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Full Length Research Paper

Phenotypic characterization of the West Africa dwarf goats and the production system in Liberia

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Data on characterization of animal genetic resources are valuable in the development of breeding and conservation schemes to ensure their sustainable use. A survey was conducted to collect baseline data on the phenotypic characteristics, production system, traits of economic importance and challenges faced by goat farmers in Liberia. The survey was carried out in the 15 counties of Liberia and covered 1314 animals in their production environments. 1267 respondents participated in this study. A pre-tested structured questionnaire, group discussions and in-depth interviews were used in the data collection. Phenotypic descriptors were directly measured using a measuring tape and weighing scale. Results indicated that Liberia goats are predominantly West Africa dwarf (WAD) breed (99%) and either docile or moderate in temperament. Majority of WAD goats have solid/uniform/plain coat colour pattern (68%) and black or white coat colour (63%). Most goats are horned (70%) and have curved horns (50%). The main motivation for keeping local goats is their relative adaptation to the environment, fast growth and efficient meat production. Average body weight, body length, chest girth and height at withers were 39 kg, 65, 79 and 51 cm, respectively. Government should address the issue of feed, access to veterinary care and medicines, disease control and also assist goat farmers to put up housing and fencing for their animals. There is a need for the government to improve policies on AnGR management in Liberia. In particular, the recently adopted NSAP on AnGR which provides a clear framework for the development of the livestock sector should be validated and implemented by the MOA/CARI and other stakeholders. I*n situ* and *ex situ* conservation strategies including establishment of national breeding and conservation centres and community-based breeding programs for goat farmers are viable options which should be pursued.

Key words: Liberia, phenotypic characterization, West African dwarf goat, production system, AnGR.

INTRODUCTION

Goats have multi-purpose roles, providing food, hides, and manure, generating income directly as cash

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or as goods for bartering and thus benefiting the world's poorest people (Richards, 2002; Perry et al., 2002; Ershaduzzaman et al., 2007). Goats show higher survival rates than cattle under drought conditions (Ndikumana et al., 2000). Their relatively short reproductive cycle and prolificacy coupled with their small size and early maturity make them suitable for use on small farms. Goats perform better than cattle under low input conditions and climatic stress. They are also tolerant to infectious diseases and parasites as well as heat stress (Philipsson et al., 2006; Kosgey and Okeyo, 2007). These traits enable them to cope with the stressful nature of the unproductive and marginal lands in which they are often kept. On the other hand, and as indicated by Hanssen et al (2012), indiscriminate crossbreeding of indigenous goats can cause genetic erosion, loss of genetic diversity, reduction of adaptive values and opportunities for their efficient utilization.

Goat meat is a popular livestock product in Liberia whose consumption rates has been rising rather quickly in recent years (FED, 2016; MOA, 2008) and with a huge market potential as it is eaten by all ethnic and religious groups. Other NGOs such as BRAC International and Food and Enterprise Development (FED) in Liberia are promoting goat production through restocking following years of civil unrest. The hardiness of the local goats has made it a ruminant of choice among many households. Despite the importance of goat production, there is practically no information in Liberia on goat production and research. Investment in livestock research and animal production is a key factor in increasing livestock productivity, stimulating growth, and reducing poverty, enhancing incomes for the poor and alleviating childhood malnutrition. Goat populations from different sub-regions of sub-Saharan Africa have remained relatively genetically distinct, with considerable variation in terms of size and coat colours (Chenyambuga et al., 2004; Seidu et al., 2016). Morphometric data are key information to evaluate the characteristics of breeds of animals and provide key insight on the suitability of animals for sustainable breeding and their conservation (Nesamvuni et al., 2000; Mwacharo et al., 2006; FAO, 2012) to ensure food security. The objective of this study is to carry out phenotypic characterization of the local goats in Liberia, including their morphology, production system and challenges confronting goat farmers and make appropriate recommendation to address them for increased productivity and wealth creation.

MATERIALS AND METHODS

Study area and data collection

Liberia is a Sub-Saharan nation in West Africa with an estimated human population of 4 million. It is located on latitude 6°N and longitude 9°W, borders the North Atlantic Ocean to the southwest and three other African nations. In total, Liberia comprises 110,000sqkm dominated by flat to rolling coastal plains that contain mangroves and swamps (MOA, 2008). Those plains slope into a rolling plateau and rainforest-covered hills central, and into relatively low mountains in the northeast (CASS-Lib, 2007). The methodology followed in data collection has been described by Karnuah et al. (2018). Briefly, a survey was conducted in 15 counties in Liberia – Bassa, Bomi, Bong, Cape Mount, Gbarpolu, Grand Gedeh, Grand Kru, Lofa, Margibi, Maryland, Montserrado, Nimba, River Cess, River Gee and Sinoe (Figure 1). Based on FAO's Guidelines for phenotypic characterization of AnGR (FAO, 2012), a checklist and questionnaires for phenotypic characterization of goats were developed. Training of supervisors and enumerators for the survey and characterization of Liberia's AnGR took place in February 2016 before the data collection using an electronic data capture system with the EpiCollect application (EpiCollect, 2009) (http://www.epicollect.net/).

The data collected included general information on household characteristics from 1267 goat farmers, goat production and management practices, as well as the phenotypic characteristics of the goats. Linear and morphological measurements of 293 male and 1021 female goats including heart girth, whither height and body length were measured using measuring tape; body weight was determined with a weighing scale.

Data analysis

Data were analysed using Statistical Analysis Systems (SAS) software (SAS, 2012) and the *Survey* Package in R (R Core Team, 2016). These software tools have very flexible options for summarizing categorical and quantitative variables as well as producing clear figures and were used complementarily in this study. Analysis carried out included categorical analysis of qualitative data using chi square, descriptive analyses of quantitative data, regression analysis to determine the effect of linear body measurements on body weight and correlation between the parameters. Relative frequencies of various characterization parameters and the results are summarized in tables and figures.

RESULTS AND DISCUSSION

Background of respondents

A total number of 1267 respondents were involved in the study. The number of farmers interviewed by gender, ages, household sizes and educational status are shown in Table 1. The largest number of respondents were from Grand Gedeh County (146), followed by Maryland county (140) and River Gee County (114), respectively. Goat farming in Liberia is very much a male-dominated activity (67% of respondents). Chi square values indicated no significant association between gender of farmer and educational status or membership of farmers' association. About a third of the goat farmers surveyed had no formal education (Table 1). Such a situation can negatively affect the adoption of innovative animal husbandry practices. Education is an approach to help farmers in making informed decisions, solving problems and learning new technologies (IFPRI, 2010).

The vast majority of goat farmers in Liberia are not members of any livestock associations. Only 13% of farmers keeping goats belong to livestock associations. This is a common phenomenon in West Africa region

Figure 1. Political Map of Liberia.

Table 1. Household characteristics of goat farmers.

N= 1206	Male	Female	Chi square value	Prob	df
Gender of farmers	844 (67%)	423 (33%)			
Educational status					
None	241 (29%)	136 (32%)	4.50ns	0.2121	3
Basic	337 (40%)	165 (39%)			
Secondary	208 (25%)	104 (25%)			
Tertiary	58 (7%)	18 (4%)			
Membership of livestock association					
Yes	115 (14%)	56 (13%)	0.04ns	0.8431	1
No	726 (86%)	366 (87%)			
Average age of farmer	46.5 ± 0.4				
Average household size	8.7 ± 0.2				

NB: ns – not significant.

where such associations for livestock farmers are weak or non-existent. The reason for this may be that farmers are not organized or do not see the benefits of belonging to such groups. The absence of well-organized farmer/breeder associations to support governmental initiatives has hindered efforts to develop an appropriate and

Table 2. Summary statistics of key quantitative variables of Goats in Liberia.

Variable	Males			Females		
	Mean ± SE*	n*	CV* (%)	Mean ± SE	n	CV (%)
Body weight (kg)	39.5 ± 0.75	292	32	38.4 ± 0.45	1020	38
Body length (cm)	66.4 ± 0.67[a]	292	17	64.8 ± 0.33[b]	1020	16
Height at withers (cm)	50.6 ± 0.53	292	18	50.4 ± 0.19	1020	12
Chest girth (cm)	79.5 ± 0.63	292	14	78.7 ± 0.39	1020	16
Horn length (cm)	17.0 ± 0.36[a]	291	36	15.3 ± 0.18[b]	1006	37
Ear length (cm)	15.9 ± 0.34[a]	292	37	14.3 ± 0.18[b]	1019	39
Tail length (cm)	22.0 ± 0.32[a]	292	25	21.4 ± 0.16[b]	1014	24
Estimated age of goat (years)	1.9 ± 0.05[b]	290	48	2.8 ± 0.04[a]	1017	47

NB: SE = Standard error of mean; n – sample size; CV – coefficient of variation.
Within rows means followed by different superscripts are significantly different

Table 3. Spearman correlation coefficients of key quantitative variables of Goats in Liberia.

Variable	Body weight	Body length	Height at withers	Chest girth	Horn length	Ear length	Tail length
Body weight	1.00	0.57**	0.12**	0.86**	0.08*	0.09*	0.05*
Body length	<.0001	1.00	0.10*	0.18**	0.06*	0.09*	0.07*
Height at withers	<.0001	0.0002	1.00	0.09*	0.09*	0.14**	0.17**
Chest girth	<.0001	<.0001	0.0014	1.00	0.07*	0.09*	0.03 ns
Horn length	0.0032	0.0434	0.0015	0.0093	1.00	0.17**	0.19**
Ear length	0.0004	0.0006	<.0001	0.0020	<.0001	1.00	0.15**
Tail length	0.0503	0.0115	<.0001	0.3206	<.0001	<.0001	1.00

NB: ** Significant at 0.01; * Significant at 0.05 level of significance. ns – not significant.
Upper diagonal – correlation coefficients; Lower diagonal – P values.

integrated livestock recording system for Liberia's AnGR (MOA, 2008). The larger numbers of goat farmers in Grand Gedeh, Maryland, River Gee and Nimba Counties suggest that these may be the most logical places to establish goat farmer associations or breeder associations. Such associations can safe guard breed conservation and utilization of animal genetic resources.

Phenotypic characterization

The total number of goats characterized were 1314 which were almost 99% of all West African Dwarf (WAD) goats. This corroborates a report by Koikoi (2011) and confirms the WAD as the predominant goat breed in Liberia which should be targeted for improvement and conservation. The WAD has different names across the different counties including *Bablee*, *Weleebla*, *Welee*, *Blabee*, and *Gborkolor*. Goats in the mixed crop livestock production system were characterized by small flock size than the agro-pastoral system. Goats are kept in the areas for multiple production objectives contributing to household income and food security (Fantahun et al., 2016).

Summary statistics and correlation coefficients of some key quantitative characterization variables on the goats are shown in Tables 2 and 3. In general more variation was observed in body weight, horn and ear length than the other variables. The results obtained on the quantitative variables are higher than those reported by Oseni and Ajayi (2014). These differences could be due to age differences and environmental factors such as the availability of forages, good nutrition, adaptation and ecotype. There are two major WAD ecotypes, corresponding to the humid zone and the savanna zone. Liberia WAD goats are of the savannah type which is generally heavier with larger body size (Chiejina et al., 2009; Rotimi et al., 2017) and some degree of trypanotolerance (Geerts et al., 2009). The body weight and linear measurements obtained in the current study are comparable to those reported for Benis Arrous goats (Hilal et al., 2013).

According to Cam et al. (2010), morphometric measurements and how they relate to one another can describe roughly the animal's production status and breed characteristics. The highly significant correlation (86%) between chest girth and body weight indicates that
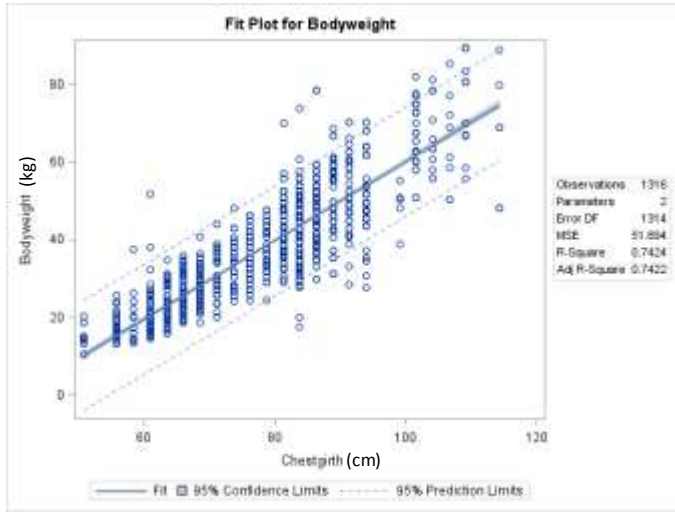
a. Prediction equation: y = - 41.5 + 1.02 x
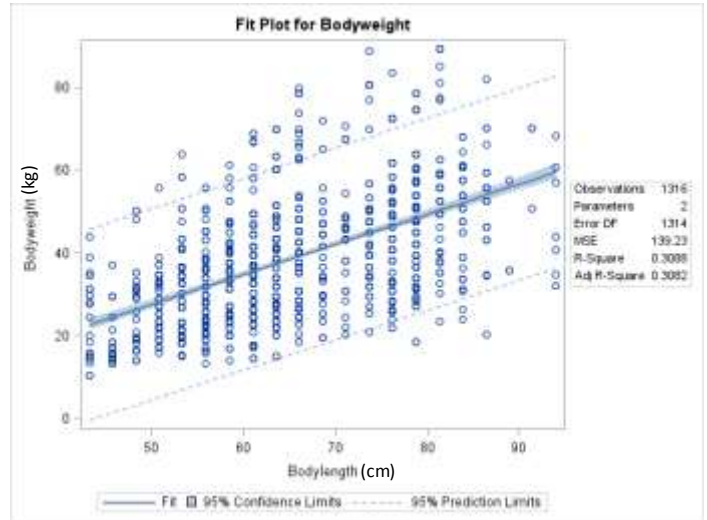
b. Prediction equation : y = - 8.6 + 0.73x

Figure 2. Fit plots for body weight of goats based on chest girth (a) and body length (b).

Table 4. Frequency of coat colour pattern of goats by sex.

Coat colour pattern	Sex of animal		Total	X^2	P
	Female (%)	Male (%)			
Spotted	84	16	134 (10%)		0.1502
Patch/Pied	77	23	291 (22%)	3.79ns	
Solid/Uniform/Plain	77	23	881 (68%)		
Total	78	22	1306 (100%)		

NB: X^2 - Chi square; ns – not significant.

chest girth can be used to predict body weight of WAD goats using appropriate regression models (Table 3). In addition, correlation between body length and body weight was moderate (57%), but highly significant. Regression of these phenotypic measurements on the body weight of animal indicated that body length and chest girth can significantly predict weight of goats (Figure 2) with chest girth being the best predictor of body weight (R^2 = 74%). Oseni and Ajayi (2014) observed that chest girth accounted for over 77% of total variability in the weight of WAD goats. This confirms that the best prediction model for live weight of WAD goats should include chest girth and body length. Morphological characterization results indicate that WAD goats in Liberia have solid/uniform (68%), patchy/pied (22%) and spotted (10%) coat colour patterns (Table 4) with no effect of sex of animal on coat colour pattern. The main coat colour types of the WAD goats (Table 5) were black and white (40%), white (14%), black (9%) and black and brown (5%) and several other mixtures which gives a strong indication of admixture as a result of the

uncontrolled random mating in the free range extensive husbandry systems. Although most of the goats were black and white in colour the significant chi square value indicates that more female goats than males were brown, fawn-black or dark red. Black and white coat colours accounted for 63% of the coat colour. This result is not in agreement with Odubote (1994b) who reported that the predominant colour observed among WAD goats in Nigeria is black (53%). The frequency of the spotted coat colour pattern was not high (10%) among the goats. Coat colour may vary through adaptation of animals to climatic zones and may influence the performance for other traits (Odubote, 1994a). Coat colour plays an important role in the evolved adaptation of goat type. Reproductive fitness as manifested by prolific breeding is a major factor of adaption (Daramola and Adeloye, 2009).

Table 6 shows that the Liberia WAD goats are mostly horned (70%) with significantly more females lacking horns than males. This result is in agreement with those of Odubote (1994a) and Abebambo et al. (2002). Ozoje (2002) also reported high presence of horns (87%)

Table 5. Frequency of coat colour type of goats.

Coat colour type	Sex of animal		Total	X²	P
	Female (%)	Male (%)			
Black and White	74	26	378 (40%)		0.0005
White	70	30	134 (14%)		
Black	80	20	88 (9%)		
White and Brown	95	5	72 (8%)		
Black and Brown	84	16	67 (7%)		
Black, White and Brown	95	5	56 (6%)		
Brown	94	6	49 (5%)	100.3**	
Dark red	79	21	14 (2%)		
Fawn and Black	92	8	13 (1%)		
Light red	83	17	12 (1%)		
Fawn	73	27	11 (1%)		
Mixed Colours	77	23	62 (6%)		
Total	78	22	956 (100%)		

NB: X² - Chi square; ** Significant at 0.01.

Table 6. Frequency of horn presence in goats.

Horn presence	Sex of animal		Total	X²	P
	Female (%)	Male (%)			
Present	69	31	908 (70%)		
Absent	96	4	383 (30%)	111.24**	< 0.0001
Total	77	23	1291 (100%)		

NB: X² - Chi square; ** Significant at 0.01.

Table 7. Frequency of horn shape of goats.

Horn shape	Sex of animal		Total	X²	P
	Female (%)	Male (%)			
Curved	74	26	392 (50%)		
Straight	63	37	273 (35%)		
Scurs	64	36	97 (12%)	17.1**	0.0042
Spiral	100	0	13 (2%)		
Corkscrew	40	60	5 (1%)		
Total	69	31	780 (100%)		

NB: X² - Chi square; ** Significant at 0.01.

among WAD goats in Nigeria. Kolo et al. (2015) reported 100% horn among local goats in Niger State in Nigeria. Female shows higher frequency of horn (69%) compared to the male (31%). Rodero et al. (1992) found very high frequency of both populations (horned and polled) in Blanca Serana goat breeds. The WAD goats of Liberia were characterized as having mostly curved (50%), straight (35%) horns with some scurs (damaged horns 12%; Table 7). With the exception of the cockscrew horn shape a higher proportion of female goats had curved, straight spiral or scurs. The vast variety of horn shapes in the population may indicate the presence of sexual dimorphism in horn shape as confirmed by the significant chi square value. This finding is in agreement with that reported by Sykes and Symmons (2007) that horn shapes are sexually dimorphic.

WAD goats in Liberia have straight facial profile (82%), followed by concave (17%) with a few goats having
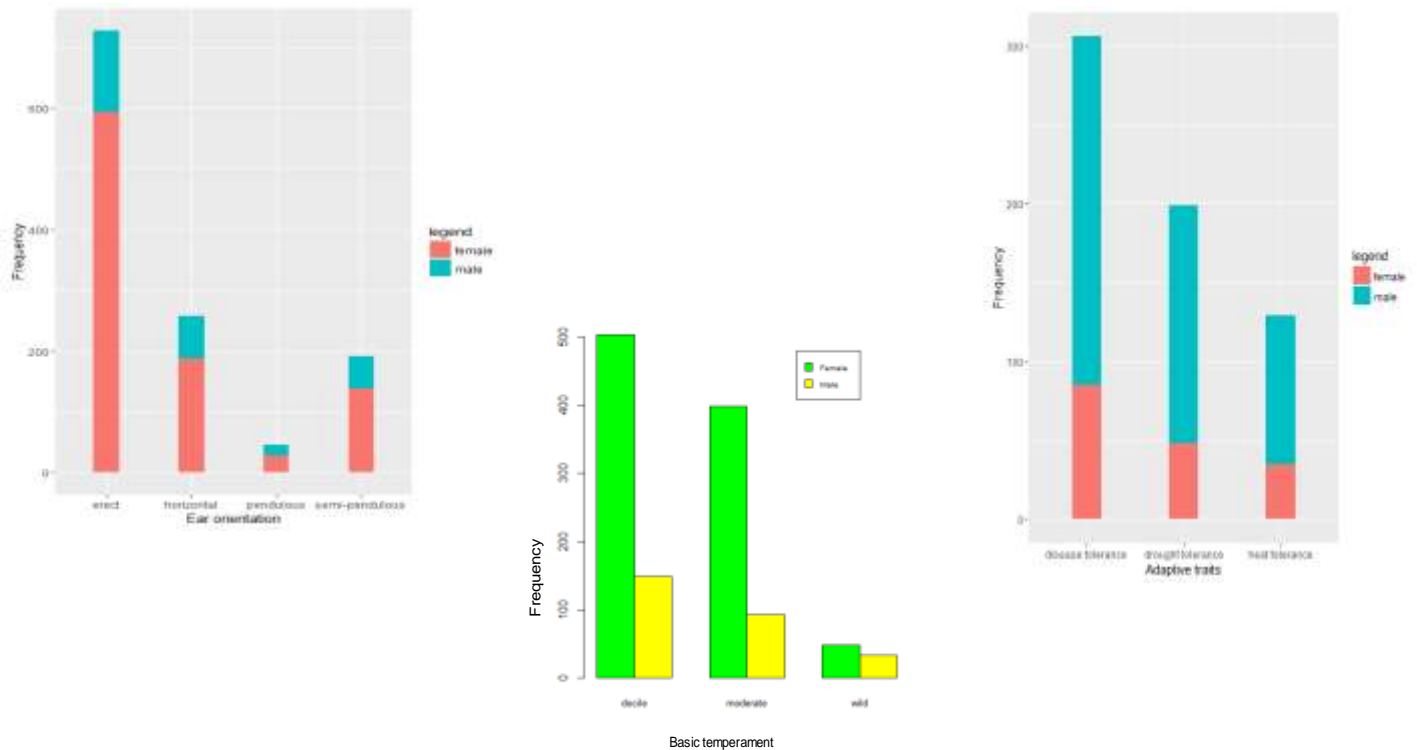
Figure 3. Variation in ear orientation, basic temperament and adaptive traits by sex of local goats in Liberia.

convex facial profiles (1%). The backline profile of the goats was either straight (72%), sloping up (20%) and slopping down (7%). WDG goats in Liberia also showed variation in their rump profile. Flat rump accounted for 47%, followed closely by slopping rump (44%) and roofy rump (9%). Male goats showed 38% flat rump and female goat, 9%. Goats have mostly smooth hair (65%), glossy (12%) and curly hair (11%) with the rest having straight or dull hair types. This finding is in agreement with that of Ozoje (2002) who reported that the predominant coat type found among goats in Nigeria is smooth hair. The wide variation in goat hair types seems to suggest polymorphism among WAD goats on hair types. Hagan et al. (2012) also reported smooth hair as the predominant hair type among WAD goats in the Coastal Savannah and Forest Eco-zones of Ghana. It was shown from the survey that the WDG goats in Liberia have erect ears (59%), followed by horizontal (21%) and semi-pendulous ears (16%) (Figure 3). This finding agrees with that of Hagan et al. (2012) who reported erect ears (40%) and horizontal ears (48%) among goats in Ghana. It is well known that West Africa Dwarf goats have erect ears and it is the predominant goat breed in Liberia.

Majority of the WAD goats in Liberia are docile and moderate in action (Figure 3). This is not surprising given the fact the WAD goat, which is not known to be wild in action is the major breed in Liberia. Common to local animal genetic resources of the tropics, goat farmers in

Liberia reported disease, drought and heat tolerance as the major adaptive traits of their animals. Over forty percent of goat farmers (41%) reported diseases tolerance as an important adaptive trait followed by drought tolerance (33%) and heat tolerance (26%) as shown in Figure 3. This result agrees with the report of Adedeji (2012) that heat tolerance is the attribute of WAD goats reared extensively. Odubote (1994b) reported that heat tolerance is directly related to the degree of coat pigmentation. The adaptive features of WAD goats such as disease and heat tolerance, efficiency of feed use enable them to thrive on natural resources left untouched by other domestic ruminants (Daramola and Adeloye, 2009).

Production system characterization

The production system for goats in Liberia is basically subsistence. Goats are kept by peasant farmers and close to half of the farmers (46%) reported ranching, the grassland-based management system, tethering (27%) with pastoralism accounting for 25%. Majority of farmers kept their goats on free range (82%) or shepherd (10%), while only 8% of farmers practiced zero grazing, referred to as cut and carry (Figure 4). Oseni and Ajayi (2014) also reported such production system, mainly extensive, among goat farmers in Nigeria. In Liberia 87% of the
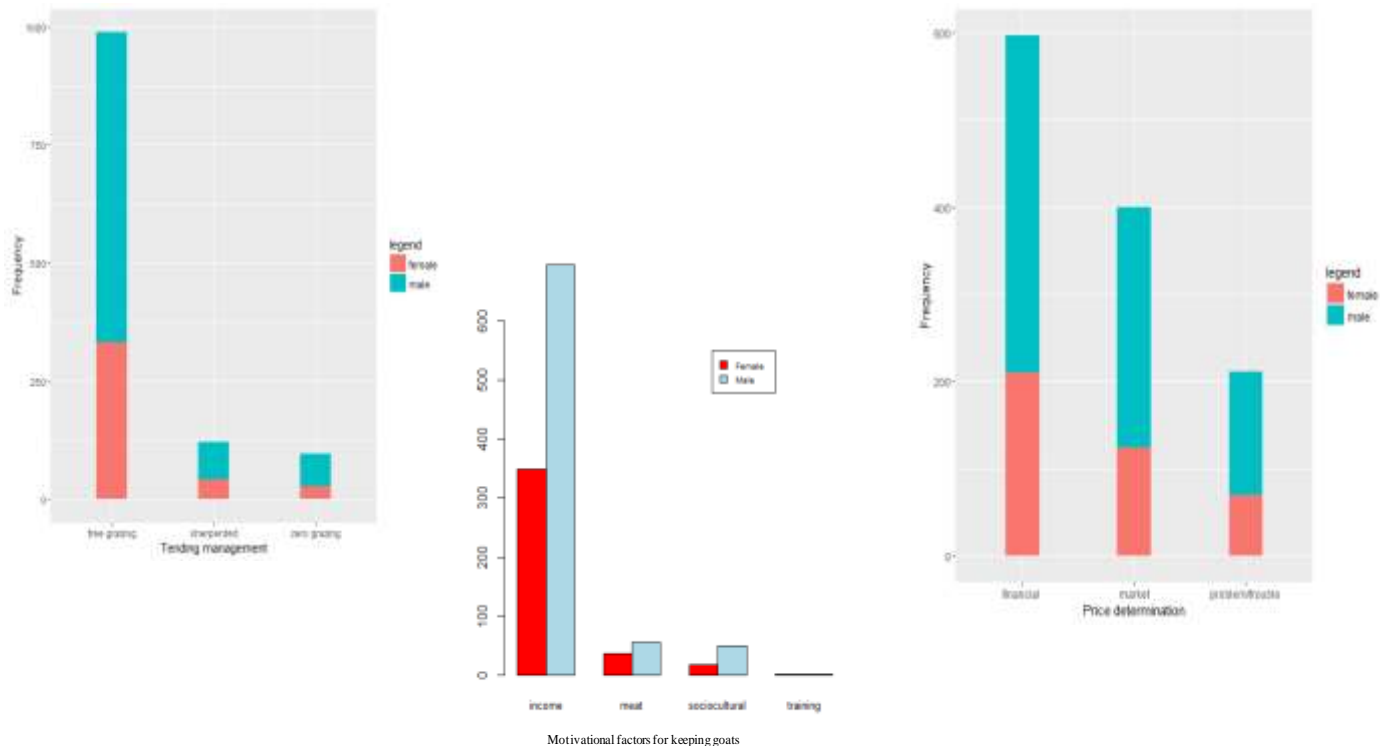
Figure 4. Effect of gender of farmers on tending management, motivational factors and price determinants on goat keeping practices in Liberia.

farmers indicated that income generation is the main motivation for raising goats, followed by source of meat (8%) and socio-cultural values (5%). This strengthens the need to purposely develop pasture and grasslands for the genetic resources in Liberia. This finding is not in agreement with that of Oseni and Ajayi (2014) who reported that WAD goats are raised principally as a source of meat. This result is in disagreement with that reported by Webb and Mamabolo (2004) that the principal reasons for raising goats by farmers in the Moutsi District of Mpumalange, South Africa, are for prestige and status. The determination of markets price for goat in Liberia depends on many factors (Figure 4). The farmers indicated that the price of goat depends either on the market value because they sell when the animal is ready for market or when there is financial need. The determinants of price for goats were financial need (49%), market readiness (33%) and problem/trouble (18%). The WAD goats of Liberia have very high reproductive efficiency with the ability to produce twins and triplets in the litter, but due to poor housing (Figure 4) and kid management, mortality can reach as high as 50% in some situations and this negatively affects productivity (FED, 2016). Webb and Mamabolo (2004) reported high mortality (40.6%) in goats in communal systems in South Africa.

Liberia's AnGR particularly the ruminants are mostly kept extensive with little or no provision for housing facilities. About 67% of goat farmers provided no housing, 15% had a permanent structure and 18% provided some shed for their goats. The type of mating system practiced by the goat farmers in Liberia was uncontrolled, non-seasonal, natural mating with multiple sires. This type of mating practice was reported by 91% of the goat farmers. Due to the free-range husbandry system, there is no control in which male of preference can be crossed with female of preference and this explains the high proportion of uncontrolled year-round natural mating of AnGR in Liberia. The traits of economic importance among the goat farmers were fast growth and meat production. The goat farmers indicated that fast growth and meat production (65%) as the most preferred production traits with the rest indicating either meat production (19%) or fast growth (16%) as essential. The predominant source of water for goat production in Liberia is river, followed by deep well. These are relatively less expensive and sustainable sources of water which should be a motivation for potential goat farmers. It was noted that pipe-borne water is not a major source of water for animal genetic resources in Liberia. Pipe-born water in Liberia is treated and pumped from the well up to the water tank/towel and distributed via pipe or pumped directly from the water plant. The degree of phenotypic variations among the WAD goats was reflected among others in body size and colour pattern as shown in their natural environment (Figure 5).

Figure 5. Variation in phenotypic attributes and production environments of West African Dwarf Goats in Liberia.

Table 8. Challenges of goat farming in Liberia.

Challenge	No. of farmers	Percentage
Feed	500	42
Diseases	332	28
Housing	196	16
Medicine	74	6
Theft	54	5
Others	46	3
Total	1202	100.0

Challenges of goat production in Liberia

The main challenges of goat farmers in Liberia include cost and availability of feed, housing and fencing, and disease conditions (Table 8). Goat farmers indicated feed cost and availability (42%), diseases (28%), housing and fencing (16%) and cost of veterinary medicines (6%) as the major challenges in their production. This finding confirms that of Ademosun (1987) that lack of veterinary care also raises problems of diseases and parasitic infestation leading to heavy mortality and low productivity. The problem of feed availability and costs is more acute with livestock farming in Liberia and these challenges need to be addressed not only to increase productivity but motivate more farmers to go into livestock production. The cost and accessibility of veterinary services and medicines is a huge challenge to livestock farming (MOA, 2008).

Animal diseases are a major constraint to livestock development and there is little information available on major diseases of goat. In addition, there is limited or no research programs on animal diseases or on the improvement of animal productivity in Liberia. Lack of veterinarian medicine and farm inputs also need to be addressed urgently (MOA, 2008). The Liberian goat production is also beset with the poor housing and fencing facilities resulting in theft of goats on one hand and damages to crop farms on the other hand. An improvement in the housing and fencing infrastructure for goats will help curb these challenges. Record keeping was also a great challenge as most of the respondents could not supply the basic production data and this may require building up their capacity through training workshops and regular monitoring.

Conclusion

The WAD goats of Liberia are kept in subsistence husbandry systems. Family labour is the main source of labour and the main reasons for raising goats are for income and as source of meat. Goats in Liberia are

docile to moderate in temperament, with black coat colour pattern and black and white coat colour. Most of the goats are horned with curved horn morphology. The goats are also known to have productive traits such as fast growth and meat production and are disease and drought resistant in terms of adaptive traits. WAD goats have straight facial profile, followed by concave, with mostly straight back profile and smooth hair type.

The MOA should address the issue of feed, access to veterinary care and medicines, disease control and also assist farmers to put up housing and fencing for their animals. There is a need for the government to improve policies on AnGR management in Liberia. In particular, the recently adopted NSAP on AnGR which provides a clear framework for the development of the livestock sector should be validated and implemented by the MOA/CARI and other stakeholders. To ensure that Liberia's valuable local AnGR are never lost, both *in situ* and *ex situ* conservations should be pursued. On transboundary breed like WAD, there is a need to have national breeding and conservation centers to ensure that these breeds are maintained. In terms of breeding programs, community-based breeding program for small ruminants is a viable option.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Production performance evaluation of koekoek chicken under farmer management practice in Tigray region, northern Ethiopia

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The objective of the study was to introduce and evaluate production performance of Koekoek chicken under smallholder farmers' management practice and enhance their household income. This on farm experiment was conducted in eastern and south eastern zone of Tigray region. About 53 food insecure smallholder farmers were selected in collaboration with the experts and village administrators. Eighty seven percent of the beneficiaries were female headed householders and the remaining 13% were male headed housed holders. Each farmer received 20 koekoek chicks 45 days old, which were grown under on-station to decrease chicken mortality. Data on live weight, egg weight, egg color, sexual maturity, hatchability, adaptability and the overall farmers' perception on breed were collected by preparing checklist points. The collected data were analyzed using SPSS software. The breed was adaptable to both zones and non-selective for feed. It was also good scavenger and it could survive and give good production (meat and egg) under farmers' management practice. The average weight was recorded as 1.33, 1.87 and 2.47 kg at five eight, eight and twelve month's age for male koekoek, respectively, whereas 1.2, 1.64 and 1.59 kg was recorded for female at five, eight and twelve months age, respectively. The decrease in body weight of female indicates that layers chicken have decrease in weight at the time of laying and when their age increased. Sexual maturity of both male and female koekoek chickens were at 6 months. Egg production potential of the chicken was ranging from 180-240 hen^{-1} year^{1} depending on the farmers management practice mainly feeding, watering and housing. Egg weight of the koekoek chicken range from 50.63 to 53.67 g. About 87.5% of the eggs were brown and the remaining 12.5% were white. This breed has good acceptance in terms of their body weight, egg weight, adaptability to wide climatic conditions, feeding behavior and their color which has a market value. Therefore, this breed is suitable and recommended for scavenging and semi-scavenging chicken production system.

Key words: Adaptability, dual chicken, exotic chicken breed.

INTRODUCTION

In Ethiopia, chickens are widely distributed in almost every rural family, in some private chicken producers and governmental institutions like universities and agricultural research centers. Currently, because of the shortage of cultivating land, lack of grazing land, rapid population growth and urbanization, unemployment of youth and high protein demand of humans, chicken has become the most preferred animal. Chickens are also used as

sources of meat and egg, cash income mainly for rural poor farmers and their faces as animal feed and organic fertilizer. But in rural areas of Ethiopia, smallholder farmers consider chicken production as a side line activity in addition to their main agricultural farming like cropping and other livestock production; so, the production is mainly for home consumption. Chicken meat is nutritionally rich, providing protein, fats, minerals and vitamins and can be a good source of cheap nutrition for resource poor people, the sick, malnourished and children under the age of five (Tadelle, 1996).

In Ethiopia, the chicken population is estimated to be 59.38 million, 96.9% of which consists of local breed types under individual farm household management with poor housing, feeding and veterinary service and the remaining 2.56 and 0.54% are exotic and cross breed chickens, respectively (CSA 2012). Similarly, recent sample survey is also indicating that total chicken population of the country is estimated to be 59.5 million and out of these, 90.85% are indigenous, 4.39% exotic and 4.76% crossbred chicken breeds (CSA, 2017). Though, there is huge chicken population with diversified chicken ecotypes and some improved breeds like horro, their production potential is limited because of poor husbandry practice and low emphasis given to genetic improvement of the indigenous chicken ecotypes. As a result, the country is enforced to introduce some improved exotic breeds to improve the livelihood of the rural poor farmers and koekoek is one of the introduced chicken breed with the objective to fill this gap.

Koekoek hens lay brown egg, about 196 eggs per year with an average egg weight of 55.7g under intensive management system (Globbelaar et al., 2010). Similar egg weight and egg production of Rhode Island Red (185±8.82 and 52.5±2.83) and White leghorn chicken breeds (173±9.35 and 52.1±3.00g) are reported respectively by Lemlem and Tesfay (2010). However, egg production of the local chicken ecotypes is 48 eggs per year under extensive production system (CSA, 2017). Similarly, according to Lemlem and Tesfay (2010) report, egg production potential of local chicken is 54.3±8.25 and egg weighs 42.2±2.65 g. However, they can lay up to 100 eggs per year under improved management system (Negussie and Ogle, 1999) but it depends on the chicken ecotypes. According to Wondmeneh et al. (2016) report, improved local horro breed can produce about 171±0.57 and 149±0.88 eggs per year under on-station and on-farm performance evaluation, respectively. They also added that average egg weight for improved horro under on station performance is 52.3±0.3 g. Similarly, egg production performance of unimproved horro chicken is 66.5±2.5 eggs per year under improved management

system (Wondmeneh et al., 2016). Whereas, the improved exotic hens can produce up to 250 eggs per year with an average egg weight of 60 g (Alganesh et al., 2003). However, egg weight and egg production can be affected by the breed type and husbandry practice including feeding, watering and housing. Koekoek breed has better production performance than the improved and unimproved local chickens. Hence, introducing these exotic chicken breeds to smallholder farmers is crucial to enhance their household income.

The koekoek chicken breed is important in medium input production system or semi-scavenging production system. It is also a popular breed in South Africa and neighboring countries due to egg and meat production as well as their ability to hatch their own offspring (Grobbelaar, 2008) which has similar characteristics with Ethiopian indigenous chickens ecotypes and easily manageable at farmers level. However, their broodiness behavior is observable. Considering the above importance of the breed, it was introduced to eastern and south eastern zones of the Tigray, northern Ethiopia with objectives to evaluate their production performance and adaptability under small holder farmers' management practice and enhance income of smallholder farmers.

MATERIALS AND METHODS

Study area

This on-farm research was conducted in eastern, south eastern and Mekelle zones of the Tigray regional governmental state. Hawzien district from eastern zone, Hintalo-wejirat districts from south eastern zones and Semien district from Mekelle zones were selected and for the on-farm research. Hayellom and Megab villages from Hawzien, Fikrealem and Adiweyane villages from Hintalo-wejirat and Adikenfero village from Semien district were selected (Figure 1). All villages are categorized under the midland agro-ecology. According to EARO (2000) report, midland agroecology is categorized under the altitude of 1500 to 2500 masl. In all zones, mixed crop-livestock farming is the feature of the area and it is the main occupation and household income source. Chicken production is taken as a side line activity and its product is mainly used as home consumption.

Selection procedures and technology beneficiaries

At the beginning, close discussion took place in the office of agriculture and rural development experts and village administrators. Farmers who were food in-secured, willing to accept a new technology, interested and had good experience in chicken production and management were selected in collaboration with experts, development agents and village administrators of the respective villages. Then after, about 54 farmers were selected from Hayelom, Megab, Fkirealem, adiweyane and Adikenfero

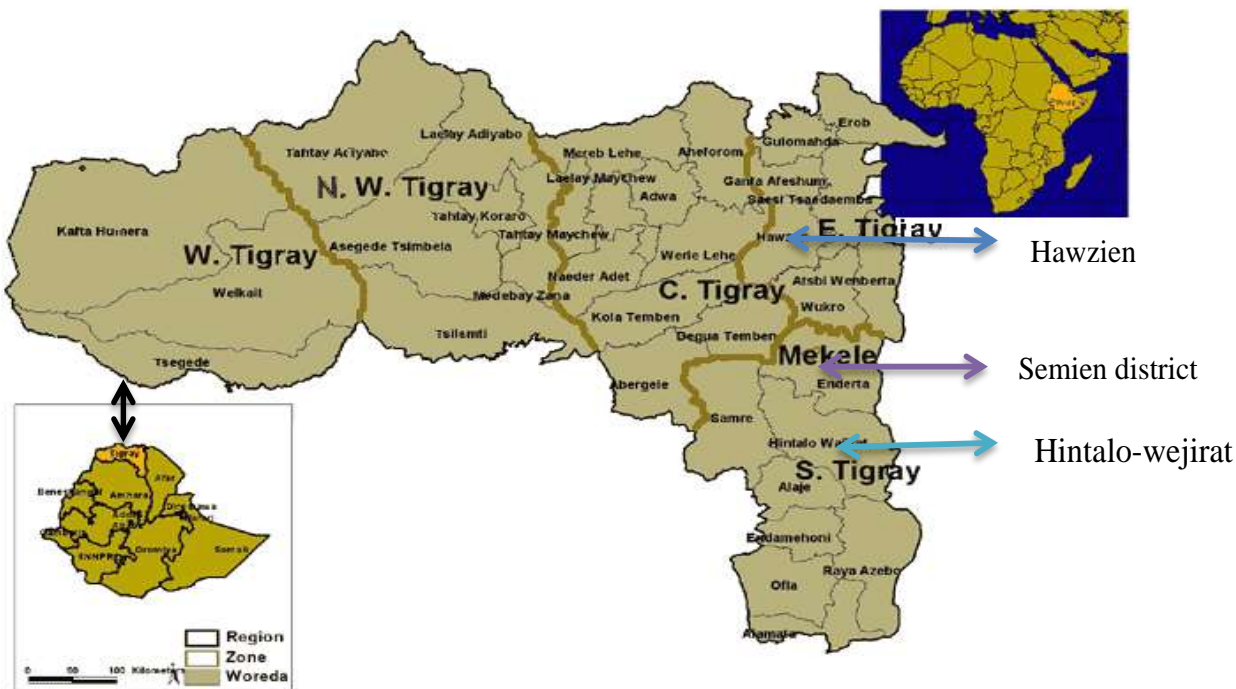*Corresponding author. E-mail: shumuyeb@yahoo.com.

Figure 1. Map of the study area.
Source: http://www.tigraionline.com/tigrayGIF.gif.

villages. In the first four villages, 10 farmers were selected from each village and given 20 chicks for each, whereas at Adi-kenfero village, a total of 14 farmers were selected and given 10 chicks for each. Chicks were grown at on-station till 45 days age to decrease chick mortality under farmer's management practice. Out of the beneficiaries, 87% were female headed households and the remaining 13% were male headed households. This encourages participation of female headed households in the on-farm research and females are the main actor in traditional chicken production system in the region.

Animal management and diet

Farmers fed their chickens using locally available feed resources such as maize, wheat, waste vegetables and some well-experienced farmers start to supplement their chickens using animal byproducts such as bone meal by grinding it into small pieces and some calcium sources of feed such as sand and calcium carbonate. Chickens were vaccinated against common chicken diseases of the area such as new castle disease or locally known as *fengel or kudum*, fowl pox and treated against salmonella and coccidiosis diseases by the help of veterinarians of the district. Beneficiaries were given training on chicken production system and their management including feeding, housing and animal health care.

Live weight, egg weight and production

Live weight of the chickens was taken at 5, 8 and 12 months of age. Data on body weight were collected every month and included in the data analysis. Egg weight was also taken and measured using sensitive balance. Egg production was collected by enumerators in collaboration with farmers using data collection sheet.

Data collection and analysis

Data were collected by preparing checklists and the beneficiaries were interviewed on the adaptability, disease resistant, feeding habit, broody behavior, color preference and other characteristics of the breed. Measurements such as live weight, egg weights and egg production were measured and analyzed using simple descriptive and inferential statistics with the help of SPSS version 20 software.

RESULTS AND DISCUSSION

Adaptability and economic merits of koekoek chicken breed

Potchefstroom Koekoek chicken breed is adaptable to the mid altitude areas of eastern and south eastern zones of Tigray region. They are ideal breed for a free-range environment, especially for the rural communities because they are highly scavengers so that there is no need of confining them to a house. It can cause death due to suffocation, cannibalism due to mineral deficiency and they can also compete with human food. This chicken breed has an observable broody behavior which has similar characteristics with the Ethiopian indigenous chicken breeds. This broody behavior helps farmers to reproduce the breed sustainably under traditional management system.

Both the koekoek and indigenous chicken have broody behavior but comparatively koekoek has low broody behavior than the indigenous one as most hens do not

Local broody hen

Koekoek broody hen

Naturally hatched Koekoek chickens

Koekoek hen gives heat to her babies

Figure 2. Broody characteristics of koekoek and indigenous breeds in study districts.

show any sign of broody behavior or not easily observed by the producers (Figure 2). Though broodness behaviour is prefered by the rural farmers, it has negative impact on egg production and this is the main reason for the low egg productivity of the indignous chicken ecotypes of Ethiopia.

Production performance of koekoek chicken

The production performances of Koekoek chicken under the farmer management are presented in Table 1. The average body weight of the male was 1.3, 1.9 and 2.5 kg 5 months, 8 months and yearling age, respectively. Similarly, average weight of the female chickens was 1.2, 1.6 and 1.6 kg with the same ages and condition of male chickens. However, both chickens mature at six months age under farmers' management practice. This result was higher than the value reported by Aman et al. (2016) in the southern part of Ethiopia which was 142 days of age at first egg laying of koekoek chicken and Desalew

(2012) reported 153 days of age at first egg laying of the same breed. Similarly, in South Africa, Koekoek chicken reaches the age of 130 days (Nthimo, 2004). However, management including feeding, watering, housing, veterinary services and environmental conditions could be the main reasons for the lateness or earliness of egg laying. The average body weight attained in this result was similar as reported; 1.5 kg for male and 1.1 kg for female at the age of 5 months (Aman et al., 2016). This might be due to the feeding and management difference of the famers and locally available feed resources across the study areas.

The egg production of Koekoek chickens ranges from 180-240 eggs per year depending on the supplementary feed and management of the farmers'. This result is higher than egg production performance of the local chickens which ranges from 40 to 63 eggs per year (Lemlem and Tesfay, 2010) with the average egg weight of 43.0±2.24 g. However, similar egg weight is reported by Nthimo (2004) and Lemlem and Tesfay (2010) on koekoek (55.7 g) and Rhode Island Red (52.5±2.83 g)

Table 1. Production performance evaluation of koekoek chickens under farmer management practice.

Parameter	Male	N	Female	N
Average weight at 5 months old	1.3	35	1.2	36
Average weight at 8 months old	1.9[a]	18	1.6[b]	36
Average weight at 12 months old	2.5[a]	8	1.6[b]	51
sexual maturity(month)	6		6	
egg production			180-240	
Average egg weight (g)			52.5	
Hatchability in percent (%)			76.5	
Egg color (%)				
Brown			87.5	
White			12.5	

[ab]Means in the same row for each parameter with different superscripts are significantly different (P<0.05).

and white leg horn (52.1±3 g) chickens, respectively. The hatchability of Koekoek chicken egg (76.5%) is similar to local chickens (74-83%) (Lemlem and Tesfay, 2010). In the rural farmers, natural hatching is important for the sustainability of the koekoek breed and breed improvement of the indigenous though it is not economically feasible as compared to artificial hatching machine using incubator as they can loss their time in brooding (21days) and caring for their offsprings.

Broody behavior

Contribution of poultry in food security

Koekoek chickens lay an average egg of >180 per hen per year with farmers' management practice. The current average egg price is 3 ETB ($0.11) so that a farmer who has 10 layers can earn more than 5400 ETB per hen per year. The beneficiaries use the money to purchase feed, food, cover educational expense for children, purchase clothes and agricultural expenses.

Chicken disease and control measures

The fatal diseases in the specific area were Newcastle disease locally known as fengel or kudum disease, fowl pox, salmonellosis and coccidosis. These diseases are the most economically important diseases in the study area and results in economic loss in the rural resource poor farmers. Majority of the beneficiaries were aware of the prevention and control mechanisms of the diseases observed in the area. Some farmers vaccinated their chickens against the viral diseases such as new castle disease (NCD) and fowl pox and bacterial diseases such as salmonella and protozoan diseases such as coccidosis. Ethno-veterinary medicines such as areki

(alcoholic drinks), garlic and others are also practiced as control mechanism of the commons diseases.

Chicken mortality (34.7%) observed under the age of one month was lower than the value reported by Aman et al. (2016) which is 79.8% chicken mortality recorded in the southern part of Ethiopia. This could be due to the seasonal and environmental variation of the study period. Chickens below one month ages are susceptible to disease and predators. The main cause of death for the present study was disease outbreak, defects and predators such as cat, rat, donkeys, etc. This chicken mortality causes economic lose in the rural farmers and the country as a whole.

CONCLUSIONS AND RECOMMENDATIONS

Koekoek chicken breed is suitable for the semi-scavenging production system, tropically adapted and farmers preferred breed. It is a good scavenger and has an egg production potential of 180-240 eggs per year depending on the management practice. Average weight for male koekoek chicken is recorded as 1.33, 1.87 and 2.47 kg at five, eight and twelve months of age, respectively, and average weight for female chickens is recorded as 1.2, 1.64 and 1.59 kg of the same age with the male. It has an observable broody behavior which is preferred by the rural farmers as farmers have no artificial incubator. Though this behavior is not recommended especially in commercial production system, it is important for sustainability of the breed under traditional production system. It has attractive color, good egg and meat production, adaptive and farmer preferred breed. Therefore, this breed should be introduced into scavenging and semi-scavenging chicken production system. However, introduction of improved breed to chicken producers cannot only make them productive and maximize the chicken production but also, good

housing, feeding, enough veterinary service provision and capacity building to all stakeholders is critical.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Livestock production system characterization in Arsi Zone, Ethiopia

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Despite its vital role in the country's economic activities, livestock sector was considered as poor investment for development in Ethiopia. But currently, it is being given due attention in government policy planning, especially in the last two growth and transformation plans. Arsi zone is known for its own cattle breed known as "Arsi breed" (one of the six local breeds of the country) and has huge livestock population. However, the production system and constraints have not been studied. Therefore, this research was initiated to characterize the production system and prioritize associated production constraints in Arsi zone. In general, the livestock production constraints were studied to be identified and prioritized in order of their importance in each farming system. Overall constraints were categorized into five clusters as feed related constraints, health related constraints, breed related constraints and financial and human power related constraints. Therefore, to solve these constraints, establishment of feed development research program in nearby center (most likely in Asella Agricultural Engineering Research Center) and strong extension system to promote improved forages, better health care and use of improved breeds are suggested as a solution. Provision of credit system in order to enable farmers use all the services like purchase of initial livestock, concentrates and the like must be given due attention.

Key words: Livestock, Arsi zone, production system characterization, Arsi breeds, production constraints.

INTRODUCTION

Livestock plays a vital role in Ethiopian economy by contributing food, input for agricultural production (manure to manage soil fertility, draught power, transportation, threshing, etc), fuel source, raw material for industry, cash, employment for more than one-third of rural population and social functions (Solomon et al., 2003). According to MEDC (1998), AAPBMDA (1999) and CSA (2011), the livestock sub-sector contributes about 12 to 16% of total GDP and 30 to 35 agricultural

GDP. Due to some structural changes in economic sector of Ethiopia, the share of livestock sector in national GDP is decreasing. For instance, the share of the sector in 2005 was estimated to about 14% of overall GDP (Gelan et al., 2012).

Nevertheless, livestock production was considered as a poor investment for development in the last years in Ethiopia. However, in few recent years, livestock issues are beginning to be raised on Ethiopia's development

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agenda and livestock sector development was given great attention in Growth and Transformation Plan (GTP). This sector is expected to be promoted through expansion of fattening and milk production through breed improvement as well as pasture development and animal health (MOFED, 2010). The Ethiopia's ten years policy and investment road map (2010/11 to 2019/20) shows that agriculture is dominated by cereals (32% of agricultural GDP) and livestock (32%) while export crops and other agriculture accounts for 17 and 18%, respectively (MoARD, 2010).

Having about 53.4 million of cattle population (CSA, 2011), Ethiopia is reported to be endowed with largest livestock population in Africa. Out of this, more than 99% is indigenous breeds which have by-far low productivity in all aspects and only 1% of 30,000 are dairy cows. This proportion of cross breed is by far low as compared to neighboring countries like Kenya which is 3 million crossbreds (Tegegne and Hoekstra, 2011).

According to CSA (2015), Arsi zone is one of nationally and regionally known zones in terms of livestock population. However, the production system characterization and associated production constraints of livestock sub-sector was not yet studied. Therefore, in general, this research work tried to characterize the production systems, and related production bottlenecks of livestock sector in Arsi zone by taking samples from seven representative districts.

METHODOLOGY

Description of the study areas

The research was conducted in Arsi zone. Arsi was purposively selected since it is the main station of Asella Agricultural Engineering Research Center and most of the center's interventions were in this zone. Moreover, similar research works were undertaken by other research centers in the region in the rest zones of the Oromia regional state.

Arsi Zone is found in the central part of the Oromiya National Regional State. The zone astronomically lies between 6° 45' N to 8° 58'N and 38° 32 E to 40° 50' E. It shares borderlines with west Arsi, Bale, west/Hararghe and east Shewa zones. It has 25 administrative districts including one especial district. Asela is the capital town of the zone. It is located at 175 km from Addis Ababa on Addis Ababa-Adama-Bale Robe main road (BOFED, 2011).

As it is shown in table 1a and 1b, because of its great diversity in altitude, Arsi zone has great physiographic diverse also. Based on the altitude, there are four major identified physiographic divisions. The first one is the cool agro-climatic zone with altitude of above 3500 masl, which covers the highest altitudes areas of the zone and constitutes about 2.74% of the total area of the zone. The second one is the cool temperate agro-climatic zone that includes the mountain ranges, massifs and high plateaus of Arsi (2500 to 3500 m) that lies in the central part of the zone, stretching from the border of NNPSE (Nations, Nationalities and People of Southern Ethiopia) to Aseko district and belongs to the Arsi-Bale Massifs. It covers about 22.74% of the total area of the zone. The third is the warm temperate agro-climatic zone (1500 to 2500 m), which comprises low plateaus of the zone and covers about the 49.60% of zonal land surface. While the fourth is lowlands of the zone (less than 1500 m) constituting about

24.92% of the total area of the zone. This type of physiographic region of the zone is found in the Awash River valleys and southeastern lowlands. In general, the zone has the lowest altitude in extreme east of Seru district located in Wabe gorge which is 805 masl and highest point on peak of mount Kaka which is 4195 masl (BOFED, 2011).

Data type, source and method of collection

Both primary and secondary data sources were employed in this research. Primary data sources were farmers, agricultural and natural resource development offices and livestock resource development, health and marketing agency at different levels (regional, zonal, districts and PAs), rural land administration offices, different NGOs and stakeholders working on rural development. Secondary data were collected from different research output materials and other official reports of different offices. In general, data were collected by Rapid Rural Appraisal (RRA) and Participatory Rural Appraisal (PRA) methods, and household level interview methods through structured and unstructured survey schedule and focus group discussion, and key informants interview and discussion.

Sample and sampling mechanism

Multi-stage sampling techniques were used to select districts and peasant associations (PAs). Even though attempt was made to stratify the zone into three based on traditional agro-ecological classifications as highland, mid highland and lowland, considering the accessibilities and other production factors which have impacts on farming system characteristics, the zone was further stratified as mid highland wheat-belt and mechanized areas, high land barely belt areas, mid to low land teff-maize and spices majoring areas, mid altitude heavy soil areas, lowland maize majoring areas, mid highland and highland un mechanized wheat-barley belt areas and coffee and fruits majoring areas. From each cluster, one district was sampled and from each district, one or two peasant associations were selected for FGD. A total of 15 farmers FGD were held with each group having eight to fifteen group members who were systematically selected based on their farming experience, gender, educational background and etc. discussion with experts from each areas of agriculture, natural resource management and livestock were also conducted at each level. Development agents (DAs) at each peasant association were considered as key informants and they were interviewed separately. Finally, household level interview was conducted to supplement those community level data.

Data analysis method

Data analysis technique was used for the research and determined by types of data collected and purpose of research output (report). Therefore, in this case, since the data that were collected were more of qualitative in nature, descriptive and inferential statistics such as mean, median, cross tabulations and bar-graph methods of analysis were utilized in this study. The qualitative data collected through FGD, KII and transect walk were analyzed qualitatively using narration methods.

RESULTS AND DISCUSSION

Livestock production system of the study area

Livestock was found to be the most important farm

Table 1a. Basic information of sampled districts. Agro-ecologies and altitudes of the sample districts.

District	Percent of agro-ecology				
	Highland	Mid-highland	Lowlands	High altitude	Low altitude
Lemunabilbilo	80	20.00	0.00%	4180	1500
Shirka	24	56.00	20%	3700	500
Zuwaydugda	0	10.30	89.7%	1750	1600
Hetosa	26	47.80	26%	400	1700
Arsi-robe	24	62.00	14%	1150	800
Cholle	50	22	28%	3574	1040
Merti	10%	29%	61%	-	-

Table 1b. Basic information of sampled districts. Temperature and rainfall of the sample districts.

District	Average rain	Average temperature
Lemunabilbilo	1100	16
Shirka	1000	12.50
Zuwaydugda	650	25.50
Hetosa	800	21.00
Arsi-robe	1000	22.50
Cholle	1000	16
Merti	-	26

Source: Respective district's Office of Agriculture and Rural Development

Table 2. Livestock possession of households across districts

District	Oxen	Cow	Total cattle	Cross cattle	Ratio*	Sheep	Goat	Donkey	Poultry
L/Bilbilo	2.28	1.86	6.47	2.20	34%	4.2	1.9	1.4	2.5
Shirka	2.77	2.30	9.23	3.20	34%	4.9	0.7	1.4	3.6
Z/dugda	1.83	2.40	6.10	0	0%	2.4	1.8	0.9	3.3
Hetosa	2.37	0.94	4.80	0.5	6%	1.4	0.7	1.2	5.8
A/robe	1.83	1.90	6.40	1.40	13%	2.3	1.0	1.1	2.0
Chole	1.86	2.00	6.80	1.20	21%	2.9	1.3	0.5	4.3
Merti	1.50	1.40	5.30	0.40	6%	2.3	0.7	1.3	8.0
Total	2.11	1.80	6.20	1.20	15%	2.9	1.3	1.1	3.9

*Proportion of crossed breed cattle with total cattle.

activity in both agro-pastoral and crop-livestock mixed farming system. The overall mean livestock holding of the household was 7 TLU. However, there is difference in livestock type based on climate and intensity of crop farming across districts. The major livestock type was cattle with overall mean of 6.2 followed by poultry birds and sheep having means of 3.9 and 2.9 heads each per household, respectively. According to the responds in the FGD, the major cattle breeds in the zone were the local "Arsi breed" with mix of other local breeds like Boren and Arsi with exotic breed crossed breeds. In Merti district,

there were about 36283 head of camel population (Tables 2 and 3). There was lowest cattle possession in Hetosa district which may be due to extensive crop production as expected and the highest cattle possession per household was found in Shirka and Chole districts.

Livestock breed improvement in Arsi zone

According to CSA (2015) (Table 3), Arsi zone was ranked first in livestock population having 2.5 million cattle, 1.66

Table 3. Livestock population in Arsi zone.

Livestock type	Total population	Indigenous	Hybrid	Exotic
Cattle	2,528,903	2,404,996	111,852	12,055
Sheep	1,662,797	1,662,797	-	-
Goats	738,729	-	-	-
Horses	240,559	240,559	-	-
Mule	20,337	20,337	-	-
Donkey	421,733	421,733	-	-
Camel	28,942	28,942	-	-
Poultry	1,885,492	1,784,449	70,947	30,096
Beehives	122,779	121,815[1]	0[2]	964[3]

Source: CSA (2015). [1] Traditional beehives. [2] Intermediate beehives. [3] Modern beehives.

million sheep, 0.74 million of goats, 0.24 million of horse, 0.02 million mules, 0.4 million donkeys, 0.03 million camels, 1.88 million poultry birds and 0.12 million beehives which shows that there is huge potential for this sector. In general, when considering the composition of cattle herd, each household has on average of 1.2 cattle per household with largest mean in Shirka and Lemu-bilbilo, each possessing 3.2 and 2.2 crossed breed, respectively.

Shirka district has largest proportion of crossed breed (about 34%) followed by Lemuna-bilbilo, Chole and Arsi-robe districts with mean proportion of 26, 21 and 13%, respectively (Table 2). Only 27% of the households used AI service to improve their breed quality, while 32% used neighbors' bulls for free and 8% used rented neighbors' bull. About 10% of them used their own bull and the rest did not use improved breed. Even though there is high livestock potential in the lowland maize-sorghum based farming system, there is no significant activity carried out so far to improve the breed. The KII result from Zuway-dugda revealed that Asella is the main dairy product supplier to Ogolcho town.

To classify livestock in terms of their keeping purpose, cattle especially, the male ones were majorly kept for draught forces, and followed by other social values (prestige) and beef, while female cattle were kept for breeding purposes, followed by milk production and social values. The mean milk production per household in Arsi zone was about 2.2 L per household per day. The productivity of local cow per day was 1.52 L/day/cow and productivity of crossed cow was 3.16 which was not significant. But the potential for both local and crossed breed were much higher than mean value, 6 and 26 L/day/cow, respectively. Therefore, working on all aspects of the dairy cows like feed and health can improve the production and productivity. Furthermore, livestock in Arsi zone were also important sources of household cooking energy (animal dung) especially in highland and mid highland areas.

Pack animals (donkey, horses and mules) were all important means of transportation in farm and non-farm activities (petty trading); productive and reproductive activities and both for human and agricultural products. In all clusters of farming system, these animals were ranked next to cattle (which are main sources of draught power) in terms of their economic importance.

Small ruminants were kept for immediate/emergency cash obligations, unplanned emergency issues, educating children, to purchase agricultural inputs like fertilizer, seed and chemicals. While poultry birds were mostly owned by children and female spouses, and used for household consumption and sold to purchase household consumables which were non-agricultural products (result from focus group discussion).

Livestock production constraints

Cattle and small ruminants production constraints

In general, the livestock production constraints were identified and prioritized in order of their importance in each farming system. Overall constraints were categorized into five clusters as feed related constraints, health related constraints, breed related constraints, and financial and human power related constraints (Table 4). Feed related constraints are ranked first in both farmers FGD discussion done with experts at each district and household level survey data in all farming system clusters.

With regards to feed, shortage of grazing land due to expansion of farm land to marginal areas, inaccessibility and high price of supplementary feeds, lack of improved forage varieties, lack of awareness and skill on improving nutritional value and palatability of aftermaths and straws due to poor extension service on livestock sector were the main production constraints in all clusters. High water shortage for their stocks were reported for lowland maize based crop-livestock mixed farming, agro-pastoralists of Merti areas and parts of wheat-barely based mid highland parts around Lemu-bilbilo districts (Sirbo, Siraro PAs, etc).

The main problems related with health were absence of

Table 4. Livestock production constraints in Arsi zone across different.

Constraint	District							
	L/bilbilo	Shirka	Z/dugda	Hetosa	A/robe	Chole	Merti	Overall
Feed related	81%	77	86	94	78	79	100	85%
Health related	45.3%	54	49	29	33	38	58	42%
Breed related	11.3	0	0	3	17	13	25	8%
Labor shortage	36	48	72	39	23	51	47%	58%
Capital shortage	16	51	13	76	34	69	39.7%	12%

Table 5. Overall poultry possession in Arsi zone.

Breed type	Mean number of birds	Standard deviation
Improved breed	0.88	4.2
Local breed	2.97	4.8

vaccines and medicines, poorly equipped animal clinics, shortage of skilled staffs in the clinics and location of health posts/clinics at distant places from farmers' villages. These problems forced farmers to use non-prescribed medicines without the knowledge of health professional and created drug resistant diseases, opened black marketing of drugs trading; high priced drugs and invited expired and ineffective drugs to the market.

Main problems related to breeds were absence of AI service in most districts and its ineffectiveness in most of the cases. According to the information from districts' experts, the ineffectiveness was due to three main reasons. The first one was unskilled inseminators, and the second was wrong approach of the hormone synchronization campaign which is centrally planned at regional level and did not consider the situation at each specific area. For instance, in some areas, program may start during peak dry season when animals body conditions were not appropriate for conceiving pregnancy. The third reason was inadequate facilities for AI service provision.

Absence of breeding policy in general where individuals participate without any control (uncontrolled breeding activities) which harm even the merits of local breeds, poor market linkage for output, low mechanization technological interventions both at production and processing stages, poor research and extension service on animal feed improvement were most important constraints identified by discussion with districts' livestock experts.

For small ruminants livestock, there was no recorded improved breed in Arsi zone which is similar to CSA (2015) report which show that there were no attempt to improve the existing breed. In Ethiopia in general, improved breeds of sheep were only found in Amhara region which may be due to high research and development intervention in the region. In Oromia also, there were two research centers (Yabello and Adami-

Tullu) which were working on small ruminant improvements and Arsi zone has to use this opportunity to improve the breed in the zone. In the case of small ruminant, absence (supply shortage) of vaccine and medicines for treatment, feed shortage, low productivity of the breeds, and low extension support were the major constraints.

Poultry production and its constraints in Arsi zone

Highest household proportion of improved poultry breed possessors were found in Shirka, Arsi-robe, and Meri districts each accounting for about 54, 44 and 33% of households, respectively. But when considering the per household improved poultry birds possession, the highest was found in Hetosa district followed by Shirka and Arsi-robe each having 2.03, 1.69 and 1.33 birds per households. The overall mean improved poultry birds and local breed possession was 0.88 birds and 2.97 birds per household (Table 5).

Disease was the first ranked poultry production constraint where there all vaccine and medicine were not available or where it was available, indivisibility of vaccine was the main challenges in extension service provision. The available poultry vaccine was packed for 500 poultry birds and it did not consider the small scale production system of Ethiopia's farmers where a household is keeping on average, about 3 to 5 poultry birds. The second constraint was shortage of improved breeds and infertility of existing commercial improved breed. The third major production constraint was lack of poultry feed supply.

Beekeeping activities and its production constraints in Arsi zone

Only 16.8% of the households practice beekeeping and

Table 6. Reasons for not participating in beekeeping activities.

Reasons for not practicing beekeeping	Frequency	Non-practicing percentage	Rank
Inconvenience of weather condition	16	8.4	6
Ignorance	60	38.0	1
Fear of chemical	34	21.5	3
Feed shortage	23	14.6	4
Fear of stinging	20	12.7	5
Labor shortage	5	31.6	2

Table 7. Constraints of beekeeping activities in Arsi Zone.

Beekeeping constraints	Number of respondents	Rank
Chemicals applied to different crops	26	1
Bee forage and water shortage	15	2
Predators	7	3
High price and supply shortage of modern beehives	4	4
Labor shortage	1	5
Land shortage	1	2

Table 8. Feed type and season of their availability in the year.

Feed type	Percent of users	Time of most availability
Communal grazing	21.6	June-October
Own grazing	57.4	June-October
Crop residue	75	Throughout the year as contingency
Fodder	5.8	July-September
Crop aftermath	63	October to February
Cut and carry	45	July to September
Concentrate	34	When livestock get weak
Purchase straws and grazing land	74	April to October
Prepare feed at home from grains	19	During plowing (mostly for oxen)
Move livestock to other places	4	July to September

about 83% of the households did not practice beekeeping because of different reasons. The most important reason that was ranked first was because of own ignorance. But the rest were not practicing due to labor shortage, fear of chemicals and others (Table 6).

According to Table 7, application of chemicals on crops for different pests like herbicides, fungicides, pesticides were the most important beekeeping constraint in the study area. Bee forage and water shortages and predators like spiders, lizards and birds were also the next most important beekeeping constraints of the area.

Livestock feed availability status throughout the year

The most important livestock feed types were own/ purchased crop residue like straw (about 78%), grazing land (74%), crop aftermath (63%), own grazing land (57.4%), cut and carry (45%) and use of concentrate (about 34%). There is no single way of feeding animal and all household use one or more combination of these feeding systems (Table 8). From Table 9, it can be observed that forage production culture is too low (only about 6% of the respondents are producing) and there must be technological support in household level livestock feed preparation which could improve both nutritional and palatability of feeds like straw, crop aftermaths and grasses. From Table 9, it is observed that livestock feed is ample during the months September and October, at normal status during November, December and January while there is high feed shortage during February, March, April and May.

During period of feed shortage, farmers supplement their feed by buying other fodder, straws, hay from

Table 9. Animal feed availability status across the months of the year

Status	September	October	November	December	January	February	March	April	May	June	July	August
Ample	56	52	42	28	11	5	4	3	5	24	35	44
Short	20	11	10	15	38	55	56	57	56	42	35	30
Normal	23	37	47	56	50	40	40	40	40	34	30	26

Source: Own survey result.

purchased grazing land and concentrates. The per-annual mean cost of purchasing supplementary animal feed was estimated to be about 2105.47 Birr. The highest cost for supplementary feed purchase was recorded in Lemu-bilbilo, Shirka and Hetosa districts with 4030, 2790 and 2005 ETB per annum, respectively.

In most cases, the feed during dry seasons is insufficient and the farmers/keepers feed their animals only for survival. Because of this, the animals do not provide the intended output and the female ones do not conceive due to poor body conditions. Moreover, drinking water for livestock is the serious production constraint in all farming systems of the study area.

CONCLUSION AND RECOMMENDATION

Livestock production in Arsi zone is the most important sub-sector which is entirety of crop-livestock mixed farming system. It serves as farm power, manure, source of household energy for cooking purpose, means of transportation, source of income, etc. Almost all farmers have at least a type of livestock. But the sector is not given an attention equivalent to its importance. In this research, the production constraints in Arsi zone were categorized into four: feed related, health related, breed related, labor shortage and capital shortage.

To alleviate the problem of feed and feed related issues, training farmers on how to use the existing feed resources like grazing lands, crop straws and after mazes; how to prepare feeds from different sources and planting forages should be organized by experts. Supply of improved forage seed options should be given due attention. Despite the potential of livestock potential in the study area, there is less or/no research activity to improve and promote animal feed, whether it is forage development/ improvement or use of concentrates and demonstration of the feed technologies, skills and knowledge on animal feed importance and utilization.

In health related issues, the main problems were occurrence of seasonal diseases based on whether conditions, shortages of health facilities like clinics and health posts and illegal medicines in black market. Therefore, improving the capacity of health posts and livestock clinics established somewhere in terms of skilled manpower and equipment and establishing new ones to increase accessibility can reduce the potential risk. As mentioned earlier, majority of the livestock populations in the study area are comprised of local breeds having low production and productivity. Even though there is good start in cattle breed improvement using AI and improved bull system and supply of improved poultry birds, it is a drop in an ocean as compared to potential in the area.

In general, to increase the production and productivity of livestock in the study area, the sub-sector should be supported by research system in all aspects like breed improvement, health and forage development and demonstration and popularization of the technologies. Strengthening of the existing extension system is also a good option. Therefore, the researcher believes that establishment of research program in Asella could be the best solution to the problem. For the rest constraints, facilitating credit facilities should be planned by the government.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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Full Length Research Paper

Poultry manure as a protein supplement in indigenous goat production in Zimbabwe

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The abundance of poultry litter in most farms in the sub-Saharan Africa is becoming an environmental problem. The objective of this study is to evaluate the proximate value, *in-vitro* digestibility of dried poultry manure (DPM) and its subsequent effect on growth, pH, and volatile fatty acid production of indigenous goats in Zimbabwe. Eighteen goats were randomly allocated to two treatment diets: grazing veld grass plus *ad libitum* browsing of *Luecaena leucocephala* (T1) and 25% dry poultry manure plus 75% maize meal (MM) (T2), in a completely randomised design. Three samples of 2 g each T_1 and T_2 diets were subjected to standard procedures, for proximate analysis; a two stage Tilley and Terry was used to evaluate dry matter (DM) and organic matter (OM) digestibility of the diets. The results show no significant differences between treatment diets for DM, ether extract (EE) and Ash; however T_1 had higher (P<0.05) CP, ADF and CF compared to T_2. The NDF content of T_2 was significantly higher (P<0.05) than T_1. There was a significant difference (P<0.05) in DM and OM digestibility between treatments; T_1 showed higher DM and OM digestibility compared to T_2. Diet and sex of animals significantly (P< 0.05) influenced DMI, ADG and total gain (TG). Male animals in the control diet consumed more feed, gained more per day and showed the highest growth rate compared to female animals (P<0.05). The rumen liquor pH for animals in T_1 was significantly higher (P<0.05) compared to T_2; however the sex of animal did not influence overall pH of rumen liquor (P>0.05). Diet and sex of animals significantly influenced (P<0.05) the total VFA production. Male animals in T_2 exhibited the highest (P<0.05) total VFAs. In conclusion, although there were some nutrient inadequacies (ash, ADF) in poultry manure feed, it can support goat production at a marginal scale and positively influence pH and VFA production.

Key words: Goats, digestibility, poultry manure, nutritive value.

INTRODUCTION

The poultry industry is one of the largest and fastest growing sectors of livestock production. Throughout the

world there has been a 35% increase in meat and egg production in the past decade (FAO, 2010). According to Ghaly and Mac Donald (2012), rearing of birds has improved from a side-line occupation into a fully-fledged commercial enterprise. The 2010 world annual census data estimated the world flock to be over 18 billion birds with an estimated yearly output of 22 million tons of manure (FAO, 2010). A greater component of this poultry manure is left idle and decomposes in unfavorable areas that pose a challenge to nearby habitants. It is therefore envisaged that a more climate smart disposal way of poultry manure should be developed. One of such practical ways is its incorporation into ruminant animal diets. This is particularly important in sub-Saharan Africa due to the scarcity of animal feed during the dry period. Earlier studies by Nadeem et al. (1993) and Alam et al. (2008) demonstrated that agricultural and industrial wastes can be used for ruminants. The use of poultry manure would decrease the cost of feed and its polluting effects. Poultry manure is a form of non-protein nitrogen supply with crude protein (CP) content ranging between 15-30% (Nadeem et al., 1993). More than half of this CP is true protein, while the other half is non – protein nitrogen (Ajayi et al., 2016). A greater component of non-protein nitrogen in poultry manure is in the form of uric acid, which ruminant animals are able to utilize. This is possible through the rumen microbes that convert nitrates to ammonia (Ajayi et al., 2016). Ammonia is then absorbed by microbes for their own rumen microbial protein synthesis, with excess being absorbed into the blood stream or excreted as urine. Dried poultry manure has been used to feed goats (Reddy et al., 2012; Ajayi et al., 2016) sheep (Bello and Tsado, 2013) and cattle (Alam et al., 2008) with positive results. The main aim of this study is to evaluate the proximate value, digestibility and the subsequent effects of poultry manure on feed intake, growth, rumen pH and total volatile fatty acid production of Zimbabwean indigenous goats.

MATERIALS AND METHODS

Study site

The project was conducted at Africa University Farm, located in Old Mutare in Manicaland. The farm lies at a latitude of S 18° 53,786 and longitude of E 032° 36,036, with an altitude of 1104 m above sea level; its average annual rainfall is 772 mm. The average annual temperature is about 21.5°C, with January being the hottest month and June being the coldest month of the year. The variation in annual temperature is around 7.7°C. The area is dominated by sand clay loam, sand clay soils.

Animal management

Eighteen -one year old goats of 16.75 kg ± 0.35 average weight were randomly divided into two treatment groups (T_1 control; grazing veld grass plus 30% *Luecaena leucocephala*; T_2 grazing plus supplement with poultry manure (PM) and maize meal (MM) in a 1: 4; PM: MM by weight) with an equal sex representation. All

goats grazed an abandoned pasture dominated with star grass *Luecaena* browse trees. The experiment was done over a period of 50 days. In treatment two, animals were allowed to graze after consuming the treatment diet which was made up of 20% poultry manure (PM) and 80% maize meal (MM). This diet was fed at 3% of body weight and left overs were used to determine daily dry matter intake (DMI) by difference. Animals were allowed to adapt to the diet for 14 days and weight gain measurements were taken weekly from week two to week five. Feeding was done in individual pens every day in the morning from 06.30 to 10.00 h. Animals were housed over-night and allowed to graze after 10.00 h every day until 16.00 h. The DMI for the control group was calculated using a 3% factor of average live weight and was adjusted over time (McDonald et al., 2011). A flexible polyvinyl chloride stomach tube was used to extract rumen liquor for pH and VFA analyses at day zero and after every twelve days from week two to week five of the experiment. All animals were dewormed using Valbazin, Pfizer and dipped using coopers ASSASSIN Sheep Dip - COOPERS - temephos 35% - organophosphate dip, prior to the experiment.

Chemical composition and In-vitro digestibility

A 1 m^2 quadrant was used to collect ten veld grass samples which were cut into a 10 cm stubble height from a 20 m^2 paddock, of which only 20% of the consortium was used. A proportional 30% of *Luecaena* leaves were also harvested from within the paddock. The samples were oven dried at 68°C for 48 h, ground through a 1 mm sieve and packed in khaki bags awaiting chemical analysis. Three samples weighing 2 g each of both treatments (T_1 veld grass plus 30% *L. leucocephala*; T_2 25% DPM: 75%MM) were subjected to proximate analysis and *in-vitro* digestibility in the Animal Science lab at Africa University. Crude protein (CP) was determined using the Kjeldahl procedure (AOAC, 2005); CF, EE, was also determined by standard procedures of AOAC (2005), while Neutral detergent fiber (NDF), acid detergent fiber (ADF) was analyzed by methods described by Goering and Van Soest, (1970). Total ash was obtained by igniting a dried sample in a muffle furnace at 500^0C for 24 h cooled to room temperature before determining ash content by difference. The Tilley and Terry (1963) method was used to determine the *in vitro* dry matter and organic matter digestibilities for the two diets. VFA production was determined by a method described by Mpofu (2006)

Poultry manure management

Raw, sun dried and not treated poultry litter was obtained from layers raised in a battery cage system at the university farm and bagged under room temperature. Prior to feeding, manure was crushed in a maize crusher through a 2 mm sieve and mixed with maize at a ratio of 1: 4, DPM: MM.

Statistical analysis

A general linear model of SAS version 9.3, (2003) was used to analyze the effects of PM inclusion to the diet on DMI, growth, rumen pH and VFA production of the goats. The general form of the model is presented as follows:

$$Y_{ij} = \mu + S_i + T_j + (ST)_{ij} + e_{ij}$$

where Yij is the dependent variable (DMI, VFA, weight gain), μ is the overall mean, S is the sex effect (i = 1, 2), T is treatment effect (j =1, 2), $(ST)_{ij}$ is the interaction between sex and treatment, e_{ij} is the residual error. The differences between means were assessed using the Tukey's Studentised Range Test of SAS.

Table 1. Proximate composition of treatment diets used to feed indigenous goats at Africa University.

Proximate fraction (%)	Treatments		SE	P -values
	T_1	T_2		
DM	88.66	88.80	8.875	0.489
CP	15.05[a]	12.82[b]	1.493	0.017
NDF	49.24[b]	64.73[a]	5.692	0.001
ADF	17.25[a]	11.99[b]	1,443	0.012
EE	2.82	2.69	2.758	0.495
CF	19.79[a]	6.87[b]	1.336	0.001
ASH	8.00	8.00	0.001	0.526

[ab] Row means with different subscripts are different at $P < 0.05$; T_1; veld grass, + 30% *L. leucocephala* T_2 : 20% poultry manure plus 80% maize meal, DM – dry matter , CP – crude protein, NDF – neutral detergent fiber , ADF – acid detergent fiber, EE – ether extract, CF – crude fiber.

Table 2. Growth rate of Indigenous goats at Africa University.

Proximate fraction	Treatments			Sex			P values		
	T_1	T_2	SE	M	F	Se	T	S	T x S
DMI(kg)	0.57[b]	1.48[a]	0.004	1.12[a]	0.92[b]	0.006	0.001	0.001	0.001
Initial weight (kg)	16.73	16.73	0.001	18.12[a]	15.43[b]	0.035	0.901	0.02	0.871
Final weight (kg)	19.61[a]	17.8[b]	0.294	20.29[a]	17.14[b]	0.294	0.001	0.001	0.001
ADG (g/day)	57.6[a]	21.4[b]	2.94	43.4[a]	34.2[b]	2.94	0.001	0.001	0.001
Total gain (kg)	2.88[a]	1.07[b]	0.12	2.17[a]	1.71[b]	0.21	0.023	0.032	0.04

[ab] Row means with different subscripts are different at $P < 0.05$; T_1; veld grass + 30% *L. leucocephala,* T_2 : 20% poultry manure plus 80% maize meal, DMI – dry matter intake , ADG average daily gain.

RESULTS

The two treatment diets were subjected to proximate analysis and results are shown in Table 1. There were no significant differences between treatment diets for DM, EE and Ash; however T_1 had higher (P<0.05) CP, ADF and CF compared to that of T_2. The NDF content of T_2 was significantly higher (P<0.05) than T_1. The treatment diets and sex of animals significantly (P<0.05) influenced DMI, ADG and total gain (TG) of goats (Table 2). Male animals consumed more feed, gained more per day and showed the highest growth rate compared to female animals (P<0.05) in both treatments.   Male animals exhibited a higher DMI of 0.2 kg, higher ADG of 9.2 g and a higher total gain of 0.46 kg. Although the average initial weight of goats was the same for both treatments, the ADG, final weight and total gain were significantly different (P< 0.05) for the two treatments. The average initial weight for male animals in the control group was significantly higher (P<0.05) than T_2 group (Figure 1). The highest rate of gain was exhibited by animals in T_2 from day 38 onwards. The same is also true for male and female animals, but this is not exhibited by animals in T_1. Animals in T_2 exhibited a significant loss (P<0.05) of 1.3 kg LW from day zero until day 26. The rumen pH for animals in T_1 was significantly higher (P<0.05) compared to T_2; however the sex of animal did not influence the overall pH of rumen liquor (Table 3). Diet and sex of animals significantly influenced (P<0.05) the total VFA production. Male animals in T_2 exhibited the highest (P<0.05) total VFAs production. There was a significant difference in DM and OM digestibility between treatments; T_1 showed higher (P<0.05) DM and OM digestibility compared to that of T_2. The total VFA production did not change with time for T_1 while there is a significant change (P<0.05) for T_2. Male and female animals showed a significant increase in VFA production with time. This phenomenon was not exhibited by animals in T_1. The total VFA production plumates by 98% from day 26 to day 50 for T_2 (Figure 2). There is no significant difference (P>0.05) in VFA production between sexes. The sex of animals had no effect on pH values over time; however treatment diets significantly (P<0.05) influenced pH of rumen liquor over time. Animals in T_1 maintained rumen pH between 6.5 and 6.7 while animals in T_2 exhibited a significant (P<0.05) drop in pH from 6.6 to 5.6 over the fifty days of the experiment (Figure 3). Animals in T_2 exhibited a significant (P<0.05) drop in pH within the first fourteen days of the experiment

DISCUSSION
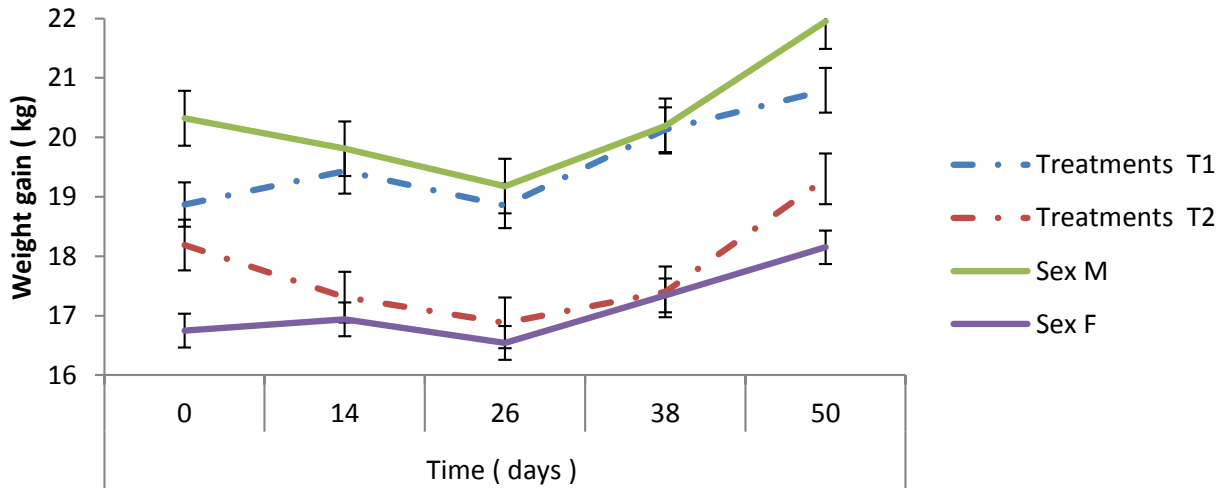
The DM and ash content observed in this study are within

Figure 1. Changes in weight gain over time for Indigenous goats at Africa University; T$_1$; veld grass + 30% *L. leucocephala* T$_2$: 25% poultry manure plus 75% maize meal.

Table 3. *In- vitro* digestibility co-efficiencies of Indigenous goats on two treatment diets.

Proximate fraction	Treatments			Sex			P values		
	T$_1$	T$_2$	Se	M	F	Se	T	S	T x S
pH	6.51[a]	6.00[b]	0.002	6.25	6.25	0.002	0.001	0.999	0.999
IVDMD	84,90[a]	73.40[b]	2.469	nd	nd	1.493	0.002	-	
IVOMD	61.8[a]	48.6[b]	2.469	nd	nd	1.493	0.003	-	
Total VFAs	54.67[b]	77.05[a]	4.930	66.08[a]	65.64[b]	1.493	0.001	0.002	0.001

[ab] Row means with different subscripts are different at *P*<0.05; T$_1$; veld grass + 30% *L. leucocephala* T$_2$: 25% poultry manure plus 75% maize meal, nd – not determined.
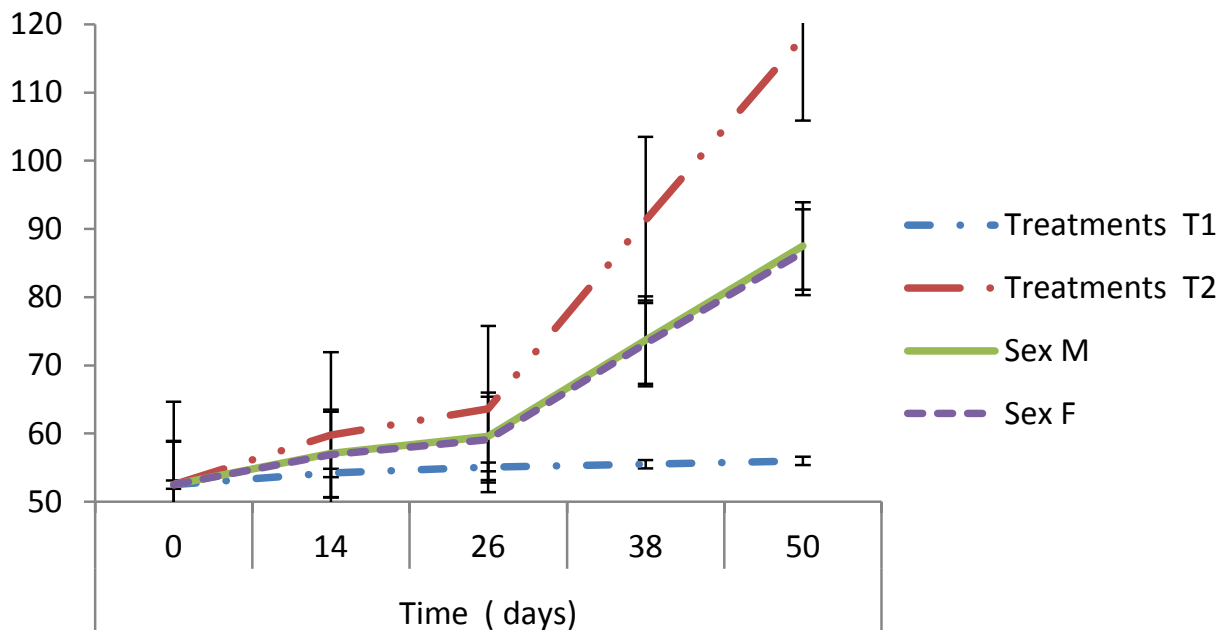

Figure 2. Total VFAs measured from rumen liquor of indigenous goats at Africa University.T$_1$; veld grass + 30% *L. leucocephala* T$_2$: 25% poultry manure plus 75% maize meal.

Figure 3. pH values measured from rumen liquor of indigenous goats at Africa University. T_1; veld grass + 30% *L. leucocephala* T_2: 25% poultry manure plus 75% maize meal.
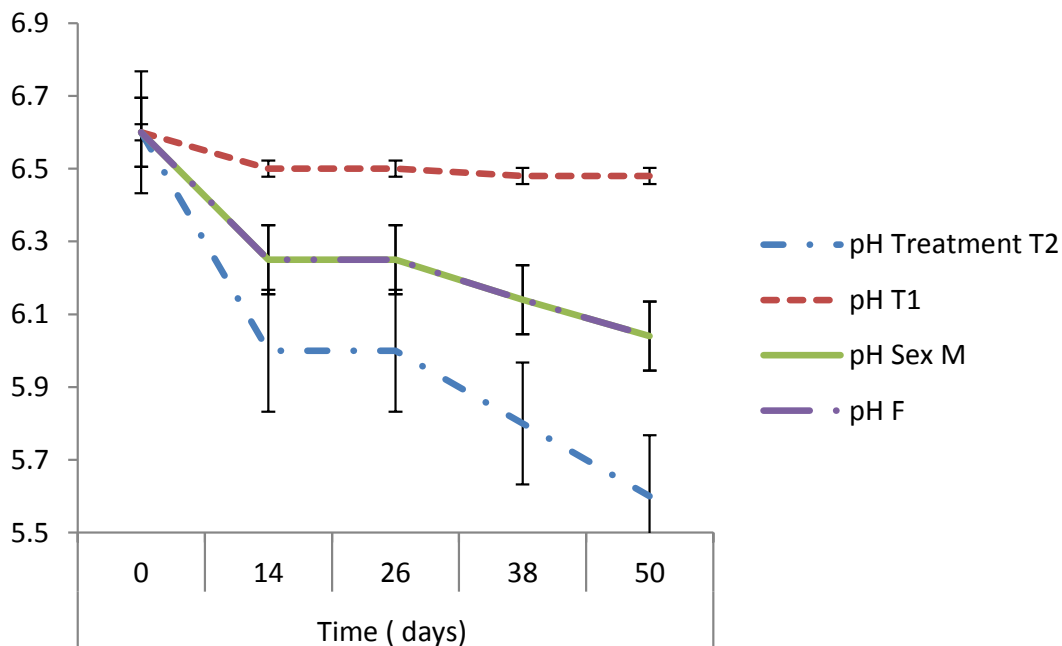
the expected limits for normal rumen functions (NRC, 2007); however, the CP content of PM was quite low compared to results by Obeidat et al. (2011) and Ghaly and MacDonald (2012). This is however, acceptable as poultry manure has a wide variability in terms of its nutrient content (Azizi et al., 2016). Furthermore, Animut et al, (2002) and Alam et al. (2008) also identified that broiler litter is more nutritious compared to layer litter which was used in this study. Nevertheless the CP content is above the dietary requirement of 7.3 – 7.8 g/kgDM as reported by NRC, (2007) for goats. The NDF content of PM in the current study is considered adequate for ruminant animals although the ADF was quite low. This was also expected since poultry litter is low in energy (Nurfeta, 2010). The CF content obtained in this study is similar to the results obtained by Ghaly and MacDonald, (2012) and has been reported to be inadequate for ruminant animals (NRC, 2007). Irrespective of some deficiencies, Obeidat et al. (2011) suggest that poultry manure is a valuable ruminant feed relative to any other environmentally-friendly way of poultry manure disposal (Elemam et al., 2009. Feed intake was relatively low in the first two weeks of the trial but steadily increased with time until the last week of the experiment. This concurs with the observations made by Bello and Tsado, (2013), who reported that, feed intake increases with time for housed goats.

In another study by Elemam et al. (2009), DMI increased in lambs fed a diet containing 450 g/kg sun-dried poultry litter compared with those fed 0, 150 or 300 g/kg of poultry litter. This suggests that generally poultry

manure does not influence DMI. The ADG and TG of goats under PM were low compared to grazing animals. This was not expected although it concurs with reports by Talib and Ahmed (2008); Abdel-Baset and Abbas, (2010) however, the major reason for this could be the effect of Star grass and *Luecaena leucocephala* browse species in which the goats had free access throughout the trial. Nevertheless the growth rates fall within the acceptable range as reported by Mirmohammadi et al. (2015) and NRC (2007).

Furthermore animals under T_2 showed a higher growth rate from day 38 to day 50 of 1.9 kg compared to 0.3 kg for T_1. This affirms the positive effect of poultry manure on the growth of goats. Ruminants usually require a balance of natural protein and non-protein nitrogen for both weight gain and feed intake (Baluch-Gharaei et al., 2015). The poor growth rate of the goats could have been attributed by an imbalance of natural proteins and non-protein nitrogen. Many rumen bacteria require specific amino acids to grow, which probably were not available in PM diet. Bacteria use peptides, amino acids and ammonia for their growth. Rumen microbes that ferment non-structural carbohydrates obtain two thirds of nitrogen from dietary amino acids or peptides whilst fibre digesting bacteria derive all their nitrogen from ammonia. Uric acid is the principle nitrogen (N) component of poultry excreta which degrades more slowly than urea (Abdel-Baset and Abbas, 2010) creating a favourable ammonia pattern for efficient utilization in ruminants. If in excess higher concentrations of ammonia limit the growth of cellulolytic microorganisms and reduce rumen fibre digestion and

hence microbial protein production (Santra and Karim, 2003; McDonald et *al*., 2011).

The gradual decline in pH for T_2 animals was expected. This is also in line with earlier conclusions made by Xie et al. (2015) and Calsmiglia et al. (2002) who concluded that feeding ruminants with concentrate diets reduces ruminal pH. In the current study as pH declines, the total amount of VFA in the undissociated state increases. This was also reported by Gäbel et al. (2002). Hence, a reduction in pH would increase the proportion of undissociated VFA that could be found in the rumen fluid. A pH between 5 and 6 has been purported to best suit VFA production in ruminants (NRC, 2007); close to neutral pH values promote production of more butyrate than acetate and propionate. In contrast pH values below 5.8 have been reported to reduce fibre and nutrient digestibility in goats by Calsamiglia et al, (2002) and Beauchemin et al. (2003) and pH of 5.6 has been reported, a threshold for acidosis (Cummins et al., 2009) of which animals in the current study maintained an average pH above this threshold. Furthermore this has significantly affected the total VFA production, with close to 98% more VFA being produced in this study. The pH of rumen liquor is negatively related to the amount of VFAs produced; this is attributed to the fact that high energy diets are quickly fermented hence produce high levels of lactic acid which lowers rumen pH as described earlier on by Sutton et al. (2003). It is well established in literature (Carro et al., 2000; Cummins et al., 2009) that a low pH decreases the acetate: propionate ratio. This is preferred because propionate acts a hydrogen sink in ruminants and reduces the loss of energy in the form of either methane or carbon dioxide (Washaya et al., 2017).

Conclusion

Based on the findings of the present study it can be concluded that DPM can be used as a protein source; however its effects on growth are marginal. The DPM contained adequate DM, CP, and NDF for goat production while the ash and ADF contents were limiting. DPM had a positive effect on pH and total VFA production.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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