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Characterization of the Indigenous Goat Populations of South Gonder Based on their Morphometric Traits and Body Indices

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በዳሰሳ ላይ የተደገፈ ጥናት በደቡብ ጎንደር ዞን የሞርፎሜትሪክ ባህሪያት እና የአካል መረጃ ጠቋሚዎች መሠረት በማድረግ በአገር በቀል ፍየል የምርት አቅም ላይ የምርምር ሥራ ተካሂዷል፡፡ የፍየሎችን የርባታ ባህሪያትን በተመለከተ ከ153 አባወራዎች በመጠይቅ የተደገፈ መረጃ የተሰበሰበ ሲሆን፣ የሞርፎሜትሪክ ባህሪያት መለኪያዎች ከፋርጣ ወረዳ 152፣ ከፎገራ ወረዳ 154፣ እና ከሊቦ ከምከም ወረዳ 204 በአጠቃላይ ከሁለቱም ፆታዎች በ510 ፍየሎች ላይ መረጃ ተወስዷል፡፡ በዚሁ መሠረት 19 የፍየል አካላት መለኪያ ኢንዴክሶች የሞሮፎሞትሪክ ባህሪያትን መሠረት በማድረግ ተሰልቷል፡፡ በጥናቱ በተገኘው ውጤት መሠረት የሴት ፍየሎች ለመጀሪያ ጊዜ የወለዱበት ዕድሜ 13.6 ወር ሲሆን በሁለት ወሊዶች መካከል ያለው ልዩነት 8.39 ወራት ነበር፡፡ ባንድ ጊዜ የተወለዱት የፍየል ግልገሎች መጠን 1.54 እንደሆነ ታውቋል፡፡ የፍየሎች ፆታ ከጆሮ ርዝመት፣ ከዳሌ ስፋት እና ከእግር አገዳ ቅልጥም ክብ ዙሪያ በስተቀር በሌሎች ባህሪት ላይ ጉልህ ተፅዕኖ ነበረው (p<0.001)፡፡ በተጨማሪም ከጆሮ ርዝመት በስተቀር የፍየሎች ዕድሜ በሁሉም የሞርፎሜትሪክ ባህሪያት ላይ የነበረው ተፅዕኖ ከፍተኛ ነበር (p<0.001)፡፡ የፎገራ ወረዳ ፍየሎች በክብደት፣ በደረት ክብ ዙሪያ፣ ከፊት እግር ጀርባ ቁመት፣ በአካል ርዝመት፣ በደርት ስፋት፣ ከኋላ እግር ፊት ቁመት፣ በዳሌ ርዝመት እና በጡት ርዝመት ከሊቦ ከምከም ወረዳ ፍየሎች የበለጡ ነበሩ፡፡ የሊቦ ከምከም ፍየሎች ከፎገራና ፋርጣ ፍየሎች ጋር ሲነፃፀሩ ጥናት በተደረገባቸው በአብዛኛዎቹ የሞርፎሜትሪክ ባህሪያት ዝቀተኛ እንደነበሩ ከጥናቱ የተገኘው ውጤት ያመላክታል፡፡ የደረት ክብ ዙሪያ እና የፊት እግር ጀርባ ቁመት ልኬቶች የሴት እና የወንድ ፍየሎችን የክብደት መጠን ለመተንበይ ቀዳሚይ ባህሪያት እንደሆኑ ተለይተው ታውቀዋል፡፡ በተገኘው የፍየል አካላት መለኪያ ኢንዴክሶች መሠረት፣ የደቡብ ጎንደር ፍየሎች አጭር እግር ያላቸው እና ለወይና ደጋ አየር ንብረት የሚስማሙ ሲሆኑ ለስጋ ምርት አቅም እንዳላቸው ታውቋል፡፡ በማጠቃለያም፣ በደቡብ ጎንደር ዞን የሚገኙ አገር በቀል ፍየሎች ለስጋ ምርት እምቅ አቅም ሊኖራቸው እንደሚችል የጥናቱ ውጤት በጉልህ አመላክቷል፡፡

Abstract

Survey-based study was undertaken to explore the potentials of indigenous goat populations of South Gondar zone based on morphometric traits and body indices. Reproductive traits were obtained from 153 households through questionnaire while morphometric measurements were taken from 510 goats of both sexes drawn *from Farta (n=152), Fogera (n=154) and Libokemkem (n=204) districts. Nineteen structural and functional indices were computed from morphometric measurements. In this study, age at first kidding and kidding intervals was 13.6 and 8.39 months, respectively with an average litter size of 1.54. Sex had significant ($p<0.001$) effect on all quantitative traits except ear length (EL), rump width and canon circumference. Except for EL, the age effect was significant ($p<0.001$) for all morphometric traits. Goats at Fogera district had higher live weight (LW), heart girth (HG), height at withers (HW), body length, chest width, rump height, rump length and teat length than those at Libokemkem. Goats from Libokemkem district were inferior for most of the studied morphometric traits as compared to those at Fogera and Farta. Both HG and HW were identified as best predictors of LW in both sexes. Based on the values of structural indices, the goat populations could be characterized as meat phenotype with short legs being well adapted to midland altitudes. In conclusion, goats reared in South Gondar zone could have a genetic potential for meat production with high prolificacy.*

Keywords: body indices; indigenous goat; morphometric traits; reproductive traits; South Gondar

Introduction

Goat production in many developing nations like Ethiopia is one of the major means of improving the livelihoods of poor livestock keepers, reducing poverty, and attaining sustainable agriculture and universal food security. Ethiopia is home of about 52.5 million goats in which nearly all are of local breeds (CSA 2020/2021). They are reared in a crop-livestock and agro-pastoral farming systems, and are widely distributed across different agro-ecological zones of Ethiopia (Halima Hassen *et al.* 2012; Dereje Dea *et al*. 2019). Goats are the most important livestock species for many smallholder farmers and pastoral communities due to their low maintenance requirements, excellent prolificacy, short generation interval, and potential to adapt a wide range of agro-ecological zones, Moreover, in areas where there is a financial and physical limitation for resources to keep large ruminants, goat milk production is valued as alternative source of income in the livelihood of the rural community. Recent studies conducted by Hiwot Desta *et al.* (2020) indicated that 78% and 64% of women and men in Ethiopia related the importance of rearing goats with food security as compared with other livestock species.

The characterization of local animal genetic resources based on morphological traits plays a fundamental role in classification of animals based on their size and shape (Aberra Melesse et al. 2013). It presents the primary step to be undertaken for the sustainable utilization of the available animal genetic resources through conservation. Data obtained from such studies could also provide valuable information on the suitability of animals for genetic improvement programs through selection. Moreover, structural and functional indices could be calculated from quantitative data that are obtained from any morphological characterization studies (Chacón *et al.* 2011).

Characterization studies conducted by various scholars have reported the existence of phenotypic variations among Ethiopian goat populations between and within these goat ecotypes (Halima Hassen et al. 2012; Hulunim Gatew et al. 2015; Dereje Dea *et al.* 2019). However, there are still limited characterization studies conducted to describe the genetic potentials of indigenous goat populations found in South Gondar zone. For example, Halima Hassen et al. (2012) conducted a morphological characterization study on indigenous goats in the representative zones of Amhara Region. Although South Gondar zone was one of them, the respective potential districts for goat production were not adequately represented in the study. Recently, Alebel Mulia *et al.* (2020) reported on the phenotypic characteristics of goats reared in three agro-ecologies of south Gondar zone. However, the authors did not consider Fogera and Libo-Kemkem districts in their sample coverage except the highland of Farta district. In addition, reports dealing with structural and functional indices of goat populations in Ethiopia in general and that of south Gondar zone in particular are scanty excepting those works reported by Chiemela *et al.* (2016) and Dereje Dea et al. (2019) for goats reared in specific locations with very few sample sizes. To the authors' knowledge, there is no information in the literature reporting on the structural indices of local goat populations in south Gondar zone. As a result, the potential of local goats as meat, dairy and dual-purpose phenotypes have never been reported in the study zone using structural indices. Therefore, the aim of this study was to systematically characterize the indigenous goat populations reared in Farta, Fogera and Libokemkem districts of South Gondar based on morphometric traits and body indices.

Materials and Methods

Study site

The study was conducted in Farta, Fogera and Libokemkem districts of South Gondar zone of the Amhara Regional State. The altitude ranges from 1920-4135, 1774-2410 and 1800-300 m a.s.l. for Farta, Fogera and Lbokemkem districts, respectively. The respective average annual rainfall for Farta, Fogera and Libokemkem districts is 1230, 1220 and 1233 mm.

Sampling procedure

The relevant secondary information was first collected from Agriculture and Rural Development office of South Gondar zone. Based on the information obtained, multi-stage purposive sampling techniques were applied to select the study districts, kebeles, and individual households. In the first stage, three districts namely Farta, Fogera and Libokemkem were selected purposively based on their goat production. In the second stage, three kebeles from each district were selected purposively based on the distribution of goat's population. In the final stage, households who possess at least five adult goats of both sexes and have long enough experiences in rearing goat were selected within kebeles. The sample size of the number of households for the interview was then determined according to the method of sampling size proposed by Arsham (2007). Based on the calculated results, a total of 153 households (51 from each district and 17 households from each kebele) were randomly sampled for interview using a semi-structured questionnaire.

For morphological characterization studies, three goats from each household of Farta and Fogera; and four goats from Libekemkem districts were proportionally sampled. Accordingly, 153 goats each from Farta and Fogera districts (306 goats for both districts) and 204 goats from Libokemkem district were sampled with a total of 510 sample size of which 153 and 357 were male and female goats, respectively. The sample size was determined based on the number of goat populations reared in the respective districts (45,634, 41,326 and 61,770 goats in Farta, Fogera and Libokemkem, respectively). Age of goats was estimated on the information from owner's experience and observing the dentition classes (pairs of permanent incisors, PPI. Accordingly, goats with 1PPI, 2PPI, 3PPI and 4PPI were classified in the age groups of yearling, 2-year-old, 3-year-old and 4-year-old, respectively (Ebert and Solaiman 2010). Each animal was further identified by its sex and sampling site.

Data collection procedures

Reproductive and morphometric traits

Data on reproductive traits and husbandry practices were collected through semi-structured questionnaire from 153 households. For morphometric traits, 14 variables were considered according to the descriptor list of FAO (2012) for phenotypic characterizations of goats. Thus, the following variables were measured: live weight (LW), body length (BL), height at withers (HW), heart girth (HG), chest depth (CD), chest width (CW), paunch girth (PG), rump height (RH), rump length (RL), rump width (RW), ear length (EL), fore cannon circumference (FCC), teat length (TL) and scrotal circumference (SC). Briefly, each character was measured as follows: BL = diagonal measurement from the point of shoulder to the pin bone; HG = body circumference just behind the forelegs with legs in a vertical position; HW = vertical distance from the ground to the withers; RH = vertical distance from the ground to the top of the pelvic girdle; PG = the circumference of the belly/abdomen at the center; CD = vertical distance from ventral surface of_sternum to the withers; CW = horizontal distance between the briskets; RL= distance from the hip (tuber coxa) to the pin (tuber ischi); RW = horizontal distance between the extreme lateral points of the hook bone (tuber coxae) of the pelvis; EL = distance from point of attachment to the tip of the ear; FCC = circumference of the lower part the fore cannon bone; TL = distance from the base of the teat to the end of the teat and SC= the widest point of the scrotum. All body measurements were taken using plastic tape while LW was measured using a suspended weighing scale with 50 kg capacity by placing each animal in a self-devised holding equipment.

Structural and functional indices

For the assessment of the type and function of indigenous goat populations in the study area, 19 structural and functional related indices were computed from the morphometric traits (Table 1).

Table 1. Methods used for assessing structural and functional indices using morphometric data

Body indices	Formula used to calculate the indices
Body index (BI)	Body length / Heart girth * 100
Body frame index (BFI)	Body length / Height at withers
Pelvic index (PI)	Rump width / Rump length * 100
Girth index (GI)	Paunch girth / Heart girth
Area index (AI)	Height at withers * Body length
Height slope index (HSI)	Rump height – Height at withers
Relative depth of thorax (RDI)	Chest depth / Height at withers * 100
Width slope index (WSI)	Rump width/Chest width*100
Proportionality index (PrI)	Height at withers/ Body length * 100
Balance index (BaI)	(Rump length × Rump width)/ (Chest depth × Chest width)
Transversal pelvic index (TPI)	Rump width /Rump height * 100
Longitudinal pelvic index (LPI)	Rump length/ Rump height * 100
Dactyl thoracic index (DTI)	Canon bone circumference /Heart girth*100
Dactyl costal index (DCI)	Cannon bone circumference/Chest width*100
Pectoral index (PtI)	(Withers height (WH) + Height at rump)/2) / (WH– Chest depth)
Thoracic development index (TDI)	Heart girth/Height at withers
Body ratio index (BRI)	Height at withers/Height at rump
Compact index (CI)	(Weight/Height at withers) *10
Conformation/Boron index (ConI)	(Heart girth)^2/Height at withers

Statistical analysis

Data on morphometric traits were subjected to GLM procedures of Statistical Analysis System (SAS 2012, ver. 9.4) by fitting district, sex and age as fixed effects while structural indices were analyzed by fitting district and sex as main effects. When F-test declared significant, least square means were adjusted for multiple comparisons by using the Tukey-Kramer test accounting for unbalanced data.

The following model was used for statistical analysis:

$Yijk = \mu + Di + Sj + Ak + eijk$

Where, Yijk = response of observed variables; μ = overall mean; Di = effect due to i^{th} district (i = Fogera, Libikemkem and Farta); Sj = effect due to j^{th} sex effect (j = male and female); Ak = effect due to k^{th} age effect (k = 1PPI….4PPI) and eijk = random error

For the analysis of body indices, the following statistical model was used:

$Yij = \mu + Di + Sj + eij$

Where, Yijk = response of observed variables; μ = overall mean; Di = effect due to i^{th} district (i = Fogera, Libikemkem and Farta); Sj = effect due to j^{th} sex (j = male and female) and eij = random error

Stepwise regression equation of SAS was used to regress the LW on morphometric traits to determine the best-fitted regression equation for LW prediction in both sexes by using the following model:

$Y_j = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots \beta_{14} X_{14} + e_j$

Where, Y_j = the response variable (body weight); α = the intercept; X_1…., X_{14} = explanatory variables (heart girth, height at withers, …..); β_1…, β_{14} = regression coefficients of the variables X_1…, X_{14}; e_j = random residual error

Results

Reproductive and morphometric traits

The mean age at first mating for males was reported by respondents to be 7.76 months while the average age at first kidding for does was 13.6 months (Table 2). Does at Libokemkem had significantly shorter kidding intervals than those at Fogera district. Similarly, the reproductive lifespan of does at Libokemkem was ($p<0.05$) higher as compared to those at Farta and Fogera districts. However, the longest lifespan was observed for bucks reared in Libokemkem.

Table 2. Average maturity ages and reproductive lifespan of goats reared in the three districts

Parameters	Farta (n=51)	Fogera (n=51)	Libokemkem (n=51)	SE
Age at first mating of bucks (month)	7.88	7.80	7.59	0.11
Age at first kidding (month)	13.8	13.7	13.5	0.12
Kidding intervals (month)	8.39^{ab}	8.51^{b}	8.27^{a}	0.07
Litter size (number)	1.47	1.49	1.65	0.08
Average reproductive lifespan of does (year)	7.63^{a}	7.76^{a}	8.16^{b}	0.11
Average reproductive lifespan of bucks (year)	5.65^{a}	6.00^{ab}	6.35^{b}	0.13

[a,b] Row means with different superscript letters are significant at $p<0.05$

SE = standard error of the mean

As shown in Table 3, except LW, HW, HR, CW, EL and SC, all morphometric traits were affected ($p<0.05$) by district. Goats at Fogera district had higher ($p<0.05$) BL, RL and TL than those at Libokemkem district. The average values of BL, CD, PG, RL, RW and TL for goats at Farta were higher ($p<0.05$) than those of Libokemkem. Goats at Fogera district had the highest LW and HG as compared to goats at Farta and Libokemkem, while the goats at Farta district had the highest CD, PG and RW. The FCC was higher ($p<0.05$) for goats raised in Farta and Libokemkem districts while it was lower for those reared at Fogera district. The effect of sex was highly significant ($p<0.001$) for all morphometric traits except for RW, FCC and EL traits.

Table 3. Least square means (± SE) of morphometric traits (in cm unless specified otherwise) of south Gondar goats displayed by study districts and sex groups

Morphometric traits	Districts			Sex	
	Farta (n=152)	Fogera (n=154)	Libok (n=204)	Male (n=153)	Female (n=357)
Live weight (kg)	28.9±0.272	29.3±0.270	28.9±0.244	30.0±0.266^{a}	28.1±0.176^{b}
Heart girth	71.5±0.207^{b}	72.1±0.206^{a}	71.9±0.186^{ab}	72.5±0.203^{a}	71.1±0.134^{b}
Height at withers	68.2±0.212	68.3±0.210	68.2±0.190	68.8±0.207^{a}	67.6±0.137^{b}
Body length	60.9±0.53^{a}	60.8±0.250^{a}	60.2±0.226^{b}	61.2±0.247^{a}	60.0±0.164^{b}
Paunch girth	76.8±0.323^{a}	76.3±0.32^{ab}	75.5±0.290^{b}	77.4±0.316^{a}	75.0±0.211^{b}
Height at rump	70.9±0.204	71.0±0.202	70.7±0.183	71.3±0.199^{a}	70.5±0.132^{b}
Chest depth	30.6±$^{a0.202}$	30.4±0.20^{ab}	30.0±0.181^{b}	30.8±0.198^{a}	29.8±0.131^{b}
Chest width	16.0±0.121	15.9±0.120	15.7±0.108	16.3±0.118^{a}	15.4±0.078^{b}
Rump length	16.1±0.095^{a}	16.0±0.094^{a}	15.7±0.085^{b}	15.7±0.093^{a}	16.1±0.062^{b}
Rump width	13.5±0.149^{a}	12.7±0.148^{b}	13.0±0.134^{b}	13.1±0.146	13.0±0.097
Ear length	14.7±0.089	14.6±0.088	14.5±0.079	14.7±0.087	14.5±0.057
FCC	8.00±0.091^{a}	7.69±0.090^{b}	7.94±0.081^{a}	7.88±0.089	7.88±0.059
SC	23.1±0.151	23.3±0.148	23.0±0.150	-	-
Teat length	3.74±0.025^{a}	3.73±0.025^{a}	3.65±0.021^{b}	-	-

$^{a-c}$ Row means with different superscript letters within district and sex are significant at $p<0.05$
FCC = fore cannon circumference; SC = scrotal circumference; SE = standard error of the mean

As shown in Table 4, ear length was not affected by age within sex group. Except RW, FCC and SC, all other morphometric traits consistently increased ($p<0.05$) with the age of both sex groups. The RW was similar ($p>0.05$) between 2PPI and 3PPI age categories in both sexes. Similarly, SC did not differ between 3PPI and 4PPI age groups. No significant difference was also observed for FCC of bucks between 1PPI and 2PPI as well as that of 3PPI and 4PPI age groups. Likewise, the FCC of does was similar ($p>0.05$) between 2PPI and 3PPI as well as that of 3PPI and 4PPI age groups.

Table 4. Comparison of least square means (±SE) of morphometric traits between ages within sex group (in cm, unless specified)

Traits	Males				Females			
	1PPI	2PPI	3PPI	4PPI	1PPI	2PPI	3PPI	4PPI
Live weight (kg)	26.7±0.150[d]	29.2±0.175[c]	33.6±0.202[b]	35.5±0.256[a]	24.1±0.117[d]	26.5[c]±0.121	29.3±0.119[b]	31.9±0.112[a]
Heart girth	70.2±0.148[d]	72.2±0.172[c]	74.9±0.201[b]	76.3±0.253[a]	68.0±0.118[d]	70.2±0.123[c]	72.2±0.121[b]	73.8±0.114[a]
Height at withers	66.3±0.117[d]	68.6±0.137[c]	71.4±0.158[b]	72.8±0.200[a]	64.4±0.090[d]	66.4±0.093[c]	68.6±0.090[b]	70.7±0.080[a]
Body length	58.1±0.207[d]	60.4±0.240[c]	64.5±0.278[b]	66.0±0.352[a]	56.6±0.125[d]	58.6±0.130[c]	60.8±0.128[b]	63.7±0.121[a]
Paunch girth	74.0±0.318[d]	77.2±0.370[c]	80.3±0.429[b]	82.9±0.542[a]	70.5±0.193[d]	72.6±0.200[c]	77.2±0.197[b]	79.0±0.186[a]
Height at rump	68.8±0.155[d]	71.2±0.180[c]	73.5±0.208[b]	75.0±0.263[a]	67.5±0.113[d]	69.4±0.117[c]	71.7±0.116[b]	73.1±0.109[a]
Chest depth	28.5±0.132[d]	30.8±0.153[c]	32.9±0.180[b]	34.2±0.225[a]	26.8±0.094[d]	28.4±0.097[c]	31.0±0.096[b]	32.8±0.091[a]
Chest width	14.8±0.105[d]	16.3±0.122[c]	17.7±0.141[b]	18.6±0.178[a]	13.7±0.079[d]	15.1±0.081[c]	16.0±0.080[b]	16.9±0.076[a]
Rump length	14.9±0.138[d]	15.6±0.161[c]	16.3±0.186[b]	17.4±0.236[a]	15.1±0.077[d]	15.7±0.080[c]	16.4±0.079[b]	17.1±0.075[a]
Rump width	11.4±0.173[c]	13.6±0.201[b]	14.1±0.232[b]	15.0±0.294[a]	11.0±0.139[c]	13.2±0.144[b]	13.9±0.143[b]	14.0±0.134[a]
Ear length	14.6±0.136	14.7±0.158	14.7±0.183	15.0±0.231	14.4±0.115	14.5±0.119	14.6±0.118	14.6±0.111
FCC	7.38±0.133[b]	7.70±0.154[b]	8.53±0.179[a]	8.70±0.226[a]	7.09±0.09[c]	7.69±0.099[b]	7.95±0.098[b]	8.72±0.092[a]
SC	21.9±0.137[c]	23.1±0.159[b]	23.6±0.184[a]	23.9±0.232[a]	-	-	-	-
Teat length	-	-	-	-	3.03±0.027[d]	3.49±0.028[c]	4.02±0.028[b]	4.23±0.026[a]

[a-d] Row means with different superscript letters within sex group are significant at $p<0.05$
FCC = fore cannon circumference; SC = scrotal circumference; SE = standard error of the mean

Stepwise multiple regressions were used to predict LW from morphometric traits, which showed a significant positive phenotypic correlation with this variable. According to the results of the regression analysis, either HG or HW could be used to estimate the LW of female and male goats (Figures 1 and 2). As shown in the figures, HG appeared to be a better predictor of LW in does than in bucks. On the other hand, LW in bucks seemed to be better estimated with HW as compared with does.

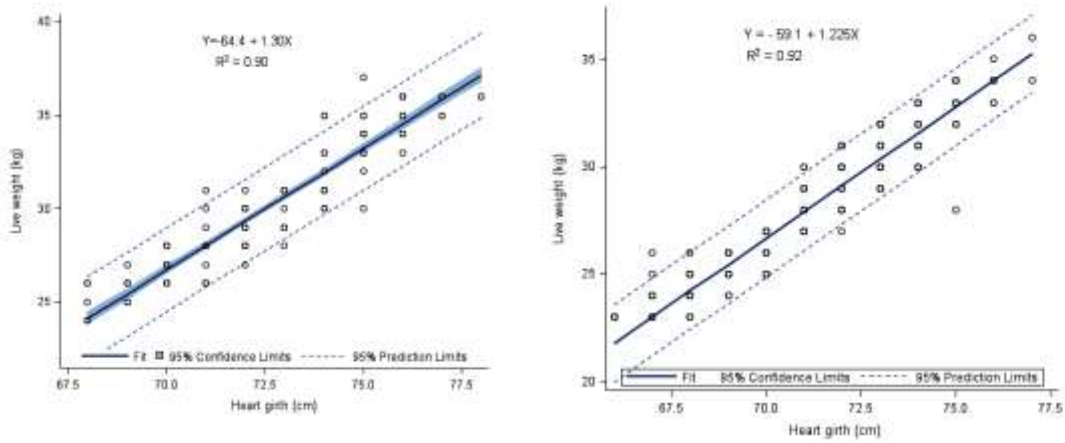

Figure 1. Live weight (Y) prediction of south Gondar bucks (left) and does (right) by fitting heart girth (X) in the regression model

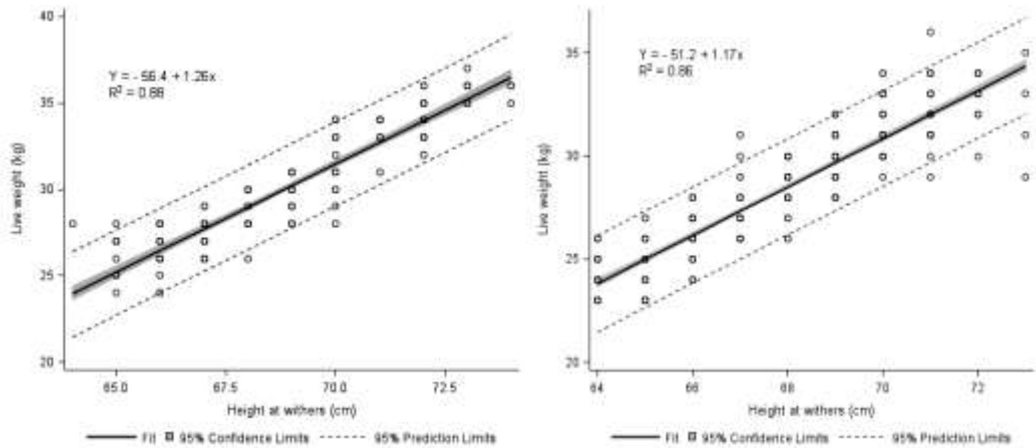

Figure 2. Predicting the live weight (Y) of south Gondar bucks (left) and does (right) by fitting height at withers (X) in the regression model

Zoometric indices

As shown in Table 5, only LPI, GI, DCI and BI were markedly affected by district. Regardless of sex, goats at Farta district had higher LPI and GI index values than those at Libokemkem district. On the other hand, DCI and BI index values were higher for goats at Farta than Fogera district. The effect of sex was significant for DCI, BRI, HSI LPI, ConI, GI and CI indices. Female goats had larger ($p<0.05$) DCI, HSI and LPI values than males, whereas males were superior in BRI, ConI, GI and CI indices.

Table 5. Least square means of body indices of south Gondar goat populations by district and sex

Structural/functional indices	Districts				Sex		
	Farta (n=152)	Fogera (n=154)	Libok (n=204)	SEM	Male (n=153)	Female (357)	SEM
Body index	85.3	84.4	84.2	0.550	84.9	84.4	0.450
Body ratio index	0.963	0.961	0.965	0.002	0.968[a]	0.958[b]	0.001
Body frame index	0.893	0.893	0.886	0.004	0.894	0.887	0.003
Conformation/baron index	75.3	76.5	76.0	0.829	77.2[a]	77.7[b]	0.677
Balance index	0.450[a]	0.419[b]	0.429[ab]	0.003	0.410[b]	0.457[a]	0.002
Pelvic index	84.3	80.1	83.6	1.906	84.4	80.9	1.556
Transverse pelvic index	20.1	18.7	19.2	0.527	19.4	19.3	0.430
Longitudinal pelvic index	22.9[a]	22.5[ab]	22.1[b]	0.266	22.2[b]	22.8[a]	0.217
Relative depth of thorax	44.9	44.7	44.3	0.656	45.2	44.0	0.543
Thorax development index	1.048	1.055	1.053	0.003	1.053	1.051	0.002
Dactyl thoracic index	11.2	10.7	11.2	0.208	11.0	11.1	0.170
Dactyl costal index	49.8[a]	48.2[b]	50.7[a]	0.674	48.1[b]	51.0[a]	0.571
Proportional index	89.4	89.0	88.6	0.433	89.3	88.8	0.353
Compact index	4.27	4.34	4.28	0.122	4.47[a]	4.13[b]	0.099
Pictorial index	1.853	1.846	1.833	0.021	1.859	1.828	0.017
Width slop index	0.193	0.178	0.183	0.005	0.186	0.183	0.004
Height slope index	2.63	2.64	2.62	0.166	2.35[b]	2.92[a]	0.136
Area index	4213	4216	4188	134.7	4358	4054	110.0
Girth index	1.074[a]	1.060[ab]	1.054[b]	0.006	1.071[a]	1.054[b]	0.005

[a-d]Means with different superscript letters across the column within a group are significant
SEM = standard error of the mean; Libok = Libokemkem

Body frame index, PrI, TPI, RDI, DTI, PtI and AI and did not vary across districts and sex groups. In terms of figures, goats at Fogera had relatively lower PI value than goat populations in the other two districts. Bucks had slightly higher PI and AI values than females. There was no marked difference for TDI value among goats reared in all districts but the index value was the lowest in goat populations at Farta. With regard to sex effect, bucks had higher ($p<0.05$) values for BRI, ConI, CI and GI than females. Conversely, BaI, LPI, DCI and HIS values were significantly higher in females than males.

Discussion

Designing genetic improvement schemes for sustainable conservation and utilization of indigenous animal genetic resources should be based on the assessment of the phenotypic characteristics of populations reared in various production environments. There is an increasing interest in the phenotypic characterization of the local farm animal populations in Ethiopia. Such kinds of studies are particularly becoming common research areas among small ruminant animals in general and in goats in particular due to their social, economic and adaptation potentials in a wide range of environments where other farm animals may not survive and perform effectively. The first comprehensive information compiled on physical description and management system revealed that there were 14 goat types in Ethiopia and Eritrea of which eleven were found in Ethiopia (Peacock 1996).

Reproductive traits

Kidding interval is one of the important reproductive traits that influence the general performance of farm animals. The average kidding interval in the current study is in line with that of local goats reported by Bekalu Muluneh et al. (2016). Sheriff et al. (2019) who have reported a kidding interval of 7.2 to 7.8 months for goats in north-west Ethiopia, which is slightly lower than observed in the present study. Reducing the number of days for kidding interval and reducing kid mortality are some of the most important indicators of increased reproductive efficiency. It is affected by the breed and year of kidding, season and parity of does, type of management, nutrition and type of mating. Thus, appropriate intervention strategies are essential to improve the reproductive efficiency of does by tacking these problems into considerations.

The reproductive life spans of male and female goats in the study area were 6.35 and 8.2 years, respectively, which indicate that goats stayed in the reproduction cycle for an extended period providing services to their owners. One important reason for prolonged lifespan for does could be related to limited availability of replacement females as farmers usually sale them as means of income generation. From the animal breeding point of view, allowing bucks to stay in service for an extended period will enhance the accuracy of its estimated breeding value as it produces more progenies. The observed long-life span in the present study is slightly lower than reported by Sheriff et al. (2019) for Arab and Oromo goats in north-west Ethiopia. Such variations in the lifespan of goats might be associated with the genetic makeup of the breed, management of animals and purpose and cultural practices of the farmers.

The major part of the income in any small ruminant production system such as goat is supplied through high number of litter production. The overall average litter size in the current study was 1.54, which may suggest the practice of selecting female goats for improved litter size. Our finding is higher than that of Asefa et al. (2015) who reported a litter size of 1.33 in Eastern Ethiopia. Apart from the genetic makeup of animals, environment and management practices are considered as important factors to affect litter production by modifying the expected value of the phenotype (José et al. 2016). Favourable environmental conditions coupled with good management practices have the same influence as selection and hence more multiple births can occur under such conditions (Petrovic et al. 2012). Moreover, litter size has an important indirect effect on the improvement of quantitative traits. Higher litter size allows more selection pressure to be applied on other economically important traits (Shaat et al. 2004). Traditionally litter size is considered as a trait of female that depends on ovulation rate and is affected by the number of fertilized oocytes. Since the heritability of litter size is usually low, selection on phenotype will be quite ineffective in improving litter size, rather it could be improved by within breed selection and by combining prolific breeds in a crossbreeding scheme.

Morphometric traits

In the present study, goats in the three districts have showed different morphometric characteristics which might be attributed to environmental variations such as nutrition, health, management which may not equally favor these animals to express their genetic potentials. Moreover, such differences might be explained by the existence of disparity in the genetic makeup of these ecotypes particularly between the goats of Libokemkem and those of the other two districts. The LW of male and female goats increased as dentition class increased from 1PPI to 4PPI age group. These changes are explained by the skeletal muscle development as the age of the animal increases over time.

Ear length in goats is considered as important trait in adaptation to various climatic environments. More specifically, the goat populations in the study zone possessed larger ears, which are one of the important type traits responsible for longevity under stressful environments. However, goats in reared the lowland and midland areas of Gamo zone reported to have lower ear length (Dereje Dea et al. 2019) compared to the current finding. The current study also indicated that EL was not affected by age in both sexes. These observations may suggest that the EL development is less dependent on the size of the animal.

The SC is an important trait that is closely associated with the testicular growth and sperm production capacity of domestic animals. Hulunim Gatew et al. (2015) reported relatively higher SC values for bucks raised in eastern Ethiopia than observed in the current study (27 vs. 23 cm). Since SC size is dependent on the sexual maturity of the buck, such differences could be related to the physical development of the animal. It has been reported that SC showed a significant positive correlation with the body weight (Birara Tade, 2018), which substantiated the dependency of SC on the body development of the animal. Consistent with the current results, Raji and Ajala (2015) reported a significant effect of body weight on SC for West African Dwarf buck. Since SC is a direct measurement of testicular size, knowing the size of testis may be used as indicator in the onset of active spermatogenesis and, hence, the possibility of using bucks for breeding at an earlier age than normally recommended. Such knowledge might be particularly essential if young bucks are not kept together with the does for reasons related to control of inbreeding. Such practices will further allow the buck to produce more kids thereby reducing the generation interval of the flock.

Teat length has positively affected milk production capacity of does (El-Gendy *et al.* 2014). Merkhan and Alkass (2011) reported 3.6 cm TL for Iraqi Black and Meriz goats, which is comparable with the current observation (3.7 cm). However, Alemayehu *et al.* (2015) reported much lower TL (3.4 cm) for goats reared in West Amhara region of Ethiopia. The type of genotype, feed availability, season, and health conditions of animals might explain such differences. Teat length significantly increased with the age of the does indicating that its development in size is dependent on the sexual maturity of the does. Teat length is a part of udder morphology and is considered a very important traits in dairy type goat selection. Selection toward more optimal teat characteristics has reported to result in improved milk quality and udder health (Zwertvaegher *et al.*, 2013). Heritability of teat length in dairy type goats ranged from 0.46 to 0.50 (Rupp *et al.*, 2011) which suggest that this trait can be improved through selection. Positive correlations between teat length and milk flow rate and yield were also reported (Peris *et al.,* 1999).

Body indices

Morphology of an animal expresses a strong relationship with productive potential, since it contains the structure, which supports the biological functionality of the animal (Alpak et al. 2009). Relative depth of thorax, BFI and PrL belong to the group of ethnological indices, which contribute to the breed characteristics. Conversely, index of TDI, DTI and ConI are functional indices, which contribute to the information about the type, purpose and performance of the breed. Based on the results of BI, goats in south Gondar could be classified as brevigline indicating that they are short in their body length. The TDI was slightly above 1.0 indicating smaller thoracic capacity, which suggests that south Gondar goats are inherently adapted to mid altitude rather than at higher elevations.

The PI serves as a racial diagnostic index and is used to determine the proportionality of the hindquarters and thus, related to the reproductive capacity of female goats (Cerqueira *et al.* 2011). According to the current result (PI = 82.7), the goats' rump is described as a convex curve, with a predominance of the rump length over the width. Chacón et al. (2011) found lower PI (76.0) for Cuban Creole goats while Dereje Dea et al. (2019) reported much higher values for lowland Gamo goats than the current findings. These variations attributed to differences in breed and environment effect as well as age and sex of goats when the morphometric measurements were taken.

Proportionality index relates the body height to the body length and designates the shape of a given animal populations (Barragán 2017). A PrI value less than 100 indicates that the animal's body tends to be rectangular which is a characteristic of meat phenotype, while greater than 100 denotes a square shape, which is an attribute of dairy phenotype (Barragán 2017). In the current study, the lower PrI (89.0) would classify the goat populations of south Gondar as meat type. The DTI helps to classify animals as hypermetric (large format), eumetric (medium format), or elipometric (small format) (Chacón et al. 2011). According to the current DTI result (11.0), the goats in south Gondar could be classified as eumetric possessing characteristics of medium meat type. The CI and LPI values further imply that goats in the study region could be suitable for meat production. The CI of bucks in this study is significantly higher than that of females suggesting the former being more suitable for meat production than the latter. Nevertheless, when assessed by RDI and TPI that serve to estimate the meat aptitude of a given breed (Arredondo-Ruiz *et al.* 2012; Barragán 2017), the goat populations of south Gondar showed low tendency for meat production.

The RDI further indicates that goats of south Gondar are characterized by relatively short leg that is close to the ground, which may reveal their adaptation to flat land and mountain terrains. In the present study, the PtI value is similar across districts and sex groups suggesting that they possess comparable adaptations with short-sized legs. The average BFI in the current study was 0.89 which indicates that the goats in the study area possess large body frame with respect to their height at withers, which provides sufficient space for the development of internal organs and carcass yield.

The BRI in the present study is less than 1.0, which suggest that goats of the south Gondar zone possess a lower body dimension when viewed at the front than they are at the rear side. This has been clearly observed in female goats where they had significantly lower BRI value than the bucks. Since HIS is the difference of height at rump to that of at withers, the female goats of south Gondar are characterized by elevated body dimension at the rear view than in the front and this phenomenon is more noticeable in in does than in bucks.

Conclusion

The structural and functional indices indicated that the goat populations in south Gondar are characterized as meat type with short legs. Focused genetic evaluation with a proper recording system at the community level could be helpful to evaluate and exploit the genetic potential of these animals. Further environmental studies are also recommended to validate their meat production and prolific potentials.

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