non-arable land uses of Kafta Humera, Welkait and Tsegede districts are presented (Table 1).

2.2 Data Collection

An on-farm indigenous sheep characterization; Begait (173), Rutanna (151) and Arado (164) adult sheep which totaled 488 sample animals were randomly involved in the field data collection. Dentition was used to determine the age of the animals and were included from one permanent pair of incisor (1PPI) up to four permanent pair of incisors (4PPI) (Fig. 1).

Table 1. Agro-climatic and non-arable land use of the study districts

Agro-climate and land use	Kafta Humera	Welkait	Tsegede	Zonal ranges
Altitude (MASL)	500-1849	700-2354	680-3008	500-3008
Agro-ecology (%)				
Lowland (*Kola*)	86	60	70	60-86
Midland (*Weina dega*)	14	40	22	14-40
Highland (*Dega*)	-	-	9	9
Rainfall (mm)	650-750	700-1800	1200-2500	650-2500
Temperature (℃)	25-48	18-25	12-35	12-48
Non-arable land use (%)				
Forestry land	33	19	35	19-35
Pastureland	5	18	22	5-22

Meter Above Sea Level (MASL), millimeter (mm)
Source: Tesfay *et al.* [16]

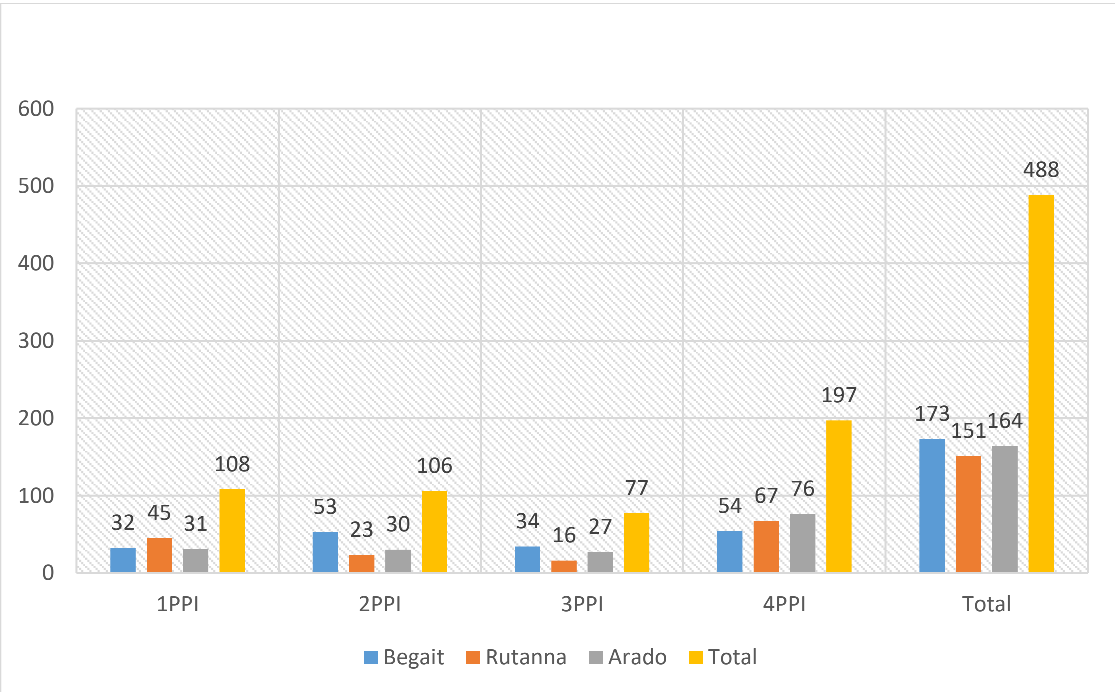

Fig. 1. Number of observations of animals by breed and age class

The quantitative and qualitative data were collected according to the standard breed descriptor list for the sheep breeds developed by FAO [10] guideline. The linear body traits were measured using flexible measuring tape while body weight (BW) was measured using suspended spring balance having 100 Kg capacity with 0.2 Kg precision. The qualitative traits (16 major traits) of the indigenous sheep were observed and recorded. The observed major qualitative traits included Coat color pattern, Coat color type, Hair type, Fiber type, Wool type, Tail type, Tail form, Horn presence, Horn shape, Horn orientation, Ear orientation, Face profile, Wattle presence, Ruff presence, Back profile, and Rump profile. There were eighteen (18) linear body traits measured (in centimeter) which comprised of Body length (BL), Heart Girth or Chest circumference or Chest girth (ChG), Chest depth (ChD), Height at withers (HW), Rump height (RuH), Rump length (RuL), Rump width (RuW), Hair/wool length (HWL), Scrotal circumference or Scrotal girth (ScG), Scrotal depth (ScD), Teat length (TtL), Head length (HdL), Head width (HdW), Ear length (EL), Horn length (HL), Shin circumference (ShC), Tail length (TL) and Tail width (TW).

2.3 Statistical Analysis

Statistical Package for Social Sciences [17] software was used for data analysis. Statistical method of mean comparison analysis of the linear body traits and body indices of the indigenous sheep across sex and age class (1PPI-4PPI) was performed. ANOVA was used to test the differences in sex, age class and breed effect (Begait and Rutanna) of the indigenous sheep. Sexual dimorphisms of the indigenous sheep were determined by dividing means of the linear body traits of the males to the means of the linear body traits of the females. The qualitative traits of the indigenous sheep were summarized by frequency and percentages, and chi-square (X^2) test was used to compare some of the proportions of the qualitative traits of the indigenous sheep.

The morphological or body indices of the indigenous sheep were calculated according to the formulas used by different authors (Table 2). Index of Body Frame (IBF) indicates how compact the animal is [16]. Baron-Crevat index (BCI) or Index of conformation (IC): $(ChG)^2$/ HW; the higher the index: the more robust is the animal.

3. RESULTS

3.1 Exterior Linear Body Traits of the Indigenous Sheep

The linear body measurements (cm) of BL (72.8±0.26), ChG (77.1±0.33), ChD (37.7±0.17), HW (74.9±0.26), RuH (75.6±0.25), TL (54.5±0.35), and BW (40.4±0.49 Kg) of Begait sheep and BL (74.0±0.38), ChG (82.0±0.52), ChD (39.3±0.29), HW (77.7±0.38), RuH (78.2±0.35), TL (56.7±0.47), and BW (48.3±0.94 Kg) of Rutanna sheep were significantly

Table 2. Formulas of body indices of indigenous sheep populations

Body indices	Formula	Sources
Index of length or index of Body Frame (IBF)	$IBF = \frac{BL}{HW}$ x100	[18, 19, 20, 21]
Index of body proportion or index of height (IH)	$IH = \frac{HW}{RuH}$ x100	[18, 19, 20, 21]
Chest depth index (CDI)	$CDI = \frac{ChD}{HW}$ x100	[18, 19, 20, 21]
Index of thorax development (ITD)	$ITD = \frac{ChG}{HW}$ x100	[18, 19, 20, 21]
Dactyl thorax index (DTI)	$DTI = \frac{ShC}{ChG}$ x100	[18, 19, 20, 21]
Baron-Crevat index (BCI) or Index of conformation (IC)	$IC = \frac{ChG2}{HW}$	[18, 19, 20, 21]
Relative cannon bone index (RCBI)	$RCBI = \frac{ShC}{HW}$ x 100	[18, 19, 20, 21]
Index of body weight (IBW)	$IBW = \frac{BW}{HW}$ x100	[18, 19, 20, 21]
Body index (BI)	$BI = \frac{BL}{ChG}$ x100	[18, 19, 20, 21]
Index of proportionality (Ipr)	$Ipr = \frac{HW}{BL}$ x100	[18, 19, 20, 21]
Area index (AI)	$AI = HW\ x\ BL$	[18, 19]

(P<0.001) different. The ScG (30.4±0.79) of Begait sheep and ScG (30.9±0.64) of Rutanna sheep were not significantly (P>0.05) different. Arado sheep or the Tigray highland sheep of the study area exhibited a BL (66.7±0.24), ChG (70.2±0.29), ChD (34.6±0.15), HW (70.2±0.23), RuH (71.3±0.23), ScG (23.8±0.99), TL (15.7±0.19) and BW (28.3±0.29 Kg) (Table 3).

Except few, most linear body traits were significantly (*P*<0.001) different across sex and age class of each breed. Moreover, except few, most linear body traits were significantly (*P*<0.001) different across Begait and Rutanna sheep. All the indigenous sheep have marked sexual dimorphisms in almost all the linear body traits because adult males have larger linear body traits than females, however, Rutanna in HaL (0.92) and Arado in EL (0.89) did not exhibit sexual dimorphism (Table 4). Body indices of the indigenous sheep were calculated, and the IC (86.7±0.86) and IBW (61.8±0.98) of Rutanna sheep indicated that Rutanna sheep is more preferred for mutton production than the Begait and Arado sheep (Table 5). The correlation coefficients of the body indices of the indigenous sheep were also analyzed. There were negative non-significant (*P*>0.05) correlations between IC and IH and IBW and IH of Begait sheep. The IBW of Begait was non-significant (*P*>0.05) correlation with RCBI. The IC and IBW of Rutanna sheep were highly negatively correlated (*P*<0.01) with BI (-0.660, -0.413) and Ipr (-0.194, -0.241) and the IC and IBW of Arado sheep were also highly negatively correlated (*P*<0.01) with BI (-0.589, -0.283) and Ipr (-0.252, -0.304), respectively (Table 6).

3.2 Exterior Body Qualitative Characteristics of the Indigenous Sheep

Plain coat color pattern was the dominant coat color pattern in Begait (93.1%), Rutanna (90.6%) and Arado sheep (86.6%). The dominant coat color types of Begait was white (99.4%) whilst Rutanna (69.8%) and Arado (51.8%) sheep was brown red. Arado sheep are wool sheep (100%) and can be used for wool production because they exhibited 5.0±0.13 cm long wool. Arado sheep were short fat tailed (100%) sheep whilst Begait and Rutanna sheep were long thin tailed (100%) sheep. Begait (100%) and Rutanna (99.3%) sheep were polled whereas 30.5% of Arado sheep were horned. Laterally/small (34.7%) and backward (38.8%) were the major horn orientations of Arado sheep (Table 7 and Figs. 2, 3 and 4).

Sample Photos of Adult Indigenous Sheep in Western Zone of Tigray, Ethiopia

Fig. 2. Indigenous Begait sheep female (upper) and male (lower)

Fig. 3. Indigenous Rutanna sheep female (right end) and males (left of the female)

Fig. 4. Indigenous Arado sheep female (upper) and male (lower)

Table 3. Morphometric traits (Mean±SEM) of indigenous sheep populations and breed effect (Begait*Rutanna)

LBT	Sheep breeds (n =488)									
	Begait (B) (M=13, F=160)			Rutanna (R) (M=19, F=132)			Breed effect (B*R)	Arado (M=6, F=158)		
	Male	Female	Overall	Male	Female	Overall	(*P*<0.05)	Male	Female	Overall
BL	78.5±0.63	72.4±0.24	72.8±0.26	81.5±1.04	73.0±0.32	74.0±0.38	0.009	71.8±1.14	66.5±0.23	66.7±0.24
ChG	84.2±1.10	76.5±0.30	77.1±0.33	92.9±0.87	80.5±0.44	82.0±0.52	0.000	76.8±1.42	70.0±0.28	70.2±0.29
ChD	42.5±0.39	37.3±0.15	37.7±0.17	46.8±0.73	38.3±0.19	39.3±0.29	0.000	39.7±0.92	34.4±0.13	34.6±0.15
HW	81.0±0.65	74.4±0.24	74.9±0.26	86.6±0.78	76.4±0.28	77.7±0.38	0.000	76.0±1.34	70.0±0.22	70.2±0.23
RuH	80.6±0.66	75.2±0.24	75.6±0.25	85.1±0.88	77.2±0.28	78.2±0.35	0.000	76.7±1.38	71.1±0.22	71.3±0.23
RuL	19.6±0.24	18.7±0.11	18.8±0.10	20.4±0.43	18.5±0.12	18.8±0.13	0.881	15.3±0.49	14.9±0.09	14.9±0.09
RuW	18.3±0.39	17.3±0.08	17.4±0.08	18.3±0.42	17.3±0.13	17.5±0.13	0.701	16.7±0.33	16.1±0.08	16.1±0.08
HWL	2.2±0.13	2.4±0.05	2.4±0.05	3.3±0.21	3.3±0.24	3.3±0.21	0.000	5.5±0.26	5.0±0.13	5.0±0.13
ScG	30.3±0.79	-	30.4±0.79	30.9±0.64	-	30.9±0.64	0.593	23.8±0.99	-	23.8±0.99
ScD	19.0±0.81	-	19.00±0.81	20.2±0.50	-	20.2±0.50	0.191	14.0±0.52	-	14.00±0.52
TtL	-	2.3±0.04	2.3±0.04	-	2.7±0.05	2.7±0.05	0.000	-	1.8±0.03	1.8±0.03
HdL	25.4±0.35	23.0±0.07	23.2±0.09	25.6±0.33	22.6±0.09	23.0±0.12	0.076	23.8±0.31	21.8±0.07	21.8±0.07
HdW	14.5±0.27	13.4±0.06	13.5±0.06	14.6±0.28	12.6±0.07	12.8±0.09	0.000	12.8±0.17	11.7±0.04	11.7±0.04
EL	15.4±0.29	15.3±0.16	15.3±0.15	17.2±0.39	17.2±0.12	17.2±0.12	0.000	9.9±0.49	11.1±0.13	11.0±0.13
HL	-	-	-	-	-	-	-	42.5±6.13	7.4±0.42	12.0±1.9
ShC	11.8±0.15	10.7±0.06	10.8±0.07	13.1±0.25	10.9±0.09	11.2±0.11	0.001	9.8±0.17	8.2±0.07	8.3±0.07
TL	61.3±0.65	53.9±0.34	54.5±0.35	64.3±1.20	55.6±0.43	56.7±0.47	0.000	20.0±1.32	15.5±0.19	15.7±0.19
TW	11.3±0.51	9.3±0.12	9.5±0.12	15.2±0.42	11.5±0.17	11.9±0.18	0.000	12.7±0.49	11.2±0.15	11.2±0.15
BW	52.7±1.25	39.5±0.44	40.4±0.49	70.5±1.92	45.3±0.70	48.3±0.94	0.000	36.6±2.25	28.0±0.28	28.3±0.29

Standard Error of the Mean (SEM), Male (M), Female (F), Linear Body Traits (LBT), Body length (BL), Chest girth (ChG), Chest depth (ChD), Height at withers (HW), Rump height (RuH), Rump length (RuL), Rump width (RuW), Hair/Wool length (HWL), Scrotal girth (ScG), Scrotal depth (ScD), Teat length (TtL), Head length (HdL), Head width (HdW), Ear length (EL), Horn length (HL), Shin circumference (ShC), Tail length (TL), Tail width (TW), Body weight (BW)

Table 4. Mean comparison (P<0.05) of morphometric traits of the indigenous sheep breeds across sex and age class (AC), and sexual dimorphisms (SexD) of the indigenous sheep

Morphometric traits	Begait sheep			Rutanna sheep			Arado sheep		
	Sex	AC	SexD	Sex	AC	SexD	Sex	AC	SexD
BL	0.000	0.000	1.08	0.000	0.000	1.12	0.000	0.000	1.08
ChG	0.000	0.000	1.10	0.000	0.000	1.15	0.000	0.000	1.10
ChD	0.000	0.000	1.14	0.000	0.000	1.22	0.000	0.000	1.15
HW	0.000	0.007	1.09	0.000	0.001	1.13	0.000	0.002	1.09
RuH	0.000	0.015	1.07	0.000	0.037	1.10	0.000	0.100	1.08
RuL	0.015	0.028	1.05	0.000	0.752	1.10	0.333	0.002	1.03
RuW	0.001	0.000	1.06	0.016	0.000	1.06	0.159	0.000	1.04
HWL	0.280	0.000	0.92	0.985	0.176	1.00	0.438	0.000	1.10
ScG	-	0.259	-	-	0.780	-	-	0.065	-
ScD	-	0.976	-	-	0.306	-	-	0.230	-
TtL	-	0.000	-	-	0.000	-	-	0.000	-
HdL	0.000	0.061	1.10	0.000	0.000	1.13	0.000	0.000	1.09
HdW	0.000	0.068	1.08	0.000	0.000	1.16	0.000	0.000	1.09
EL	0.842	0.807	1.01	0.933	0.944	1.00	0.098	0.693	0.89
HL	-	-	-	-	-	-	0.000	0.025	5.74
ShC	0.000	0.015	1.10	0.000	0.004	1.20	0.000	0.824	1.20
TL	0.000	0.037	1.14	0.000	0.241	1.16	0.000	0.002	1.29
TW	0.000	0.235	1.22	0.000	0.167	1.32	0.054	0.524	1.13
BW	0.000	0.000	1.33	0.000	0.000	1.56	0.000	0.000	1.31

Table 5. Body indices (mean±SEM) of indigenous sheep populations

Body indices	Begait (B) (n=172)	Rutanna (R) (n=147)	Breed effect B*R (*P*<0.05)	Arado (n=161)
Index of length or index of Body Frame (IBF)	97.4±0.28	95.3±0.38	0.000	95.0±0.33
Index of body proportion or index of height (IH)	99.1±0.19	99.3±0.24	0.385	98.5±0.19
Chest depth index (CDI)	50.4±0.17	50.5±0.24	0.581	49.3±0.16
Index of thorax development (ITD)	103.02±0.35	105.48±0.46	0.000	99.9±0.33
Dactyl thorax index (DTI)	13.9±0.08	13.6±0.11	0.008	11.8±0.09
Baron-Crevat index (BCI) or Index of conformation (IC)	79.5±0.55	86.7±0.86	0.000	70.2±0.48
Relative cannon bone index (RCBI)	14.4±0.08	14.4±0.12	0.889	11.8±0.09
Index of body weight (IBW)	53.8±0.55	61.8±0.98	0.000	40.3±0.37
Body index (BI)	94.6±0.32	90.6±0.41	0.000	95.1±0.33
Index of proportionality (Ipr)	102.86±0.29	105.13±0.42	0.000	105.42±0.36
Area index (AI)	5456.3±35.42	5767.3±55.66	0.000	4680.7±27.62

Pendulous ear orientation was in Begait (98.3%) and Rutanna (100%) sheep whilst Arado sheep were with small ear (100%). Concave face profile was in Begait (98.8%) and Rutanna (100%) sheep. Wattle and ruff were absent in Begait (98.3%, 91.9%), Rutanna (80.8%, 100%) and Arado (76.2%, 98.8%) sheep, respectively. Straight back profile was exhibited in Begait (99.4%), Rutanna (98.7%) and Arado (100%). It was noted that roofy rump profile was observed in Begait (86.7%), Rutanna (63.1%) and Arado (87.8%) sheep (Table 7).

Table 6. Pearson's correlation coefficients of body indices of the indigenous sheep (Top matrix- Begait , Middle matrix- Rutanna and Bottom matrix- Arado sheep)

	IBF	**IH**	**CDI**	**ITD**	**DTI**	**IC**	**RCBI**	**IBW**	**BI**	**Ipr**	**AI**
IBF	1	-0.246**	0.519**	0.438**	-0.051^{ns}	0.239**	0.213**	0.244**	0.415**	-0.999**	0.023^{ns}
IH	-0.201*	1	-0.229**	-0.233**	-0.043^{ns}	-0.058^{ns}	-0.180*	-0.047^{ns}	0.029^{ns}	0.239**	0.251**
CDI	0.336**	-0.095^{ns}	1	0.763**	-0.157*	0.709**	0.299**	0.586**	-0.329**	-0.517**	0.137^{ns}
ITD	0.402**	-0.116^{ns}	0.591**	1	-0.384**	0.870**	0.205**	0.627**	-0.635**	-0.437**	-0.055^{ns}
DTI	0.119^{ns}	-0.173*	0.056^{ns}	-0.151^{ns}	1	-0.399**	0.823**	-0.235**	0.347**	0.050^{ns}	-0.066^{ns}
IC	0.196*	0.125^{ns}	0.618**	0.865**	-0.118^{ns}	1	0.110^{ns}	0.816**	-0.676**	-0.239**	0.408**
RCBI	0.323**	-0.225**	0.368**	0.383**	0.854**	0.343**	1	0.134^{ns}	-0.023^{ns}	-0.213**	-0.100^{ns}
IBW	0.240**	0.136^{ns}	0.659**	0.643**	0.071^{ns}	0.859**	0.406**	1	-0.425**	-0.246**	0.529**
BI	0.476**	-0.060^{ns}	-0.287**	-0.611**	0.244**	-0.660**	-0.093^{ns}	-0.413**	1	-0.415**	0.069^{ns}
Ipr	-0.998**	0.195*	-0.333**	-0.397**	-0.121^{ns}	-0.194*	-0.322**	-0.241**	-0.480**	1	-0.023^{ns}
AI	0.084^{ns}	0.384**	0.336**	0.117^{ns}	0.091^{ns}	0.561**	0.148^{ns}	0.702**	-0.044^{ns}	-0.090^{ns}	1
IBF	1										
IH	-0.259**	1									
CDI	0.463**	-0.190*	1								
ITD	0.483**	-0.083^{ns}	0.617**	1							
DTI	-0.037^{ns}	-0.223**	-0.113^{ns}	-0.184*	1						
IC	0.260**	0.064^{ns}	0.533**	0.882**	-0.203**	1					
RCBI	0.164*	-0.255**	0.149^{ns}	0.239**	0.910**	0.172*	1				
IBW	0.302**	-0.018^{ns}	0.493**	0.610**	-0.141^{ns}	0.717**	0.115^{ns}	1			
BI	0.537**	-0.176*	-0.130^{ns}	-0.478**	0.148^{ns}	-0.589**	-0.057^{ns}	-0.283**	1		
Ipr	-0.998**	0.250**	-0.457**	-0.476**	0.039^{ns}	-0.252**	-0.159*	-0.304**	-0.544**	1	
AI	0.095^{ns}	0.190*	0.102^{ns}	0.058^{ns}	-0.088^{ns}	0.463**	-0.059^{ns}	0.447**	0.035^{ns}	-0.094^{ns}	1

*^{ns} non-significant, **Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed)*

Table 7. Frequency (%) of qualitative traits of indigenous sheep populations

Categories	Traits	Indigenous sheep breeds		
		Begait	Rutanna	Arado
Coat color pattern	Plain	161(93.1)	135(90.6)	142(86.6)
	Patchy	12(6.9)	2(1.3)	15(9.1)
	Spotted	0	12(8.1)	7(4.3)
Coat color type	Black	1(0.6)	0	10(6.1)
	White	172(99.4)	1(0.7)	8(4.9)
	Brown	0	0	11(6.7)
	Dark red	0	3(2.0)	5(3.0)
	Light red	0	26(17.4)	27(16.5)
	Brown red	0	104(69.8)	85(51.8)
	Gray	0	4(2.7)	6(3.7)
	Beige	0	11(7.4)	12(7.3)
X^2			319.685	247.902
P value			0.000	0.000
Hair type	Short and smooth hair	173(100)	151(100)	0
	Long and coarse hair	0	0	164(100)
Fiber type	Hair sheep	173(100)	151(100)	0
	Wool sheep	0	0	164(100)
Wool type	Coarse/carpet	0	0	164(100)
Tail type	Short fat tailed	0	0	164(100)
	Long thin tailed	173(100)	151(100)	0
Tail form	Curved up at the tip	0	0	164(100)
	Straight	173(100)	151(100)	0
Horn	Absent	173(100)	150(99.3)	114(69.5)
	Present	0	1(0.7)	50(30.5)
Horn shape	Straight	0	0	15(30.6)
	Curved	0	0	32(65.3)
	Corkscrew	0	0	2(4.1)
Horn orientation	Laterally/small	0	0	17(34.7)
	Backward	0	0	19(38.8)
	Forward	0	0	12(24.5)
	Downward	0	0	1(2.0)
Ear orientation	Lateral/semi-pendulous	3(1.7)	0	164(100)
	Pendulous	170(98.3)	151(100)	0
Face profile	Straight	2(1.2)	0	164(100)
	Concave	171(98.8)	151(100)	0
Wattle	Absent	170(98.3)	122(80.8)	125(76.2)
	Present	3(1.7)	29(19.2)	39(23.8)
Ruff	Absent	159(91.9)	151(100)	162(98.8)
	Present	14(8.1)	0	2(1.2)
Back profile	Straight	172(99.4)	149(98.7)	164(100)
	Slopes up towards the rump	1(0.6)	1(0.7)	0
	Slopes down from the withers	0	1(0.7)	0
Rump profile	Flat	0	0	1(0.6)
	Sloping	23(13.3)	55(36.9)	19(11.6)
	Roofy	150(86.7)	94(63.1)	144(87.8)
X^2		93.231	10.208	221.939
P value		0.000	0.001	0.000

Numbers in parentheses are in percent

4. DISCUSSION

The indigenous sheep (Begait, Rutanna and Arado) were kept at low input extensive production system. The agro-climatic condition of the breeding track of Begait and Rutanna sheep was arid lowland. However, the linear body measurements (cm) of Begait sheep which comprised of BL (72.8±0.26), ChG (77.1±0.33), ChD (37.7±0.17), HW (74.9±0.26), RuH (75.6±0.25), TL (54.5±0.35), and BW (40.4±0.49 Kg) and Rutanna sheep which comprised of BL (74.0±0.38), ChG (82.0±0.52), ChD (39.3±0.29), HW (77.7±0.38), RuH (78.2±0.35), TL (56.7±0.47), and BW (48.3±0.94 Kg) were significantly (P<0.001) different. These traits revealed that Rutanna sheep is a large framed animal as compared with Begait.

ChG (80.1±0.23) of Zulu sheep aged at two or more permanent incisors [22] are similar with the measurements of Begait and Rutanna sheep. ChG (77.13±0.36), HW (72.81±1.31) and TL (52.07±0.44) of *Watish* sheep [23], HW (74.7±0.37), RuH (73.7±0.36) and TL (52.1±0.54) of Begait sheep and ChG (77.4±0.40) of Gumuz sheep [24] are similar with the same traits of Begait sheep. BL (65.30±0.37) and BW (37.37 ±0.46 Kg) of *Watish* sheep [23] and ChG (81.4±0.42) of Begait sheep [24] are not similar with Begait sheep. BL (64.1±0.18), HW (62.6±0.17), RuH (63.8±0.21), TL (27.6±0.37) and BW (34.7±0.24) of Zulu sheep aged at two or more permanent incisors [22], measured traits of BL (65.6), ChG (69.5), HW (57.7), TL (18.2) and BW (27.2 Kg) of Blackhead Somali sheep [25] and HW (70.0±0.36), RuH (68.8±0.35) and TL (38.7±0.52) of Gumuz sheep [24] are not in agreement with the same traits of Begait and Rutanna sheep. Moreover, ChG (male =113.07 and female =97.33) and BW (male =95.87 Kg and female =61.27) of Ouled Djellal sheep of Algeria [26] are not comparable with Begait and Rutanna sheep. The differences could be due to genotype, environment, the interaction effects of genotype and environment, time of measurement and conditions of animal stand and body score.

ChG (82.7±0.39) and HW (75.0±0.34) of Rutanna sheep [24] are similar with the present the same traits of Rutanna sheep whilst RuH (74.3±0.34) and TL (49.9±0.50) of Rutanna sheep [24] are not similar with the current measurements of Rutanna sheep. Although the TL of Djallonke ewes in Cote d'Ivoire [27] is thin, it is shorter (24.7±3.4) than the TL of Begait and Rutanna ewes. The ScG (26.4±0.32) of Zulu sheep aged at two or more permanent incisors [22] are not similar with the measurements of Begait and Rutanna rams. The differences could be due to genotype, environment and the interaction effects of genotype and environment. The ScG of Begait (30.4±0.79) and Rutanna (30.9±0.64) rams are comparable with the ScG (33.94) of Ouled Djellal sheep rams of Algeria [26]. The ScG of Arado rams is similar with the ScG of rams of indigenous sheep populations (24.63±2.04) in North Shoa Zone, Central Ethiopia [28]. ChG (72.96±0.53), RuH (69.71±0.46), BW (28.75±0.49) and ScG (26.16±0.93) of Awassi sheep [29] are similar with the same traits of Arado sheep.

Arado sheep or the Tigray highland sheep of the study area exhibited a BL (66.7±0.24), ChG (70.2±0.29), ChD (34.6±0.15), HW (70.2±0.23), RuH (71.3±0.23), ScG (23.8±0.99), TL (15.7±0.19) and BW (28.3±0.29 Kg). These traits also revealed that Arado sheep is small framed animal as compared with Rutanna and Begait sheep. BL (64.1±0.18) of Zulu sheep [22] BL (65.6) and BW (27.2 Kg) of Blackhead Somali sheep [25] and ChG (69.95±0.38) of *Holla* sheep types in Ethiopia [30] are similar with the measurements of Arado sheep. ChG (80.1±0.23), HW (62.6±0.17), RuH (63.8±0.21), TL (27.6±0.37) and BW (34.7±0.24) of Zulu sheep aged at two or more permanent incisors [22], ChG (69.5), HW (57.7) and TL (18.2) of Blackhead Somali sheep [25], BL (60.82±0.49) and HW (65.94±0.43) of Awassi sheep [29], BL (52.40±0.34), HW (58.43±0.33), RuH (61.31±0.34) and BW (22.09±0.19 Kg) of *Holla* sheep types in Ethiopia [30], and BL (54.55±3.48), ChG (66.73±4.79), HW (55.13±3.83), TL (26.62±2.66) and BW (20.26±3.60 Kg) of Gamo highland sheep population in Gamo Zone, South Ethiopia [31] are not in agreement with the traits of Arado sheep. The differences could be due to genotype, environment, the interaction effects of genotype and environment, time of measurement and conditions of animal stand and body score.
BL (71.96±0.15) and ChG (83.84±0.18 cm) of Creole wool ewes [32] are similar with Begait and Rutanna ewes, and BW (40.31±0.21 Kg) of Creole wool ewes [32] is in line with Begait ewes. BL (63.94±0.24) and ChG (71.29±0.22) of Blackhead Somali ewes [33] are similar with Arado ewes whilst HW (59.97±0.21), TL (20.21±0.19) and BW (25.80±0.20 Kg) of Blackhead Somali ewes [33] are not similar with Arado ewes. The differences could be due to genotype, environment, the interaction effects of

genotype and environment, time of measurement and conditions of animal stand and body score. With the exception of Begait in HaL (0.92) and Arado in EL (0.89), the indigenous sheep have a marked sexual dimorphism in all their linear body traits. There is no sexual dimorphism in EL in Arado sheep which is in line with Zulu sheep in EL (0.91) [22]. There may be other breed(s) with sexual dimorphisms in hair length (HaL) and/or ear length (EL).

The index of conformation (IC) (86.7±0.86) and index of body weight (IBW) (61.8±0.98) of Rutanna sheep indicated that Rutanna sheep is more preferred for mutton production than the Begait and Arado sheep. The index heights (IHs) of Begait, Rutanna and Arado sheep are not similar with IHs of Awasi (95.58±0.27), Il de France (94.97±0.34), Shkodrane (95.34±0.4) and Lara e Polisit (93.8±0.25) sheep in Albania [34]. Moreover, the body indices (BIs) of Begait, Rutanna and Arado sheep are much higher than the BIs of Awasi (34.16±0.47), Il de France (31.09±0.5), Shkodrane (30.27±0.29) and Lara e Polisit (26.8±0.28) sheep in Albania [34]. The differences might be due to genotype, environment, the interaction effects of genotype and environment. Except the chest depth indices (CDI) of Il de France (53.41±0.63) and Lara e Polisit (55.09±0.43), Awasi (51.48±0.47) and Shkodrane (50.58±0.36) sheep in Albania [34] have similar CDI with Begait and Rutanna sheep. The IC and IBW of Rutanna sheep were highly negatively correlated ($P<0.01$) with BI (-0.660, -0.413) and Ipr (-0.194, -0.241) and the IC and IBW of Arado sheep were also highly negatively correlated ($P<0.01$) with BI (-0.589, -0.283) and Ipr (-0.252, -0.304), respectively. The negative correlations among the indices (IC, IBW, BI and Ipr) indicates that selection of the linear body traits of index of conformation (IC) and index of body weight (IBW) negatively affect to the body index (BI) and index of proportionality (Ipr) and vice versa.

Plain coat color pattern was the dominant coat color pattern in Begait (93.1%), Rutanna (90.6%) and Arado (86.6%) sheep. The coat color pattern of Begait, Rutanna and Arado sheep is not comparable with Blackhead Somali sheep (58.7% plain coat color) [25] and Indigenous Sheep Populations (46%) in North Shoa Zone, Central Ethiopia [28]. The difference might be due to genotype and ecology. The dominant coat color types of Begait was white (99.4%) whilst Rutanna (69.8%) and Arado (51.8%) sheep was brown red. The body coat color type of Begait is comparable with Blackhead Somali sheep (83.8% White body and black head) [25] with the exception of head coat color type. Arado sheep are wool sheep (100%) and can be used for wool production because they exhibited 5.0±0.13 cm long wool. Zulu sheep (0.8% wooled) [22] is not comparable with Arado sheep (100%). The difference might be due to genotype and ecology.

Arado sheep were short fat tailed (100%) sheep whilst Begait and Rutanna sheep were long thin tailed (100%) sheep. The tail morphotypes of Begait, Rutanna and Arado are not in agreement with Zulu sheep (33.7% long thin) [22], Blackhead Somali sheep (rumped tail type) [25], Indigenous Sheep Types (100% long fat tailed) in Selale Area, Central Ethiopia [35] and Indigenous Sheep Populations (59.9% short fat tail type and 40.1% long fat) in North Shoa Zone, Central Ethiopia [28]. The difference might be due to genotype and ecology. The tail type of Begait and Rutanna ewes is in line with the tail type of Djallonke ewes (100% thin) in Cote d'Ivoire [27] and Gamo highland sheep population (100% thin-tailed) in Gamo Zone, South Ethiopia [31] but shorter in lengths (Djallonke ewes of mean =24 cm and Gamo highland sheep =26.6) than the TL of Begait and Rutanna ewes. The tail type and length of sheep could be a major distinguishing traits of the sheep populations in the world and differences might be arisen due to genotypic, environment and interaction of genotype and environment.

Begait (100%) and Rutanna (99.3%) sheep were polled whereas 30.5% of Arado sheep were horned. Horn presences of Begait, Rutanna and Arado are not in agreement with Zulu sheep (73% polled) [22], Ouled Djellal sheep (100% males and 7.8% females horned) of Algeria [26], and Indigenous Sheep Populations (77.2% polled) in North Shoa Zone, Central Ethiopia [28]. The difference might be due to genotype and sex. Begait and Rutanna sheep are polled sheep which are in line with Blackhead Somali sheep (100% polled) [25]. Arado sheep (65.3% curved) has no similar horn shape with Zulu sheep ((35.8% curved) [22]. The difference might be due to genotype. Laterally/small (34.7%) and backward (38.8%) oriented horns were the major horn orientations of Arado sheep which are not similar with Indigenous Sheep Populations (46% backward and 38.1% lateral) in North Shoa Zone, Central Ethiopia [28]. The difference might be due to genotype and sex.

Pendulous ear orientations were in Begait (98.3%) and Rutanna (100%) sheep whilst Arado sheep were with small ear (100%). The ear orientations of Begait, Rutanna and Arado sheep are not in agreement with Zulu sheep (28.9% dropping) [22], Indigenous Sheep Populations (47.8% semi-pendulous) in North Shoa Zone, Central Ethiopia [28] and Djallonke ewes (87% erected ear) in Cote d'Ivoire [27]. The difference might be due to genotype, sex and ecology. Ear orientations of Begait (98.3%) and Rutanna (100%) sheep are in line with Blackhead Somali sheep (100% dropping) [25]. Concave face profile was in Begait (98.8%) and Rutanna (100%) sheep, but straight face profile was exhibited in Arado sheep (100%). The face profiles of Begait, Rutanna and Arado sheep are not in line with Zulu sheep (66% straight face) [22], Blackhead Somali sheep (46% concave face profile) [25] and Indigenous Sheep Populations (58.5% straight) in North Shoa Zone, Central Ethiopia [28]. The difference might be due to genotype. The face profile of Arado ewes is in line with the face profile of Djallonke ewes (100% straight) in Cote d'Ivoire [27] and Gamo highland sheep population (96.9% straight) in Gamo Zone, South Ethiopia [31].

Wattle and ruff were absent in Begait (98.3%, 91.9%), Rutanna (80.8%, 100%) and Arado (76.2%, 98.8%) sheep, respectively. No wattle in majority of Begait, Rutanna and Arado sheep which is not comparable with Blackhead Somali sheep (96.8% exhibited wattle) [25], Indigenous Sheep Populations (89% no wattle) in North Shoa Zone, Central Ethiopia [28] and Gamo highland sheep population (92.5% no wattle) in Gamo Zone, South Ethiopia [31]. The difference might be due to genotype. About 94.2% of female *Holla* sheep types in Ethiopia have no wattle [30] which is similar with Begait sheep. Absence of ruff in Begait sheep is in line with Indigenous Sheep Populations (92.3% no ruff) in North Shoa Zone, Central Ethiopia [28]. Rutanna sheep has no ruff which is in line with Blackhead Somali sheep (100% no ruff) [25] but not similar with Indigenous Sheep Types in Selale Area, Central Ethiopia (82.1% no ruff) [35]. The difference might be due to genotype.

Straight back profile was exhibited in Begait (99.4%), Rutanna (98.7%) and Arado (100%) which is not comparable with Ouled Djellal sheep of Algeria (60.64% sub-concave) [26] and Indigenous Sheep Populations (43.8% straight) in North Shoa Zone, Central Ethiopia [28]. The differences could be due to genotype, environment and the interaction effects of genotype and environment. It was noted that roofy rump profile was observed in Begait (86.7%), Rutanna (63.1%) and Arado (87.8%) sheep. Different studies reported that ewes with roofy rump profile do not face with birth difficulty or dystocia.

5. CONCLUSION AND RECOMMENDATIONS

The indigenous sheep (Begait, Rutanna and Arado) were kept at low input extensive production system. Rutanna sheep is large framed, Begait sheep is medium framed and Arado sheep is small framed breed of sheep. The indigenous sheep have a marked sexual dimorphism in almost all linear body traits because adult males have larger linear body traits and body weight than females. The IC (86.7±0.86) and IBW (61.8±0.98) of Rutanna sheep indicated that Rutanna sheep is more preferred for mutton production than the Begait and Arado sheep. The negative correlations among the indices (IC, IBW, BI and Ipr) indicates that selection of the linear body traits of index of conformation (IC) and index of body weight (IBW) negatively affect to body index (BI) and index of proportionality (Ipr) and vice versa.

Begait (93.1% plain, 99.4% white), Rutanna (90.6% plain, 69.8% brown red) and Arado sheep (86.6% plain, 51.8% brown red), respectively were the dominant coat color patterns and coat color types. Arado sheep can be used for wool production and are short-fat-tailed sheep whilst Begait and Rutanna sheep are long-thin-tailed sheep. Begait (100%) and Rutanna (99.3%) sheep were polled whereas 30.5% of Arado sheep were horned. Pendulous ear orientation was in Begait (98.3%) and Rutanna (100%) sheep whilst Arado sheep were with small ear (100%). Concave face profile was in Begait (98.8%) and Rutanna (100%) sheep. Wattle and ruff were absent in Begait (98.3%, 91.9%), Rutanna (80.8%, 100%) and Arado (76.2%, 98.8%) sheep, respectively. Roofy rump profiles was exhibited in Begait (86.7%), Rutanna (63.1%) and Arado (87.8%) sheep.

Conservation and improvement of the valuable indigenous sheep of the study area should be the first task of breeders and stakeholders. Genetic characterizations of the indigenous sheep populations should be conducted to identify the most economical candidate genes and diversity within breed.

ETHICAL APPROVAL

Animal Ethic committee approval has been collected and preserved by the author(s)

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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