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Husbandry practices and phenotypic characterization of indigenous sheep types in Gurage Zone, Southern Ethiopia

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The study was conducted to characterize the husbandry practices, phenotypic characteristics and determination of live body weight using morphometrical measurements of indigenous sheep types under smallholder management condition in highlands of Gurage zone, Southern Ethiopia. Two districts, Gumer and Ejha were selected purposely based on sheep population distribution, flock size and their contribution to the farmers. Questionnaire survey was used to collect data from 156 households of smallholder farmers who own sheep. Qualitative trait, live body weight and body measurement were taken from a total of 402 indigenous sheep. Live body weights were also associated and predicted using linear body measurements. The mean flock size owned per household was 5.20 and 4.40 sheep at Gumer and Ejha district, respectively. In both districts generating income was the main purpose of sheep rearing followed by saving, meat consumption and manure. Natural pasture and crop residue were found to be the major sources of feed during wet and dry seasons. The main constraints of sheep production were feed scarcity, disease prevalence, market price fluctuation and water shortage. The overall mean age at first lambing and lambing interval were (13.8± 0.4) and (8.3± 0.15) months, respectively, while mean litter size was 1.5head. The majority of sheep were characterized by patchy color pattern and the combinations of brown and / or black and /or white color type which is locally called it "Gerebet". The overall mean live body weight of male and female sheep was 28.3 and 23.4 kg, respectively. Gumer sheep population had significantly higher linear body measurements (P<0.05) than Ejha district. Sex, age, and sex by age interaction exerted significant differences (p<0.05) on live body weight and linear body measurements. Body weight was significantly (P<0.01) correlated with all linear measurement traits considered in this study. Chest girth and body length were found to be the best predictor of live body weight. Phenotypic characterization indicated variations within the studied population in qualitative and quantitative traits. Hence, there is a great possibility for genetic improvement through selection of rams within the studied population. Thus, implementation of planned genetic improvement strategy through community based breeding program that considers the major constraints hampering sheep production need to be addressed.

Key words: Characterization, husbandry practice, body weight, qualitative and quantitative traits.

INTRODUCTION

Ethiopia has huge livestock resources of varied and diversified genetic pool with specific adaptations to wide range of production environments, production systems and ethnic communities (Duguma, 2010; Melesse et al., 2013). Sheep production is one of the integral components of livestock production activities under small holders. The country has about 31.3 million heads of sheep (CSA, 2017/2018) and 14 traditional populations (Gizaw et al., 2007). The majority of sheep are reared in the highlands and mid-altitude of Ethiopia where mixed crop-livestock production dominates (Berhanu and Haile, 2009; Tibbo, 2006). For the smallholder farmers, sheep have multipurpose roles as generating income, meat, skin, wool, manure, and risk alleviation during crop failures and social function (Nigussie et al., 2015). Increasing population, urbanization and income level, increases the demand for animal source food; export and domestic market for mutton and live animal has created more opportunity for sheep production in Ethiopia (Mohammed et al., 2015).

Even though multipurpose role and large size of Ethiopian sheep population, productivity is relatively low (Getachew et al., 2010). Furthermore, the production system is constrained by several factors such as feed scarcity, lack of technical capacity of the farmer, disease and parasite prevalence, low genetic potential for functional traits of the animal, lack of appropriate breeding strategies and limited understanding of the production systems (Gizaw et al., 2013a; Gatew et al., 2017). The severity of constraints varies with different production system and agro-ecological zones. Therefore, there is a need to design sheep breeding improvement scheme that consider the existing smallholder production system. Characterizing sheep genetic resources, assessment of productivity level of sheep population in its existing production environment, and identification and prioritization of the constraints of production are important to design sustainable genetic improvement programs and to develop effective intervention strategies which are compatible with the production system (Kosgey and Okeyo, 2007).

Sheep populations in Ethiopia as identified by Gizaw et al. (2007) are highly linked with ethnic groups and agro-ecology. Most traditional sheep types are reared by and named after specific communities. Some communities related special cultural values to their sheep and exclude the use of breeding stock from other populations resulting in cultural barrier to gene flow (Melesse et al., 2013). Studies also indicated that morphological diversity follows ecological patterns and production systems (Wagari et al., 2020). Sheep production in the mixed crop-livestock production systems of the highland areas has a vital role in contributing to the food security and generating cash income in Ethiopia in general, in Gurage zone in particular. There is high integration between *enset* and livestock production in *enset*-cattle based mixed production system of Gurage zone which has a strong bond in determining the livelihoods and food security of the rural farming families (Wonchesa et al., 2019). Sheep production has versatile roles in areas across hill sides of Zebidar Mountain of central highland which is not accessible for crop production. Indigenous sheep can efficiently utilize marginal land and able to produce under adverse climatic conditions. So that given the adaptive potentials of the existing sheep, improving sheep productivity can be used for poverty reduction and improving the livelihoods of smallholders in such very cool areas of Gurage zone.

Information on husbandry practices and phenotypic characterization of indigenous sheep types can serve as basis for sustainable improvement and determining productive performance variation between and within breeds (Gizaw et al., 2013b). Husbandry practices such as management, production constraints, feeding and breeding aspects are among the factors which can affect the phenotypic characteristics of animals (Dagnew et al., 2017; Gatew et al., 2017). In addition, information on body weight with other body measurements is important to monitor the growth potential of the sheep population and to estimate correlations between body weight and morphometrical measurements (Asefa et al., 2017). Prediction of body weight using linear body measurement is also important to determine medication dosage during treatment and the amount of feed required for the animal without weighing scale, and simplicity of measurement under field condition (Abera et al., 2014).

However, information on phenotypic traits of indigenous sheep types and their husbandry practices in Gurage Zone is limited. Furthermore, updating of the previous findings is important since genetic resources and husbandry practices are dynamic (Solkner et al., 1998). Thus more detailed phenotypic characteristics and understanding husbandry practices of indigenous sheep in Gurage zone are important. Therefore, the study was conducted to generate information on husbandry practices, phenotypic characteristics and determination of live body weight using morphometrical measurements of indigenous sheep types in Gurage zone of Southern Ethiopia, so that the information generated can be used to design sustainable genetic improvement programs and to develop effective intervention strategies which are compatible with the production system.

MATERIALS AND METHODS

Descriptions of the study area

The study was conducted from September 2019 to April 2020 in Gurage zone, which is found in the Southern Nations, Nationalities and Peoples' Region of Ethiopia. It is located between 37° 28' and 38° 38' East longitude and 7° 28' and 8° 27' North latitude with altitudinal ranges from 1600 to 3650 m above sea level. The annual rainfall of the area ranges between 800 and 1400 mm. The average

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annual temperature is about 18°C. The agricultural practice in these areas is Enset based crop-livestock production system in which livestock play important role for crop production and the livelihood of the farmers (Wonchesa et al., 2019). According to CSA (2016a), Gurage zone livestock population constituting 1,678,455 cattle, 776,900 sheep, 260,420 goats, 1,020,000 chickens, 128,532 horses and 9,464 mules and donkeys.

Sampling methods

First, discussions were made with Gurage zone livestock and fishery resource development bureau officers to select districts. Ejha and Gumer districts were purposively selected based on sheep population distribution, flock size, their contribution to farmers and availability of transportation. Within the selected districts, a rapid field survey and discussions were made with respective zonal and district livestock experts, leaders and elders to locate appropriate peasant associations for the baseline data collection. Accordingly, 12 peasant associations (6 from Gumer and 6 from Ejha district) were selected. A total of 156 households head (13 households from each peasant association) who own at least three sheep were randomly selected and interviewed using pre-tested semi-structured questionnaire; adopting a questionnaire developed by International Livestock Research Institute and Oromia Agricultural Development Bureau for survey of livestock breeds in Oromia (Workneh et al., 2004).

Data for the assessment of quantitative and qualitative traits were collected from 402 sheep (288 ewes and 114 rams) that were drawn from sampled households. Two ewes from each household were randomly selected while all adult male sheep were recorded due to their limited number. Age of the sheep was estimated from dentition class following the procedure described by Wilson and Durkin (1984). The sheep were categorized by age group as 0PPI, 1PPI, 2PPI, and 3PPI which represents no pair of permanent incisor (6-12 months), one pair of permanent incisors (1-1.5 years), two pairs of permanent incisors (1.5-2 years), and more than two pairs of permanent incisors (>2 years), respectively.

Data collection procedure

Information on husbandry practices like flock structure, production objectives, selection criteria, production constraints, production performance and other related issues were collected from 156 household head using questionnaires. Field measurements and observations were implemented based on the description of FAO (2012). Qualitative and morphometrical measurements like: coat color pattern, color type, hair coat type, horn presence or absence, horn shape, horn orientation, facial (head) profile, wattle (presence or absence), and ruff (presence or absence) were observed and recorded using a format developed for the purpose. The quantitative traits measured were body weight (BW), body length (BL), height at wither (HW), chest girth (CG), pelvic width (PW), canon length (CL), canon circumference (CC) and tail length (TL). Linear body measurements were made using measuring tape while live body weight were taken using suspended spring balance having 50 kg capacity.

Data management and statistical analysis

All the data obtained from field observations and measurements were coded and recorded into Microsoft EXCEL softwares. The survey data was analyzed and presented in the form of descriptive summaries (mean, standard deviation, frequency and percentage). Indices for ranking sheep production constraints, feed sources, sheep production objectives, and ram and ewe selection criteria by the smallholder farmers were computed for the first three ranks following the formula: Index = sum of (3 for rank 1 + 2 for rank 2 + 1 for rank 3) given for an individual attribute divided by the sum of (3 for rank 1 + 2 for rank 2 + 1for rank 3) for overall attributes. Qualitative data was analyzed following the frequency procedures of statistical Analysis System (SAS release 9.1, 2008). The General Linear Model (GLM) procedure of SAS was employed to analyze quantitative variables. When analysis of variance declares significance, least square means was separated using adjusted Tukey-Kramer test. The model employed for analyses of body weight and other linear body measurements used were:

$$Y_{ijk} = \mu + S_i + A_j + (SA)_{ij} + D_k + e_{ijk}$$

where Y_{ijk} = observed variable of i^{th} sex, j^{th} age and k^{th} district, μ = overall mean, Si = effecet of the i^{th} sex (i= 1, 2), Aj= effect of the j^{th} age group (j = 1, 2, 3, 4), $(AS)_{ij}$ = the interaction effect of the i^{th} sex by the j^{th} age, D_k= effect of the k^{th} district (k=1, 2), and e_{ijk} = random residual error.

Pearson's correlation coefficients were estimated between live body weight and other body measurements within sex and age group. Within each age and sex group, stepwise regression procedure (SAS, release 9.1, 2008) was used to determine the best-fitted regression equation for the prediction of body weight from body measurements; which were selected based on the values of coefficient of determination (R^2). The following models were used for the analysis of multiple linear regressions.

$$Y_j = \beta 0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + e_j,$$

where Y_j = the dependent variable bodyweight, β0 = the intercept; X_1, X2, ..., X_7 are the independent variables of body length, height at wither chest girth, pelvic width, canon bone length, and canon bone circumference and tail length, respectively. β_1, β_2 ... β7 are the regression coefficient of the variables X_1, X_2 …X7, respectively. e_j = the residual random error.

RESULTS AND DISCUSSION

Livestock composition and holding pattern

The major livestock species observed in the study area were sheep, cattle, goats, horse, mule and donkey (Table 1). Sheep were the predominant species in both areas accounting for 5.19±0.27 and 4.41±0.1 in Gumer and Ejha districts, respectively. The least square mean (±SE) sheep flock size per household in Gumer was significantly (p<0.05) higher than in Ejha district. The overall mean number of sheep holding per household found in this study (4.80±0.1) was comparable with the previous study of Kocho (2007) in the Alaba area (reported five sheep). On the other hand, the overall mean number of sheep per household in the current study area was relatively higher than those reported by Shenkute (2009) and Ferew (2008) who reported four and two sheep per household for south west Ethiopia. The present study revealed that, households in both areas keep sheep as the primary animal probably because of their ability to survive in a poor management and production environment.

Table 1. Mean (+SE) of livestock composition and holdings per household (in number).

Livestock species	Gumer	Ejha	Overall Mean
	Mean (SE)	Mean (SE)	Mean (SE)
Cattle	4.32±0.2	3.81±0.1	4.06±0.1
Sheep	5.19±0.2	4.41±0.1	4.80±0.1
Goat	0.24±0.1	0.23±0.1	0.24±0.1
Hoarse	0.47±0.1	0.56±0.1	0.52±0.0
Mule	0.01±0.0	0.08±0.0	0.09±0.0
Donkey	0.26±0.1	0.28±0.1	0.27±0.0

SE = Standard error.

Table 2. Ranks for the purpose of rearing sheep in the study areas.

Purpose	Ejha				Gumer			
	R_1	R_2	R_3	Index	R_1	R_2	R_3	Index
Income	56	14	8	0.44	61	9	9	0.47
Saving	16	50	10	0.34	13	55	9	0.36
Meat	6	12	45	0.19	4	9	21	0.11
Manure	-	2	14	0.04	-	4	15	0.05

Index= sum of (3for rank1) + (2for rank 2) + (1 for rank 3) divided by the sum of all the purpose of keeping sheep values mentioned by the respondents.

Sheep flock structure

From the flock inventory, 41% of ewes and 7% males were above one year of age. The percentage of young female and male lambs which are less than six months of age were 14 and 15%, respectively; while 13% female and 6% male were within six to twelve months of age. Castrates constitute only 3%. The higher proportion of ewes is in good agreement with the findings of Kocho (2007) and Shenkute (2009). According to respondents, only few males are required for breeding and the remaining males should be sold at early age because of feed shortage and the need to maximize their breeding female animals in the flock. The remaining rams were castrated and finished for markets. In most cases, male animals are castrated at about 2.5 to 3 years of age for fattening purpose. Farmers sell fattened males at about 2 to 3 years of age. The proportion of intact male (ram) to ewe ratio was 1:22, which is in the range of the recommended breeding male to female ratio (1:25) for sheep under traditional production system (Wilson and Durkin, 1984).

Purpose of keeping sheep

According to respondents in all study area mentioned that cash income was the primary reason of keeping sheep, followed by saving, meat consumption and manure with index values of 0.47, 0.36, 0.11 and 0.05, respectively (Table 2). The purpose of sheep keeping identified in this study is in line with that of previous studies (Legesse, 2008; Zelealem et al., 2012). Gizaw et al. (2013b) also reported that, male lambs are mainly kept for income generation and risk mitigation while females are reared for reproduction/breeding. However, during money shortage and unavailability of male lambs, ewes can also be sold for income generation to purchase agricultural inputs. These imply that indigenous sheep can play important roles in poverty reduction at the smallholder level, if adequate efforts are made to improve their productivity.

Feed resources

The major feed resources during wet and dry seasons of the year in the study area indicated in Table 3. Natural pasture was the main feed resource during the wet season followed by crop thinning and improved forage with the corresponding index values of 0.55, 0.36 and 0.09, respectively. However, during dry season, crop residues, natural pasture, improved forage, conserved hay and concentrated feeds were the main feed resources recorded with index value of 0.37, 0.34, 0.07 and 0.04, respectively. Improved grass species and forage trees, especially *Tree Lucerne* species planted on around homesteads, boarders, hedge and sides of

Table 3. The major feed resources in the study area.

Feed resource	Ejha				Gumer			
	R_1	R_2	R_3	Index	R_1	R_2	R_3	Index
Wet season								
Natural pasture	65	12	0	0.54	68	9	0	0.55
Crop thinning	6	52	16	0.34	3	62	13	0.36
Conserved feeds/hay	0	0	0	0.00	0	0	0	0.00
Improved forage	7	6	14	0.12	6	7	4	0.09
Concentrate feeds	0	0	0	0.00	0	0	0	0.00
Dry season								
Crop residue	37	21	19	0.37	37	17	20	0.37
Natural pasture	24	27	21	0.32	23	29	25	0.34
Conserved feeds/hay	4	9	10	0.09	2	10	8	0.07
Improved forage	12	14	13	0.17	12	16	12	0.18
Concentrate feeds	1	5	13	0.06	0	4	11	0.04

Index= sum (3for rank1) + (2for rank 2) + (1 for rank 3) divided by the sum of all feed resources values mentioned by the respondents.

Table 4. Ranking of the selection criteria for breeding ewes and rams in the study districts.

Selection criteria	Ejha				Gumer			
	R_1	R_2	R_3	Index	R_1	R_2	R_3	Index
Breeding ewe								
Mothering ability	56	40	12	0.62	46	51	16	0.61
Body size	19	25	11	0.28	30	22	8	0.34
Color	2	9	12	0.08	0	3	11	0.04
Horn	0	3	4	0.02	0	1	0	0.01
Breeding ram								
Body size	33	21	6	0.34	38	23	16	0.38
Growth rate	17	19	4	0.21	11	34	21	0.27
Color	14	14	20	0.20	16	13	19	0.20
Horn	7	16	10	0.18	9	5	16	0.11

Index= sum (3for rank1) + (2for rank 2) + (1 for rank 3) divided by the sum of all selection criteria value mentioned by the respondents in the study area.

cropping land. In the highlands of Ethiopia, the major basal feed resources are natural pasture, crop residues and stubble grazing, and their contribution varies from area to area based on cropping intensity and population pressure (Tolera et al., 2012). The author also indicated that in the mixed cereal livestock production systems of Ethiopia, crop residues provide on average about 50% of the total feed source for ruminant livestock during the dry period.

Selection criteria and breeding practices

Preference for breeding ewes and rams by sheep producers are summarized in Table 4. For sheep keepers in Ejha district, the most important selection criteria for breeding ewes were mothering ability, body size, coat color and horn with the index values of 0.62, 0.28, 0.08 and 0.02, respectively. Likewise, mothering ability, body size, color and horn were important selection criteria by farmers in Gumer district with index values of 0.61, 0.34, 0.04 and 0.01, respectively. This result is in agreement with Duguma et al. (2011) who reported a high choice preference for good mothering ability of ewes in four indigenous sheep breeds (Horro, Menz, Afar and Bonga) of Ethiopia.

Body size followed by growth rate and coat color were found as the most important selection criteria of breeding ram in both study districts. The preference of big body size and fast growth rate as the preferred attributes, since the main purpose of keeping sheep was for cash source. The animals with big size are highly demanded in market

Table 5. The main sheep production constraints as perceived by the respondents.

Main constraint	Ejha				Gumer			
	R_1	R_2	R_3	Index	R_1	R_2	R_3	Index
Feed shortage	49	25	3	0.43	53	25	0	0.45
Disease prevalence	17	22	25	0.26	14	26	32	0.27
Market demand fluctuation	8	18	28	0.19	7	11	23	0.14
Water shortage	0	7	12	0.06	2	8	9	0.07
Predator	0	1	5	0.02	2	5	5	0.04
Labor shortage	3	4	4	0.05	0	3	9	0.03
Poor genetic potential	-	-	1	-	-	-	-	-

Index= sum (3for rank1) + (2for rank 2) + (1 for rank 3) divided by the sum of all constraints value mentioned by the respondents.

and fetch good local market prices (Abebe et al., 2020; Abera et al., 2014). For ram selection, farmers target was not only for breeding purpose but also they take into account the traits that affect the market value. For instance, rams with either completely black color, or abnormal legs, or without horn or small size are not selected as such rams showing these features do not attract buyers and obtained low price (Nigussie et al., 2015). Sheep producers further reported that, rams with any defects or visible injuries on testis was not selected for breeding.

The mean number of breeding ram per flock within the interviewed households was 0.34 head. Sheep producers who do not have breeding ram stated that they tend to borrow ram from neighbor or mating took place at random with rams present in the flocks in adjacent grazing land and watering point. Uncontrolled natural mating was common in the study districts.

Major constraints associated with sheep production

The major constraints associated with sheep production in the study areas are shown in Table 5. Feed shortage, disease and market price fluctuation were the first, second and third major constraints of sheep production with the corresponding index values of 0.43, 0 26 and 0.19 for Ejha; and 0.45, 0.27 and 0.14 for Gumer respondents, respectively. The study revealed feed scarcity was the main challenges of sheep production and productivity. This is mainly due to shortage of land for grazing and fodder production as the result of expansion of crop agriculture in the expense of grazing land (Gizaw et al., 2010a; Tibbo, 2006).

According to respondents, all species of animals graze together in grazing lands and fallow lands. In this type of herding, lambs usually are more vulnerable to the effects of feed shortage and malnutrition. Mortalities due to feed scarcity and malnutrition are common especially during the late dry seasons (March to June). Disease is the second most important sheep production constraints as reported by sheep owners of both study districts. The most prevalence diseases of sheep in the study areas include: *Ovine* pasteurollosis, *Orf*, internal and external parasites. Mortality rate before weaning reaches about 20 to 24%. Similar studies also reported mortality rates greater than 20% for Horro and Menz sheep breeds (Gizaw et al., 2008a; Kocho, 2007) under smallholder management condition.

Reproductive performances

Age at first service (AFS)

The least squares mean (LSM ± SE) age at first service of male and female sheep at both districts is shown in Table 6. The mean value of age at first service for male sheep were 7.63±0.1 and 8.1±0.2 months at Gumer and Ejha districts, respectively, while for female sheep 7.80±0.6 and 8.42±0.8 months at Gumer and Ejha study areas, respectively. At Gumer district, both male and female sheep indicated significantly ($P<0.5$) shorter age at first service than at Ejha district. The location difference may be attributed to management practices of farmers in the respective areas to attain earlier puberty.

Age at first lambing (AFL)

The estimated age at first lambing (AFL) at Gumer and Ejha study area were 13.5±0.2 and 14.0±0.2 months, respectively (Table 6). The shorter age at first lambing significantly ($p<0.5$) observed at Gumer than Ejha district ewes. The overall mean value of age at first lambing found in the current study is comparable with those of previous reports in Alaba area (Kocho, 2007) 13 months, Bonga sheep (Shenkute, 2009) 12.9 months in western Ethiopia and in eastern Ethiopia (Nigussie et al., 2015) 13.8 months. Age at first lambing is a function of puberty, age at first breeding, conception and completeness of pregnancy. These reproductive traits influenced by genotype of an individual, environment, nutrition and season of birth. So that shorter age at first lambing at

(a) Female sheep (b) Male sheep

Figure 1. Physical appearances of indigenous sheep types in the study area.

Gumer could be due to management and environmental effects.

Lambing interval (LI)

The estimated mean lambing interval of indigenous sheep at Gumer and Ejha districts were 8.2±0.22 and 8.4±0.12 months, respectively (Table 6). The finding of lambing interval under the current study confirms with previous studies of Marufa et al. (2017) reported 8.2 months for Abera sheep; Nigussie et al, (2015) 8.6 months for eastern Ethiopia sheep, Shenkute (2009) reported 8 months for Bonga sheep, Abegaz (2007) 8 months for Gumuz sheep, Kocho (2007) 7.8 months for Arsi-Bale sheep. Longer lambing interval (15 months) was reported for Washera (Taye et al., 2010). The variations observed between the different findings could be differences in management, breed and production system. Early weaning and proper feeding was reported as the most important measure in improving conception rate and shortening of lambing interval (Adane and Girma, 2008). Improving management and early weaning practice can help to achieve shorter lambing interval.

Litter size

Mean litter size of indigenous sheep type in the current study area was 1.51±0.07 and 1.47±0.12 for Gumer and Ejha districts, respectively (Table 6). Higher litter size (1.51±0.07) was recalled by Gumer than Ejha respondents. The overall mean value (1.49±1.15) of this report is comparable with that of previous studies on the other breeds in different parts of Ethiopia. For example, an average litter size of 1.5 for Adillo sheep was reported by Legesse (2008) and Shenkute (2009) reported 1.4 for Bonga sheep; Similarly, Taye et al. (2010) reported litter size of 1.34 for Horro Sheep and Abegaz (2007) 1.3 for Gumuz sheep. Gizaw et al. (2008a) reported 1.17 for Arsi-Bale sheep in Alaba district. Litter size for tropical breeds varies between 1.08 and 1.75 with an average of 1.38 lambs per parturition per ewe (Kosgey and Okeyo, 2007). The study indicated that the sheep in the current study area have acceptable litter size.

Qualitative characteristics

The overall observed phenotypes of coat color and hair type of indigenous sheep types in the study area are presented in Table 7. The sheep in the study area have predominantly patchy coat color patterns (52.0%) followed by plain (31%) and spotted (17%). The result is consistent with Arsi Bale sheep reported by Gizaw et al. (2007). The most commonly observed coat color types were brown dominant (brown with black and/or white) (35.8%), followed by black dominant (black with brown and/or white) (20.4%), white dominant (white with brown and/or black) (19.2%), brown (14.2%), white (8.2%), and black (2.2%). About 75% of the sheep possess the combinations of brown and/or black and/or white color (Figure 1). The possible explanations could be the presence of strong selection pressure by sheep keepers as they believe that sheep with this coat color type (which is locally called "*Gerebet*") are prolific and productive. However, almost all sheep keepers dislike sheep with solid black coat color as the sheep usually sold with cheap prices than those with other colors. This is probably related to their cultural beliefs. Gizaw et al. (2008c) reported that coat color is among the qualitative characteristics which are used by the local communities to select breeding rams and ewes. The majority of the sheep had long and coarse hair (55.7%) whereas short and coarse hair accounted to 44.3%. Gizaw et al. (2008c) reported long coarse wool hair coat type for fat tailed sheep in central high land areas. Such hair type is frequently seen across the cool to very cool mountains

Table 6. Least square means (±SE) of reproductive performance traits as stated by respondents.

Trait	Gumer	Ejha	Overall
Age at first service for male (months)	7.63±0.1	8.1±0.2	7.86±0.15
Age at first service for female(months)	7.80±0.6	8.42±0.8	8.11±0.84
Age at first lambing (AFL) (months)	13.5±0.2	14.0±0.2	13.8±0.4
Lambing interval (LI) (months)	8.2±0.22	8.4±0.12	8.3±0.17
Litter size (LS)	1.51±0.07	1.47±0.12	1.49±1.15
Number of lambs born/ewes life time	17.0±0.5	17.0±0.4	17.0±0.4

SE = Standard error.

Table 7. Observed phenotypes of coat color and hair type.

Trait	Attribute	Ejha			Gumer			Overall		
		Female N (%)	Male N (%)	Total N (%)	Female N (%)	Male N (%)	Total N (%)	Female N (%)	Male N (%)	Total N (%)
Coat color pattern	Patchy	75 (55.6)*	35 (53.9)*	110 (55.0)*	80 (52.3)*	19 (38.8)	99 (49.0)*	155 (53.8)*	54 (47.4)*	209 (52.0)*
	Plain	37 (27.4)	21 (32.3)	58 (29.0)	48 (31.3)	19 (38.8)	67 (33.2)	85 (29.5)	40 (35.1)	125 (31.1)
	Spotted	23 (65.7)	9 (13.9)	32 (16.0)	25 (16.3)	11 (22.5)	36 (17.8)	48 (16.7)	20 (17.5)	68 (17.0)
	χ^2-value	32	15	47	42		39	75	15	86
Coat color	Brown dominant (brown with black/white)	54 (40.0)*	19 (29.2)*	73 (36.5)*	64 (47.4)*	7 (14.3)*	71 (35.2)*	118 (41.0)*	26 (22.8)	144 (35.8)*
	White dominant (white with brown/black)	27 (20.0)	12 (18.5)	39 (19.5)	30 (22.2)	8 (16.3)	38 (18.8)	57 (20.0)	20 (17.5)	77 (19.2)
	Black dominant (black with brown/white)	21 (15.6)	12 (18.5)	33 (16.5)	27 (20.0)	14 (28.6)	41 (20.3)	48 (16.7)	34 (29.8)*	82 (20.4)
	Brown	20 (14.8)	11 (16.9)	31 (15.5)	17 (12.6)	9 (18.4)	26 (13.0)	37 (13.0)	20 (17.5)	57 (14.2)
	White	7 (5.2)	8 (12.3)	15 (7.5)	10 (6.5)	8 (16.3)	18 (9.0)	17 (6.0)	16 (11.1)	33 (8.2)
	Black	3 (2.2)	3 (4.6)	6 (3.0)	0 (0.0)	3 (6.1)	3 (1.5)	3 (1.0)	6 (5.3)	9 (2.2)
	Others	3 (2.2)	0 (0.0)	3 (1.5)	5 (3.3)	0 (0.0)	5 (2.5)	8 (2.8)	0 (0.0)	8 (2.0)
	χ^2-value	77	23	121	88	15	112	164	30	231
Hair type	Long and coarse	78 (57.8)	35 (53.6)	113 (56.5)*	88 (57.5)	23 (46.9)	111 (55.0)*	166 (57.6)*	58 (51.0)	224 (55.7)*
	Short and smooth	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
	Short and coarse	57 (42.2)	30 (46.2)	87 (43.5)	65 (42.5)	26 (53.1)	91 (45.1)	122 (43.4)	56 (91.1)	178 (44.3)
	χ^2-value			2			3.22	3		3

χ^2-Pearson chi-square, p<0.05.

and plateau of the central highlands of Ethiopia. Almost all sampled sheep were exclusively characterized by long fat tail type and the dominant tail shape is cylindrical with straight tail (93.3%) (Table 8). Most of the female sheep (91.3%) showed straight facial profile while the

Table 8. Observed frequency and percentage values for some phenotypic qualitative traits.

Trait	Attributes	Ejha			Gumer			Overall		
		Female N (%)	Male N (%)	Total N (%)	Female N (%)	Male N (%)	Total N (%)	Female N (%)	Male N (%)	Total N (%)
Tail type	Long fat tail	135 (100)	65 (100)	200 (100)	153 (100)	49 (100)	202 (100)	288 (100)	114 (100)	402 (100)
	Short fat tail	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
	Thin tail	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Tail form	Cylindrical + straight end	122 (90.4)*	64 (98.5)*	186 (93.0)*	144 (94.1)*	45 (91.8)*	189 (93.6)*	266 (92.4)*	109 (95.6)*	375 (93.3)*
	Cylindrical + turned up end	13 (9.6)	1 (1.5)	14 (7.0)	9 (6.0)	4 (8.2)	13 (6.4)	22 (7.6)	5 (4.4)	27 (6.7)
	χ^2-*value*	88	61	148	119	343	153	214	95	119
Facial profile	Slightly Concave	0 (0.0)	8 (12.3)	8 (4.0)	2 (1.3)	6 (12.4)	8 (4.0)	2 (0.0)	14 (12.3)	16 (4.0)
	Straight	112 (83.0)*	57 (87.7)*	169 (84.5)*	151 (99.0)*	39 (79.6)	190 (94.1)*	263 (91.3)*	96 (84.2)*	359 (89.3)*
	Slightly Convex	23 (17.0)	0 (0.0)	23 (11.5)	0 (0.0)	4 (8.2)	4 (2.0)	23 (8.0)	4 (3.5)	27 (6.7)
	χ^2-*value*	59	37	237	83	28	264	142	65	501
Horn	Present	110 (81.5)*	63 (97.0)*	173 (86.5)*	133 (87.0)*	46 (94.0)	179 (88.6)*	243 (84.4)*	109 (95.6)*	352 (87.6)*
	Absent	25 (18.5)	2 (3.0)	27 (13.5)	20 (13.1)	3 (6.1)	23 (11.4)	45 (15.6)	5 (4.4)	50 (12.4)
	χ^2-*value*	51	57	104	83	38	120	133	95	231
Horn shape	Straight	38 (28.2)	11 (16.9)	49 (24.5)	40 (26.1)	10 (20.4)	50 (24.8)	78 (27.1)	21 (18.4)	99 (24.6)
	Curving upward	85 (63.0)*	13 (20.0)	98 (49.0)*	107 (70.0)*	11 (22.5)	118 (58.4)*	192 (66.7)*	24 (21.1)	216 (53.7)*
	Curving downward	(0.0)	34 (52.3)*	34 (52.3)	1 (06.5)	24 (49.0)*	25 (12.4)	1 (0.03)	58 (51.0)*	59 (14.7)
	Rudimentary	12 (9.0)	7 (10.8)	19 (9.4)	5 (3.3)	4 (8.2)	9 (4.5)	17 (5.9)	11 (10.0)	28 (7.0)
	χ^2-*value*	15	16	117	124	21	161	212	35	275
Wattle	Present	6 (4.4)	0 (0.0)	6 (3.0)	8 (5.2)	0 (0.0)	8 (4.0)	14 (5.0)	0 (0.0)	14 (3.5)
	χ^2-*value*	112			177	123		171	235	
Ruff	Present	0 (0.0)	4 (6.2)	4 (2.0)	0 (0.0)	3 (6.1)	3 (1.5)	0 (0.0)	7 (6.1)	7 (1.7)
	Absent	135 (100)	61 (94.0)*	196 (98.0)*	153 (100)	46 (94.0)	199 (98.5)*	288 (100)	107 (94.0)*	395 (98.3)*
	χ^2-*value*		50	184		38	190		87	374

χ^2-Pearson chi-square, $p<0.05$.

Table 9. Means (±SE) for effects of sex, age (dentition), district and sex by age on the body weight (kg) and linear measurements (cm) of sheep

Effects and level	BW	BL	HW	CG	PW	CL	CC	TL
Overall	25.8±0.3	57.0±0.3	61.5±0.3	70.5±0.4	14.4±0.1	12.7±0.1	7.1±0.0	29.8±0.2
Sex	*	*	*	*	*	*	*	NS
Female	23.4±0.2^{b}	55.6±0.2^{b}	59.8±0.2^{b}	68.0±0.3^{b}	13.6±0.1^{b}	12.4±0.1^{b}	6.9±0.0^{b}	29.3±0.2
Male	28.3±0.3^{a}	58.7±0.3^{a}	63.9±0.3^{a}	73.8±0.4^{a}	15.3±0.1^{a}	13.0±0.1^{a}	7.5±0.0^{a}	30.2±0.3
Age	*	*	*	*	*	*	*	NS
0PPI	18.5±0.4^{d}	50.4±0.4^{c}	54.7±0.4^{c}	62.1±0.4^{d}	11.5±0.1^{d}	11.6±0.1^{c}	6.40±0.1^{c}	26.10±0.4
1PPI	23.4±0.4^{c}	55.7±0.4^{b}	59.6±0.4^{b}	68.2±0.4^{c}	13.7±0.1^{c}	12.6±0.1^{bc}	7.1±0.1^{b}	28.9±0.4
2PPI	28.7±0.4^{b}	60.1±0.4^{ab}	65.5±0.4^{a}	75.1±0.5^{b}	15.8±0.7^{b}	13.2±0.1^{ab}	7.6±0.1^{ab}	32.2±0.4
>2PPI	33.0±0.4^{a}	62.5±0.4^{a}	67.6±0.4^{a}	78.3±0.5^{a}	16.8±0.2^{a}	13.4±0.1^{a}	7.7±0.1^{a}	31.9±0.4
Sex by age	*	*	*	*	*	*	*	NS
0PPI F	17.2±0.5^{h}	49.7±0.5^{h}	53.8±0.5^{i}	60.0±0.6^{g}	11.1±0.2^{g}	11.1±0.1^{f}	6.3±0.1^{cd}	25.4±0.5
1PPI F	22.7±0.4^{ef}	55.4±0.4^{f}	59.0±0.5^{g}	67.0±0.5^{e}	13.4±0.2^{de}	12.5±0.1^{cd}	6.8±0.1^{bc}	29.9±0.5
2PPI F	25.6±0.4^{d}	58.2±0.4^{de}	62.4±0.5^{def}	71.1±0.5^{cd}	14.4±0.2^{bcd}	12.9±0.1^{bc}	7.1±0.1^{b}	30.9±0.5
>2PPI F	28.2±0.3^{c}	59.4±0.3^{cd}	63.9±0.3^{cd}	73.9±0.4^{bc}	15.5±0.1^{bc}	13.1±0.1^{ab}	7.2±0.0^{b}	30.8±0.3
0PPI M	19.7±0.6^{g}	51.0±0.5^{gh}	55.6±0.6^{hi}	64.2±0.7^{f}	11.9±0.2^{fg}	12.1±0.1^{ef}	6.5±0.1^{cd}	30.0±0.6
1PPI M	24.0±0.6^{de}	56.0±0.6^{ef}	60.2±0.6^{fg}	69.4±0.7^{de}	13.9±0.2^{cde}	12.6±0.1^{cd}	7.3±0.1^{b}	28.0±0.6
2PPI M	31.7±0.7^{b}	62.1±0.7^{ab}	68.7±0.7^{b}	79.0±0.8^{a}	17.2±0.3^{a}	13.5±0.2^{a}	8.1±0.1^{a}	33.4±0.7
>2PPI M	37.8±0.7^{a}	65.7±0.7^{a}	71.2±0.7^{a}	82.7±0.8^{a}	18.1±0.3^{a}	13.7±0.2^{a}	8.2±0.1^{a}	33.0±0.7
District	NS	*	*	*	*	*	*	NS
Ejha	25.7±0.3	57.1±0.2	61.6±0.3	70.4±0.3	14.1±0.1	12.5±0.1	7.3±0.0	29.6±0.3
Gumer	25.9±0.3	57.3±0.3	62.1±0.3	71.5±0.3	14.9±0.1	12.8±0.1	7.1±0.0	30.0±0.3

[a,b,c]Means in the same columns and class level with different superscript letters are significantly (P < 0.05) different, BW= body weight, BL= body length, HW= height at wither, CG= chest girth, PW= pelvic width, CL= canon length, CC= canon circumference, TL= tail length, , 0 PPI = 0 pair of permanent incisors; 1PPI = 1 pair of permanent incisor; 2 PPI = 2 pairs of permanent incisors and > 2 PPI = more than 2 pairs of permanent incisors; *significant at (p<0.05)and NS =non significant.

rest had small proportion of slightly convex head (8%). Most of the male sheep (84.2%) were characterized by having straight facial followed by slightly concave (12.3%) and slightly convex (3.5%) shape. Almost all male sheep (95.6%) and the majority of female (84.4%) possessed horn. The dominant horn shape in the male sheep was curving downward (51%) followed by horn shape curving upward (21.1%), and straight (18.4%) and rudimentary (10%).

Live body weight and linear body measurements

The means (±SE) for effects of sex, age, district and sex by age on the body weight (kg) and linear measurements (cm) of sheep are shown in Table 9. The main sources of variation on live body weight and linear body measurements were sex, age and the interaction between them. The overall mean live body weight of male and female sheep was 28.3 and 23.4 kg, respectively. Sex of the sheep in the current study area exerted significant differences (p<0.05) on live body weight and other linear body measurements, except for tail length. The finding of the current report is in line with the reports of Taye et al. (2010) who reported a significant effect of sex on body weight, body length, height at wither and chest girth in Washara sheep. The mean value of body weight (kg) at age group 0PPI, 1PPI, 2PPI and >2PPI was recorded as 19.7±0.6, 24.0±0.0, 31.7±0.7 and 37.8±0.7 kg, respectively for male sheep. The mean body weight for female sheep for the respective age categories was 17.2±0.5, 22.7±0.4, 25.6±0.4 and 28.2±0.3 kg. As the age of the animal increased, the live body weight and other linear body measurements of sheep increased significantly (p<0.05). The report of the current finding is in line with previous studies by Melesse et al. (2013) who reported that age had a significant (p<0.05) effect on body weight and other morphometrical measurements of indigenous sheep in Southern Ethiopia. Similar finding was reported by Abera et al. (2014) who noted that body

Table 10. Pearson's correlation coefficients between body weight body measurements for rams (above diagonal) and ewes (below diagonal).

Traits	BW	BL	HW	CG	PW	CL	CC	TL
BW		0.91**	0.90**	0.95**	0.89**	0.70**	0.81**	0.65**
BL	0.86**		0.93**	0.88**	0.87**	0.70**	0.76**	0.70**
HW	0.84**	0.89**		0.91**	0.89**	0.75**	0.80**	0.72**
CG	0.91**	0.84**	0.86**		0.89**	0.73**	0.82**	0.67**
PW	0.84**	0.79**	0.78**	0.85**		0.71**	0.76**	0.68**
CL	0.60**	0.67**	0.64**	0.63**	0.66**		0.67**	0.62**
CC	0.64**	0.65**	0.63**	0.60**	0.59**	0.48**		0.58**
TL	0.47**	0.47**	0.43**	0.47**	0.48**	0.48**	0.40**	

**Correlation is significant at p<0.01, BW= body weight, BL= body length, HW= height at wither, CG= chest girth PW= pelvic width, CL= canon length, CC= canon circumference, TL= tail length.

weight and morphometrical measurements increased with increasing age of sheep in Debrelibanos and Wuchale districts. Moreover, similar reports were revealed by Tilahun et al. (2014) for Elle sheep breed and Gebreyowhens et al. (2016) for Tigray sheep.

The report of the current study also indicated that, the interaction effect of sex and age group was significant (p<0.05) for all quantitative traits considered except for tail length, but the effect of sex by age was prominent in male sheep as a result of hormonal difference between males and females (Çilek, 2014). In the current study, area location had no effect on body weight but significantly affected the linear body measurements. Accordingly, the Gumer sheep population had significantly larger linear body measurements (P<0.05) than Ejha sheep population.

Correlations of body weight and morphometrical body measurements

The Pearson's correlation coefficient between the body weight and morphometrical measurements is shown in Table 10. Body weight was significantly (p<0.01) correlated with all body measurements considered in this study.

A strong correlation of body weight was recorded with chest girth; body length and height at wither in which the r values were 0.95, 0.91, and 0.90 for rams and 0.91, 0.86 and 0.84 for ewes, respectively. The coefficient of correlation was relatively higher in rams sheep (r = 0.95) than in ewes (r = 0.91) between body weight and chest girth.

The higher correlation coefficient observed in rams indicated that, the live bodyweight could be predicted with higher precision in rams as compared to their counterpart ewes. The highest correlation of chest girth with body weight than other body measurements was in line with previous studies of Gizaw et al. (2008c), Zewdu (2009), Melesse et al. (2013) and Mohamed et al. (2015).

Prediction of body weight using body measurements

Stepwise multiple linear regression analysis for prediction of live body weight using morphometrical measurements was carried out within each sex and age group (Tables 11 and 12). The prediction results were best assessed by including chest girth, body length and pelvic width values of morphometrical traits from overall rams and ewes. As presented in Table 11, the body weight of rams 0PPI (6-12 months of age) is best predicted by fitting measurements of chest girth, pelvic width and body length. The best predictor for male 1PPI (1-1.5 year old) was found to be chest girth alone, while the body weight of rams above 2 years of age is best predicted by fitting measurements of chest girth and body length. Similarly, the best predictors of ewes at different age group are shown in Table 12. The best predictor for ewes aged 0PPI (6-12 months of age) was found to be chest girth alone. The body weight of ewes above 1PPI (1-1.5 year of age) can be assessed by chest girth, body length and canon circumference. However, the body weight for ewes with 2PPI (1.5-2 years old) can be predicted by chest girth only. The study also indicated that for determination of body weight of ewes over 2 years old was found to be best by fitting measurements of chest girth and body length. The report of the current finding is consistent with previous studies by Melesse et al. (2013) for indigenous sheep types in southern region (Kambata, Hadya, Sidama, Geddeo, Wolita, Silte and Gurage).

The regression study indicated that chest girth was the most variable to estimate reliable body weight. Hence, chest girth alone or in combination with body length and pelvic width could be used as reliable predictors of live weight for all age groups of both sexes in the study area. However, better correlation coefficient was obtained as more variables were included in the prediction equation. These findings are in line with those reported by Tadesse and Gebremariam (2010) for Northern Tigray sheep and Melesse et al. (2013) for sheep in South Ethiopia.

The prediction of overall live body weight of sheep best

Table 11. Stepwise multiple regression equations for estimation of live body weight of rams by fitting quantitative morphometrical measurements.

Age group (PPI)	Equation	Intercept α	Regression coefficients				
			B_1	B_2	B_3	B_4	R^2_{adj}
0	CG	-21.13	0.64	-	-	-	0.63
	CG+PW	-26.51	0.49	1.26	-	-	0.73
	CG+PW+BL	-32.15	0.38	1.02	0.30	-	0.78
1	CG	-34.58	0.84	-	-	-	0.87
2	BL	-26.31	0.94	-	-	-	0.69
	BL+CC	-43.03	0.72	3.69	-	-	0.84
	BL+CC+PW	-41.41	0.47	3.84	0.76	-	0.87
>2	CG	-67.48	1.27	-	-	-	0.73
	CG+BL	-61.71	0.82	0.48	-	-	0.88
Overall	CG	-37.79	0.90	-	-	-	0.89
	CG+BL	-39.73	0.60	0.40	-	-	0.92
	CG+BL+PW	-36.52	0.53	0.34	0.39	-	0.92

R^2_{adj}=adjusted coefficient of determination; BW= body weight; BL= body length; HW= height at wither; CG=chest girth; PW=pelvic width; CL=canon length; CC= canon circumference; 0 PPI = no pair of permanent incisors; 1PPI = 1 pair of permanent incisor; 2 PPI =2 pairs of permanent incisors and >2 PPI =more than 2 pairs of permanent incisors.

Table 12. Stepwise multiple regression equations for estimation of live body weight of ewes by fitting quantitative morphometrical measurements.

Age group (PPI)	Equation	Intercept α	Regression coefficients				
			B_1	B_2	B_3	B_4	R^2_{adj}
0	CG	-12.81	0.50	-	-	-	0.60
1	CG	-5.36	0.42	-	-	-	0.49
	CG+BL	-14.58	0.28	0.34	-	-	0.56
	CG+BL+PW	-14.57	0.21	0.28	0.56	-	0.61
2	CG	-18.96	0.63	-	-	-	0.56
>2	CG	-19.10	0.64	-	-	-	0.60
	CG+BL	-30.29	0.54	0.31	-	-	0.65
Overall	CG	-24.05	0.70	-	-	-	0.84
	CG+BL	-29.68	0.51	0.33	-	-	0.86
	CG+BL+PW	-27.04	0.42	0.29	0.41	-	0.87
	CG+BL+PW+CC	-29.02	0.42	0.25	0.38	0.69	0.87

R^2_{adj} =Adjusted coefficient of determination; BW= body weight; BL= body length; HW= height at wither; CG= chest girth; PW= pelvic width; CL=canon length; CC=canon circumference; 0 PPI = no pair of permanent incisors; 1PPI =1 pair of permanent incisor; 2 PPI = 2 pairs of permanent incisors and >2 PPI =more than 2 pairs of permanent incisors.

assessed by including CG and BL values for both ramsand ewes:

(1) Fitted equation for prediction of ram's body weight: BW = -37.79 + 0.90×CG; considering CG alone or BW= -39.73+0.60×CG+0.40×BL

(2) Fitted equation for prediction of ewes body weight: BW = -24.05 + 0.70*CG; considering CG alone or BW=-29.68+0.51×CG+0.33×BL

CONCLUSIONS AND RECOMMENDATIONS

Indigenous sheep production has multifunctional roles and contributing a lot to the livelihoods of the small holder farmers. However, feed scarcity, diseases and parasite prevalence, marketing and poor infrastructure were the major constraints hampering sheep productivity in the study areas. The majority of sheep were characterized by patchy color pattern and the combinations of brown and/or black and/or white color type which is locally called it "*Gerebet*". The study indicated variations within the studied sheep population in qualitative and quantitative trait, so that there is a great possibility for genetic improvement through selection of rams within population. In the current study, location had no effect on body weight but significantly affected the linear body measurements. Accordingly, the sheep in Gumer district had significantly ($p<0.05$) higher linear body measurements ($P<0.05$) than Ejha district. The regression study indicated that chest girth was the most variable to estimate reliable live body weight. Hence, heart girth alone or in combination with body length could be used as the best predictor of live weight for all age groups of both sexes where sensitive weighing scales are not readily available. Furthermore, well organized on-farm monitoring and genetic breed characterization is very important to fully characterize sheep breed types found in the study area. Finally, implementation of planned genetic improvement strategy through community based breeding program that considers multifunctional roles of sheep and the existing production system.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

REFERENCES

Abebe AS, Alemayehu K, Johansson AM, Gizaw S (2020). Breeding practices and trait preferences of smallholder farmers for indigenous sheep in the northwest highlands of Ethiopia: Inputs to design a breeding program. PLoS ONE 15(5):e0233040. https://doi.org/10.1371/journal.pone.0233040

Abegaz S (2007). *In-situ* characterization of Gumuz sheep under farmer's management in north western lowland of Amhara region. M.Sc. Thesis presented to the School of Graduate Studies of Alemaya University of Agriculture, Dire Dawa, and Ethiopia 128 p.

Abera B, Kebede K, Gizaw S, Feyera T (2014). On-farm phenotypic characterization of indigenous sheep types in Selale Area, Central Ethiopia. Journal of Veterinary Science Technology 5:180. https://doi.org/10.4172/2157-7579.1000180

Adane Y, Girma A (2008). Economic significance of sheep and goats. In: Alemu and Yami and RC Markel. Sheep and goat production handbook for Ethiopia. Ethiopia Sheep and Goats Productivity Improvement Program, Addis Ababa, Ethiopia 2-24.

Asefa B, Abate T, Adugna E (2017). Phenotypic characterization of indigenous sheep types in Bale Zone, Oromia Regional State, Ethiopia. Journal of Veterinary Science Technology 8:452. https://doi:10.4172/2157-7579.1000452

Berhanu B, Hile A (2009). Factors affecting growth performance of sheep, under village management condition in the south western part of Ethiopia. Livestock Research for Rural Development (11):21. http://www.lrrd.org/lrrd2/11/cont2111.htm.

Central Statistical Agency of Ethiopia (CSA) (2017/2018). Agricultural Sample Survey, report on livestock and livestock characteristics (private peasant holdings). Statistical Bulletin (2):587. http://www.csa.gov.et/survey-report/category/370-eth-agss-2018.

Central Statistical Agency of Ethiopia (CSA) (2016a). Agricultural sample survey, report on livestock and livestock characteristics, Volume II. Addis Ababa, Ethiopia.

Çilek S (2014). Determination of body weight and body measurements of Akkaraman sheep reared at Malya State Farm in Middle Anatolia Region Conditions of Turkey. Bulgarian Journal of Animal Science 6:33-39.

Dagnew Y, Urge M, Tadesse Y, Gizaw S (2017). Sheep production and breeding systems in northwestern lowlands of Amhara Region, Ethiopia: Implication for conservation and improvement of Gumz sheep breed. Open Journal of Animal Sciences 7(2):179-197.

Duguma G (2010). Participatory definition of breeding objectives and implementation of community-based sheep breeding programs in Ethiopia. PhD Thesis. University of Natural Resources (BOKU), Vienna.

Duguma G, Mirkena T, Haile A, Okeyo AM, Tibbo M, Rischkowsky B (2011). Identification of smallholder farmers and pastoralists' preferences for sheep breeding traits: a choice model approach. Animal 5(12):1984-1992. https://doi.org/10.1017/S1751731111001029.

FAO (Food and Agricultural Organization of the United Nations) (2012). Phenotypic Characterization of Animal Genetic Resources. Animal Production and Health Guidelines 91-105. Rome, Italy.

Ferew F (2008). On-farm characterization of blackhead Somali sheep breed and its production system in Shinile and Erer districts of Shinile zone. M.Sc. Thesis Presented to the School of Graduate Studies of Alemaya Universiy of Agriculture, Dire Dawa, Ethiopia 115 p.

Gebreyowhens W, Tesfay Z, Tesfay Y (2016). Management and breeding objectives of indigenous smallholder highland sheep in northern Ethiopia. Journal of Biology, Agriculture and Healthcare 6(1):96-106.

Getachew T, Haile A, Tibbo M, Sharma AK, Sölkner J, Wurzinger M (2010) . Herd management and breeding practices of sheep owners in a mixed crop-livestock and a pastoral system of Ethiopia. African Journal of Agricultural Research 5(8):685-691.

Gatew H, Hassen H, Kebede K, Haile A, Lobo R N B, Yetayew A, Rischkowsky B (2017). Husbandry practices and phenotypic characteristics of indigenous goat populations in Ethiopia. African Journal of Agricultural Research 12(36):2729-2741.

Gizaw S, Abegaz S, Rischkowsky B, Haile A, Mwai AO, Dessie T (2013a). Review of sheep research and development projects in Ethiopia: International Livestock Research Institute (ILRI). Nairobi, Kenya.

Gizaw S, Getachew T, Edea Z, Mirkena T, Duguma G, Tibbo M, Rischkowsky B, Okeyo AM, Dessie T, Wurzinger M, Solkner J, Haile A (2013b). Characterization of indigenous breeding strategies of the sheep farming communities of Ethiopia: A basis for designing community-based breeding programs, working paper Aleppo, Syria; ICARDA.

Gizaw S, Komen H, Hanotte O, van Arendonk JAM (2008a). Indigenous sheep resources of Ethiopia: Types, production systems and farmers preferences. Animal Genetic Resources Information 43:25-40.

Gizaw S, Komen H, van Arendonk JAM (2008c). Selection on linear size traits to improve live weight in Menz sheep under nucleus and village breeding programs. Livestock Science 118(1-2):92-98.

Gizaw S, Tegegne A, Gebremedhin A, Dirk H (2010a). 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 (International Livestock Research Institute), Nairobi, Kenya. P 58. https://cgspace.cgiar.org/handle/10568/2238(2010a).

Gizaw S, Van Arendonk JAM, Komen H, Windig JJ, Hanotte O (2007). Population structure, genetic variations and morphological diversity of indigenous sheep types in Ethiopia. Animal Genetics 38(6):621-628.

Kocho T (2007). Production and marketing of sheep and goats in Alaba, South Nation Nationality People Region. M.Sc thesis. Hawassa University, Hawassa, Ethiopia.

Kosgey IS, Okeyo AM (2007). Genetic improvement of small ruminants in low input, smallholder production systems: technical and infrastructural issues. Small Ruminant Research 70:76-88. https://bit.ly/2XyIgRd

Legesse G (2008). Productive and economic performance of small ruminant production in production system of the Highlands of Ethiopia. Ph.D. Dissertation. University of Hohenheim, Stuttgart-Hoheinheim, Germany.

Marufa E, Taye M, Abebe G, Tera A, Jimma A (2017). Effect of Non-Genetic Factors on Reproductive and Growth Performance of Abera Sheep under Community Based Breeding Program in SNNPRS Ethiopia. Journal of Advanced Dairy Research 5:196. https://doi:10.4172/2329-888X.1000196.

Melesse A, Sandip B, Admasu L, Fikadu M, Fsahatsion H, Shimelis T, Tafesse M (2013). Morphological characterization of indigenous sheep types in Southern Regional State, Ethiopia. Animal Genetic Resources 52:39-50.

Mohammed T, Kebede K, Mekasha Y, Abera B (2015). On-farm phenotypic characterization of native sheep types in North Wollo zone, Northern Ethiopia. Direct Research Journal of Agriculture and Food Science 3(3):48-56.

Nigussie H, MekashaY, Abgaz S, Kebede K, Kumar Pal S (2015). Indigenous sheep production system in Eastern Ethiopia: Implications for genetic improvement and sustainable use. American Scientific Research Journal for Engineering, Technology and Sciences 11(1):136-152.

Statistical Analysis System (SAS) (2008). SAS for Window, Release 9.1. SAS Institute, Inc., Cary, NC, USA.

Shenkute B (2009). Production and marketing systems of small ruminants in Goma district of jimma zone, Ethiopia. M.Sc Thesis. Hawassa University, Hawassa, Ethiopia pp. 38-54.

Solkner J, Nakimbigwe H, Valle-Zarate A (1998). Analysis of determinants for success and failure of village breeding programmes. Proceedings of 6th World Congress on Genetics Applied to Livestock Production 25:273-280.

Tadesse A, Gebremariam T (2010). Application of linear body measurements for live body weight estimation of highland sheep in Tigray Region, North Ethiopia. Journal of the Dry lands 3(2):203-207.

Taye M, Abebe G, Gizaw S, Lemma S, Mekoya A, Tibbo M (2010). Growth performances of Washera sheep under smallholder management system in Yilmanadensa and Quarit districts, Ethiopia. Tropical Animal Health and Production 42(4):659-667.

Tibbo M (2006). Productivity and health of indigenous sheep breeds and crossbreds in the central Ethiopia highlands. Ph D Dissertation. Swedish University of Agricultural Science (SLU), Uppsala, Sweden 74 p.

Tilahun M, Kefelegn K, Abebe G, Goetsch AL (2014). Feed intake, digestibility, weight gain, and slaughter characteristics influenced by genetic percentage of Boer in goats and Dorper in sheep in the central highlands of Ethiopia. Tropical Animal Health and Production 46(4):593-602.

Tolera A, Yami A, Alemu D (2012). Livestock feed resources in Ethiopia: Challenges, opportunities and the need for transformation. Animal Feed Industry Association, Addis Ababa, Ethiopia.

Wagari G, Getachew T, Bayou E (2020). Multivariate analysis of phenotypic traits of indigenous sheep revealed new population in western part of Ethiopia. International Journal of Agricultural Science and Food Technology 6(1):050-057. DOI: https://dx.doi.org/10.17352/2455-815X.000055

Wilson RT, Durkin JW (1984). Age at permanent incisor eruption in indigenous goats and sheep in semi-arid Africa: Livestock Production and Science 11(4):451-455.

Workneh A, Van Dorland A, Rowlands J (2004). Design, execution and analysis of the livestock breed survey in Oromiya Regional State, Ethiopia**.** OADB (Oromiya Agricultural Development Bureau), Addis Ababa, Ethiopia: ILRI (International Livestock Research Institute), Nairobi, Kenya 260 p.

Wonchesa D, Wossen A, Negia G (2019). Feed resources assessment, laboratory evaluation of chemical composition of feeds and livestock feed balance in enset (*Ensete ventricosum*)-based mixed production systems of Gurage zone, southern Ethiopia**.** International Journal of Livestock Production 9(6):112-130.

Zelealem T, Anal K, Gebrezgiher G (2012). Assessment of the sheep production system of Northern Ethiopia in relation to sustainable productivity and sheep meat quality. International Journal of Advanced Biological and Biomedical Research 2(2):302-313.

Zewdu E, Haile A, Tibbo M, Sharma AK, Assefa D, Sölkner J, Wurzinger M (2009). Morphological characterization of Bonga and Horro indigenous sheep breeds under smallholder conditions in Ethiopia. Ethiopian Journal of Animal Production 9(1):117-133.