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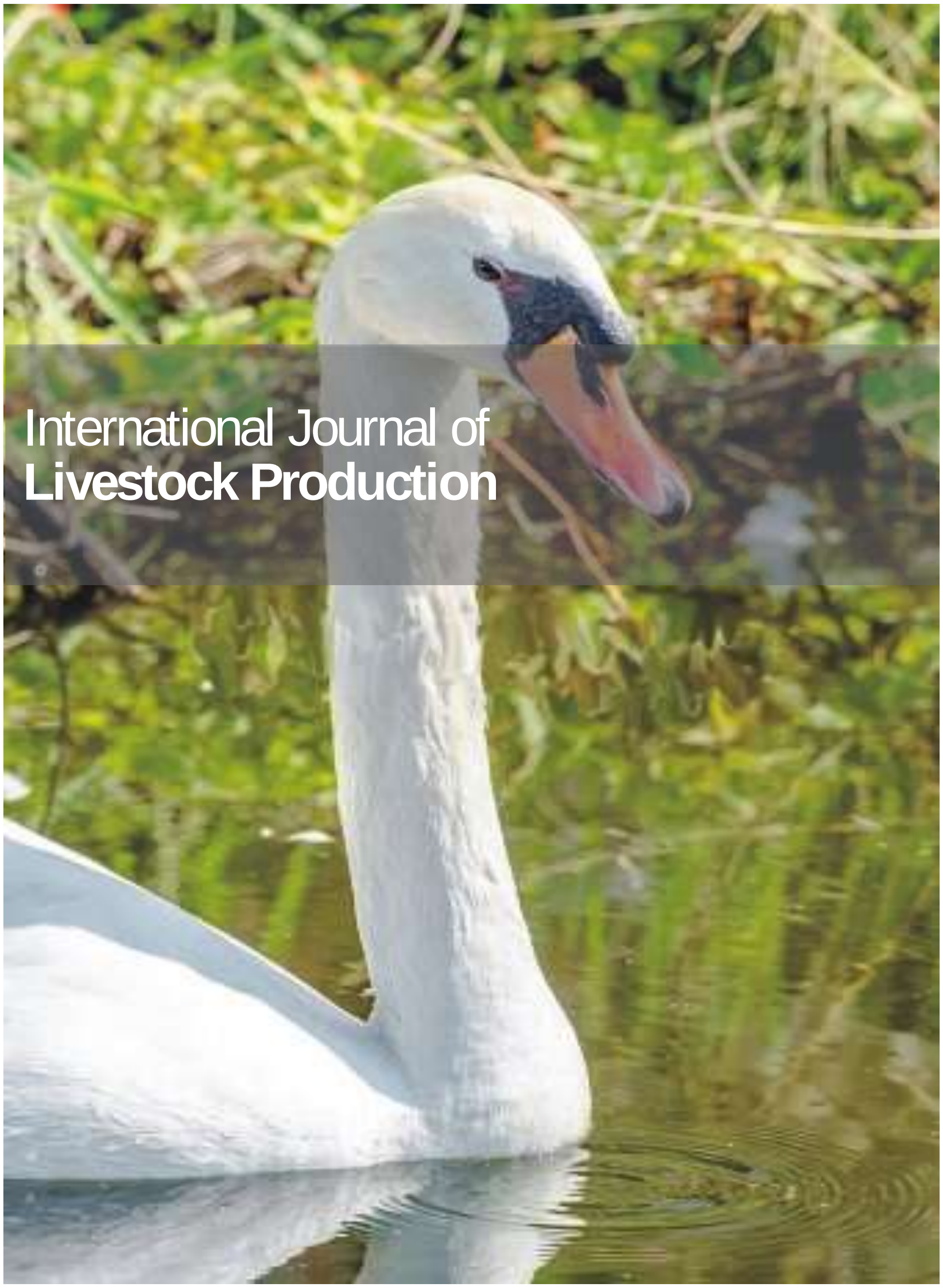

June 2018
ISSN 2141-2448
DOI: 10.5897/IJLP
www.academicjournals.org

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Vol. 9(6), pp. 102-107, June 2018
DOI: 10.5897/IJLP2018.0467
Article Number: 93B44CC56969
ISSN 2141-2448

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International Journal of Livestock Production

Full Length Research Paper

Success drivers of pig artificial insemination based on imported fresh semen

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Received 6 March, 2018; Accepted 17 April, 2018

This study was conducted to assess the factors that affect pig litter size, proportion of live pigs at birth, number of inseminations per conception, and efficiency of artificial insemination. The main factors assessed were sow breed (n = 2), sire breed (n = 3), sow parity (n = 7) and insemination method (n = 2). The sow breeds used were Landrace, LL (n = 27) and Landrace × Pietran crossbreds, LP (n = 37); boar breeds used were Landrace (LL), Pietran (PP) and Landrace × Pietran crossbreds (LP). Sows were randomly inseminated either by boar or artificially, with semen freshly imported from Belgium to Rwanda. Landrace (LL) sows had significantly smaller (P<0.05) litter sizes at birth (9.04±0.72) compared to LP sows (11.49±0.45). On the other hand, the litter size for LL (9.04±0.58) and LP (11.49±0.67) sires did not differ, while PP sires had the highest (P<0.05) litter size (13.37±1.43). Interestingly, the method of insemination, whether use of a boar or artificially did not (P>0.05) affect the number of inseminations per conception, litter size, and proportion of piglets born live. Sow parity was found to have a linear relationship with a mean litter size at birth of 6.9±0.43 piglets for primiparous sows and 15.2±1.12 piglets for a sow of parity 7. However, the number of piglets born dead increased with parity, peaking at 3.0±0.66 (parity 7), while it was only 0.2±0.2 for parity 1. Therefore, the LP crossbred sows and Pietran sires are recommended. Artificial insemination should be promoted since it performed as well as natural insemination but provides other advantages such as African swine fever and inbreeding prevention, and avoids boar management costs.

Key words: Breeding, genetic merit, performance, Pietran, pigs.

INTRODUCTION

The global pig population in 2017 was estimated at 784.83 million head (National Hog Farmer, 2017), with China leading in pig population at 435.04 million head, the top pork-producing country at 51.85 million tons (47.9% of world total), top pork-importers (40% of world total), and also the leading per capita pork consumer at 40.9 kg (National Hog Farmer, 2017; Statista, 2018). In Africa Uganda leads the per capita pork consumption at a meagre 3.5 kg (Birungi et al., 2015; Kugonza et al., 2015), and hence a lot still has to be done on the

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continent. Pig production has been growing on the African continent, and particularly in Rwanda; the growth has been consistent especially during the post-conflict years. The most recent census put the national pig herd at 706,000 animals (NISR, 2011), having risen by 35.4% during the period 2005 to 2010. The massive shifts are being driven by increased demand for pork and pork products such as sausages, bacon and special cuts. Along with other livestock species, notably cattle, goats and sheep; pigs contribute 12% of the Rwandan GDP, and a significant 32% to the agricultural GDP (NISR, 2017). Pig farming in peri-urban areas is highly competitive when compared to goat and cattle farming (Nabikyu and Kugonza, 2016). This is attributed to pigs requiring less land per livestock unit for acceptable levels of production. Farmers in peri-urban areas in much of East Africa also have access to agro-industrial by-products such as wheat pollards, brewers waste, molasses, and brans of maize, rice and wheat (Mwesigwa et al., 2013; Kugonza et al., 2015). These feedstuffs form the basal diet of pigs under commercial production. A major drawback to improving productivity is the breeding management, especially regarding unavailability and limitations in propagation of superior pig genetic material.

The use of artificial insemination (AI) technique for pigs and non-bovine livestock is very limited in Rwanda. The major driver of AI use is the need to disseminate superior genes within a given population at a reasonable cost. The greatest advantage of promoting AI use is that it will make possible, the widespread use of outstanding breeding sires and dissemination of valuable genetics to both big and small farms. This will lead to faster genetic improvement of the national pig herd. Pig AI technology has been in use in Northern Rwanda at a private farm but is yet to be tried out at community level, where breeding boars are still communally used through natural service. Small/medium scale farmers who do not own boars on their farms rely on a neighbour's boar to breed their sows. This has also been reported in neighbouring Uganda where over 52% of smallholder pig farmers do not own a breeding boar (Bamundaga et al., 2018). However, this practice of communal boars promotes the spread of diseases especially African swine fever and various reproductive diseases because of the movement and contact between animals. Also, the sharing of the boar by many farmers leads to its overuse which might explain the occurrence of small litter sizes at subsequent births. This ultimately leads to a low number of pigs per sow per year and economic loss.

AI of the pig involves collection of semen from a boar and then introducing it into a sow or gilt later on by means of a catheter (Ikani and Dafwang, 1999; Bamundaga et al., 2018). It differs from natural service which involves a boar mounting the sow and introducing his semen by copulation. Sperm, the main ingredient in semen was first seen by Leeuwenhoek and Hamm in 1678 (Foote, 2002). Then, the first successful insemination was performed in dog by Spallanzani in 1784 and over a century later, in 1897, AI in livestock specifically rabbits and horses was then reported (Foote, 2002). Pig AI was first performed by Ivanoff in Russia almost a century ago (Ombelet and Van Robays, 2015) however, its wide commercial application in pig production is more recent. It is just over two decades ago when insemination protocols for pig AI were standardized (Gadea, 2003), and related work continues. A contemporary study (Bamundaga et al., 2018) has recently established that single and double AI protocols lead to non-varying conception rates (94.4 versus 89.6%), and litter sizes (8.16±0.34 versus 9.00±0.39 piglets).

Recent estimates put pig AI at nineteen million inseminations worldwide per year and of these, almost all (99%) are done using boar semen preserved at temperatures of 15 to 20°C (Johnson et al., 2000). AI in pigs: (i) Allows for the wider use and distribution of boars of high genetic merit; (ii) Allows up to 25 sows to be served with semen from one boar ejaculate, each dose given to a sow containing 2 to 3 billion spermatozoa in 80 to 100 ml (Maes et al., 2010); (iii) Prevents the transmission of diseases from farm to farm by the movement of sows to and from the boar as well as the sale of diseased boars; (iv) Helps to overcome the challenge of differences in size of males and females, especially the limited use of heavy boars which may be of high genetic caliber; (v) Eliminates the need to purchase, house and feed boars especially on small scale agriculture; (vi) Reduces the farmers risk of handling boars for use in natural service (Ikani and Dafwang, 1999).

Currently, the pig breeds reared in Rwanda include Large White (on 22.9% of pig farms), Landrace (37.7%), Pietrain (7.3%), Duroc (1.6%), Local (2.3%) and non-descript crossbred (28.1%) pigs (Mbuza et al., 2016). The local pigs are black in colour or black in mixture with white. The productivity of the local pigs is still very low, characterised by low birth weight and slow growth rate. The average age at first farrowing of sows is between 18 and 24 months, while the number of piglets born from the black pigs range from 8 to 10 piglets, and a mature weight of 120 kg is attained in pigs aged 18 months (RARDA, 2010). For the Large White breed, the average weight of 70 kg is attained at 5 months, while first farrowing occurs at 12 months, with a litter size of 10 to 12 piglets. Growth performance of the Landrace breed is generally better than the Large White although performance data is not readily available (RARDA, 2010). Pietrain pigs on the other hand generally have lower growth rates but produce predominantly lean carcasses when the effect of feed is accounted for. This study was therefore conceived to study the major factors that influence the success of an artificial insemination programme that uses imported fresh boar semen.

MATERIALS AND METHODS

Ethical approval

This research followed ethical standards and complied with regulations of the Rwanda National Council for Science and Technology.

Study location

The study was conducted at *Centre de Perfectionnement agricole et elevage de Kisaro* (1°37'41.99''S; 30°01'39.11''E), a private farm located at Kisaro sector, Rulindo district in the Northern province of Rwanda. The site is at around one and half hours' drive from Kigali City.

Experimental animals

Sixty-four sows of Landrace breed (n = 27) and Landrace × Pietrain crossbreed (n = 37) were used in this study. The sows were of parities ranging from one to seven. Semen or boars used were of Landrace breed (n = 28), Pietrain breed (n = 15) and Landrace × Pietrain crossbreeds (n = 21). Forty of the total experimental sows were bred using artificial insemination, while twenty four were bred using natural mating with the boar. The experiment was conducted over eight month duration.

Source of semen for artificial insemination

Fresh semen was imported from Hypor (a Hendrix genetic company), a breeding company based in Belgium (HYPor Belgium V, Leie Rechteroever19870, Olsene Belgique, T 014 63 53 47, F014 63 54 79, (www.hyvarselect.be). Semen collection was performed the day prior to shipment to Rwanda. Semen was collected from several boars, pooled and then extended using standard protocols before being shipped.

Housing

All pigs at the farm were kept indoors, adults in individual pens, while weaners and growers were reared in groups of up to ten. Individual pens were made of a concrete floor, with walls of brick measuring up to 1.5 m in height. The average floor space area per adult pig was up to six square metres. Farrowing pens measured 2.5 m by 2.5 m, boar pens measured 2.5 m by 1.25 m while grower pigs were kept in pens measuring 2.5 m by 1.25 m. Pig house roofs were made of corrugated iron sheets.

Feeding

The main diet of the pigs was a composite ration made of maize bran, wheat bran, bone meal, soybean meal, fish meal, vitamin mineral premix and salt. The wheat and maize used in feed formulation was largely produced on the farm. The pigs were fed twice a day, at 09:00 to 10:00 h, and at 15:00 to 16:00 h. On average, each mature pig was given 2.5 kg of the composite ration per day, with bigger sows getting proportionately higher amounts. Water was provided *ad libitum*.

Piglets were farrowed in specialized farrowing pens (2.5 m x 2.5 m) and received an injection of iron on the 3rd day of their lives. Piglets stayed with their mother from birth until weaning at two months, though they had access to creep feed placed in a specialized creep area, accessible only to piglets. Castration of male piglets was done within one to two and a half months of age. At weaning sows were removed from the pens and the weaned piglets were allowed to stay in the pens for extra one week. Afterwards, the weaners were segregated by sex and relocated to grower pens (2.5 m x 1.25 m) in groups of up to ten.

Breeding and health management

Sows naturally came on heat 3 to 7 days after weaning their litters, and had never been induced using hormonal treatment, but were regular breeders. Gilts were bred on their second heat, at the age of seven months. The sows were allocated individual pens next to adult boars to enable estrus detection. In addition, the back pressure test for standing heat reflex was performed and those that responded were considered to be in estrus. The sows were either taken to the boar for supervised service or were inseminated with imported extended fresh semen. Twenty four sows were served by boars twice using the AM-PM rule, so as to maximize on the conception rate. Each boar was allowed to serve a maximum of four sows a week to avoid them being overworked. Sows and gilts were served by boars in rotation to mimic AI where semen from several boars was pooled, in consideration of the desired breed. On the other hand, 40 sows were artificially inseminated twice, about 24 h between the inseminations using the AM-PM rule. Each dose inseminated by AI contained 2.5 billion spermatozoa in 80 ml. The intra-cervical method was used in all inseminations (Darwin, 2007), with extra care taken to minimize backflow. Conception was indicated by a non-return to heat after 18 to 22 days, the few gilts that did not conceive on first insemination were served again on the subsequent natural heat.

The pigs were washed every week using water and soap. There was no practice of spraying against ecto-parasites, instead, double-acting dewormer Ivermectin® was used for this purpose. The pigs were dewormed once every three months. Disease outbreaks were described by the farm management as being very rare on the farm.

Record keeping

Records on each piglet farrowed were kept on the farm. Records that were taken included farrowing date, sow breed, boar breed, parity of sow, litter size (number born alive and stillborn), method of insemination used, and live body weight (taken monthly). Dates of treatment in cases of disease, inseminations and routine animal management practices were recorded as well. The farrowing rate recorded was 86% and above.

Study design, data collection and data analysis

The study used a completely randomized design with sows that were recruited into the study randomly selected from the herd. Also, sows that were subjected to artificial insemination were randomly selected from the experimental group so as to avoid bias. Data were collected over an eight months period following specified/standard procedure, taking care to avoid stressing the animals, in consonance with the national provisions on animal welfare and ethics in handling experimental animals.

Data was checked for validity and was then entered into MS Excel spreadsheets. It was then subjected to analysis of variance using the generalized linear model procedure of Statistical Analysis Systems, version 9.2 (SAS, 2004). The fixed effects were sow breed, boar breed, sow parity, and insemination method. The model used for data analysis was:

$$Y_{ijklm} = S_i + B_j + P_k + I_l + SB_{ij} + SP_{ik} + BP_{jk} + PI_{kl} + e_{ijklm} \; N(0, \sigma^2_e) \quad \text{(i)}$$

Table 1. Least square mean litter size, piglets born alive, stillborn piglets, inseminators per conception.

Factor	Level	Litter size	Piglets born alive	Stillborn piglets	Inseminations per conception
Sow breed	Landrace × Pietrain (n = 37)	11.49[a]	10.81[a]	0.67	1.02
	Landrace (n = 27)	9.04[b]	7.79[b]	1.25	1.11
Boar breed	Landrace × Pietrain (n = 21)	7.99[a]	7.51[a]	0.47	1.09
	Landrace (n = 28)	9.43[a]	8.29[a]	1.14	1.10
	Pietrain (n = 15)	13.37[b]	12.09[b]	1.27	1.01
Parity	1st (n = 21)	6.91[a]	6.76[a]	0.15[a]	1.06
	2nd (n = 15)	8.27[ab]	7.77[a]	0.50[a]	1.12
	3rd (n = 9)	9.96[ab]	8.75[ab]	1.21[ab]	0.98
	4th (n = 6)	9.28[ab]	8.28[a]	1.00[ab]	1.24
	5th (n = 5)	9.84[ab]	8.66[ab]	1.17[ab]	1.01
	6th (n = 4)	12.29[ab]	12.44[c]	-0.14[a]	1.02
	7th (n = 4)	15.29[c]	12.44[c]	2.85[b]	1.02
Insemination method	AI[§] (n = 40)	8.06	7.45	0.61	1.17
	NS[∫] (n = 24)	12.47	11.15	1.31	0.97
SEM		0.429	0.404	0.164	0.025
LSD		1.48	1.32	0.60	0.10

[§]AI = artificial insemination; [∫]NS = Natural service. [abc] = means with similar superscripts within column and factor are not different (P<0.05)

Where, Y_{ijklm} = observation of the variable for the a sow breed *i*, mated to boar breed *j*, for sow parity *k* and for insemination method *l*; μ = overall mean; S_i = effect of sow breed (i = 1,2); B_j = effect of boar breed (j = 1,2,3); P_k = effect of sow parity (k = 1,2,3,4,5,6,7); I_l = effect of sow insemination method (l = 1,2); SB_{ij} = effect of the interaction between sow and boar breed; SP_{ik} = effect of the interaction between sow breed and parity; BP_{jk} = effect of the interaction between boar breed and sow parity; PI_{kl}, = effect of the interaction between sow parity and insemination method; e_{ijklm} is the random effect on the trait, independently and identically distributed with mean = 0 and variance = σ_e^2.

Model (i) above was used in the preliminary analysis. Due to the finding that the sow and boar breed interaction effect SB_{ij}, the sow breed and parity interaction effect SP_{ik}, the boar breeds and sows parity interaction affect BP_{jk}, and the sow parity and insemination method interaction effect PI_{kl} did not significantly affect the variables, they were eliminated from the model, subsequently, the model finally used is shown as follow:

$$Y_{ijklm} = S_i + B_j + P_k + I_l + e_{ijklm} \quad N(0, \sigma^2_e) \qquad \text{(ii)}$$

Duncan's multiple range test was used to separate means.

RESULTS

The mean number of piglets born alive was 39% higher for crossbred sows compared to pure landrace sows (Table 1). However, the differences in number of piglets born live between boars of the two breed types were not significant; instead, it is the value for Pietrain boars that stood out; 53% piglets more than the other categories. Parity of the sow did not influence the number of piglets born alive, but it did significantly influence the total litter size. Litter size clearly increased with parity, rising consistently from 6.91 piglets for sows of first parity to 15.29 piglets for sows of parity 7, a 121% increment. The litter size as well as the number of piglets born alive did not differ between sows bred using artificial insemination and those that were bred using natural service.

The number of stillborn piglets was not affected by sow breed, boar breed, and insemination method; but was influenced significantly (P<0.05) by parity of the sow. In general, the number of stillborn piglets increased with parity (Figure 1), rising from 0.15 for primiparous (first parity) sows to 2.85 for 7th parity sows.

Considering the number of inseminations per conception, all the factors namely sow breed, boar breed, sow parity, and insemination method did not show significant differences (P>0.05).

DISCUSSION

This study focused on establishing the determinants of success in a pig artificial insemination programme using semen freshly imported from Europe to Central Africa. Sows inseminated artificially had a litter size of 8.06±0.42 piglets quite comparable to 9.06±0.4 piglets reported by Bamundaga et al. (2018) and 10.8±2.2 (Chanapiwat et al., 2014), and despite being in varying locations, the studies used landrace breed and its combinations with other breeds. Improvements in the management of

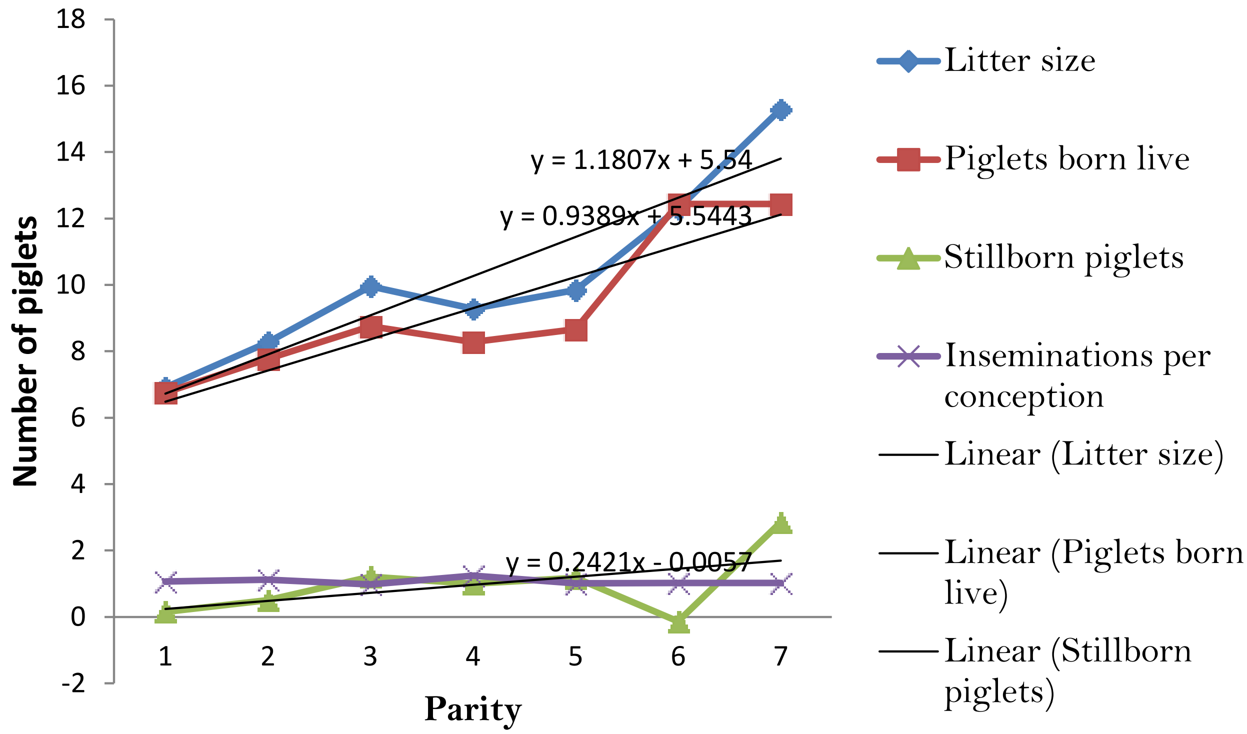

Figure 1. Effect of parity on litter size, piglets born alive and those born dead.

artificial insemination imply that the technology can continue to impact the pig industry. Despite Chanapiwat et al. (2014) reporting that the main limitation of the extended fresh semen is the short timing of semen storage, and the likelihood that semen cannot be transported for a long distance, results of this study that used semen transported from Northern Europe shows that this is not an issue. Instead, the chance of distributing a good genetic resource across countries and particularly, enabling locally raised sows to be bred with semen having the best estimated breeding values available in Europe is very real. Use of AI for breeding pigs has become instrumental for facilitating global improvements in fertility, genetics, labour, and herd health (Bortolozzo et al., 2015; Knox, 2016).

The differences in number of piglets born live between boars of the two breed types in this study were not significant (Table 1), instead, it is the value for Pietrain boars that stood out over the other categories. The establishment of AI centers for management of boars and production of semen has allowed for selection of boars for fertility and sperm production using *in vitro* and *in vivo* measures (Ringwelski et al., 2013; Knox, 2016).

Parity of the sow did not influence the number of piglets born alive (Table 1), but it did significantly influence the total litter size. Second parity sows have been reported to produce an average litter size of 8.36±0.28 when artificially inseminated, and 10.6±0.64 when naturally served by the boar (Ronald et al., 2013). While that study found the differences between the two methods were significant, this study found contrary results. Though the superiority of natural mating in both studies is vivid and indeed, this study found a higher litter size (12.47) than that of the Indian study, which was also done at a private farm. Low parity females especially pregnant gilts and primiparous sows have also been reported elsewhere to have lower reproductive performance than sows in parities between second and fifth parity (Koketsu et al., 2017). Sow fertility is also closely associated with varying doses of semen volume and spermatozoa count for AI (Apic et al., 2015).

While stillbirths were found in both artificially and naturally inseminated sows, other studies (Ronald et al., 2013) reported still births only in naturally inseminated sows. The variance between the two studies could be attributed to the parity factor, since the study had mixed parities, with older sows having high stillbirths and the values must have been responsible for swaying the overall mean.

Other contemporary studies also strongly support the position that number of piglets born and the number of live born piglets are highest in 2 to 3 parity sows and drop significantly in sows of more than five parities (Wegner et al., 2014). While the number of still born piglets was lowest in second parity sows (0.5), Wegner et al. (2014) found the lowest (0.8) in first parity sows, and the highest (1.44) in sows of more than five parities, slightly higher than 1.17 that was found in the current study.

Conception failures in pigs have been known to result from effects of the season, mode of insemination, age of the sow, and the number of times the female is inseminated, and the females' birth litter sex ratio (Drickamer et al., 1997; Wegner et al., 2014), this study differs having found that the mode of insemination and number of times the female is inseminated did not have significant effects.

Conclusion

Litter size of weaned sows bred by natural service or AI was the same. In addition AI has the significant advantage of enabling locally raised sows in Rwanda to be bred with semen having the best estimated breeding values available in Europe, from Belgium. AI relying on imported semen should be promoted especially for introduction of superior genetics for which grade boars may not be manageable in tropical Africa.

ACKNOWLEDGEMENTS

The comments of the reviewers are strongly appreciated as they have contributed to improvements to the manuscript.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests.

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Vol. 9(6), pp. 108-111, June 2018
DOI: 10.5897/IJLP2015.0280
Article Number: F8375D456973
ISSN 2141-2448

http://www.academicjournals.org/IJLP

International Journal of Livestock Production

Full Length Research Paper

Relationships between sperm morphology and semen cation concentrations in red sokoto goats (*Capra aegagrus hircus*)

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Received 12 November, 2015; Accepted 4 February 2016

The study evaluated the relationships between sperm morphology and semen cation concentrations in Red Sokoto bucks. A total of 31 Red Sokoto bucks were used for the study. Semen samples were collected from each animal on weekly basis for 52 weeks using an electro-ejaculator. Sperm morphological traits: detached mid-piece and tail (DMT), detached head (DH), mid-piece droplet (MPD), coiled and bent tail (CBT), and acrosomal abnormality (ACR) as well as semen cation parameters: sodium ion (Na^+), potassium ion (K^+) and calcium ion (Ca^{2+}) were respectively determined. Correlation analysis procedure (Pearson correlation) of SAS was used to assess the relationship between the measured characteristics. The results showed that correlations among the sperm morphological characteristics were generally low and not significant except the correlation between DH and DMT which was perfect ($P < 0.01$; $r = 1.0$). Semen cations correlated positively but non-significantly among themselves except the correlation between Na^+ and K^+ ($P < 0.05$; $r = 0.3$) which was significant. Relationship between semen cations and sperm morphological traits were generally negative and significant ($P < 0.05$; $r = -0.28$ to -0.40) except ACR which was positively and significantly correlated with Ca^{2+} ($P < 0.01$; $r = 0.37$). The study revealed that DH is highly associated with the DMT, while Na^+ concentration was an indicator of K^+ level in the semen, as positive and significant relationtions were observed between each pair. The negative and significant relationship between sperm morphological traits and semen cations, as observed in the present study suggest that the level of morphological defects of spermatozoa can be determined based on information on semen cations of the bucks.

Key words: Red Sokoto goats, sperm morphology, semen cations.

INTRODUCTION

The main criterion for keeping a buck at an insemination station is the production of buck ejaculates containing a high quantity of spermatozoa with high fertilization ability.

The optimal production of semen of high biological value is influenced by numerous factors, including: breed (Kondracki et al., 2007; Smital et al., 2004), season of the

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year (Ciereszko et al., 2000; Wysokinska et al., 2005), age of the animal, and frequency of sperm collection (Deka et al., 2002). Examination of sperm morphology and determination of number of spermatozoa with morphological defects play a significant role in semen quality assessment, thus enabling the elimination of males with potentially low fertility prior to the preservation of their semen (Rodriguez-Martinez and Barth, 2006). Among the reproductive traits, quality semen plays a major role in determining the fertility and reproductive efficiency of any livestock production.

Abnormalities of the spermatozoa occur due to disorder of the seminiferous tubules, during ejaculation or in manipulation of the ejaculate including excessive agitation, over-heating to rapid cooling, mixture of water, urine or antiseptic in the semen (Hossain et al., 1990). The sperm head plays a significant role in the fertilization process. Experiments have revealed that the presence of 10% or more of any single type of head, mid-piece and tail defects and 20% or more of total abnormalities of spermatozoa is often coupled with reduced fertility in ruminant (Hancock, 1956). Semen volume, sperm motility, and sperm concentration have been reported to be negatively correlated with abnormal spermatozoa in Red Sokoto goats (Ambali et al., 2013). Reddy et al. (1975) also reported significant negative correlation between abnormal spermatozoa and conception rate.

Cation concentrations in the seminal plasma provide the congenial milieu for the survival of sperms (Kalita et al., 2006). The concentrations of different ions in seminal plasma also reflect the quality of semen and physiological status of reproductive accessory gland (Kalita et al., 2006). A large number of reports on the biochemical composition of cattle semen have been published (Rattan, 1990). But there is scarcity of parallel information about the semen of the Red Sokoto bucks maintained in the northern part of Nigeria. The objective of the study was therefore to determine the relationships between sperm morphology and semen cation concentrations in Red Sokoto bucks.

MATERIALS AND METHODS

Study location

The study was conducted at the Experimental and Research Farm of the Department of Animal Science, Faculty of Agriculture, Ahmadu Bello University, Zaria, Nigeria. The area is situated at latitude 11° 09' 06' N and longitude 7° 38' 55' E, at an altitude of 706 m above sea level. It falls within the Northern-Guinea Savannah Zone with marked period of rainfall ranging from 1102 to 1904 mm. The mean maximum temperature varies from 26 to 35°C depending on the season. Detailed description of Zaria was given elsewhere by Akpa et al. (2002).

Experimental animals and their management

A total of thirty-one Red Sokoto bucks were used for the study. The animals are among the research animals owned and managed by Department of Animal Science, Ahmadu Bello University, Zaria. The bucks were reared under semi-intensive system. Supplemental feed (concentrates) was provided. Animals were subjected to dipping against ectoparasite as well as anti-helminthic drenching (deworming) and vaccination againt endemic diseases. Fresh drinking water was provided *ad libitum*. The experiment commenced when the bucks were 9 to 12 months of age and ended when they were 21 to 24 months.

Data collection

Semen collection and evaluation

Semen samples were collected from each animal on weekly basis for 52 weeks using an electro-ejaculator and were labeled accordingly. This was done in the morning hours throughout the duration of the experiment. Smear of each semen sample was prepared, air dried, labeled and kept for the determination of sperm morphology. A total of 1488 records were generated for each of the observed characteristics. Determination of sperm morphology and semen cations is given subsequently.

Sperm morphology

A smear of individual semen sample was prepared using eosin-nigrosin stain immediately after collection using the following procedures. A small drop of semen is placed on the edge of a clean slide and a ribbon of eosin-nigrosin stain is placed slightly closer to it. The corner of a second slide is dipped into the semen drop, and the resultant “hanging drop” of semen is mixed with the ribbon of stain. The second slide is then pulled across the first slide in a manner similar to the one used in creating a blood smear. The slide was dried, labeled and examined at 1000x with an oil-immersion lens. Fifty spermatozoa were examined from each sample. The total number of abnormal spermatozoa was counted and recorded. Types of abnormality observed were: detached mid-piece and tail, detached head, mid-piece droplet, coiled and bent tail, and acrosomal abnormality (acrosome membrane detached, acrosome outlines and acrosome cap defect). Acrosomal abnormalities were determined by using smears made from the raw semen and stained by Giemsa stain according to Watson (1975).

Semen cations

Cation analysis was performed at the chemical pathology laboratory in Pathological Department of Ahmadu Bello University Teaching Hospital, Shika, Zaria, with a Coleman 21 Flame Photometer. This instrument is calibrated with five standard stock solutions for concentration of ions as described by Cragle et al. (1958). The semen samples were centrifuged for separation of seminal plasma. Seminal plasma was then processed and different cations: Ca^{2+}, Na^{+} and K^{+} were estimated.

Statistical analysis

Correlation analysis procedure (Pearson correlation) of SAS (2002) was used to assess the relationship between the measured characteristics. The weekly data (1488 records) on sperm morphology and semen cation concentrations were used for estimating their relationships.

Table 1. Correlation coefficients (r) among sperm morphological traits in Red Sokoto bucks.

Correlation	MPD	DH	CBT	ACR
DMT	0.02	1.0**	-0.12	0.12
MPD	-	0.02	-0.05	0.03
DH	-	-	-0.12	0.12
CBT	-	-	-	-0.03

**P<0.01, MPD: Midpiece droplet; DMT: detached midpiece and tail; DH: detarched head; CBT: coiled and bent tail; ACR: acrosomal abnormality.

Table 2. Correlation coefficients (r) among semen cations in Red Sokoto bucks.

Correlation	Potassium ion	Calcium ion
Sodium ion	0.3*	0.23
Potassium ion	-	0.04

*P<0.05.

Table 3. Correlation coefficients (r) between sperm morphology and semen cations in Red Sokoto bucks.

Correlation	DMT	MPD	DH	CBT	ACR
Sodium ion	0.02	-0.28*	0.02	0.04	-0.01
Potassium ion	-0.40*	-0.38*	-0.40*	-0.36*	-0.31*
Calcium ion	-0.03	-0.30*	-0.31*	0.02	0.37*

*P<0.05, MPD: Midpiece droplet; DMT: detached midpiece and tail; DH: detarched head; CBT: coiled and bent tail; ACR: acrosomal abnormality.

RESULTS AND DISCUSSION

The result of the correlation analysis between semen morphological characteristics is presented in Table 1. The correlations amongst the semen morphological characteristics were generally low and not significant, except the correlation between DH and DMT which indicated perfect correlation (P<0.01; r =1.00). This signified that all the abnormal spermatozoa showing DMT also showed DH, thus increase or decrease in the number of DMT spermatozoa will lead to direct correlated response in the number of DH spermatozoa. This is consistent with Akpa et al. (2012) who also reported perfect correlation (r = 1.0) in Yankasa rams and Cevik et al. (2007) who reported r = 0.45 in bull, though lower but highly significant as the present study.

The result of the correlation analysis between semen cation concentrations is presented in Table 2. The correlation amongst the semen cations were generally positive but non-significant except the correlation between Na^+ and K^+ (r = 0.3; P<0.05) which was significant. The moderate, positive and significant correlation between Na^+ and K^+ confirmed the responsibility of the two ions in maintaining osmolarity and metabolic activities of the spermatozoa. This finding agrees with Akpa et al. (2012) who reported r = 0.37 in Yankasa rams and Quinn et al. (1965) who reported r=0.51 in rams, respectively. Nath (1988) also reported a positive and significant correlation between Na^+ and K^+ content in buffalo semen.

Table 3 shows the correlated relationship between sperm morphology and semen cation concentrations in Red Sokoto bucks. The results showed that the sperm morphological traits were negatively and significantly correlated with semen cations (P < 0.05; r = -0.28 to -0.40) except ACR which was positively and significantly correlated with Ca^{2+} (P < 0.05; r = 0.37). The positive correlation between Ca^{2+} and ACR signifies that an increase in the seminal concentration of Ca^{2+} will lead to corresponding increase in occurrence of acrosome defect in spermatozoa, thus stressing the role of Ca^{2+} in semen quality. Meseguer et al. (2004) have reported that Ca^{2+} concentrations in seminal plasma are good predictors of post-thaw semen quality. However, it has been reported that Ca^{2+} at all concentrations in the semen of rams is somewhat deleterious (Blackshaw, 1953).

Potassium ion was found to be negatively and significantly correlated with all the sperm morphological traits (P < 0.05; r = -0.31 to -0.40). This indicates that an increase in potassium ion in the seminal fluid will lead to a corresponding decrease in the occurrence of sperm defect in the bucks. This is contrary to the report that K^+ is a natural metabolic inhibitor and that higher K^+ concentration in seminal plasma decreases sperm metabolism, thereby, decreasing sperm motility and contributing to sperm defects (Massányi et al., 2003). Zamiri and Khodaei, (2005) showed that low levels of Na^+ and K^+ ions were associated with high percentage of motile sperm. However, (Akpa et al., 2013) reported positive and significant correlation between seminal potassium ion and sperm motility in Red Sokoto goats.

Conclusions

The study revealed that DH is highly associated with the DMT, while Na^+ concentration was an indicator of K^+ level in the semen as positive and significant relationtions were recorded between each pair. The negative and significant relationship between sperm morphological traits and semen cations, as observed in the present study suggest that the level of morphological defects of spermatozoa can be determined based on information on concentration of semen cations of the bucks.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Vol. 9(6), pp. 112-130, June 2018
DOI: 10.5897/IJLP2018.0454
Article Number: 295014756975
ISSN 2141-2448

http://www.academicjournals.org/IJLP

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International Journal of Livestock Production

Full Length Research Paper

Feed resources assessment, laboratory evaluation of chemical composition of feeds and livestock feed balance in *enset (Ensete ventricosum)*-based mixed production systems of Gurage zone, southern Ethiopia

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Received 26 January, 2018; Accepted 4 April, 2018

The study was conducted in four districts of Gurage zone, Sothern Nations Nationalities and People's Region to determine the quantity and quality of available feed resources and to measure the livestock feed balance. A total of 360 households from *dega* (highland) and *weinadega* (midaltitude) peasant associations were selected using proportional sample size determination (Cochran, 1909; Thrustfield, 2013). The DM produced from leaf and leaf midribs of *enset* (*Ensete ventricosum*), crop reissues and natural grasses in tons, respectively, were 506.4 (52.73%), 312.33 (32.52%) and 141.62 (14.75%) in *dega* and 662.96 (49.36%), 472.83 (35.2%) and 207.33 (15.44%) in *weinadega.* The DCP produced from *enset* leaf and leaf midribs, crop residues and natural pasture, respectively, were 51819.91 kg, 8401.16 kg and 10335.43 kg in *dega,* 55217.94 kg, 13799.32 kg and 11490.23 kg in *weinadega.* The ME produced in *dega* was 4420872, 2296269.8 and 1188191.8 MJ whereas it was 6013047.2, 3430459.7 and 1689739.5 MJ in *weinadega* from *enset* parts, crop residues and natural pasture, respectively. The amount of DM, DCP and ME produced by individual household per year in *weinadega* agroecology were significantly higher (p<0.05) than the amount produced in *dega* agroecology. The annual feed supply in the study areas met only (76.81%) DM and (69.9%) DCP of the maintenance requirement of livestock in TLU but available ME was (1.67%) surplus. Conversely, the annual feed supply met only (64.98%) DM, (66.24%) DCP and (85.66%) ME of the maintenance requirement of livestock at *dega* agroecology, whereas in *weinadega,* agroecology about 88.31% DM and 73.46% DCP of the maintenance requirement were met but the estimate of ME was 17.22% above the requirement. This indicates that the livestock in the study areas of Gurage zone are in serious feed deficit which needs a special attention in supplementing the livestock with concentrates of protein sources for both agroecologies and energy for *dega* agroecology to overcome deficiency, especially during dry periods for reasonable livestock production.

Key words: Chemical composition, *Dega*, feed balance, feed resource, Gurage zone, Weinadega.

INTRODUCTION

Throughout their long history, Ethiopians have constantly relied on livestock in order to survive. Livestock in Ethiopia are extremely important as they serve a wide variety of functions in society from social to subsistence purposes (Kimball, 2011; Dereje et al., 2014). Despite relatively low notice they are afforded, livestock are estimated to contribute to the livelihoods of 60 - 70% of the Ethiopian population (Halderman, 2004). As the oldest form of assets in Ethiopia, livestock have and still today serve as a significant indicator of wealth. An estimate indicates that the country is home to about 54 million cattle, 25.5 million sheep, 24.06 million goats, 1.8 million horses, 5.4 million donkeys, 335 thousand mules, 760 thousand camels and 38.1 million poultry (Tilahun and Schmidt, 2012; CSA, 2013a).

Livestock provides a significant nutritional supplement to vulnerable groups, increase the flexibility of smallholder households in the face of food crises, and help to maintain traditional social safety nets (Randolph et al*.,* 2007; Dereje et al., 2014). The agricultural sector contributes 52% to the gross domestic product (GDP) and 90% to the foreign exchange earnings (CSA, 2008). The livestock subsector contributes about 16.5% of the GDP and 36% of the agricultural GDP and the subsector currently support and sustain livelihoods for 80% of all rural population (Metaferia et al., 2011). It also contributes 15% of export earnings and 30% of agricultural employment (Behnke, 2010). Despite high livestock population and existing favorable environmental conditions, the current livestock contribution is below its potential due to various reasons associated with a number of complex and inter-related factors such as feed shortage and disease (Berhanu et al*.,* 2009; Selamawit et al., 2017), less efforts in introducing the appropriate package of improved livestock technologies of cross breeding, improved feed management practices and adequate healthcare services which enhance the current livestock production and productivity (Getahun, 2012) and inadequate feed, water scarcity, poor health management, low productivity of local breeding stock (Dawit et al., 2013).

Based on degree of integration of livestock with crop production, level of input and intensity of production and agroecology, livestock production systems in Ethiopia has been classified into four major production systems of smallholder crop-livestock mixed system, pastoral and agro- pastoral, urban and peri-urban, and intensive dairy farming (Azage and Alemu, 1998). The mixed-farming system occupies the central part of Ethiopia and cover about 40% of the country's land area and 90% of the human population. In this farming system, the entire feed requirement for livestock is derived from native pasture and the balance comes from crop residues and stubble grazing (Tolera, 2009; Funte et al., 2010; Dereje et al., 2014; Selamawit et al., 2017).

Agricultural production systems in Ethiopia are predominantly subsistence smallholder mixed farming, with crop and livestock husbandry typically practiced within the same management unit and the Gurage zone is part and parcel of this system of production where *enset* and livestock have highly been integrated. The integral production components of this *enset*-livestock based production system of the study areas of Gurage zone is milk and manure production followed by meat, draught power and cash income. Though the number of livestock in Gurage area are enormous, shortage of feeds, especially during dry season become a major constraint and affects productivity of livestock. In this study area livestock production constraints and farmers' needs have not yet been fully studied. Improvement in livestock productivity can be achieved through identification of production constraints and introduction of technologies which have capability of improving the existed production bottlenecks and compatible with the system of production.

Therefore, it is important to assess the quantity and quality of the available feed resources in relation to the requirements of livestock on annual basis in a given area. Hence, this study was conducted in *dega* and *weinadega* agroecologies of Gurage zone with the following specific objectives:

1) To identify available livestock feed resources and determine chemical compositions of the major feeds in the study area, and
2) To assess livestock feed balance in the study area.

MATERIALS AND METHODS

Description of the study area

The study area, Gurage zone, is found in the Southern Nations, Nationalities and Peoples' Region (SNNPR) of Ethiopia. It is located between 37° 28' and 38° 38' longitude and 7° 28' and 8° 27' latitude, covering an area of about 5,932 km^2. Based on the data from Gurage zone Department of Finance and Economy Development (DOFED), the zone has thirteen administrative *woreda (*districts) with 412 peasant associations (PAs) and two town administrations. The zone bounds with Oromiya regional state in the north, northeast and northwest, Silti zone in the south east, Hadiya zone in the south, and Yem special woreda in west directions. Wolkite, the capital of the zone, is 155 km away from Addis Ababa in the Addis-Jimma road (DOFED, 2015).

Human population size of the zone is estimated to be 1,624,125(51.4% women and 48.6%, being men) and 88.2% of the population are farmer entirely dependent on subsistent agriculture (CSA, 2013b; DOFED, 2015). Gurage zone is one of the most densely populated areas in the country, with an average of 273.5 people/km^2 mainly concentrated in the agroecology of *dega* (highland) and *weinadega* (midaltitude). *Wirch* (cold) ((4.1%), *dega*

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(27.5%), *weinadega* (65.3%) and *Kola* (hot) (3.1%) are four agroecological zones of the area. Annual rainfall ranges between 801 and 1400 mm (DOFED, 2015). Based on data from the Department of Agriculture and Natural Resource Development of Gurage zone (DANRD), three different zonations with distinct farming systems are identified: First, localities with an altitude above 2200 masl and growing mainly *Enset (Ensete ventricosum*), Barely (Hordeum vulgare), Field pea (*Pisum sativum*) and Fababean (*Phaseolus vulgaris*). Second, altitudinal range between 1800 and 2200 masl and growing major crops of *Enset (E. ventricosum*), *Teff* (*Eragrostis teff*), Maize (*Zea mays*) and Khat *(Catha edulis)*. Third, altitudinal range between 1600 to 1800 masl and growing major crops of *Teff* (*E. teff*) and Maize (*Zea mays*) (DANRD, 2016).

The average annual temperature of the zone is about 18°C. The current land use pattern of the zone, is 398,887 ha of land for crop production, 92,421 ha for grazing, 42,933 ha for forest, 17,168 ha degraded land and 41,791 ha of land for other social services giving institutions. A livestock population of 3,611,159 is found in the zone, of which 1,678,455 cattle, 616,900 sheep, 260,420 goats, 820,269 chickens, 128,532 horses, 9,464 mules and 97,119 donkeys (DOFED, 2015).

Sampling and sample size determination

Information on nature of peasant associations (PAs) in relation to livestock population and other agricultural practices, particularly *enset* (*E. ventricosum*) production was obtained from zonal and each of four selected *woreda* (districts) offices of livestock and fishery resource development and agriculture and natural resource development. PAs were identified after having *enset* and livestock population data at each PA and a total of eight (8) PAs, (2) PAs from each *woreda* (one *dega* and one *weinadega*) were purposively selected based on the number of livestock, enset production and accessibility.

The sample size of households (HHs) were determined using Cochran (1909) and Thrustfield (2013) sample size determination formula: $n = Z^2*P(1-p)/e^2$; n adjusted = n/ [1+ ((n-1) /N)]; where: n = sample size in the population, Z-score = 1.96 for confidence level 95%, N = total HHs in the 4 study *woreda*, P = proportion of population score of 1= 0.5, 1-p = 0.5 and e = standard error of the proportion = α = 0.05. A total of three hundred and sixty (360) HHs from eight PAs (45 HHs from each PA) were selected for the study. The selected PAs of *dega* and *weinadega* from each *woreda* for the study, respectively, were *Shamene* and *Shehrem*o from *Ezia woreda*; *Achene* and *Wukiye* from *Muhir* and *Aklil woreda*; *Moche* and *Yeferezy*e from *Cheha woreda* as well as *Agata* and *Kochira* from *Enemor* and *Aner woreda*.

To design the questionnaire used in the study, information was gathered from a total of purposively selected 40 HHs (5 from each PA) through rapid field survey and consultations with experts, DAs from respective zonal and woreda offices. It was summarized and used as a basis to design structured questionnaires to quantify the most important information to the study. The survey questionnaires were also pre-tested with two HHs from each PA and the necessary adjustment was made and translated into local language (Amharic) prior to actual survey based on the pre-test. One-day training was organized for enumerators on how to administer the questionnaire. Interview was done by the researcher together with the enumerators and DAs from HHs of target peasant associations. The interviews was done at the farmer's home to make possible counterchecking of the respondent's response with respect to the types of feed resources, livestock feeding system, number of livestock population, types of species owned, types of annual crop produced, *enset* production and *enset* uses, interaction of livestock-*enset* production, land holding and the overall farming management system of the HH.

Data types and methods of data collection

Primary and secondary data sources were collected from all PAs selected for the study. Secondary sources including: climate, soil, topography, agro-ecology, human population, livestock population, *enset* production and its use, crop production and associated problems were collected from respective zonal and *woreda* offices of livestock and fishery resource development as well as agriculture and natural resource development and through review of different documents. Primary data such as family size, land holding, land use pattern, major livestock feed resources, grain and crop residues produced, seasonal feed resources, herd size and herd structure of HH were generated by field visits, interviews and group discussions. Feed samples taken for laboratory analysis were those feeds used by the HHs of study areas to feed their animals that include: leaf and leaf midribs of *enset* plant, natural grasses, and straws and stubbles of wheat, barley, *teff*, field pea, faba bean as well as stover of maize.

The feed quantity and potentially available crop residues was assessed from December 2016 to March 2017 when almost 100% of annual crops had fully been harvested. Group discussions comprising elder farmers, experts of livestock and crop agriculture and development agent (DA) were made at each *woreda* (district) zonal level to clarify issues not well addressed thought survey and to validate some information collected from individual interview. A total of 32 individuals, 6 (2 farmers, 2 experts and 2DAs) from each *woreda* as well as 8 experts at zonal offices (6 from livestock and 2 from crop agriculture) were participated in the group discussion. The discussion focused on identifying constraints related to feed, livestock and *enset* production.

Feed quantity estimation

The quantity of potentially available DM from leaf and leaf midribs of *enset* (*E. ventricosum*) used for animal consumption was estimated by considering a mean of 8 (eight) tons per year per hectare of enset growing land as reported by Bureau of Agriculture and Rural Development (BoARD, 2009) of SNNPR. The quantity of DM feed obtainable from natural grasses were determined by multiplying the hectare under each land use category by their respective estimated annual DM yield per hectare, that is, 2.0 t/ha (FAO, 1984, 1987). The quantity of available DM from crop residues produced by HHs was estimated by conversion of grain yields to straw ratio using multipliers of 1.5 for wheat, barley and *teff* straws; a multiplier of 1.2 for DM yield of field pea and faba bean straw as suggested by FAO (1987). A multiplier of 2.0 was employed for estimation of DM output from maize stover, as proposed by *De* Leeuw and Tothill (1990). The quantity of crop residues potentially available for animal consumption was estimated by assuming 10% wastage either during utilization or used for other purposes or both (Adugna and Said, 1994). The amount of crops grain yield was quantified by interviewing the HHs and cross checked it with the data recorded by DAs and the respective offices of agriculture and natural resource development for any deviation. The grazing potential of crop stubbles was estimated using a mean of 0.5 ton per hectare of land as reported by FAO (1987).

To determine the potential forage biomass yield and DM production, representative samples of grasses was taken from an enclosure of individual HH holdings of the studied PAs by making transect lines and grasses species was identified together with herders and range experts (Ahmed, 2006). Samples were taken from mid of August, 2017 to mid of September, 2017 when almost all the pasture plants were fully grown to their 50% flowering. From randomly selected HHs, a sample size of 80 quadrants (1 m × 1 m) was considered per agroecological zone (5 HHs per PA and 4 samples per HH). In each quadrant, harvesting was done at the ground level.

Table 1. Characteristics of the households in the study areas of Gurage zone.

Agroecological zones	Household variables (%)		
	Male	Female	Overall
Dega (n=180)	92.8	7.2	100
Weinadega (n=180)	74.4	25.6	100
Total (N = 360)	83.6	16.4	100

Dega = highland, *Weina Dega* = mid altitude, n = sample HHs per agroecology, N = total sample HHs of the study.

To undertake chemical analysis, a composite sample was taken from the bulk.

Assessment of livestock feed requirement

The total annual available feed was compared with the annual requirements of the livestock population. Livestock populations were converted into Tropical Livestock Unit (TLU) as suggested by Gryseels (1988) and Bekele (1991). Nutrients supplied by each feed types was estimated from the total DM output and nutrient contents of that feed on DM basis (Abdinasir, 2000). The total nutrient requirements of crude protein (CP) and metabolizable energy (ME)) per day per TLU were estimated based on the recommendations of Kearl (1982) and McCarthy (1986) for one tropical livestock unit.

Chemical analysis of sample feeds

Representative samples of feed resources of leaf and leaf midribs of *enset (E. ventricosum)*, crop residues (stover, straws and stubbles) and natural grasses from *dega* and *weinadega* agroecological zones were collected, bulked, dried, sub-sampled and ground to pass through 1 mm mesh sieve and packed in an airtight clean plastic bag and stored until required for determination of (DM), ash, organic matter (OM), nitrogen (N), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) and *in vitro* dry matter digestibility (IVDMD). The DM content of feed samples was determined by an oven at 60°C for 72 h until constant weight before chemical analysis. Sub samples from partially dried sample feeds were taken and ignited in a muffle furnace at 550°C for 6 h to determine the ash and OM contents of each feed following the methods described by AOAC (1990).

Chemical analysis of each feed for Ca and P were performed at Wolkite Regional Soil Analysis Laboratory by atomic absorption spectrophotometer following the methods described by Perkin (1982). Determination of (IVDMD) from feed samples was performed at Holetta Agricultural Research Center's Animal Nutrition Laboratory following the modified Tilley and Terry method (Van Soest and Robertson, 1985).A chemical analysis on (ADF), (ADL) and, (NDF) in the sample feeds were performed at Animal Nutrition Laboratory of College of Agriculture and Veterinary Medicine of Jimma University, following the procedures of Goering and Van Soest (1970). Similarly, (N) content of feed samples was determined at Animal Nutrition Laboratory of College of Agriculture and Veterinary Medicine of Jimma University using Kjeldahl method and crude protein (CP) was calculated as N × 6.25 (AOAC, 1995).

Metabolizable energy (ME) and digestible crude protein (DCP) content of a particular feed was estimated from (IVDMD) and (CP) contents, respectively, as per the following equations:

A. ME (MJ/kg DM) = 0.015*IVDMD (g/kg) (MAFF, 1984)

B. DCP (g) = 0.929*CP (g/kg) -3.48 (Church and Pond, 1982)

Data analysis

The collected data were analyzed in such a way that they meet research objectives and answer research questions. Statistical package for social sciences (SPSS, version 20) was used for the analysis of collected data after checking, correcting and coding. Descriptive statistics such as table, figures or charts, percentage, mean, and standard error was used to present the results.

RESULTS AND DISCUSION

Characteristics of household

In the study area of *dega,,* agroecology male HHs accounted for 92.8% whereas female HHs accounted for 7.2%. In the *weinadega* agroecology, however, 74.4% HHs were male and the remaining 25.6% were female headed (Table 1). Overall, average of male headed HHs (83.6%) in current study is higher than the result (67%) made by Azage (2004) in Addis Ababa, 52.3% for Hawassa town was reported by Haile et al. (2012) as well as (75.9%) in Jimma town reported by Belay and Janssens (2016). The observed difference in the percentage of female headed HHs among *weinadega* and *dega* rural areas in particular and in the study areas of Gurage zone in general (Table 1), respectively, could probably be attributed to the greater rate of evacuation of males from *weinadega* to the different cities and towns of the country in search of job opportunity leaving the rural HH occupation to their wives and cultural issues might force females to get married and/or push aside the females from being having power of bargaining on economic motives (Group Discussion).

As indicated in the Table 2, about 65% of the farmers in *dega* areas have got better opportunity of education when compared to those 57.3% HHs found in *weinadega areas*. The overall mean of 61.1% observed in the current study for educated HHs is lower than the result 98.1% reported by Belay and Janssens (2016) in Jimma town. The differences observed in level of education between the study areas of Gurage zone as well as between Gurage zone and that of Jimma area could be attributed to difference in access to schools. Group discussion with experts with different fields of studies in agriculture was made whether or not education has importance for HHs on performing different agricultural activities. All group members of discussion agreed on the advantages of education to improve production and productivity of HHs through utilizing different technologies of production.

In most cases, literate HHs are supposed to be very eager to accept extension services and other income generating activities which enable them to enhance their productivity and production level. Ekwe and Nwachukwu

Table 2. Level of education of households in the study areas of Gurage zone.

Agroecological zones	Level of education of household head (%)				
	Illiterate	Grade 1-6	Grade 7-8	Grade9-10	Grade ≥ 11
Dega (n=180)	35.0	57.2	3.3	3.9	(0.6)
Weinadega (n=180)	42.7	42.8	6.7	7.8	0.0
Over all (N = 360)	38.9	50.0	5.0	5.8	0.3

Dega = highland, *Weinadega* = mid altitude, n = number of sample HHs per agroecology, N = total sample HHs of the study.

Table 3. Mean (±SE) family size of HHs in sex and age group in the study areas of Gurage zone.

Agroecological zones	Age of HHs	Family size of HHs in sex and age group				
		Total	Male	Female	Age between 15 and 65	Age ≤14 and ≥65
Dega	49.44±0.7	7.34±0.25[b]	3.64±0.13[b]	3.63±0.13[b]	5.66±0.18	1.68±0.1[b]
Weinadega	48.44±0.6	8.09±0.25[a]	4.02±0.14[a]	4.07±0.14[a]	6.03±0.18	2.04±0.11[a]
Total	48.94±0.5	7.71±0.18	3.83±0.1	3.85±0.13	5.85±0.13	1.86±0.07

[a-b] Means in the same column sharing different letters of superscripts are significantly different (P<0.05), *Dega* = highland, *Weinadega* = mid altitude, HHs = households

Table 4. Households keeping local and cross cattle breed in the study areas of Gurage zone.

Agroecological zones	Types of cattle breeds owned by households (%)	
	Local cattle only	Both local and cross cattle
Dega(n = 180)	85.0	15.0
Weinadega(n = 180)	88.3	11.7
Overall (N= 360)	86.7	13.3

Dega = highland, *Weinadega* = midaltitude, n = sample HH per agroecology, N = total sample HHs of the study.

(2006) reported that farmers with educated background adopt usually new technologies more rapidly and easily than uneducated farmers to ensure good results. Similarly, Mulugeta (2005) indicated that HHs with low level of education can have an influence on the transfer of agricultural technologies and their participation in development which is in line with the result of current study.

The average family size per HH across the agroecologies of *dega* and *weinadega* was 7.71 (Table 3). The family size in the *weinadega* agroecology was significantly higher (P<0.05) than the *dega* areas. The average size of the family members in the study area is lower than the average family size of 9.92 reported from Adami Tullu Jiddo Kombolcha district of east Showa zone of Oromiya region by Dawit et al. (2013). However, it is higher than the average family size of 6.2 reported from highland and midaltitude of Basona worana woreda of north Shoa (Ahmed, 2006); 7.05 reported from Aleta Chukko *woreda* of Sidama zone in southern Ethiopia by Beriso et al. (2015); 6.02 reported from Jimma area by Belay and Janssens (2016) and 6.6 reported from north Achefer district in Amhara region by Selamawit et al. (2017). The large family size in the study areas of Gurage zone could probably be related to the agricultural activities (*enset*) which are relatively labor intensive.

About 15 and 11.7% of the HHs in the *dega* and *weinadega* agroecology, respectively, possessed some crossbred cattle along with their indigenous cattle and most of these crossbred animals are of calves of 1 - 2 years and heifers of younger age majority of which are obtained by purchase from neighboring zones and region. Conversely, 85% of farmers in *dega* and 88.3% in *weinadega* agroecology kept indigenous cattle breeds only (Table 4). Though the level of products obtained from indigenous cattle are low, the nature of cattle association with production of *enset* (*E. ventricosum*) and to overcome risks and calamities of nature, HHs of the study areas urged to keep these low productive indigenous cattle breeds. Major bottlenecks and uncertainties which forced HHs to manage indigenous cattle were lack of advantages of AI services and opportunities of getting appropriate technologies to improve livestock productivity which corresponds with

Table 5. Mean (±SE) landholdings and land use pattern in both agroecology of Gurage zone.

Land allocation for different activities in hectare	Agroecological zones		
	Dega **(n =180)**	***Weinadega*** **(n =180)**	**Overall (N= 360)**
Land holding per HH	1.44±0.04^{b}	2.08±0.09^{a}	1.75±0.05
Annual crops	0.58±0.02^{b}	0.71±0.04^{a}	0.64±0.02
Khat, coffee and fruits	--	0.20±0.01	0.10±0.01
Enset	0.29±0.01^{b}	0.46±0.02^{a}	0.37±0.01
Grazing	0.35±0.02^{b}	0.51±0.03^{a}	0.43±0.02
Forest	0.12±0.01^{b}	0.20±0.01^{a}	0.16±0.01
Potato and vegetables	0.10±0.01	--	0.05±0.00

$^{a-b}$ means in the same row with different letter of superscripts are significantly different (P<0.05), n = number of respondents, *Dega* = highland, *Weinadega* = mid altitude, -- = not available.

Minale and Yilkal (2015), who reported that the owner of the cattle in southern Ethiopia at Chencha and Kucha districts had a problem of getting AI services through which they can upgrade the genetic makeup of their low producing dairy animals.

Average landholdings and land use pattern

Households of Gurage zone included in this study are engaged in a mixed crop-livestock production systems and have possessed their own land which is used for different activities of livestock and crop agriculture. Out of the total land holdings of HHs in the *weinadega* agroecology, 0.71, 0.46, 0.51, 0.20 and 0.20 ha were allocated for the production of cereal crop, *enset* (*E. ventricosum*), grazing, forest and perennial crops of *Khat*, coffee and fruits, respectively. Similarly, the allocation of land by HHs in the *dega* agroecology was 0.58, 0.29, 0.35, 0.12 and 0.10 ha for cereal crop, *enset*, grazing, forest and potato and vegetables production (Table 5). Of the total land holdings owned by HHs across the study areas the average of land allocated for *enset (E. ventricosum)* production was 0.37 ha.

The average land holding per HH in *weinadega* agroecology was 2.08 and 1.44 ha for *dega* agroecology. The overall average land holding, average land holding for *enset* production and grazing per HH per agroecology was significantly higher (P<0.05) for *weinadega* than the *dega* agroecology of the study area. The overall average land holding per household across the agroecologies of study areas was 1.75 ha (Table 5) which is more comparable with the result of 2.18 ha reported by Selamawit et al. (2017) from north *Achefer* district in Amhara region but is much lower than the value of 3.3 ha reported by Yitaye et al*.* (2007) in the highland areas of *Amhara* region; 2.5 ha by Yeshitila (2008) in southern Ethiopia at *Alaba* district; 2.34 ha reported by Misgana et al. (2015) at selected districts of east Wollega Zone; 4.25 and 2.75 ha by Dereje et al. (2014), respectively, from *Humbo* and *Dembi* villages of Diga woreda in east Wollega zone of Oromiya Region.

Grain and crop residues production in the study areas

The average grain yield of field crops and their residues in both *dega* and *weinadega* agroecologies in the study areas of Gurage zone are very limited in type and it is not more than three crops grown in each agroecology and that limit the amount of crop yield for human and crop residues used in livestock feeding. In the study areas, farmers have mainly focused on the production of *enset (E. ventricosum*) which provides not only the food for the family but also major source of feed for the livestock particularly of cattle (Table 11). During the study period, group discussion was made with farmers from each of agroecology engaged in crop production and experts of livestock and crop agriculture. The discussants disclosed that the main reason of farmers to focus on *enset* production is due to reduced available land for grazing and crop cultivation as well as lack of appropriate farming technologies to produce enough food crops to feed the family and crop residues that can support their livestock which agreed with the report of Risse et al. (2006), who reported that in *enset* production systems there is a shortage of grazing as well as arable land, which in turn tends to limit production of annual crops and/or pastures that contributed to shortage of livestock feed resources.

Herd size and structure between agroecologies

Cattle ownership varies depending on the type of agroecology, wealth status and the overall farm production objectives. The average cattle holding per household in both *dega* and *weinadega* agroecologies in the study areas of Gurage zone, respectively, was 3.34 TLU and 3.37 TLU with overall mean of 3.35 whereas the average number of cattle owned by HH of *dega* and *weinadega* agroecology, respectively, was 4.86 and 4.88

Table 6. Grain and crop residue yield (t HH^{-1}) for common field crops grown in *dega* and *weinadega* agroecologies of the study areas of *Gurage* zone.

Crop types	Agroecologies of the study area					
	Dega		*Weinadega*		Overall	Overall
	Grain	Straw	Grain	Straw	Grain	Straw
Wheat	0.15±0.02[b]	0.23±0.02[b]	0.21±0.02[a]	0.31±0.03[a]	0.18±0.01	0.27±0.02
Barely	0.65±0.02	0.97±0.03	--	--	0.32±0.02	0.49±0.03
Teff	--	--	0.51±0.02	0.77±0.06	0.26±0.02	0.38±0.04
Field pea	0.16±0.01	0.19±0.01	--	--	0.08±0.01	0.09±0.01
Fababean	0.06±0.01	0.07±0.01	--	--	0.03±0.00	0.03±0.00
Maize	--	--	0.65±0.03	1.3±0.06	0.32±0.02	0.65±0.05

[a-b] means in the same row with different letter of superscripts are significantly different (P<0.05), -- = not available, tHH^{-1} = ton per HH, *Dega* = highland, *Weinadega*= mid altitude.

with the overall average of 4.87 as indicated in Table 7. The average number of cattle per household for current study (4.87) is a bit higher than the average cattle number of 4 at Akaki and Lemu, central Ethiopia reported by Bayush et al. (2008); however, it is tremendously lesser than 15.5 in mixed crop livestock production system of Central Rift Valley, 17.9 around Debre Birhan and 19.4 cattle around Ziway Central Rift Valley, 8.27 at Adami Tullu Jiddo Kombolcha district in Oromiya Region, respectively, reported by Lemma et al. (2005), Ahmed (2006), Zewdie (2010) and Dawit et al. (2013).

There was no significant difference (P> 0.05) on the average cattle holding per household in both agroecologies. However, marked difference (P<0.05) was observed on the average holdings of sheep, goats, horses, and donkeys per HHs. Sheep and horses per HH were higher (P<0.05) in *dega* agroecology whereas goats and donkeys were higher (P<0.05) at *weinadega* agroecology of the study area of Gurage zone (Table 7). The differences observed in the average number of sheep and horses in the *dega* as well as goats and donkeys in the *weinadega* agroecologies could be due to suitable weather conditions, availability of feeds suitable for the specific classes of livestock in each agroecology. Moreover, the owning of higher average number of horses in *dega* as well as donkeys in *weinadega* agroecology, could be related to the animals suitability to overcome the transport problems of people and luggage associated with rugged terrains.

Major constraints affecting livestock production

As indicated in Table 8, about 87% of HHs in the study areas indicated feed shortage as the first major constraint in affecting livestock production and productivity. This is mainly due to shortage of land for grazing and fodder production as the result of expansion of crop agriculture in the expense of grazing land. It was also indicated during group discussion that the quantity and quality of natural grass is very low to meet the nutrient requirement of animals. Prolonged dry period, erratic rainfall and uneven distribution of rainfall affected growth performance of natural grass and residues from crop production. Moreover, absence or inadequate forage seeds availability and extension service rendered to this regard was almost insignificant which aggravated the shortage of livestock feed in the study area. According to the perceptions of participants, introduction of extension service on storage and efficient utilization of crop residues, establishment and management practices of improved forages and providing technical interventions to improve the existing grazing lands were some of the recommendations of the participants to alleviate livestock feed shortage.

Low performance of local cattle was the second important problem prioritized by 65% of the participants (Table 8). It was emphasized that indigenous animals of the area are generally characterized by small in size, low milk yield, slow growth rate and remain unproductive for long period. The amount of milk obtained/cow/day was not more than 1.5 L on average, which is insufficient to satisfy family consumption. The report of group discussion revealed that uncontrolled mating system and mating between relatives which are common in the area together with feed shortage considered as major causative factor for low productivity of these animals.

Fifty-five (55%) of the HH respondents ranked water as the third major problem for livestock production (Table 8). For most HHs especially

Table 7. (Mean ±SE) herd size and structure per HH in the *dega* and *Weinadega* agroecologies in the study area of *Gurage* zone.

Livestock species	Herd size and structure (in number)			Herd size and structure (in TLU)		
	Dega	***Weinadega***	**Overall**	***Dega***	***Weinadega***	**Overall**
Cattle	4.86±0.17	4.88±0.18	4.87±0.12	3.34±0.12	3.37±.14	3.35±0.1
Cows	2.08±0.070	2.21±0.094	2.14±0.059	1.78±0.068	1.87±.088	1.82±0.06
Oxen	0.23±0.032	0.21±0.033	0.22±0.023	0.26±0.035	0.23±0.037	0.24±0.03
Bulls	0.61±0.039	0.57±0.040	0.59±0.028	0.67±0.043	0.62±0.044	0.65±0.03
Heifers	0.73±0.058	0.83±0.065	0.78±0.044	0.38±0.031	0.43±0.034	0.40±0.02
Calves	1.21±0.068	1.07±0.052	1.14±0.043	0.25±0.015	0.22±0.012	0.24±0.01
Sheep	$1.94±0.079^{a}$	$.56±0.066^{b}$	1.25±0.063	$0.19±0.007^{x}$	$0.06±0.006^{y}$	0.12±0.01
Goats	$.01±0.006^{b}$	$1.42±0.103^{a}$	0.71±0.063	$0.01±0.001^{y}$	$0.14±0.010^{x}$	0.07±0.01
Horses	$0.55±0.04^{a}$	$0.02±0.010^{b}$	0.28±0.024	$0.44±0.031^{x}$	$0.01±0.008^{y}$	0.23±0.02
Mules	-	0.47±0.037	0.24±0.022	-	0.38±0.030	0.19±0.02
Donkeys	$0.09±0.021^{b}$	$0.35±0.036^{a}$	0.22±0.022	$0.04±0.011^{y}$	$0.18±0.018^{x}$	0.11±0.01
Total herd	-	-	-	4.02±0.029	4.14±0.03	4.07±0.03

$^{a-b}$ means with different letters of superscripts in the same row for *Dega* and *Weinadega* agroecologies differ significantly (*P*<0.05) for livestock number, $^{x-y}$ means with different letters of superscripts in the same row for *Dega* and *Weinadega* agroecologies differ significantly (*P*<0.05) for TLU, TLU = Tropical Livestock Unit, *Dega*= highland, *Weinadega*= mid altitude.

Table 8. Major problems hindering livestock production in study area of Gurage zone.

Major constraints (N = 360)	Priority levels (n)					Rank
	1	2	3	4	5	
Feed shortage	313(87)	27(7.5)	20(5.5)	-	-	1st
Performance of local animals	62(17.2)	234 (65)	14(3.9)	19(5.3)	31(8.6)	2nd
Water scarcity in dry season	59(20)	53(10)	187(55)	32(5)	29(8.1)	3rd
Livestock diseases	54(15)	38(10.5)	54(15)	180(50)	34 (9.5)	4th
Land degradation	73(20.3)	49(13.6)	43(11.9)	51(14.2)	144(40)	5th

N = total sample population of the study, n = number of respondents, number in the brackets indicate the percentage of respondent HHs of the study.

living in *dega* (highland) agroecology and for those living far from permanent rivers, water supply was crucial for survival of their animals particularly during dry periods. Members of group discussion suggested that moving livestock to distant places in search of drinking water is time consuming, tedious work, causes energy loss and needs intervention on the use of different water harvesting techniques to harvest runoff in the wet season to partially solve the problem and construction of appropriate water harvesting structures like deep wells and pond construction by making common theme among every concerned body of government, non-government organizations and the community.

Animal disease was the fourth constraint prioritized by 50% of the participants (Table 8) and prevalent diseases of the study area include: Anthrax, Blackleg, Foot and Mouth Disease (FMD), Bovine Pasteurollosis, Lump Skin Disease (LSD) and most of these diseases have mostly occurred between months of July to December. However, Anthrax was reported to occur during dry season of the year (November to April) when the conditions of animals become poor due to inadequate feeding. Mastitis, pneumonia and metritis are other common disease of livestock and these diseases have no common time to occur but they can attack the animals at any time within the year when the environments become suitable.

Ecto parasites of tick, lice, fleas, minge mites were common in the area and their infestation was also reported to be high immediately after long rainy season (October to December) of the year. The other parasitic diseases in the study area were the internal parasites including Faciolla (liver fluke), Lung worm and Ascaris which was common in wet season of the year (early June to September).In most of the cases, measures of disease prevention and control have been undertaken by the regional and local government bodies which is in line with the report of MoARD (2008), which revealed that those vaccines and medicines required for the handling of livestock are typically provided on a highly subsidized basis by the Veterinary Department of the Regional Agricultural Bureaus and sometimes through project finance.

Table 9. Percentage of grasses, forage legumes and forbs from area closure in the study areas of Gurage zone.

Production systems	Total grazing land (ha)	Proportion of sample grasses in dry matter (kg) and percent							
		Grasses		Forage legumes		Forbs		Total	
		%	DM (kg)	%	DM (kg)	%	DM (kg)	%	DM (kg)
Dega	84.94	89	126121.9	4.2	5951.82	6.8	9636.28	100	141710
Weinadega	127.39	86	178286.6	3.1	6426.61	10.9	22596.79	100	207310
Overall	212.33	87.5	304408.5	3.65	12378.43	8.85	32233.07	100	349020

Dega **=** highland, *Weinadega* = mid altitude, DM =dry matter, kg = kilogram, ha = hectare.

Groups that participated in the discussion indicated the existence of complaints on low preventive capability of (LSD) vaccine which is the only imported one and free of charge. In addition to inability of having drugs and vaccines with enough quantity as well as in a scheduled manner (in time), livestock owners in the study area were forced to buy and utilize some drugs and vaccines delivered by illegal traders which were not good enough to heal sick animals and to protect the animals from being affected. The constraints of livestock production identified in current study corresponds with the results made by Berhanu et al. (2009), Negassa et al. (2011), Getahun (2012), Dawit et al. (2013) and Dereje et al. (2014) who reported that the inadequacy of feed, water scarcity, disease prevalence, low productivity of local breeding stock are the main livestock production constraints in different parts of Ethiopia.

Seasonal availability of feed resources

Feed resources available at the different months of a year for both *dega* and *weinadega* agroecological zones in the study areas are strongly influenced by seasonality of the year. Gryseels (1988) and Gashaw (1992) observed similar trends of seasonal availability of feed resources in the central highlands of Ethiopia. In the study areas of Gurage zone leaf and leaf midribs of *enset (E. ventricosum)*, crop residues and natural pasture were the major feed resources for livestock feeding in different seasons. Among feed resources leaf and leaf midribs of *enset* took the largest share and the most common feed used by HHs to feed their animals mainly of cattle in dry seasons covering about eight (8) months within a year between (October to May).

The amount of DM feed produced from *enset* leaf and leaf midribs from *dega* and *weinadega* agroecology, respectively, were 506.4 tons (52.73%) and 662.96 tons (49.36%) from a total feed dry matter available for livestock feeding (Table 11). The result of current study agreed with the result reported by Brandt et al. (1997), who forwarded that following harvest, crop residues are given to the cattle, and among all *enset* growing groups *enset* leaves form an integral part of the dry season cattle diet and they may be used for as long as seven to eight months, depending on area and ethnic group. This indicates that *enset* plant is not only the plant that provides staple food (*kocho*) to the farming families but it is also the plant that safeguards life of cattle thereby keeping the livelihood of HH from being at risk. Feed problem is one of the major factors that hinders the development and expansion of livestock production. There was a definite time to utilize grazing land in the study area and it was dominantly utilized in the wet season of the year, mainly between the months of late August to December. Crop residues (straws of barley, field pea, wheat and faba bean) in *dega* and (*teff* and wheat straws as well as maize stover) in *weinadega* agroecology were also used as main feed during both dry and rainy seasons of the year (December to August). The result of the current study corresponds with the report of Alemayehu (2004), Tolera et al. (2012), Dereje et al. (2014) and Selamawit et al. (2017), who stated natural pasture and crop residues to be the major feed resources in different areas of Ethiopia.

Composition of natural grasses in the study areas

Measurement was made on the potential biomass yield and DM production of grasses and herbaceous species. Grasses species represented 89 and 86%, whereas legumes represented 4.2 and 3.1% DM biomass production from *dega* and *weinadega* agroecology, respectively. Biomass yield of grasses, forage legumes and forbs in kilogram, respectively, was 1484.84, 70.07 and 113.45 for *dega,* whereas it was 1399.53, 50.45 and 177.38 for *weinadega* areas per hectare of land (Table 9).

The lower proportion of legumes monitored in the study areas might probably be due to sprawling nature of growth of the legumes which make them more susceptible to be lost through grazing. Furthermore, the percent biomass composition of legumes in *weinadega* agroecology area was found to be lower than that in the *dega* agroecology. The variation observed among *dega* and *weinadega* areas of the study might be associated with the altitudinal differences in elevation of highland and midaltitude. This result is in line with the results made by Alemu (1990) and Alemayehu (2005), who reported that the proportion of legumes tends to increase with increasing altitude and particularly above 2,200 masl and at lower altitudes, native legumes are less abundant.

Feeding priority of cattle

Feeding strategy depends on the nature of the farming system, objective of herding animals and the availability of feed resources in specific area which is to be affordable by the farmers. In line with this, farmers were ranked feeding priority of crop residues and supplements to their livestock. From a total of 360 HHs that participated in the study, about 188(52.2%) of HHs were given priority of feeding to lactating cow-calf-week animal-oxen. Whereas, around 141(39.2%) of the HHs gave more attention to lactating cow-calf-oxen-week animal while the rest 31(8.6%) of HHs gave priority of feeding for plowing oxen-lactating cow-calf-weak animal. The mode of feeding priority in the current study area has given more attention to the lactating cows, calves, weak animals than the plowing oxen which is different from the report made by Mekuanint and Girma (2017) in *Gasera* and *Ginnir* districts in Bale zone of Oromiya region.

Group discussion on feeding priority of cattle was made and the report of group discussion confirmed that most HHs in the study areas (*enset* growers) have given first priority to lactating cows because of its advantage in providing: milk and milk products for home consumption with *kocho* (food prepared from a mixture of scraped pulp of the enset pseudo stem excluding the fibers and decorticated *Amicho* (corm of *enset*) and other purposes, manure to fertilize the *enset* garden and calf for replacing the herd. The calves were given the second priority because of their advantages for permanent milk production of the milking cows (if the calf dies, the cow will stop giving milk) and to produce replacement stock in the herd. Furthermore, as the land holding by individual HH is limited, most of the HHs have given less attention to produce annual cereal and pulse crops by giving more attention for *enset* (*E. ventricosum*) cultivation to produce *kocho* enough to feed the family members and this *enset* production system encourages the use of human labor to cultivate the land than the utilization of oxen for plowing.

Chemical composition and nutritive value

Dry matter (DM) and ash content

Chemical composition and nutritive value of the major feedstuffs utilized for livestock feeding in the study areas of Gurage zone was analyzed (Table10) and the dry matter (DM) content of the feeds available for livestock feeding in both *dega* and *weinadega* agroecologies was above 90%, which corresponds with the reported results of different scholars in different parts of the country (Ahmed, 2006; Sisay, 2006). The ash content of the major cereal crop residues in the study area ranged from (6.49 to 9.32%) for straws and from (4.23 to 9.81%) for stubbles. Wheat straw had the highest ash content (9.32%) in *weinadega*, followed by barely straw (9.02%) in *dega* agroecology (Table 10). The value reported for barely straw in this study was lower than the value (14.6%) reported by Yitaye (1999) and (19.7%) by Solomon (2004) but comparable with the value (9.11%) reported by Mekuanint and Girma (2017). On the other hand, the value of ash content for wheat straw (9.32%) was similar with (9.34%) reported by Mekuanint and Girma (2017), but higher than (8.94%) reported by Alemu et al. (1989) and (8.22%) reported by Solomon (2004). The ash content of maize stover recorded in this work (9.98%) is far greater than the result reported by Yitaye (1999), which was 7%. The variations observed on ash contents of crop residues of cereal crops could be associated with environmental factors of rainfall, soil character, temperature, and contamination of the residues by other external factors. The ash content of native grasses was 10.88% for *dega* and 11.97% for *weinadega* agroecology (Table 10). The variation observed could possibly be due to variation in agroecology of the study areas that corresponds with the report of Little (1982), who stated that the ash content of natural grasses increase as elevation in altitude decreases and such variations could possibly arise from difference in climate and soil types. However, Mekuanint and Girma (2017) reported (10.99%) ash content of native grasses from highland (*dega*) and (9.89%) from midaltitude (*weinadega*) which disagreed with the statement made by Little (1982) and the results recorded in the current study.

Crude protein (CP)

The crude protein (CP) content of crop straws varied from barley (2.63%) to field pea (5.54%). Lower CP value for barley straw reported in this study agrees with the report of Yitaye (1999), Solomon (2004) and Ahmed (2006). In general, the percentage of CP obtained from crop straws that are considered as available feed resources for livestock feeding in the study areas is much lower than that set as a minimum level of nitrogen (7%) to limit intake (Milford and Minson, 1966; Van Soest, 1982). The stubbles of barely, wheat, field pea and faba bean in the study areas had higher CP content than that of their corresponding straws (Table 10). Even though, there are findings that crop stubbles have lower leaf to stem ratio than the corresponding straws that limits the CP contents of the stubbles to minimum level (Ørskov 1988), the content of CP found in most of the stubbles in the current study was found to be higher than the CP content of the corresponding straws. This may be associated with the presence of grasses and other species of legumes that had grown on the crop field and left aside with the stubbles

Table 10. Chemical composition and nutritive value of feedstuffs in the study areas of Gurage zone.

Feedstuffs (*dega*)	Chemical composition of feedstuffs (%)							Nutritive value of feedstuffs				
	DM	Ash	OM	NDF	ADF	ADL	CP	DCP (g/kg)	IVDMD (%)	ME (MJ /kg DM)	Ca (g/kg)	P (g/kg)
Field pea straw	92.3	6.53	93.47	55.64	63.2	14.44	5.54	47.99	52.64	7.90	3.0	1.57
Field pea stubble	91.22	4.23	95.77	55.88	65.6	13.31	4.96	42.60	47.91	7.19	2.6	1.07
Faba bean straw	94.05	6.49	93.51	65	47.2	12.62	3.50	29.04	55.5	8.33	2.0	1.12
Fababean stubble	93.01	4.28	95.72	51.4	45.6	11.02	5.84	50.77	48.23	7.24	0.5	1.01
Barley straw	93.44	9.02	90.98	48.94	50.2	10.5	2.63	20.95	50.99	7.65	2.99	1.4
Barley stubble	92.13	6.1	93.9	57.44	35.2	9.49	3.79	31.76	44.89	6.73	1.7	1.07
Wheat straw	93.22	9.11	90.89	67.6	66	10.62	2.92	23.65	40.74	6.11	2.99	0.41
Wheat stubble	92.31	6.38	93.62	56.4	49.2	8.22	3.38	27.92	36.38	5.46	2.5	1.4
Enset leaf	92.65	7.12	92.88	64.92	38.34	6.37	11.39	102.33	58.18	8.73	3.99	1.28
Natural pasture	92.54	10.88	89.12	74.1	40.01	7.69	8.23	72.98	55.91	8.39	1.12	1.51
Feedstuffs *(Weinadega)*												
Wheat straw	93.62	9.32	90.68	62.4	64.4	10.62	3.19	26.16	40.74	6.11	2.80	0.37
Wheat stubble	92.01	5.97	94.03	55.08	51.4	8.46	2.34	18.26	35.68	5.35	2.36	1.23
Maize stover	94.03	9.98	90.02	68.8	47.6	10.59	3.79	31.73	49.93	7.49	2.0	0.47
Tef straw	93.12	9.07	90.93	69.4	49.2	10.12	3.5	29.04	51.02	7.65	2.61	0.9
Tef stubble	93.18	9.81	90.19	61.26	46	6.95	2.63	20.95	43.13	6.47	1.8	0.35
Enset leaf	92.40	7.31	92.69	61.06	39.18	6.31	9.34	83.29	60.45	9.07	3.29	1.09
Natural pasture	92.60	11.97	88.03	75.54	41.08	7.81	6.34	55.42	54.35	8.15	1.05	1.35

Dega = highland, *Weinadega* = mid altitude, DM = dry matter, OM = organic matter, NDF = neutral detergent fiber, ADF = acid detergent fiber, ADL = acid detergent lignin, CP = crude protein, DCP = digestible crude protein, IVDMD = In vitro dry matter digestibility, ME = metabolizable energy, MJ = mega joule.

of crops on crop grown fields during harvest. The CP content reported in current study from all residues of crops (Table 10), however, is at lower level to fulfill the optimum CP requirement of livestock which agreed with the general statement made by Preston and Leng (1984) which indicated that all cereal crop residues have low nitrogen content and are composed of cell wall components with little soluble cell contents.

Grasses from *dega* and *weinadega* agro-ecologies of the study areas, respectively, had CP content of (8.23%) and (6.34%). The value for CP content of grasses from *dega* agroecology was higher than that of *weinadega* area. Such differences may be associated with the reduction in the proportion of legumes in the pasture with a decrease in altitude and this is in line with the finding of Alemayehu (1985) and Mekuanint and Girma (2017). The CP values from natural grasses are closer to the minimum value reported by Milford and Minson (1966) and Van Soest (1982), required for optimum rumen microbial function, hence, can support maintenance requirement of ruminants with slight supplementation. Conversely, 11.39 and 9.34% CP contents (Table 10) were recorded from leaf and leaf midribs of *enset* (*E. ventricosum*) in *dega* and *weinadega* agroecology, respectively. The CP values obtained from *enset* parts in both agro ecologies have been far exceeded from all available livestock feeds in the study area and also higher than the minimum value (7%), required for optimum rumen microbial function that can support maintenance requirement of ruminants.

Neutral detergent fiber (NDF)

The neutral detergent fiber (NDF) content of straws of cereal crops in current study was between *teff* (69.4%) to barley (48.94%). Stubbles of most cereal crops had slightly lower NDF contents than their straws (Table 10). Sisay (2006) reported greater than 70% average NDF contents for cereal crop residues. Similar results of 79.4 and 72.98% were reported for the straws of cereal crops, respectively, by Alemu et al. (1989) and Solomon (2004). The NDF content of 78.6, 81.5 and 82.13%, respectively, for wheat straw, *teff* straw and maize stover were reported by Chalchissa et al. (2014). Solomon (2004) also reported 79.7% NDF content for cereal crops stubbles. Roughage feeds with NDF content of less than 45% categorized as high quality, 45 - 65% as medium quality and those with more than 65% as low quality (Singh and Oosting, 1992). The NDF content of straws of field pea, faba bean, barley and all crop stubbles identified in this study (Table 10) is found in the range of 45 - 65% and could be classified as medium quality roughages that may not impose drawbacks on animal performance. The NDF content of leaf and leaf midribs of *enset* was 64.92% for *dega* and 61.26% for *weinadega* agroecology which was laid between the ranges of 45 - 65% and it could be classified under medium quality livestock feed (Singh and Oosting, 1992). The NDF content of maize stover of current study (68.8%) is much lesser than the NDF content of maize stover (82.13%) reported by Chalchissa et al. (2014). NDF content of native grass reported in this study (74.1%) in *dega* and (75.54%) in *weinadega* were closer to the values reported by Ahmed (2006) and Solomon (2004). The higher NDF content could be a limiting factor on feed intake, since voluntary feed intake and NDF content are negatively correlated (Ensminger et al., 1990) and therefore, feeds with NDF content of greater than 65% in current study could be classified as low roughages, which could impose limitations on feed intake and animal production.

Acid detergent fiber (ADF)

The ADF content of crop straws varied from 47.2% in faba bean to 66% in wheat, whereas ADF content of crop stubbles ranged from 35.2% in barley to 65.6% in field pea. The ADF content for both crop straws and stubbles are within the range reported by Solomon (2004), Ahmed (2006) and Solomon et al. (2008). Conversely, the ADF content for native grass for *dega* and *weinadega* agroecologies, respectively, was 40.01 and 41.08%. The ADF content of maize stover was 47.6%. Kellems and Church (1998) categorized roughages with less than 40% ADF as high quality and above 40% as low quality. The results of ADF content of feeds in current study was higher than the ADF values reported by Yitaye (1999), for barley straw (39.45%), native grasses (29.98%) and maize stover (44.22%). Variation in ADF content could be attributed to differences in temperature, crop management and soil type. The ADF content of maize stover 51.72% reported by Chalchissa et al. (2014) was higher than the reported ADF value of 47.6% in current study whereas the ADF content of *teff* straw (46.8%) and wheat straw (58.1%) reported by the same authors was lower than the results of current study (Table 10). The percentage level of ADF on leaf and leaf midribs of *enset* (*E. ventricosum*) was as low as 38.34% in *dega* and 39.18% in *weinadega* (Table 10), which is lower than the higher limit category (40%) of ADF for high quality roughages (Kellems and Church, 1998) and the leaf and leaf midribs of *enset* can possibly be grouped under high quality roughages used in livestock particularly in cattle feeding.

Acid detergent lignin (ADL)

The acid detergent lignin (ADL) contained in different crop residues found in the study areas ranged from 6.95 to 14.44%. The highest concentration of lignin was found in field pea straw (14.44%) followed by faba bean straw (12.62%). The lignin content of field pea and faba bean straws found in this study is comparable with the results of 13.64 and 12.72% for pulse crops reported, respectively, from Gassera and Ginnir districts of Bale zone of Oromiya region by Mekuanint and Girma (2017). However, the results (16.37%) and (13.21%) reported, respectively, for field pea and faba bean straws by Solomon (2004) and 15.85 and 15.42% reported by Ahmed (2006) were higher than the results reported in current study. The percentage of lignin in crop stubbles reported in the current study also varies between 6.95% in *teff* stubble to 13.31% in field pea stubble. The highest lignin percentage was observed in the stubbles of field pea (13.31%) which is also in line with the ADL content of field pea stubbles (15.82%) as reported by Ahmed (2006).

The ADL content of legume crop residues recorded in this study (14.44) and (12.62) for field pea and faba bean straw as well as 13.31 and 11.02% for stubbles of field pea and faba bean (Table 10), respectively, were imperatively higher than the maximum level (7%) that limits DM intake and livestock production (Reed et al., 1986). This indicates the existence of large differences in lignification between crops residues of cereals (monocotyledons) and legumes (dicotyledons). The level of IVDMD and the ME produced from residues of legumes of the current study, however, are much better than those residues from cereal crops of non-legume origin (monocots) that could be associated with intrinsic nature of these two crop families. As reported in current study, non-legumes species (monocots) have much higher fiber concentrations (ADF and NDF) than legumes (dicots) and conversely grasses have lower concentration of readily digestible cell contents.

The result of current study is well comparable with the report of Buxton and Russell (1988), who reported that the most important difference existed between grasses (monocots) and legumes (dicots) in the concentration of fiber. Even though lignin has a negative impact on the fiber digestibility of legumes, the fact that legumes contain much lesser fiber (ADF and NDF) than grasses lessens its impact on overall digestible energy concentration. For this reason, lignin concentration is not a good indicator of digestible energy when making comparisons between grasses and legumes (Buxton and Russell, 1988). The lignin percentage in maize stover of the study area was found to be 10.59 while the percent lignin of native grasses of *dega* and *weinadega* agroecologies, respectively, was 7.69 and 7.87%, which are greater than limiting lignin content of 7%. The ADL in leaf and leaf midribs of *enset* (*E. ventricosum*) in the current study was 6.37% for *dega* and 6.31% for *weinadega agroecology* with the overall average lignin content of 6.34% for both agroecologies which is free of fear and lower than the maximum level of 7%.

In vitro dry matter digestibility (IVDMD)

The *in vitro* dry matter digestibility (IVDMD) for maize stover was 49.93% which is lower than the value reported for maize stover (58.65%) by Chalchissa et al. (2014). The level of IVDMD from leaf and leaf midribs of *enset* was about 58.18 and 60.45%, whereas it was 55.91 and 54.35% for natural grasses in *dega* and *weinadega* agroecologies, respectively. The IVDMD of straws of cereal crops ranged from 40.74 to 55.5% in which the faba bean straw had the highest (55.5%) content followed by field pea straw (52.64%). The value reported for wheat straw (40.74%) in this work (Table 10) was lower than that from all reported values for the straws of cereal crops of current study and similar results (41.92%) in Gassera and (42.22%) in Ginnir districts in Bale zone of Oromiya region was reported by Mekuanint and Girma (2017). Similarly, IVDMD content of corresponding cereal crops stubbles ranged from 35.68 to 48.23%. The highest value was recorded for the faba bean stubble (48.23%) and the lowest value recorded for wheat stubble (35.68%). From crop residues utilized for livestock feeding in the study areas, greater value of IVDMD was recorded for those straws and stubbles of legume origin. The results of the current study on IVDMD of crop residues was in line with the report of Buxton and Russell (1988) and Seyoum and Fekede (2008), who reported that cereal crop residues are normally characterized by low digestibility and energy value, which are both inherent in their chemical composition.

Metabolizable energy (ME)

The energy content of annual crops residues in the current study ranged from 5.35 MJ/kg DM (wheat stubble) to 8.33 MJ/kg DM (faba bean straw). Comparing the average energy content of residues of legume in one hand and that of other cereal crops on the other hand, the average energy content of (8.12 MJ/kg DM straw and 7.23 MJ/kg DM stubbles) of legume origin were higher in energy content than those of non-legume origin (7.14 MJ/kg DM for straws and 6 MJ/kg DM for stubbles). The average energy contents for crop straws and stubbles in this study were within the range reported by Solomon (2004) and Yitaye (1999) but the ME recorded in current study is much higher than the ME content of 5.96 MJ/kg DM for wheat straw reported by Chalchissa et al. (2014). The energy content of native grass in current study was (8.39 MJ/kg DM) in *dega* and (8.15 MJ/kg DM) in *weinadega* agroecology which is comparable with the report of Zinash et al. (1995) (8.19 MJ/kg DM) and Yitaye (1999), (8.17 MJ/kg DM). The energy content of maize stover in the study area (7.49 MJ/kg DM) was comparable with the report of Yitaye (1999) which was (7.33 MJ/ kg DM) but lower than that reported by Chalchissa et al. (2014) which was 8.79 MJ/kg DM. The energy value contained in leaf and leaf midribs of *enset* (*E. ventricosum*) from *dega* and *weinadega* agroecological zones, respectively, were 8.73 MJ/kg DM and 9.07 MJ/kg DM (Table 10). The observed variations on the value of energy content of leaf and leaf midribs of *enset* among agroecologies could probably be associated with differences in the agroecology and the type of *enset* landraces (clones) grown in each agroecology.

Calcium (Ca) and Phosphorus (P) content

Of the minerals, calcium and phosphorus are the two determining minerals in both function and amount in the production and productivity of livestock. The Ca content of crop residues in the current study for both agroecologies varied from 0.5 g/kg DM in faba bean stubble to 3 g/kg DM in field pea straw. The Ca content for natural pasture was 1.12 g in *dega* and 1.05 g/kg DM in *weinadega* agroecology. The maize stover had a Ca content of 2 g/kg DM whereas 3.99 and 3.29 g/kg DM (Table 10) was for leaf and leaf midribs of *enset (E. ventricosum) from dega* and *weinadega* agroecologies, respectively. The P in the crop residues in both agroecologies ranges from 0.35 g/kg DM (*teff* straw) to 1.57 g/kg DM (straw). The P content in natural grass from *dega* was 1.51 g/kg DM and 1.35 g/kg DM in *weinadega* agroecology. The P content of maize stover was 0.47 g/kg DM. The P in *enset* leaf and leaf midribs was 1.28 g/kg DM in *dega* and 1.09 g/kg DM in *weinadega* agroecology (Table 10). Ca Concentrations in majority of feeds except those grasses and stubbles of faba bean, barley and *tef* were at normal range. Conversely, P concentrations of nearly all feeds in the study areas were low when compared with the recommendations made by McDonald et al. (1995) and Kellems and Church (1998), (< 2 g/kg DM low, 2-3.5 g/kg DM normal and > 4 g/kg DM high) for both Calcium and Phosphorus.

Table 11. Estimated annual DM, DCP and ME produced in *dega* and *Weinadega* agroecologies in the study areas of Gurage zone.

Feedstuffs	Agroecological zones					
	Dega			***Weinadega***		
	DM(t)	**DCP (kg)**	**ME (MJ)**	**DM(t)**	**DCP (kg)**	**ME ('MJ)**
Field pea straw	33.26	1596.15	262754	--	--	--
Field pea stubble	12.61	537.17	90665.9	--	--	--
Faba bean straw	11.89	345.29	99043.7	--	--	--
Fababean stubble	4.13	209.68	29901.2	--	--	--
Barley straw	175.05	3667.3	1339132.5	--	--	--
Barley stubble	29.18	926.76	196381.4	--	--	--
Wheat straw	40.13	949.07	245194.3	55.18	1443.51	337149.8
Wheat stubble	6.08	169.75	33196.8	8.36	152.65	44726
Maize stover	--	--	--	233.14	7397.53	1746218.6
Tef straw	--	--	--	137.86	4003.45	1054629
Tef stubble	--	--	--	38.29	802.18	247736.3
Enset leaf	506.4	51819.91	4420872	662.96	55217.94	6013047.2
Natural pasture	141.62	10335.43	1188191.8	207.33	11490.23	1689739.5
Total	960.35	70556.5	7905333.6	1343.12	80507.49	11133246.4

Dega= highland, *Weinadega* = mid altitude, -- = not present, DM = dry matter, DCP = digestible crude protein, ME = metabolizable energy, t = ton, kg = kilogram, MJ = mega joule.

Estimated annual feed availability in both *dega* and *weinadega* agroecologies

Households in both agroecologies substantially depend on leaves and leaf midribs of *enset* (*E. ventricosum*) to feed their livestock particularly of cattle. The largest portion of dry DM was obtained from this *enset* parts which accounted for 506.4 tons (52.73%) of the total dry matter (TDM) produced in *dega* and 662.96 tons (49.36%) of the TDM produced in *weinadega* agroecology. In general, the amount of DM produced from *enset* parts in both agroecologies of the study areas accounted for 1169.36 tons (50.77%) of the total dry mater (TDM) of (2303.47 tons) which is greater than half of total feed produced and available for livestock feeding (Table 11).

The amount of dry matter produced from leaf and leaf midribs of *enset* in each study PA of *Shamene, Achene, Moche, Agata, Shehremo, Wukiye, Yeferezye* and *Kochira* of Gurage zone, respectively, in tons was 90.5(42.15%), 99(56.91%), 198(56.09%), 118(54.16%), 145.7(54.37%), 146.3(55.6%), 180.48(48.67%) and 190.4(49.35%). The result of current study on the leaf and leaf midribs of *enset (E. ventricosum)* is in line with reports of Brandt et al. (1997), who stated that among all *enset* growing groups *enset* leaves form an integral part of the dry season cattle diet and may be used for as long as seven to eight months of the dry season. Similar statement was made by Dereje (1996) and Menbere (2014), who reported that *enset* leaves are the major source of feed to the cattle; during the dry season cattle are substantially dependent on parts of the enset not normally eaten by humans, particularly the leaf, and leaf sheaths (midribs).

Dry matter produced from natural grass in the *dega* system was 141.62 tons (14.75%) while in the *weinadega* agroecology it was 207.33 tons (15.44%) from TDM produced in each agroecology. The DM production from maize stover accounted for 233.14 tons (17.36%). Crop straws of barley, wheat and field pea in *dega* and *teff* and wheat straws in *weinadega* agroecology represented the largest share of DM produced and used mainly as dry season feed which is in line with the report of Dereje et al. (2014) from Diga woreda of east Wollega zone indicated that crop residues are used as major sources of livestock feed during the dry season. As indicated in Table 11, the wheat straw in the study areas provided 40.13 tons (4.19%) DM; 926.76 kg (1.31%) DCP and 245194.3 MJ (3.1%) ME in *dega* as well as 55.18 tons (4.11%) DM; 1443.51 kg (1.79%) DCP and 337149.8 MJ (3.03%) ME in *weinadega* agroecology. However, HHs hardly provided wheat straw to their livestock when there is enough feed to sustain their animals but it is stored together with other crop residues as feed reserve and provided to their livestock when they were encountered in feed shortage which is similar with the report of Mekuanint and Girma (2017) from Gassera and Diga districts of Bale zone in Oromiya region. Use of improved fodder trees and those of agro industrial byproducts in the study areas were negligible, which is in agreement with the report of Alemayehu (2005), who reported that the production of improved pasture and forages in most parts of Ethiopia is insignificant and the contribution of agro industrial by products is also minimal and restricted

Table 12. Mean (± SE) DM, DCP and ME produced/HH in both agroecologies of Gurage zone.

Description	Agroecological zones				
	Dega	***Weinadega***	**Overall**	**Minimum**	**Maximum**
DM produced (t)	5.99±.19[b]	8.09±.30[a]	7.04±.19	1.456	25.980
DCP produced (kg)	397.26±14[b]	447.26±16[a]	422.26±11	100.61	1266.9
ME produced (Mj)	44951±1490[b]	61851±2232[a]	53401±1412	10939	187594

[a-b] Means in the same row sharing different letters of superscripts are significantly different (P<0.05), *Dega* = highland, *Weinadega*= midaltitude, HH = household, DM = dry matter, DCP = digestible crude protein, ME = metabolizable energy, t = ton, kg = kilogram, MJ = mega joule.

to some urban and peri urban farms. Similarly Dereje et al. (2014) indicated the importance of fodder crops as livestock feed, but farmers in the Humbo, Dapo and Dembi villages of Diga woreda in east Wollega zone hardly grow improved forage crops and the extension service to support forage development in the area appears to be weak and non-functional.

The total estimated digestible crude protein (TDCP) per annum in kilogram (Table 11) was 70,556.5 and 80,507.49 in the case of *dega* and *weinadega* agroecology*,* respectively*.* Similarly, the amount of total metabolizable energy (TME) produced in both *dega* and *weinadega* agroecologies of the study area in MJ, respectively, was 7,905,333.6 and 11,133,246.4. The annual TDM, TDCP and TME produced in each study PA of *dega* agroecology were 214.71 tons, 14177.1 kg and 1751200 MJ from *Shamene* PA; 174 tons, 13249.6 kg and 1443185 MJ from *Achene* PA; 353 tons, 27078 kg and 2924047 MJ from *Moche* PA; and 218.54 tons, 15966 kg and 1788124 MJ from Agata PA. Simultaneously, the annual TDM, TDCP and TME produced in each study PA of *weinadega* agroecology including Shehremo, Wukiye, Yeferezye and Kochira of Gurage zone, respectively, was 275 tons, 16974.8 kg and 2299757 MJ; 269.3 tons, 167344 kg and 22578814 MJ; 394.1 tons, 23037.2 kg and 3238484 MJ and 405 tons, 23736 kg and 3337348MJ (Table 13).

The mean feed DM in tons, digestible CP in kilogram and ME in mega joule produced per year per individual household in both *dega* and *weinadega* agroecological zones of Gurage zone was analyzed (Table 12). The average tons of DM produced per individual household in *dega* and *weinadega* agroecology, respectively, was 5.99 tons and 8.09 tons with the overall mean of 7.04 tons per farmer per annum. The amount of feed DM produced in the *weinadega* agroecology was significantly higher (p<0.05) than the mean annual produced feed DM in *dega* agroecology.

At the same time, the kilogram of DCP produced by individual household found in both agroecology was also analyzed and there was a significant difference (P<0.05) among the two agroecologies with the overall mean of 422.26 kg. Similar analysis on the mean annual production of ME was undertaken and the amount of ME in mega joule per individual HH of *dega* and *weinadega* agroecology, respectively, was 44951 and 61851 with the overall mean of 53401 MJ and significant difference (P<0.05) among the HHs of the two agroecologies was observed (Table 12).

Annual feed balance estimate in both *dega* and *weinadega* agroecology

The annual available feed was compared with the annual requirements of the livestock population. The daily requirement of DM, DCP and ME per TLU for maintenance were estimated based on the recommendations of Kearl (1982) and McCarthy (1986) for TLU. The overall estimated feed supply in the study area met only 76.81% and 69.9% of the maintenance DM and DCP requirement of livestock while the total estimate of ME were 1.67% in surplus per year (Table 13). Estimation on the amount of available feed supply and demand per year per agroecology of *dega* and *weinadega* were also made and there were differences in the available feed demand and supply (Table 13). In *dega* agroecology the available feed supply met only about 65.13% DM, 66.24% DCP and 85.66% ME of the maintenance requirement of livestock per farm per year. In *weinadega* agroecology, on the other hand, the available feed supply satisfied about 87.53% DM and 72.98% DCP of the maintenance requirement of livestock and the total ME estimates was 16.28% surplus per year (Table 13).

Within *dega* agroecology, the available feed on year round basis in *Moche* PA satisfied about 97.18% DM and 96.08% DCP maintenance requirement, whereas the estimated (ME) was 28.84% in surplus. On the rest of three PAs of *dega* agroecology (*Shamene, Achene and Agata)*, however, livestock were in serious negative feed balance and the available feeds could only satisfy the maintenance requirements of 53.06, 52.88 and 57.40 %DM; 48.61, 55.86 and 58.40% DCP and (69.29, 70.23 and 75.2% ME), respectively. However, there was relatively better feed availability in PAs of *weinadega* agroecology in which the available feed resources met about (79.47, 76.63, 95.61 and 98.39% DM), (68.25,

Table 13. Estimated annual nutrient supply, requirement (demand) and nutrient balance of livestock per peasant association in the study areas of Gurage zone.

Study PAs	Annual nutrient supply			Annual nutrient demand			Annual nutrient supply and demand balance		
	TDM (t)	TDCP (t)	TME (MJ)	TDM (t)	TDCP (t)	TME (MJ)	TDM (t)	TDCP (t)	TME (MJ)
Shamene TLU=198	214.71	14.18	1751200	404.72	29.17	2527282	-190 (46.94)	-15. (51.39)	-776081.9 (30.71)
Achene TLU=161	174.00	13.28	1443185.5	329.08	23.72	2055012	- 155.1(47.12)	-10.5(44.14)	-611826.6 (29.77)
Moche TLU=177.8	353.10	27.08	2924046.5	363.42	26.19	2269448.1	- 10.24 (2.82)	+0.91 (3.92)	+654598.4(28.84)
Agata TLU=186.3	218.54	15.99	1788123.7	380.80	27.45	2377942.2	- 162.31(42.6)	-11.41(41.6)	-589818.5(24.80)
Shehremo TLU=169.1	274.70	16.97	2299757.6	345.64	24.91	2158400.9	-70.96 (20.53)	-7.91(31.75)	+141356.74 (6.6)
Wukiye TLU=171.9	269.30	16.76	2257881.2	351.36	25.32	2194140.2	-82.1 (23.37)	-8.58 (33.89)	+63741.01(2.91)
Yeferezye TLU=201.7	394.10	23.04	3238484.3	412.27	29.71	2574508.9	-18.1 (4.39)	-6.67 (22.45)	+663975.4(25.79)
Kochira TLU=201.4	405.02	23.74	3337348	411.66	29.67	2570679.7	-6.62 (1.61)	-5.93 (19.98)	+766668.3 (29.8)
Total 1467.2	2303.5	151.04	19040027	2999	216.14	18727414	-695.5(23.19)	-65.1(30.1)	+312613(1.67)

Dega=highlands, *Weinadega* = mid altitude, TLU= tropical livestock unit, TDM = total dry matter, TDCP = total digestible crude protein, TME = total metabolizable energy, t =ton, kg = kilogram, MJ =mega joule, numbers in the brackets indicate the percentage of differences in annual TDM,TDCP and TME supply and demand balance between the study peasant associations.

66.11, 77.55 and 80.02% DCP) and the estimated (ME) was (6.6, 2.91, 25.79 and 29.82%) in surplus in *Shehremo, Wukiye, Yeferezye* and *Kochira* PAs (Table 13), respectively. The reason for betterment of available livestock feed in the *weinadega* agroecology might be associated with relative better availability of land for grazing, cropping and production of *enset* (*E. ventricosum*).

It was indicated in Table 13 that the total estimated annual feed supply in the study area of Gurage zone met only about 76.81% (DM) and 69.9% (DCP) maintenance requirement of livestock. The greater feed deficit encountered might be associated with poor quality of roughages and absence of supplements of different agro industrial by products. The observed negative feed balance in DM requirement in the current study agrees with earlier work of (Adugna and Said, 1994) reported for different areas in the country; the result reported by Dawit et al*.* (2013) from selected Kebeles of Adami Tullu Jiddo Kombolcha District of East Showa Zone in Oromiya region and feed deficit reported by Selamawit et al. (2017) from north Achefer district in Amhara region. However, it disagrees with the report of Sisay (2006) reported surplus DM supply than the total annual livestock requirement in North Gondar zone of Ethiopia.

Conclusion

To enhance the productivity and contribution of the livestock resources to the livelihood of the households in the study PAs in particular and in Gurage zone in general, it would be necessary to alleviate the prevailing livestock production constraints. From a total of feed produced in the study areas of both agroecologies of Gurage zone, feed from leaf and leaf midribs of *enset (E. ventricosum)* received the greatest share accounting for 506.4 tons in *deg*a and 662.96 tons in *weinadega* with overall production of 1169.36 tons (50.77%). Grasses and residues altogether provided a DM of 453.95 tons in *dega* and 680.16 tons in *weinadega* agroecology. *Enset* leaf and leaf midribs supplied 51819.91 kg of DCP and 4420872 MJ of ME in *dega* as well as 55217.94 kg DCP and 6013047.2 MJ (ME) in *weinadega* leading the champion from livestock feeds which came from grasses and residues. The availability and use of improved forages and concentrate feeds in the areas was almost nil. The available feed in general and amount of protein in particular did not satisfy the maintenance requirements of livestock of study areas. The scarcity of feed was more serious in *dega* (highland) PAs particularly in dry season of the year together with water scarcity which aggravates low productivity. To this effect, it is suggested that future interventions take the following issues into account:

a) *Enset* is not only plant that provides food (*kocho*) to the farming families but it also safeguards life of cattle and keep the livelihood of farmers from being at risk. Intervention to words improving productivity as well as reducing the risks associated with *enset* production should be in place with full involvement of all stakeholders and development actors.
b) Empower farmers through awareness creation on storage, treatment and efficient utilization of crop residues, on establishment and management practices of improved forages and improving the existing grazing lands.
c) The quality and quantity of available basal roughage feed is generally low hence strategic supplementation of protein and energy rich feeds should be required and alternative means of dry season feed production and supply should be in place.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The author appreciates Addis Ababa University for granting partial financial support. The author expresses his sincere and heartfelt appreciation to Holetta Agricultural Research Center's Animal Nutrition Laboratory, Jimma University College of Agriculture and Veterinary Science's Animal Nutrition Laboratory and Wolkite Regional Soil Analysis Laboratory for their technical support in analyzing the chemical composition of feed samples of the study.

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Vol. 9(6), pp. 131-139, June 2018
DOI: 10.5897/IJLP2018.0469
Article Number: 13725BA56977
ISSN 2141-2448

http://www.academicjournals.org/IJLP

ACADEMIC JOURNALS

International Journal of Livestock Production

Full Length Research Paper

Evaluation of the reproductive performance of Holstein Friesian dairy cows in Alage ATVET college, Ethiopia

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Received 6 March, 2018; Accepted 20 April, 2018

The objective of this study was to evaluate the reproductive performance of pure Holstein Friesian dairy cows exploring 28 years records (1987 to 2015) in Alage Agricultural Technical and Vocational Education Training (ATVET) College dairy farm. General linear model procedures of SAS version 9.2 was employed to determine the effects of period of birth, season of birth, period of calving, season of calving and parity on reproductive traits. The overall mean of age at first service (AFS), age at first calving (AFC), calving interval (CI), days open (DO) and number of services per conception (NSC) were 31.8±0.44 months, 42.5±0.46 months, 470.3±9.8 days, 228.2±10.2 days and 1.32±0.03, respectively. Period of birth (P<0.001) and season of birth (P<0.05) exerted significant effect on AFS, while AFC was not significantly influenced by season of birth. Days open and calving interval of Holstein Friesian (HF) cows affected by all fixed factors. Except period of calving (P<0.05), none of the factors influenced NSC. Except NSC, the results obtained for AFS, AFC, CI and DO were disappointing. The most probable factors accounted for the poor reproductive performances (AFS, AFC, CI and DO) in the study area were poor efficiency of estrus detection and expression, poor management practice and health problem and genotype × environmental interactions. Therefore, improving the level of management is required for optimal reproduction performance of HF breed in the area.

Key words: Alage, Holstein Friesian, reproductive performance.

INTRODUCTION

Food insecurity is an appearance of famine challenging in many developing countries, in particular to Ethiopia. Ethiopia is known for its huge livestock population and is estimated to have 59.5 million heads of cattle, about 98.59% of the total cattle in the country are local breeds; the remaining are hybrid and exotic breeds with 1.22 and 0.19%, respectively (CSA, 2016).

Livestock sector in Ethiopia is less productive as compared to its potential, contribution to the Ethiopian economy is very limited, production per animal is extremely low (Kumar and Tkui 2014). The milk production and reproductive traits are crucial factors, determinant for the profitability of dairy production (Lobago, 2007).

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There are common measures of reproductive performance such as age at first service, age at first calving, days open, calving interval, number of services per conception and breeding efficiency (Alemayehu and Moges, 2014). The relative reproductive performance of dairy breeds in Ethiopia has shown to be very poor. Poor genetic performance, poor level of management, poor breeding practice and environmental factors accounted for the poor reproductive performance of dairy cows in Ethiopia. In order to improve the low productivity of the existing breed, selection of the most promising breeds and crossbreeding of these indigenous breed with high producing exotic cattle has been considered as a practical solution (Bekele, 2002).

In Ethiopia, the genetic improvement of dairy cattle is mainly based on cross breeding and adoption of improved exotic breeds. Even though there is a concern about adaptation of pure exotic dairy cattle to tropical environment (climate, feed and disease challenge), pure Friesian and Jersey dairy breeds have been raised by large-scale private and state dairy farms in Ethiopia. But, the productivity of these animals has not been systematically studied and documented. Information on reproductive performance and the factors affecting exotic breeds of Alage ATVET College in particular and that of Ethiopia in general is periodically needed for the planning and management for maximum herd production and high fertility.

Therefore, the aim of the present study was to determine the reproductive performances and document the effects of period of calving/birth, season and parity on age at first service, age at first calving, days open, calving interval and number of services per conception of a herd of Holstein Friesian cows under Alage ATVET College dairy farm, Ethiopia.

MATERIALS AND METHODS

Description of the study area

The current study was carried out at Alage Agricultural Technical Vocational Educational Training (ATVET) College, which is positioned at 217 km southwest of Addis Ababa, near the Abijata and Shala lakes of the Ethiopian Rift Valley. The farm is geographically located at a longitude of 38°30´ east and latitude of 7°30′north, with an altitude of 1600 m.a.s.l. The mean annual minimum and maximum temperature range from 11 to 32°C, respectively. The area has the mean annual rain fall of 800 mm. The rainfall pattern in Alage ATVET College has three distinct seasons; a short rainy season (March to May), a long rainy season (June to September) and a dry season (October to February) (NMSA 2015).

Farm establishment and herd management

Alage dairy farm started in 1980 with a foundation stock of Holstein Friesian origin brought from the Stella dairy farm, Holetta and individual farms around Addis Ababa. Animals were kept under an intensive feeding and production systems, and herds were managed separately based on sex, age, pregnancy, time of calving and lactation.

Animals were stall fed individually with green fodders and roughages, concentrates were supplemented to the animals based on production level and physiological status of animals. Heifers and dry cows were mainly fed on green fodder and other roughages throughout the year. During the day of the rainy season, cows were grazed on native pastures from 1:00 to 3:00 am local time. Later on the day, animals were tied and fed with dry and green fodder, homemade concentrates and mineral licks under the shade.

Animals were fed according to calculated requirements with concentrate feeds and mineral licks during late pregnancy and lactation. Lactating cows were fed 1 kg concentrates per 2.5 kg of milk produced before each milking. Concentrates were prepared by mixing maize with wheat bran, noug cake (*Guizotia abyssinica*), salt and limestone. Hay produced from various types of annual and perennial plants of *graminaceous* and *leguminous* species were used for feeding animals.

Artificial insemination (AI) with semen of purebred HF produced from locally recruited bulls from Ethiopian National Artificial Insemination Centre (NAIC) was used for insemination. Artificial Insemination was done by AI technicians. Detection of estrus was carried out early in the morning and late in the afternoon. Pregnant cows were managed separately during the last trimester and calving was in well-constructed calving pens. Lactating cows were hand-milked early in the morning (8:00 to 9:00 A.M) and late in the afternoon (3:00 to 4:00 P.M). Daily milk yield from individual animals were weighed and recorded. Newborn calves were taken away from their dams shortly after birth and were given colostrums for the first five days of age. Fresh milk was offered twice a day in a bucket until the age of 6 months. They were kept in individual pens. Animals were regularly vaccinated against anthrax, pasteurellosis, blackleg, foot and mouth disease, lumpy skin disease, and contagious bovine pleura pneumonia. Internal and external parasitic infestation were dewormed and sprayed regularly.

Data collection

Data of all cows documented in the history sheet kept on each individual animal record book maintained at Alage dairy farm for 28 years period (1987 to 2015) were used for the study. Data on Dam and Sire ID number, dates of birth, sex of animal, service date and calving dates, calf ID, parity number, drying dates, date and reason of exit were collected from the history sheet. The variables considered as the measure of reproductive performance were age at first service (AFS), age at first calving (AFC), days open (DO), calving interval (CI) and number of services per conception (NSC). Based on climatic condition and weather of the area, seasons of the year were divided into three seasons that is, a short rainy season (March to May), a long rainy season (June to September) and a dry season (December to February). Further, periods of birth were divided into 8 groups; Period 1 (1987 to 1989), Period 2 (1990 to 1992), Period 3 (1993 to 1995), Period 4 (1996 to 1998), Period 5 (1999 to 2001), Period 6 (2002 to 2004), Period 7 (2005 to 2007) and Period 8 (2008 to 2010). For AFS and AFC, cows that were born between 1987 and 1990 were included. Similarly, period of calving was classified into 6 periods; period 1 (1990 to 1993), period 2 (1994 to 1997), period 3 (1998 to 2001), period 4 (2002 to 2005), period 5 (2006 to 2009) and period 6 (2010 to 2015). Unclear and incomplete data were cleaned out. Cases like aborted or had stillbirth were removed from the databases.

Statistical analysis

The data on reproductive traits (AFS, AFC, CI, DO and NSC) of Holstein Friesian dairy cows were entered into Microsoft excel spreadsheet and analyzed by using general linear model (GLM)

Table 1. Least square means ± standard error of age at first service and age at first calving for the fixed effects of period of birth and season of birth.

Source	N	AFS (months)	AFC (months)
		LSM±SE	LSM±SE
Overall CV	244	31.8±0.44 20.52% ***	42.5±0.46 15.67% ***
Period of birth			
P1 (1987-1989)	48	26.63 ± 0.9^{ed}	37.5 ± 0.9^{ed}
P2 (1990-1992)	13	$40.\pm1.73^{ab}$	51.9 ± 1.7^{ab}
P3 (1993-1995)	37	43 ± 1.02^{a}	52.08 ± 1.04^{a}
P4 (1996-1998)	24	33.8 ± 1.2^{cb}	45.5 ± 1.3^{cb}
P5 (1999-2001)	44	23.5 ± 0.9^{e}	34.5 ± 0.9^{e}
P6 (2002-2004)	23	30.7 ± 1.3^{cd}	42.9 ± 1.3^{c}
P7 (2005-2007)	18	32.4 ± 1.4^{c}	41.7 ± 1.5^{cd}
P8 (2008-2010)	37	24.3 ± 1.02^{e}	33.6 ± 1.1^{e}
Season of birth			
Short rainy	62	33.45 ± 0.8^{a}*	43.9 ± 0.8^{NS}
Long rainy	85	31.29 ± 0.6^{ab}*	41.9 ± 0.7^{NS}
Dry season	97	30.68 ± 0.7^{b}*	41.6 ± 0.6^{NS}

Means separated by different superscript letters under the same variable in one column are significantly different. *** = significant (p<0.001), * = (p<0.05), NS=Not significant, N = number of records, CV= Coefficient of variation, P= Period.

procedures of SAS version 9.2 (SAS, 2008). The study model includes fixed effects of period of calving, period of birth, season of calving, season of birth and parity. Only a few number of animals completed more than 7 lactations and the estimated least square means for parity numbers 7 and greater than 7 were almost similar. Therefore, all parities above 7 were pooled together in parity 7^+. Preliminary analysis showed that interaction effects of the fixed factors were not significant and thus not included in the model. The following statistical models were used to analyze reproductive traits in the farm. The model equations used were:

Model 1: For age at first service (AFS) and age at first calving (AFC)
$Yij = \mu + Bi + Sj + eij$
Where, Yij = Observation on AFS and AFC,
μ = Overall mean,
Bi = Fixed effect of i^{th} season of birth (long rainy, short rainy and dry season),
Sj = Fixed effect of j^{th} period of birth, where P1 (1987-89), P2 (1990-92)…P8 (2008-2010),
eij = Residual random error.

Model 2: For calving interval (CI), days open (DO) and number of service per conception (NSC)
$Yijk = \mu + Bi + Sj + Yk + eijk$
Where, Yijk = Observation on CI, DO and NSC,
μ = Overall mean,
Bi = Fixed effect of i^{th} season of birth (long rainy, short rainy and dry season),
Sj = Fixed effect of j^{th} period of calving P1 (1990-93)…P6 (2011-2015),
Yk = Fixed effect of k^{th} parity (1, 2…7),
eijk = Residual random error.

RESULTS AND DISCUSSION

Age at first service (AFS)

In this study, the overall least square mean of age at first service of Holstein Friesian dairy cows were 31.8±0.44 months which is longer than the age at first service of 733±16 days for Holstein Friesian cows in Ethiopia (Heyredin, 2014), 29.76±0.40 months for Holstein Friesian cows under Sudan tropical conditions (Peters et al., 2007), 24.30±8.01 months for Zebu × Holstein-Friesian dairy cows in Jimma town, Ethiopia (Belay et al., 2012). Reduced growth rate and delayed puberty as a result of poor feeding of calves and low level of nutrient intake by heifers in the farm of Alage ATVET college could have influenced the prolonged AFS obtained.

As presented in Table 1, period of birth (P<0.001) and season of birth (P<0.05) significantly affected AFS. Similarly significant effect of period of birth was reported on AFS of Holstein Friesian cows by Heyredin (2014). Significant effects of period of birth on age at first service in other breeds were also reported by Effa et al. (2011), Tadesse et al. (2010) and Menale et al. (2011). On the other hand, Tadesse et al. (2006) reported non-significant effect of period of birth on AFS on HF dairy cows in Ethiopia. The estimated mean of AFS of Holstein Friesian cows was longest for the cows that were born during P3 (1993 to 1995), while shortest at p5 (1999 to 2001) and p8 (2008 to 2010), respectively. This study indicated that an increasing trend of AFS observed from the heifers that were born in between 1987 and 1995, while decreased from 1996 to 2010 (Figure 1).

Fekadu et al. (2010) reported similar findings regarding the effect of season of birth on age at first service. Nevertheless, on purebred Holstein Friesian cows this was less clear (Lemma et al., 2010; Tadesse et al. 2010) under Ethiopian conditions. This study demonstrated that calves born in the dry season tended to be younger at first service than those born in short and long rainy season of Holstein Friesian cows, respectively. This further supports the idea that after the rainy season, grass on natural pastures develops rapidly and lasts through dry season; therefore, AFS is affected by the chances for young cattle to benefit from the wealth of grass. In order to do these calves must be able to digest fiber.

Age at first calving (AFC)

The overall mean of age at first calving for Holstein Friesian heifers was 42.5±0.46 months with coefficient of variation 15.67% (Table 1). This is in close agreement with 42.5±0.7 months for crossbred dairy cows under central highlands of Ethiopia (Effa et al., 2011),

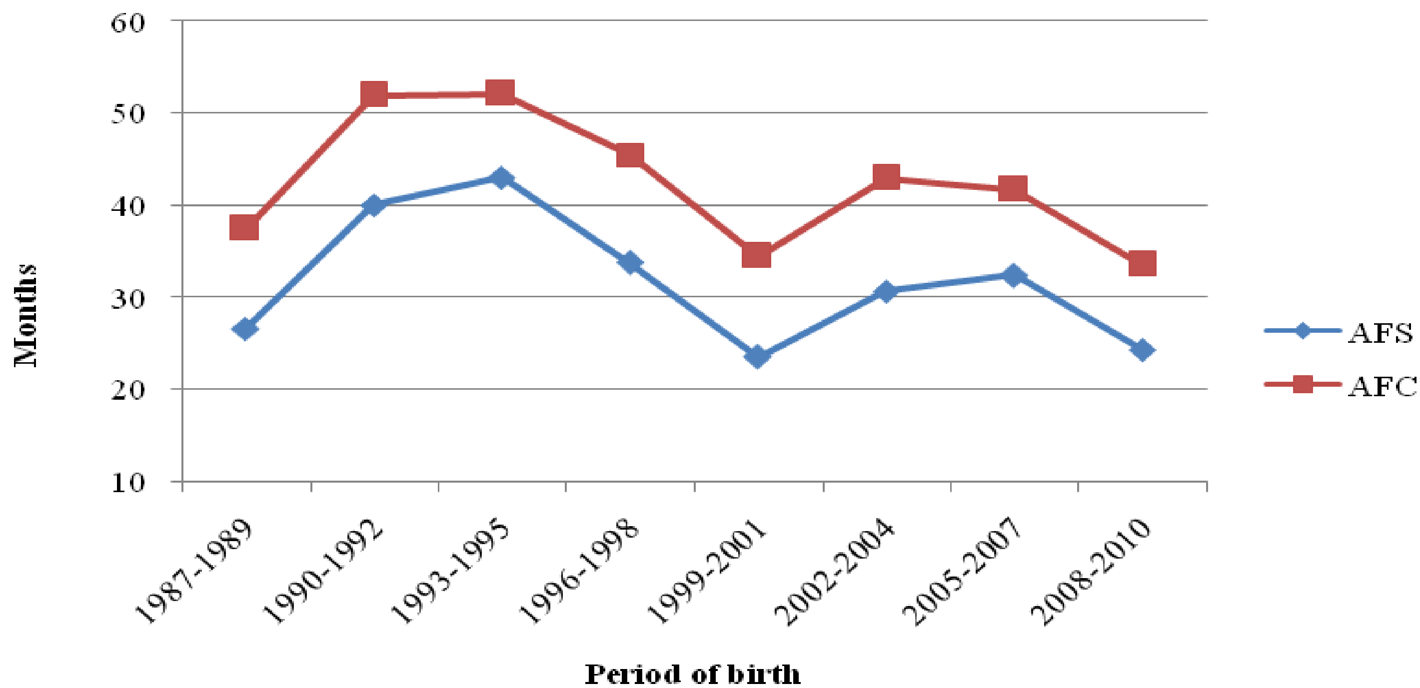

Figure 1. The trend of age at first service and age at first calving of Holstein Friesian heifers over a 23 year period in Alage ATVET College dairy farm.

respectively.

Whereas, estimates in this study for AFC found was higher than previous studies for HF cows that is; 41±6 months in Sri Lanka (Krishantan and Sinniah 2014), 39.2±7.5 months in Ethiopia (Tadesse et al., 2010), 36.48±0.55 months in Ethiopia (Kebede, 2015), 33.27 months in Sri Lanka (Kollalpitiya et al., 2012), 988±9.81 days (Sattar et al., 2005), 894 days for HF in Pakistan (Sandhu et al., 2011) and 912±13.11 days for Holstein-Friesian heifers (Irshad et al., 2011), respectively.

Therefore, the results of the present study obtained significantly differ from previous results reported in the tropics. We found longer values for AFC of Holstein Friesian heifers which deviates from the standards set for commercial dairy farms. This probably accounted for the prevailing climatic conditions and poor management including poor heat detection on heifers.

As indicated in Table 1, period of birth (P<0.001) significantly influenced AFC, while no significance difference was observed between season of birth. This finding was supported by previous findings in the study of Ansari-Lari et al. (2010), Hammoud et al*.* (2010), Suhail et al. (2010) and Heyredin (2014).

Furthermore, the study findings appear to be well substantiated by the report of Tadesse et al. (2010). In contrast to this study, Tadesse et al. (2006) has reported non-significant effect of period of birth on AFC of HF dairy cows in Ethiopia. Season of birth in this study showed non-significant effect on AFC. However, Peters (2007) reported significant effect of season of birth on AFC for HF cows under sub tropical conditions of Sudan. Analysis of data showed that the shortest value of AFC was observed during P5 (1999 to 2001) and P8 (2008 to 2010), whereas the longest value of AFC was recorded during P3 (1993 to 1995), respectively (Table 1). It is fundamental to note that, the trend of AFC over period of birth was inconsistent (Figure 1). An increasing trend of AFC observed in heifers that were born in between P1 and P3 (1987 to 1995), while decreasing trend was observed from P4- to P8 (1996 to 2010) (Figure 1).

Generally speaking, age at first calving of Holstein Friesian cows found in the present study showed a declining trend from period to period (Figure 1). This could be attributed to management fluctuation among years and the recommended amounts of energy were not fed for calves.

Calving interval (CI)

The overall least square mean of CI of 470.3±9.8 months found in this study differ from CI of 15 months (457.5±152.5 days) reported for Holstein Friesian cattle in the Hill country of Sri Lanka (Krishantan and Sinniah, 2014).

Despite this, the mean CI obtained in this study was higher than the least squares means of CI of 403.1 days (Hammoud et al., 2010), 408.09 days for HF in Pakistan (Sandhu et al., 2011), 433.12±6.70 days (Peters, 2007)

Table 2. Least square means ± standard errors of days open, calving interval and number of service per conception for the fixed effects of period of calving, season of calving and parity.

Source	N	DO (days)	N	CI (days)	N	NSC
		LSM±SE		LSM±SE		LSM±SE
Overall	56	228.2±10.2	55	470.3±9.8	98	1.32±0.03
CV (%)		60.22		23.12		42
		***		***		
P/calving						
P1 (1990-93)	74	272.6±19.9^{a}	35	467.58±20.3^{ab}	78	1.32±0.07^{ab}
P2 (1994-97)	70	245.2±19.3^{b}	72	496.9±16.2^{ab}	83	1.34±0.06^{ab}
P3 (1998-01)	163	225.4±14.2^{b}	103	436.1±14.5^{cb}	160	1.24±0.05^{b}
P4 (2002-05)	150	263.7±14.1^{ab}	153	488.8±12.7^{ab}	207	1.24±0.04^{b}
P5 (2005-09	72	214.9±18.7^{acb}	70	514.6±15.6^{a}	103	1.45±0.05^{a}
P6 (2010-15)	127	147.4±14.5^{c}	132	417.5±12.9^{c}	167	1.29±0.04^{ab}
		***		***		
S/calving						
Short rainy	148	250.7±14.5^{a}	131	476.1±12.7^{ab}	197	1.30±0.04
Long rainy	323	218.7±13.5^{b}	160	481±12.6^{a}	218	1.33±0.04
Dry	185	215.2±11.4^{b}	274	453.7±10.8^{b}	383	1.30±0.03
		***		***		
Parity						
1	208	294.7±10.5^{a}	4	433.3±57^{c}	229	1.38±0.03^{NS}
2	183	231.6±11.1^{ab}	185	538.7±8.5^{a}	204	1.29±0.04^{NS}
3	128	231.3±13.1^{ab}	149	474.9±9.5^{b}	152	1.33±0.04^{NS}
4	76	197,1±17.1^{bc}	109	466±11^{bc}	105	1.37±0.05^{NS}
5	35	196.2±24.7^{bc}	65	447±14.6^{bc}	61	1.28±0.07^{NS}
6	11	252.5±43.6^{ab}	30	452.5±20.8^{bc}	27	1.23±0.1^{NS}
7	15	194.5±37.7^{c}	23	478.7±23.7^{b}	20	1.30±0.12^{NS}

Means separated by different superscript letters under the same variable in one column are significantly different. *** = Significant (p<0.001), * = (p<0.05), NS=Not significant, N = number of records, CV= Coefficient of variation, P= Period, P/calving= period of calving, S/calving= season of calving.

and 445±90.8 days for Holstein Friesian cows in the three dairy herds; Holetta, Stella and Dinkity dairy farms of Ethiopia (Tadesse et al., 2010).

Therefore, the CI found in the present study is much longer than the value we expected from the calving interval of HF dairy cows kept under intensive management conditions. This longer calving interval would seem to show poor management of the existing farm including poor breeding management than most reports in the tropics. The LSM±SE of calving interval for the fixed effects of period of calving, season of calving and parity are summarized in Table 2. This finding demonstrated that period of calving (P<0.001), season of calving (P<0.05) and parity (p < 0.001) had source of variation on CI of HF dairy cows.

The study findings are consistent with previous reports in Ethiopia (Tadesse et al., 2010; Million and Tadelle, 2003). A study conducted by Melendez and Pinedo (2007) confirmed the significant effect (P<0.05) of season and year of calving on CI of Holstein Friesian cows in Chile. Furthermore, Peters (2007) and Iffa et al., (2006) supported the idea that parity was a source of variation for CI of Holstein Friesian cows. On the other hand, Mulindwa et al. (2006) in Uganda found that parity did not show significant affect on CI. This finding showed that, the highest calving interval was recorded at the cows that were calved during P5 (2007-10), whereas lowest during P6 (2011-15). Generally speaking, the trend of calving interval over several years was inconsistent (Figure 2).

The significant effect of season of calving is in line with the report of Hammoud et al. (2010) for Holstein Friesian cows under semi-arid conditions in Egypt. This finding noted that cows that were calved during dry season had better CI in contrast to short and long rainy season, respectively (Table 2). This might be due to rainy periods followed by dry periods, proved that cows calved in the dry season could take advantage of improved nutritional conditions during the subsequent rainy season. Cows with first parity recorded lowest CI, while highest at parity 2 (Table 2).

Days open (DO)

Days open is the part of the calving interval, longer days

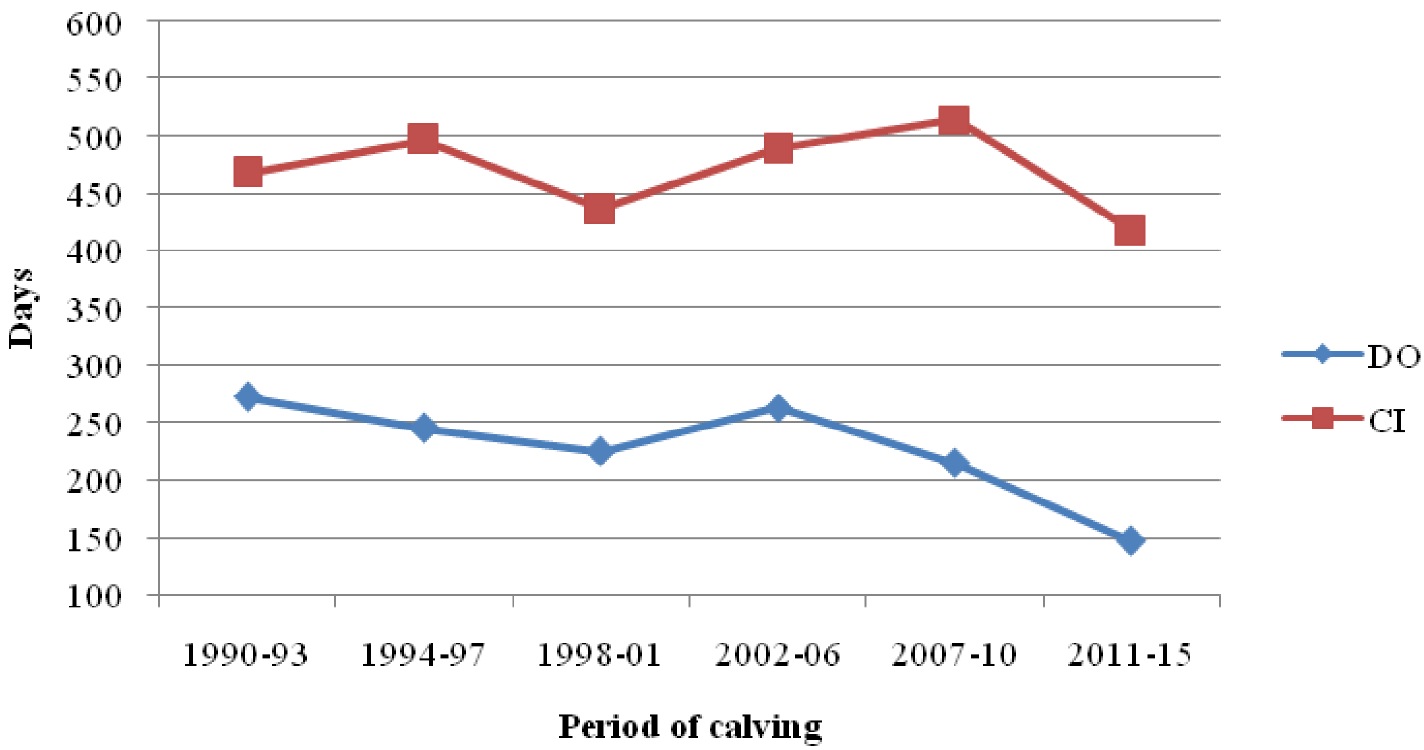

Figure 2. The trend of days open and calving interval of Holstein Friesian cows over a 25 year period in Alage ATVET College dairy farm.

open associated with decreased profitability in the private as well as state farm. The overall least square mean of DO of Holstein Friesian cows was estimated as 228.2±10.2 days (Table 2). This value was much higher than the estimates of 130.7 and 141 days as reported by Hammoud et al. (2010) and Shalaby et al. (2001), 167.79±7.08 days as reported by Peters (2007) and mean DO of 148±1.72 days with a coefficient of variation of 11% for HF cows in Ethiopia as reported by Tadesse et al. (2010). On top of that, DO of 150 and 205±2.6 days was reported for HF dairy cows in Turkey and Tanzania (Cilek, 2009; Asimwe and Kifaro, 2007), respectively.

As indicated in Table 2, period of calving (P< 0.001), season of calving (P<0.05) and parity (p< 0.001) showed source of variation on DO of HF dairy cows. Similar to the current study, significant effects of period of calving (P<0.001) on DO was reported by Asimwe and Kifaro (2007). A study by Melendez and Pinedo (2007) found that season and year of calving had significant effect (P<0.05) on DO. In contrast, Tadesse et al. (2010) reported non-significant effect of season of calving on DO of Holstein Friesian cows.

Mean days open was shortest during latter period (2011 to 2015), while longest during period 1 (1990 to 1993). The progressively decreased trend in days open over the period of calving is an indicative of improved management, adaptation of HF breed to the environment through time or both. Mean days open was highest at short rainy season, while there was no significance difference between long rainy season and dry season.

This study showed that mean days open significantly decreased from 1st to 5th parity, increased at 6th parity, while decreased again after parity seven (Table 2). Cows in the first parity had significantly longest DO, while shortest at 7th parity (Table 2). Despite the fact that, parity also resulted in significant variation for DO of Holstein Friesian cows and was lowest at first parity, while highest at 4th parity (Peters, 2007). The longer DO of cows calved in parity one and decreasing trend of DO with advancement in age in the current study agreed with the findings reported by Asimwe and Kifaro (2007).

Number of service per conception (NSC)

The average number of service per conception of Holstein Friesian cows in the present study was 1.32±0.03. The mean services per conception obtained in this study was lower than that of previous reports of 1.8±0.09 for Holstein Friesian dairy cows in Hossana, Ethiopia (Kebede, 2015), 1.81 for Holstein Friesian cows in central highlands of Ethiopia and Sri Lanka (Tadesse et al., 2010; Krishantan and Sinniah, 2014), 2.0 for Holstein Friesian cattle in Nigeria (Ngodigha et al., 2009)

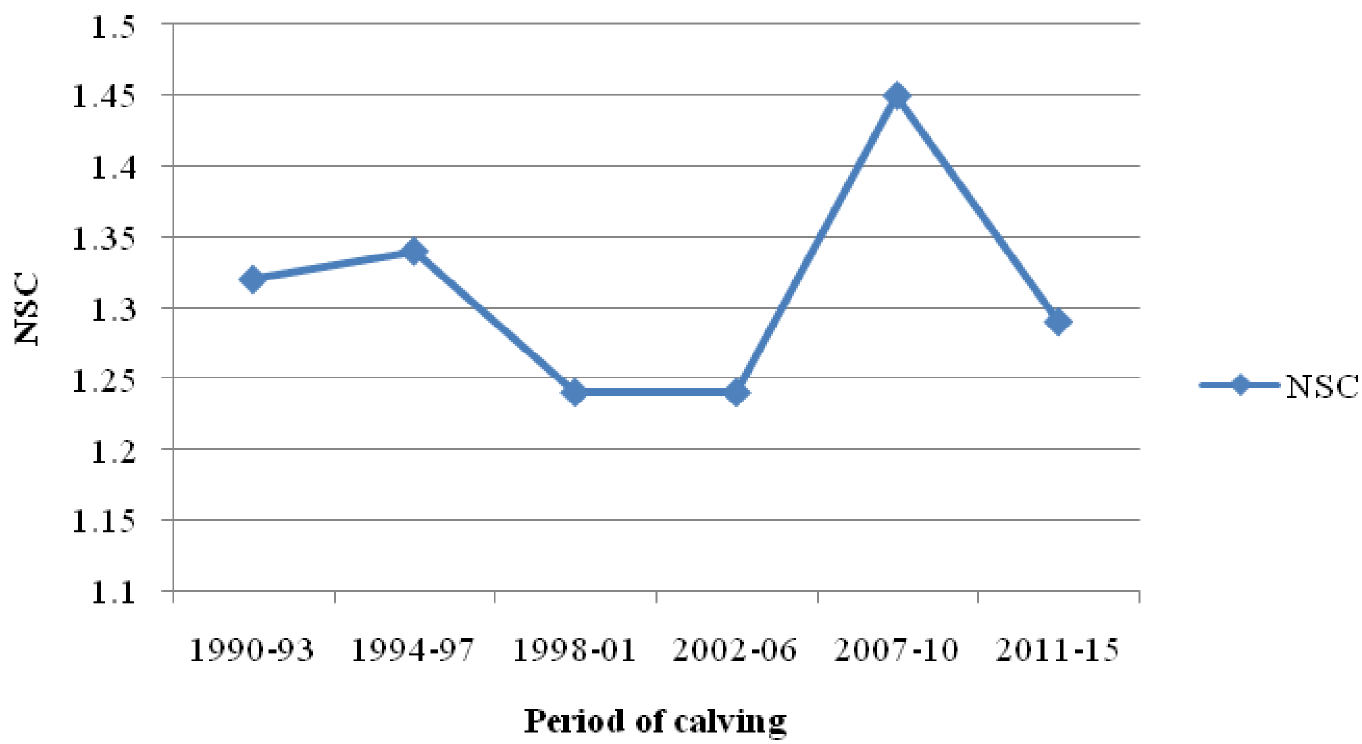

Figure 3. The trend of number of service per conception Holstein Friesian cows over a 25 year period in Alage ATVET College dairy farm

and 2.5 for Holstein Friesian in Iran (Ansari-Lari et al., 2010).

However, Heyredin (2014) reported that the NSC of HF cows was 2±1 in Holstein Friesian dairy cows at Holeta bull dam station and genesis farms, 1.67 as reported from mid Rift valley of Ethiopia (Yifat et al., 2009), 1.52 as reported by Dinka (2012). By far, NSC of 3.30 and 2.80 was reported (Lateef, 2007; Sandhu et al., 2011) for Holstein Friesian dairy cows in Pakistan. Variations in the environment, management, and the skill of AI technicians accounted for the observed differences in NSC. The study results of number of service per conception were good as compared to most reports in the tropics.

As indicated in Table 2, a significant effect of period of calving on number of service per conception (NSC) of Holstein Friesian cows was observed (P<0.05), while no significant difference was found on the effect of season of calving and parity to NSC. This study confirmed that, there was no significance difference between parities on NSC of HF dairy cows. Despite this, Heyredin (2014) and Tadesse et al. (2010) noted the significant effect of parity on NSC of HF cows. A study by Melendez and Pinedo (2007) found significant effect (P<0.05) of season and year of calving on NSC. Moreover, significant influence of period of calving on NSC (P<0.05) was reported by several authors; Besufkad (2008), Ngodigna et al. (2009), Avendaño-Reyes et al. (2010), Hammoud et al. (2010) and Motlagh et al. (2013). In contrary to the aforementioned report, non-significant effect of period of calving and season of calving was reported for NSC of HF cows in Ethiopia (Tadesse et al. 2010). The non-significant effect of season of calving in the present study well agreed to zero grazing practice in the farm, which makes the effects of seasonal variation in forage developments and feed availability minimal (Gebeyehu et al., 2007).

Mean number of service per conception was highest at the cows that were calved during P5 (2007 to 2010), while lowest at P3 and P4 (1998 to 2006), respectively. On the other hand, NSC showed inconsistent trend over period of calving. The inconsistent trend of NSC over period of calving proved negligible climatic condition, poor breeding including lack of skilled inseminator throughout the years.

CONCLUSIONS AND RECOMMENDATION

The average mean value found for NSC was surprisingly good as compared to other studies. Despite this, the values for the traits of age at first service, age at first calving, calving interval and days open were not ideal and below expectations. This poor performance was expected due to the fact that inability of higher graded cows to withstand the prevailing environmental and management condition. So there is room for improvement of these traits as better performances are also reported in the tropics.

Age at first service was significantly influenced by both period of birth and season of birth. Despite this, season of birth did not have significant effect on age at first calving. All fixed factors exerted significant variation on days open and calving interval of Holstein Friesian cows. However, there is a room for the improvement of these environmental factors to maintain the optimum calving interval and days open. This finding confirmed that highest coefficient of variation of DO would seem to suggest that poor record keeping practice and absence of selection in the farm.

The current study was also limited to see other factors like Dam line, Sire line and other dairy character traits. Therefore, further studies, which takes the above factors in to account are therefore required. Since period of calving and period of births had source variation on the reproductive traits, due attention for the inconsistent management practice across the years will help to address better productivity.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGMENTS

Above all, we would like to thank Alage ATVET College for their co-operation and support, without their help this work would not have been fruitful. We are also grateful to the farm attendants, farm managers, AI technicians and veterinary professionals working in dairy farms who agreed to participate in the study.

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Vol. 9(6), pp. 140-150, June 2018
DOI: 10.5897/IJLP2017.0444
Article Number: 9930E8A56979
ISSN 2141-2448

http://www.academicjournals.org/IJLP

International Journal of Livestock Production

Full Length Research Paper

Supplementary value of two *Lablab purpureus* cultivars and concentrate mixture to natural grass hay basal diet based on feed intake, digestibility, growth performance and net return of Horro sheep

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Received 25 December, 2017; Accepted 22 February, 2018

This study was undertaken with the aim to determine the supplementary value of Beresa-55 and Gebisa-17 cultivars and concentrate mixture to a basal diet of natural pasture hay based on growth performance, feed utilization, digestibility and net return of Horro sheep. A total of twenty five yearlings Horro sheep were stratified into five groups based on initial body weight in randomized complete block design and animals were assigned to the dietary treatments randomly: (T1) (Control): ad-lib natural grass + concentrate mixture at 2% BW, (T2): ad-lib natural grass + Gebisa-17cultivar at 1.5% BW, (T3): ad-lib natural grass + Gebisa-17 cultivar at 2% BW, (T4): ad-lib natural grass + Beresa-55 cultivar at 1.5% BW and (T5): ad-lib natural grass + Beresa-55 cultivar at 2% BW. Basal hay DM intake was relatively higher in T2 and T4, while total DM and CP intake was higher in T1 and T5. Similarly, significantly higher digestibility of DM, CP and organic matter (OM) was obtained in T1 and T5. Dietary treatments also significantly (P<0.01) influenced the weight gain of lambs. Lambs in T1 and T5 had shown better (P>0.01) weight gain and enhanced comparable growth performance than in the other treatments. However, partial budget analysis indicates that, T5 is more profitable and thus, can be used as a priority supplement in feeding of Horro sheep.

Key words: Horro sheep, *Lablab purpureus,* weight gain, digestibility, feed intake.

INTRODUCTION

Small ruminant production is an important agricultural activity and has a substantial contribution to smallholder farmers in generating income and securing food in developing countries (Kosgey et al., 2006). In Ethiopia, like other developing countries in sub Saharan Africa, small ruminant production is a major component of the livestock sector. According to CSA (2016) report, the total small ruminant population in Ethiopia is estimated to be

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about 60.9 million, out of which 30.7 million (about half) own sheep. Reports of Gizaw et al. (2013) indicated that, at the smallholder level, sheep are the major source of food security serving a diverse function including cash income, savings, cash for fertilizer purchase and socio-cultural functions.

Although, the contribution of sheep to the household economy is considerable, in the country however, their production is characterized by low productivity levels in terms of growth rate, meat production and reproductive performance (Adugna et al., 2000). Although, there are various and complex constraints which contribute to these reduced productivity of sheep, inadequacy of feed in terms of both quality and quantity is considered to be the most important limiting factor (Adane and Girma, 2008).

Maximization of livestock productivity in the tropical region largely depends on the efficiency of utilization of locally available protein sources (Kaya et al., 2006; Gul et al., 2010; Mulat et al., 2011). Concentrate feed resources especially grains are expensive and highly valued as human food. Therefore, it is imperative to look for other cheap and alternative feedstuffs to sustain and improve ruminant productivity. According to FAO (2002) suggestion, high quality feed for ruminants in developing countries can be achievable through intensive utilization of multipurpose trees and shrubs as they are easily produced and managed by livestock producers and have better nutritional quality nearly equivalent to grain based concentrates. In this regard, the use of leguminous forage crops such as *Lablab purpureus* capable of yielding quality herbage is crucial.

Gebisa-17 and Beresa-55 cultivar of *L. purpureus,* proved to produce high yields of dry matter, was released as a new variety for the study area as well as agro-ecologies similar to the study area. However, they contribute little to the much needed improvement of livestock production, because data regarding the supplementary value of these cultivars was scarce. With this in mind, this study was carried out to evaluate the supplementary value of these cultivars (Beresa-55 and Gebisa-17) and concentrate mixture supplemented on Horro sheep kept on basal diet of natural grass hay in varied levels in growth performance, feed utilization efficiency, digestibility and net return.

MATERIALS AND METHODS

Description of the study area

The study was conducted at Bako Agricultural Research Center (BARC). The location represents mid-altitude sub-humid maize growing agro-ecology of western Oromia, Ethiopia. The center is situated at latitude and longitude 9°06'N and 37°09'E, respectively, and it lies at an altitude of 1650 m above sea level with a mean monthly minimum and maximum temperatures of 11.23 and 31.74°C, respectively. During the study period, the area receives an annual rainfall of about 1316.7 mm where the highest rain was received between May and September.

Experimental feed preparation

Natural pasture grass was harvested manually from a naturally available grazing land found in the Center (Bako Agricultural Research Center) when it reached 40 to 50% flowering stage. Whereas, two newly released cultivars of *L. purpureus* labeled Beresa-55 and Gebisa-17 were established on about 0.5 hectare of land at livestock farm land of the center in early June 2016 cropping season. It was harvested at 50% flowering, chopped with chopping machine to 3-5 cm length, field-cured 2-3 days, baled and stored in a roofed hay barn. Wheat bran (WB) and linseed cake (LSC) sufficient for the entire experimental period were purchased and stored at animal farm feed storage site.

Experimental design and treatments

Randomized complete block design was used for the study in which experimental lambs were blocked in to five groups each containing five lambs. Grouping of lamb into the respective blocks were done based on their initial live weight taken in the morning before feeding and watering. The natural pasture grass composed of mainly *Cynodon dactylon*, which is a common diet that the livestock in the study area graze, this was fed *ad libitum* (allowing for a 20% refusal on DM basis). However, supplemental feeds were offered on body weight basis considering 1.5 and 2%. The composition of linseed cake (LSC) and wheat bran (WB) was calculated based on their CP content obtained from laboratory analysis with the proportions, LSC 30%; WB 70%, chosen to provide 19.93% CP to make it isonitrogenous level with one of the cultivar containing higher CP, Beresa-55 cultivar contained 19.93% CP.

Amount of supplemental feeds were adjusted every fifteen (15) days according to the body weight change. Therefore, the dietary treatments were: *Ad-lib* natural grass + concentrate mixture at 2% BW (T1); *Ad-lib* natural grass + Gebisa-17cultivar hay at 1.5% BW (T2); *Ad-lib* natural grass + Gebisa-17cultivar at 2% BW (T3); *Ad-lib* natural grass + Beresa-55 cultivar at 1.5% BW (T4) and *Ad-lib* natural grass + Beresa-55 cultivar at 2% BW (T5).

Experimental animal and their management

A total of twenty five (25) yearling Horro Lambs weighing initial body weight of 18.5 ±1.99 kg (mean ± standard deviation) were purchased in two rounds from the local market in Gobu Seyo District, western Oromia, Ethiopia. All lambs were ear tagged for ease of identification, de-wormed with antihelmintics (Fasionox 250 mg) to control internal parasites and sprayed with accaricides (Betazone diluted at 1.6 ml/L of water) for external parasites control as prescribed by the manufacturer before the commencement of the trial on their arrival at the center. At the end of the quarantine period, all lambs were tied in to their respective individual pens and offered the experimental diet for 15 days to get them accustomed to the experimental feeds before commencing the actual feeding trial lasting for 90 days.

Measurements and observations

Feeding trial

At the end of the adaptation period, the actual feeding trial took place by offering the experimental diet for 90 days. Experimental diets were offered as per the respective treatment in two equal portions at 08:00 and 16:00 h, respectively. For each experimental lamb, the amount of feed offered and the corresponding refusals were recorded daily to measure daily feed intake as a difference between feed offered and refused over the experimental period.

Samples of feed offered and refusal were pooled per treatment, thoroughly mixed and sub sampled at the end of the experiment for chemical analysis. Data on feed intake was taken on daily basis. The daily DM intake expressed as percent of body weight and metabolic body weight of lambs were calculated by dividing the mean daily DM intake during 90 days of experimental period with respective body weight of lambs taken in the same period by employing the following formula:

$$\text{Total DM intake (percent body weight)} = \frac{\text{DM intake (g)}}{\text{Body weight (kg)}} \times 100$$

$$\text{Total DM intake (metabolic body weight (g/kgW}^{0.75}) = \frac{\text{DM intake (g)}}{\text{BW}^{0.75}\text{ (kg)}} \times 100$$

Digestibility trial

Digestibility trial was started following the completion of the growth trail. Before the commencement of the actual digestibility trial, lambs in all groups were fitted with fecal collection bags and allowed to adapt for three days. Thereafter, the actual data collection was followed for another 7 days. Within these days, excreted feces were collected, weighed, recorded and thoroughly mixed per day from each lamb separately. Then, twenty percent (20%) of these daily fecal outputs of each lamb were sub-sampled and pooled in plastic bags and stored deep frozen at -20°C. The daily obtained sub-samples were thoroughly mixed and pooled for individual lamb at the end of digestibility trial for chemical analysis. The apparent digestibility coefficients of nutrients and estimated metabolizable energy intakes were calculated by using the equation of McDonald et al. (2002):

$$\text{Apparent digestibility coefficient (\%)} = \frac{\text{Nutrient in feed} - \text{Nutrient in feces}}{\text{Nutrient in feeds}} \times 100$$

Estimated metabolizable energy intakes of lambs from experimental feeds were also estimated using the formula: ME (MJ Kg^{-1} DM) = DOMD × 0.016: Where DOMD is gram digestible organic matter per kilogram dry matter. Digestible organic matter contents of treatment feeds were estimated by multiplying the OM content of feed by its digestibility coefficient.

Body weight change

Lambs in all groups were weighed on the first day of the actual feeding trial to get their initial body weight. Thereafter, weight record was taken every fifteen (15) days interval in the morning before the morning feeding and watering. Average daily BW gain, FCE and FCR for each lamb were determined using the following equation (Gulten et al., 2000; Brown et al., 2001):

$$\text{Average daily BW gain} = \frac{\text{Final body weight - initial body weight}}{\text{Number of feeding days}}$$

$$\text{FCE} = \frac{\text{Body weight gain (g/day)}}{\text{Body weight gain (g/day)}}$$

And

$$\text{FCR} = \frac{\text{DM intake (g/day)}}{\text{DM intake (g/day)}}$$

Chemical analysis

Chemical analyses of the experimental feeds and feces were conducted at Holeta Agricultural Research Center National Animal Nutrition Laboratory, Holeta, Ethiopia. Samples of feeds offered, refusals and feces were collected, dried in an oven at 65°C for 72 h and ground to pass through 1 mm sieve screen size. Dry matter (DM), nitrogen content (N) and ash were analyzed according to AOAC (2005) procedure, and organic matter (OM) was calculated by deducing the value of ash content from 100. Crude protein (CP) was estimated by multiplying N value by a factor of 6.25 as N × 6.25. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were analyzed using the procedures of Van Soest et al. (1991). The *in vitro* DM (IVDMD) digestibility was determined using Tilley and Terry (1963) method.

Partial budget analysis

The partial budget analysis was done according to Upton (1979) to determine the economic advantage of supplementing the two *Lablab purpureus* cultivars and concentrate mixture on pasture grass based diets of lambs in varied level. The partial budget analysis was based only on the variable cost of lambs, feeds and benefits from the result, without considering other cost like labor, housing, watering and veterinary service which was common for all treatments. The difference between purchasing and selling price of sheep were taken as total return (TR) in the analysis. Hence, the net income (NI) was calculated as the difference between total return (TR) and total variable cost (TVC) while, the change in net income (ΔNI) was calculated as difference between change in total return (ΔTR) and change in total variable cost (ΔTVC).

Statistical analysis

Analysis of variance (ANOVA) following the General Linear Model (GLM) procedure of SAS (SAS, 2002, version 9.1.3) was used to analyze the data. To describe the effect of CP intake on average daily body weight gain, regression analysis was also employed. Significantly different treatment means were separated using least significant difference (LSD) test at 5% level of significance. The model fitted for the experiment was:

$$Y_{ij} = \mu + T_i + B_j + E_{ij}$$

Where, Yij = response variable, μ = overall mean effect, Ti = treatment effect, Bj = block effect, Eij = random error.

RESULTS AND DISCUSSION

Chemical composition of feeds

For all experimental feeds, the dry matter (DM) and organic matter (OM) content was almost similar however, variation was observed in the remaining nutrient components. Crude protein (CP) content of Beresa-55 (19.93%) cultivar was comparable to the value 19.92 and 20.2% reported by Worknesh (2014) and Hunegnaw and

Berhan (2016), respectively. However, Gebisa-17 (16.06%) cultivar used in the current study had relatively lower CP value than the value reported by these authors. Norton (1982) reported that, most herbaceous legumes have CP content which is usually required to support lactation and growth (greater than 15%), suggesting the adequacy of herbaceous legumes to supplement basal diets of predominantly low quality pastures and crop residues. Hence, the CP content of the two *lablab* cultivars used in the current study agrees with this report and thus, can be used as a supplement to low quality feedstuff.

The linseed cake meal used in this study had higher level of DM (92.33%), CP (29.43%), ADF (19.2%) and ADL (7.17%) than the result reported by Abebe (2006) for the same nutrient types. However, higher value of NDF (39.9%) and OM (93.1%) was reported by the same authors as compared to the result obtained in the current study. The CP (15.98%) value of wheat bran used in this study was higher than 13 and 15.24% reported by Teklu (2016) and Abebe (2006), respectively. However, it was lower than the level of 17.4 and 17.9% reported by Worknesh (2014) and Dereje (2015), respectively. On the other hand, the DM, ash, DOMD, ADL, ADF and NDF obtained in the current study for WB was higher than the values, in percentage, of 88.09, 4.89, 72.35, 3.07, 13.97 and 43.73 as reported by Mekonnen et al. (2016).

Natural grass hay used in the present study contained lower levels of CP (7.07%) and DOMD (35.44%), but higher value of NDF (52.82%) as compared to the rest treatment feeds. Diriba et al. (2013) who conducted study around the current study area, reported higher value of DOMD, ADF, NDF and ash ranging in percentage from 59.3 to 61.5, 39.7 to 50.3, 55.7 to 72.1 and 9.5 to 10.1%, respectively. But, relatively lower level of ADL (5.4 to 6.5%) and CP (5.2 to 6.4%) and comparable level of DM (90.2 to 93.7%) was also reported by the same authors. Regarding hay refusal, the CP and DOMD content was reduced and that of NDF, ADF and ADL was increased as compared to the hay offered, indicating selectivity by animals for nutritious parts of the hay, although there was an attempt to decrease selectivity by chopping in this study.

Dry matter and nutrient intake

There was a significant difference (P<0.05) in hay and total dry matter intake among treatments (Table 2). Lambs in T2 and T4 had shown similar (P>0.05) intake of basal hay and significantly higher (P<0.05) than lambs in T3, but not statistically different from those in T1 and T5 (P>0.05). In line with the present study result (411.61 to 531.14 g/day), basal hay intake ranging from 365.8 to 540 g and 336 to 591 g was reported by Fentie (2007) and Berhanu et al. (2014) for Farta and Washera sheep, respectively. However, the basal hay intake reported by Jalel (2013) and Mekonnen et al. (2016) for the same sheep breed was within the range of 591.9 to 698 g and 465 to 615 g, respectively, which is somewhat higher than the values obtained in the current study. This difference could possibly be associated with provision of supplements based on BW for all treatment groups in the current study.

Lambs in T1 had consumed more total DM (P<0.05) as compared to those in T2, T3 and T4. However, the total DM intake of lambs in T1 had no significant difference (P>0.05) from lambs in T5 whereas, equal (P>0.05) amount of total DM intake was consumed among lambs in T2, T3, T4 and T5. The total DM intakes of the current study (783.57 to 893.91 g) fall within the range of values of 575 to 844.16 g and 190.1 to 883 g reported by Yohannes (2011) and Firisa et al. (2013), respectively for Black head Ogaden sheep fed different level of corn silage with linseed meal and Horro lambs fed graded level of *Vernonia amygdalina* leaves and sorghum grain. Mulat (2006) also reported DM intake of 480 to 498 g/day for local lambs fed finger millet straw basal diets and different level of concentrate supplements, which is lower than the values of the current study.

The result of total DM intake as a proportion of percent BW and per unit metabolic body weight basis of the current study had shown no significant variation (P>0.05) across treatments. Devendra and Burns (1983) reported that, the total DM intake on %BW basis was within the range of 2.5 to 3.9% for various breeds of sheep and goats in the tropics, which is in agreement with the current study (3.45 to 3.81%). Similarly, the DM intake per unit metabolic BW (75.23 to 81.69 g/kg) based on the current study agreed with the finding of Birhanu et al. (2013) and Jalel (2013) who reported 75.02 to 86.66 g/kg for Black Ogaden sheep and 76.2 to 85.9 g/kg for Horro sheep, respectively.

In the current study, dietary treatments significantly influenced intake of ADF, OM and ash but not NDF and ADL. Lambs fed concentrate mixture diets in T1 had lower value of ADF and ash intakes as compared to the rest treatment groups. The likely reason for this difference could be related to the lower content of ADF and ash in WB and LSC as compared to that contained in the two *Lablab* cultivars. The OM intake in the current study was higher for lambs fed diets in T1 and T5 than lambs fed in the other treatments which followed the same trend for DM intake as it is the reflection of total DM intake.

Intakes of CP was also significantly affected (P<0.001) by treatment diet; it was higher for lambs in T1 (116.36 g/day) fed concentrate mixture followed by those in T5 (109.68 g/day) fed Beresa-55 cultivar. However, with the exception of T2 (81.7 g/day) which had lower CP intake, no significant difference (P>0.05) in CP intake was obtained between lambs in T3 and T4. The higher value of CP intakes by lambs in T1 and T5 might be associated with their higher total DM intake attributed to their level of

Table 1. Chemical composition of experimental feeds

Feed samples	DM (%)	Nutrient composition (DM%)						
		Ash	CP	NDF	ADF	ADL	OM	DOMD
Beresa-55	91.51	9.50	19.93	41.01	37.57	6.31	90.50	55.13
Gebisa-17	92.10	9.53	16.06	45.00	39.63	7.90	90.47	57.07
LSC	92.33	7.02	29.43	34.56	19.20	7.17	92.98	71.04
WB	92.88	5.25	15.98	46.08	14.74	3.93	94.75	76.78
NG	92.71	8.40	7.07	52.82	37.59	6.71	91.60	35.44
Hay refusal								
T1	90.67	7.10	5.83	63.99	53.71	10.73	92.90	30.12
T2	92.32	7.98	5.98	67.85	52.19	10.38	92.02	31.97
T3	90.13	7.03	6.09	65.09	54.83	11.79	92.97	31.35
T4	92.07	7.55	6.17	68.8	49.89	12.01	92.45	32.07
T5	91.52	7.61	5.69	64.52	52.47	11.91	92.39	31.55

LSC = Linseed cake; WB = wheat bran; NG = natural grass; DM = dry matter; CP= crude protein; NDF= neutral detergent fiber; ADF= acid detergent fiber; ADL= acid detergent lignin; OM= organic matter; DOMD = digestible organic matter in dry matter; ME = metabolizable energy; T1 to T5 = treatments.

supplements (2% of their BW) as well as higher CP content of their supplements. Comparable values to the current study were reported by Abraham (2015) who reported CP intake of 54.78 to 114.91 g/day for Begiat sheep. However, Firisa et al. (2013) and Mekonnen et al. (2016) reported CP intake ranging from 11.2 to 86.9 and 93.9 to 145.1 g/day, respectively. CP intake of the present study was lower in the case of the first author but higher than result of the second author. The possible reason for this difference could be possibly related to the type and quality of feeds supplemented for sheep in the study.

Intake of ME also significantly varied (P<0.001) among treatments, where significantly higher (P<0.001) value was recorded for lambs in T1 (7.69 MJ/day) followed by T5 (6.02 MJ/day) and the least one was obtained from lambs in T4 (5.31 MJ/day). The higher ME intake of lambs in T1 could most probably be related to the DOMD content of their supplemental feeds (Table 1). Comparable level of ME intake with the current study was reported by Fentie (2007) for Farta sheep (4.55 to 7.52 MJ/day) supplemented with noug seed cake (*Guizotia abyssinica*), wheat Bran and their mixture. Moreover, Yeshambel et al. (2012) also reported ME intake of 5.2 to 6.4 MJ/day for Washera sheep fed mixture of lowland Bamboo (*Oxytenanthera abyssinica*) leaves and natural pasture grass hay at different ratios, which is in agreement with the present study result.

Dry matter and nutrient digestibility

Significant differences were observed among treatments in digestibility of DM, CP and OM. However, treatment effect was not significant for digestibility of NDF and ADF (P>0.05). Lambs fed diets in T1 had significantly higher digestibility of DM (P<0.01) and OM (P<0.05) as compared to those lambs in T2, T3 and T4, but not different from lambs in T5 (P>0.05). The relatively higher digestibility value of DM and OM in T1 and T5 than the rest treatments could be associated with increased nutrient, such as CP and ME (Table 2) supply to rumen microbes for their proliferation to be presented abundantly to colonize and digest more of the DM or OM consumed (Bonsi et al., 1996). Similar to the current study, Awet and Solomon (2009) reported significant variation in apparent digestibility of DM and OM for Afar sheep fed urea treated teff straw supplemented with graded level of wheat bran. Similarly, Getahun (2014) reported that lambs supplemented with 300 g/day of leucaena to untreated wheat straw significantly increased the apparent digestibility coefficients of DM and OM compared to the sole untreated straw. However, contrary to the previous authors and the current study, Dawit and Solomon (2009) reported non-significant difference in the digestibility of the same nutrients in Arsi Bale sheep fed urea treated barley straw supplemented with Lucerne or vetch hay. The difference might be related to the age of animals, level of feeding, feed and ration composition used for the study (Rajihan, 1999).

Significant variation (P<0.05) in digestibility of CP was also observed among treatments, where statistically higher value was obtained from lambs fed diets in T1 followed by lambs in T4 and T5. In agreement with the present study, significantly different apparent digestibility of CP was reported by Berhanu et al. (2014) in Washera sheep. Firisa et al. (2013) also reported significantly improved digestibility of CP in Horro lambs supplemented with graded level of *V. amygdalina* leaves and sorghum grain mixture. Furthermore, Mulat (2006) reported that

Table 2. Nutrient intake of Horro lambs supplemented with Gebisa-17 and Beresa-55 cultivars of *L. purpureus* and concentrate mixture.

Intake (g/day)	Treatments					SEM	SL
	T1	T2	T3	T4	T5		
DM intake (g/day)							
Basal hay	482.71^{ab}	531.14^{a}	411.61^{b}	498.99^{a}	459.89^{ab}	25.64	*
Beresa-55	-	-	-	281.00	387.20	-	-
Gebisa-17	-	274.90	372. 00	-	-	-	-
Concentrate mixture	411.20	-	-	-	-	-	-
Total DM intake	893.91^{a}	806.03^{b}	783.57^{b}	779.94^{b}	847.10^{ab}	25.64	*
DM intake (%BW basis)	3.52	3.81	3.55	3.45	3.51	0.11	Ns
DM intake (g/kgW$^{0.75}$)	79.00	81.69	76.91	75.23	77.82	2.10	Ns
Nutrient intake (g/day)							
NDF	430.30	404.30	384.79	378.78	401.71	13.54	Ns
ADF	247.54^{b}	308.60^{a}	302.13^{a}	293.12^{a}	318.35^{a}	9.64	**
OM	829.60^{a}	735.22^{b}	713.55^{b}	711.34^{b}	771.68^{ab}	23.49	*
Ash	64.31^{c}	70.81^{ab}	70.02^{ab}	68.60^{bc}	75.42^{a}	2.15	*
ADL	52.53	57.36	57.00	51.21	55.29	1.72	Ns
CP	116.36^{a}	81.70^{d}	88.84^{c}	91.27^{c}	109.68^{b}	1.81	***
ME (MJ/day)	7.69^{a}	5.52^{c}	5.73b^{c}	5.31^{c}	6.02^{b}	0.15	***

^{a,b,c,d}Means within a row with different superscripts differ significantly (P < 0.05); *P < 0.05; **P < 0.01; ***P < 0.001; SL: significance level; SEM (Mean ± SE) = standard error of means; ns = non-significant; T1 to T5 = treatments; BW = body weight; DM = dry matter; CP = crude protein; OM = organic matter; NDF = neutral detergent fiber; ADF = acid detergent fiber; ADL = acid detergent lignin; ME = metabolizable energy.

digestibility of CP for sheep fed basal diets of finger millet straw were improved when supplemented with different protein sources. However, non-significant variation of CP digestibility was reported by Diriba et al. (2015) who supplemented Hararghe highland sheep with fig (*Ficus sur*). This difference in CP digestibility could be due to supplements used and level of supplementation provided.

Body weight change and feed conversion efficiency

Statistically significant (P<0.01) difference were seen among experimental lambs in their final body weight (FBW) gain. The higher FBW was displayed by lambs in T1 (25.4 kg) and T5 (24.17 kg). However, lambs in T2, T3 and T4 had almost similar FBW (P>0.05) of 21.24, 22.07 and 22.64 kg, respectively. Lambs in T2, T3 and T4 grew lower by 4.1, 3.33, 2.76 and 2.93, 2.1, 1.53 as compared to the growth rate of lambs fed treatment diets in T1 and T5, respectively. Similar trend was also observed among all treatments in BW change and ADG attributes, which took similar trend like that of FBW. This appears to be consistent with difference in nutrient digestibility like, DM, CP and OM (Table 3) that might have resulted in difference in nutrient intake available for absorption and metabolism.

The absence of statistical variation in FBW, BWC and ADG attributes observed among lambs fed concentrate mixture (T1) and Beresa-55 cultivar (T5) showed that, the supplements were comparable in their potential to supply nutrients for improving the weight gains of the lambs. According to Nsahlai and Umunna (1996), the nitrogen in *L. purpureus* is rapidly degradable in the rumen which is valuable to meet the requirements of rumen microorganisms for efficient degradation of low quality roughages. Similar to this result, Koralagama et al. (2008) found no significant differences in ADG of Ethiopian sheep fed maize stover basal diet supplemented with commercial concentrate and either cowpea type (genotype 12688 and IT96D-774) at high level or between cowpeas at low level of supplementation. Similarly, Worknesh (2014) also reported the absence of significant difference in the FBW and ADG among dorper×afar f1 sheep supplemented with 300 g/day concentrate mixture and those fed 299 g/day of *Leucaena leucocephala*.

The ADG of lambs in T1 (75.56 g/day) fed concentrate mixed ration in the present study were higher than the value reported by Shashie et al. (2017). The author reported a daily live weight gain of three Ethiopian sheep breeds fed hay supplemented with concentrate mixture at two levels, 1.5 and 1.75% BW, was 59.8, 49.2 and 43.3 g/day for Horro, Black Ogaden and Washera breeds, respectively. The variation in ADG might be obtained from difference in the level of supplements, which was

Table 3. Digestibility coefficient (%) in Horro lambs supplemented with Gebisa-17 and Beresa-55 cultivars of *Lablab purpureus* and concentrate mixture

Parameters	Treatments					SEM	SL
	T1	T2	T3	T4	T5		
DM	67.62[a]	55.18[c]	59.21[bc]	55.17[c]	64.71[ab]	2.27	**
CP	69.91[a]	53.45[c]	60.36[bc]	62.13[ab]	64.21[ab]	2.84	*
OM	68.10[a]	55.93[c]	60.76[bc]	57.37[bc]	63.04[ab]	2.33	*
NDF	56.70	48.16	44.35	46.78	52.51	3.57	Ns
ADF	44.88	47.16	42.38	43.65	50.24	3.33	Ns

[a,b,c]Means within a row with different superscripts differ significantly ($P < 0.05$); *$P < 0.05$; **$P < 0.01$; SL: significance level; SEM (Mean ± SE) = standard error of means; ns= non-significant; T1 to T5 = treatments; DM= dry matter; CP= crude protein; OM = organic matter; NDF= neutral detergent fiber; ADF = acid detergent fiber.

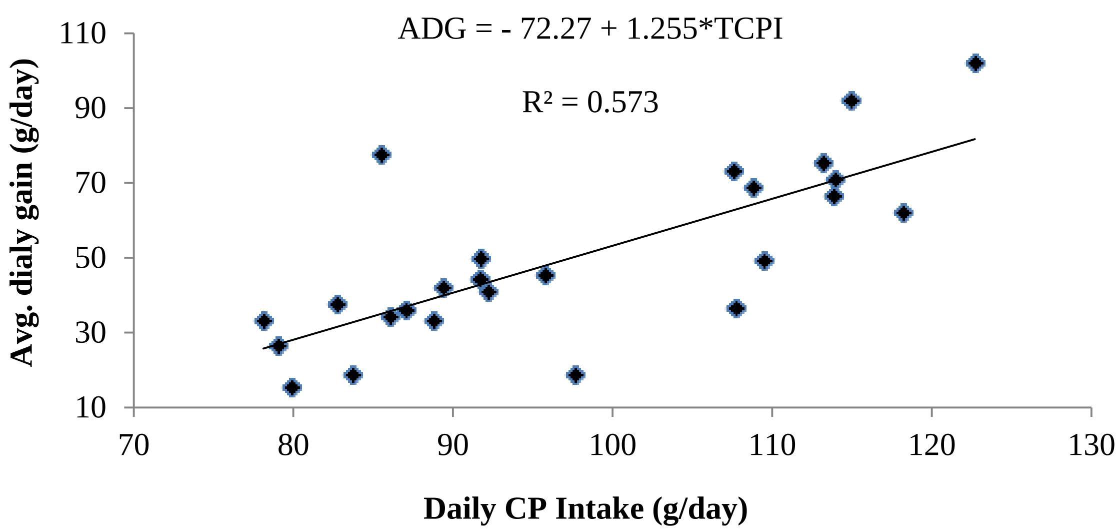

Figure 1. Regression of body weight gain on CP intake of Horro lambs supplemented with Gebisa-17 and Beresa-55 cultivars and concentrate mixture.

2% BW in the present study. On the other hand, Ermias (2008) reported higher value of ADG (87.8 g/day) for Arsi-Bale sheep fed faba bean haulms supplemented with different proportion of Barley bran and lean seed meal as compared to lambs in T1 of the present study. This variation might be the result of the variation in the basal diets used between experiments.

Similarly, lambs fed Beresa-55 cultivar in T5 of the current study had ADG of 64.11 g/day which is lower than the value reported by Mekonnen et al. (2016) who found 87.4 g/day for Horro sheep supplemented with *L. purpureus, Cajanus cajan* and their mixture. The lower ADG in the present study might be due to the lower CP intake of lambs, 109.68 g/day than 145.1 g/day reported by Mekonnen et al. (2016). However, lower value of ADG of 34.7, 20.33 and 49.36 g/day for Wollo sheep supplemented with pigeon pea (*C. cajan*), cowpea (*Vigna unguiculata*) and lablab (*L. purpureus)* respectively was reported by Hunegnaw and Berhan (2016) as compared to lambs in T5 of the present study. Moreover, Jalel (2013) who fed wild silver leaf Desmodium (*Desmodium unicinatum*) in graded level to the same sheep breeds used in the current study reported ADG of 68.9 g/day which is almost comparable value to the average daily gain obtained in T5 of this study.

The regression of ADG on the crude protein intake (Figure 1) indicated the role of CP intake on daily live weight gain which is explained by the value of coefficient of determination (r^2 = 57.3%). Thus, it can be considered that the higher daily weight gain of lambs in T1 (75.56 g/day) and T5 (64.11 g/day) might be most probably associated with their higher CP intake (Table 2). This in part could also be due to the higher digestibility of CP (Table 3) of lambs in this treatment as compared to the rest treatments. In agreement with the pattern observed in the current study, Biru (2008) reported that crude protein intake had contributed much which is about 64.38% of daily weight gain of Adilo sheep supplemented

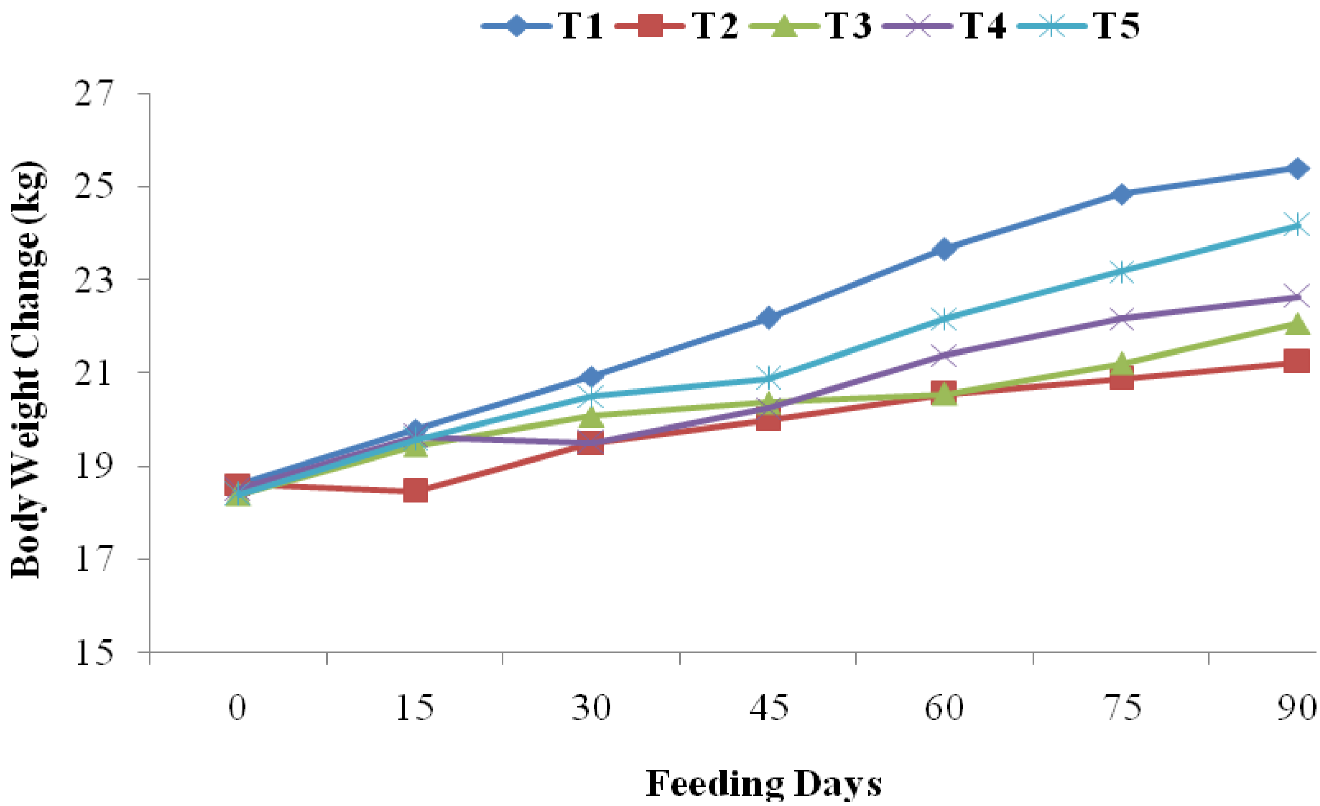

Figure 2. Body weight change trend of Horro lambs supplemented with Gebisa-17 and Beresa-55cultivars of *Lablab purpureus* and concentrate mixture

Table 4. Body weight gain of Horro lambs supplemented with Gebisa-17 and Beresa-55 cultivars of *L. purpureus* and concentrate mixture

Parameters	Treatments					SEM	SL
	T1	T2	T3	T4	T5		
Initial body weight (kg)	18.60	18.60	18.40	18.50	18.40	0.86	Ns
Final body weight (kg)	25.40[a]	21.24[c]	22.07[c]	22.64[bc]	24.17[ab]	0.68	**
Body weight change (kg)	6.80[a]	2.64[c]	3.67[c]	4.14[bc]	5.77[ab]	0.64	**
Average daily gain (g/day)	75.56[a]	29.33[c]	35.89[c]	46.00[bc]	64.11[ab]	7.33	**
Feed conversion efficiency	0.08[a]	0.04[b]	0.05[b]	0.06[ab]	0.07[a]	0.01	*
Feed conversion ratio	12.12[b]	30.10[a]	23.62[ab]	21.57[ab]	14.53[b]	4.18	*

[a,b,c]Means within a row with different superscripts differ significantly (P < 0.05); *P < 0.05; **P < 0.01; SL: significance level; SEM (Mean ± SE)=standard error of means; ns= non-significant; T1 to T5 = treatments

with sweet potato tuber and Haricot bean screening.

In the present study, higher value in FCE was obtained by lambs in T1 (0.08) followed by T5 (0.07) > T4 (0.06) > T3 (0.05) > T2 (0.04). Contrary to this, higher value for FCR was obtained by lambs fed T2 (30.10) diets followed by T3 > T4 > T5 and the least by T1. As reported by Brown et al. (2001), animals that have a high FCE and low FCR are considered as efficient users of feed. Hence, based on the finding of this study, it can be concluded that, lambs fed diets in T1 and T5 were more efficient in their feed utilization potential than those lambs fed on other treatment groups.

In general, the trend of body weight change (kg) across the ninety (90) feeding days (Figure 2) showed that, growth performances of sheep positively increased. Higher growth rate was noticed for lambs in T1 relative to those in T5 followed by T4 > T3 > T2 in their respective order (Table 4). Nevertheless, from the current study, it can be generalized that, all treatment diets positively promoted FBW, ADG and FCE which suggests the

Table 5. Partial budget analysis of Horro lambs supplemented with Gebisa-17 and Beresa-55 cultivars of *L. purpureus* and concentrate mixture.

Parameters	Treatments				
	T1	**T2**	**T3**	**T4**	**T5**
Purchase price per lamb (ETB/lamb)	740	720	725	745	730
Hay consumed (kg/lamb)	43.44	47.8	37.04	44.91	41.39
Concentrate consumed (kg/lamb)	37.01	-	-	-	-
Beresa-55 (kg/lamb)	-	-	-	25.29	34.85
Gebisa-17 (kg/lamb)	-	24.74	33.48	-	-
Feed cost (ETB/lamb)					
Cost of hay	86.88	95.6	74.08	89.82	82.78
Cost of concentrate	203.56	-	-	-	-
Cost of Beresa-55	-	-	-	75.87	104.55
Cost of Gebisa-17	-	74.22	100.44	-	-
Total Variable Cost (TVC)	290.44	169.82	174.52	165.69	187.33
Selling price of lambs	1400	1300	1320	1330	1360
Total return (TR)	660	580	595	585	630
Net return (ETB/lamb)	369.56	410.18	420.48	419.31	442.67
Change in total return	-	-80	-65	-75	-30
Change in net return (ΔNR)	-	40.62	50.92	49.75	73.11
Change of total variable cost (ΔTVC)	-	-120.62	-115.92	-124.75	-103.11

ETB/lamb = Ethiopian birr per lamb.

comparative nutritional values of the two *L. purpureus* forage cultivars in general and Beresa-55 cultivar in particular relative to the concentrate feeds used in the current study if supplemented on local lambs fed with poor quality feed resources.

Partial budget analysis

Partial budget analysis was done to determine the economic advantage of supplementing either the two *L. purpureus* cultivars or concentrate mixture to Horro lambs based on basal diets of natural grass hay and to select and recommend the best treatment with better growth performance, low cost and high net return.

In the current study, the partial budget analysis revealed that, the value of total return was higher for lambs in T1 and T5 than for lambs in the other treatments (Table 5). However, lambs in T5 (442.67 ETB/lambs) had the highest net return, whereas, the lowest net return was received by lambs fed concentrate mixture diets in T1 (369.56 ETB/lambs). In general, the partial budget analysis result suggests that, Beresa-55 cultivar fed to lambs in T5 at 2% BW resulted in relatively lower feed cost (lower by 35.5%), higher net return (higher by 19.78%) as compared to the conventional concentrate mixture based diets fed to lambs in T1. Thus, supplementation with Beresa-55 cultivar at 2% BW had high profit margin in the diets of Horro sheep based on basal diets of natural grass hay than the rest supplemental regime.

Conclusion and recommendation

Generally, for almost all measured parameters, no appreciable differences (P>0.05) in terms of sheep performance were observed among experimental sheep that received concentrate mixture (T1) and Beresa-55 cultivars (T5). Based on biological performance result, lambs in T1 and T5 induced comparable response and were better than lambs fed the other treatment diets. However, partial budget analysis result revealed that, lambs in T5 exhibited lower feed cost and higher net return as compared to those in T1, signifying the need to seize the opportunity to replace conventional and most expensive protein supplement with cost effective on-farm grown herbaceous forage legume under Ethiopian condition. Therefore, it can be concluded that supplementation of Beresa-55 cultivars (T5) at 2% body weight resulted in more profit, and could be used as an alternative feed supplement for low quality roughage in feeding Horro lambs. However, to generate additional information and fill the gap of the current study, on farm research on the supplementation to locally available crop residue and grazing has to be investigated under actual farmer management conditions.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Vol. 9(6), pp. 151-159, June 2018
DOI: 10.5897/IJLP2017.0425
Article Number: 2C4224357041
ISSN 2141-2448

http://www.academicjournals.org/IJLP

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International Journal of Livestock Production

Full Length Research Paper

Indigenous breeding practices and selection criteria of sheep breed in central zone of Tigray, Northern Ethiopia

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Received 15 November, 2017; Accepted 17 January, 2018

This study was conducted with the aim to generate organized information on traditional breeding practices and selection criteria for indigenous sheep types in three districts of central zone of Tigray, North Ethiopia. A total of 180 households were randomly sampled for the interview. A semi-structured questionnaire and group discussion were further used to gather information on sheep breeding practices and selection criteria. The primary reason for keeping sheep in Tanqua-Abergelle and Kola-Tembien districts were manure as sources of fertilizer, while in Adwa district cash income. In all the study districts the flock structure were dominated by breeding ewes and they accounted 38.5, 35.9 and 38.7% in Tanqua-Abergelle, Kola-Tembien and Adwa districts, respectively. Sexual maturity of female for Tanqua-Abergelle, Kola-Tembien and Adwa districts were 9.16±0.82, 8.75±1.34, and 8.86±1.04 months, respectively and for male 7.43±0.76, 6.67±0.91, and 6.64±0.95 months, respectively. Tail type and body size in Tanqua-Abergelle and Kola-Tembien were the most frequently reported traits in selecting breeding ram and ewes, while tail type and coat colour in Adwa district. Based on the present result on sheep indigenous breeding practices one may develop selection criteria and productivity schemes of the local sheep in the study districts.

Key words: Adwa, breeding practice, indigenous selection criteria, Kola-Tembien, phenotypes, Tanqua-Abergelle.

INTRODUCTION

Ethiopia is owing to the large sheep population of 29.33 million head (CSA, 2015). At least 9 sheep breeds and 14 traditional sheep population are found in Ethiopia (Gizaw et al., 2007). Environmental pressure also maintains a wide range of genotypes, each adapted to a specific set of circumstances (Getachew et al., 2010). In Ethiopia, the production system and marketing are almost traditional (Legesse et al., 2008). However, sheep productivity is constrained by lack of technical capacity, scarce feed, diseases, insufficient infrastructure and market

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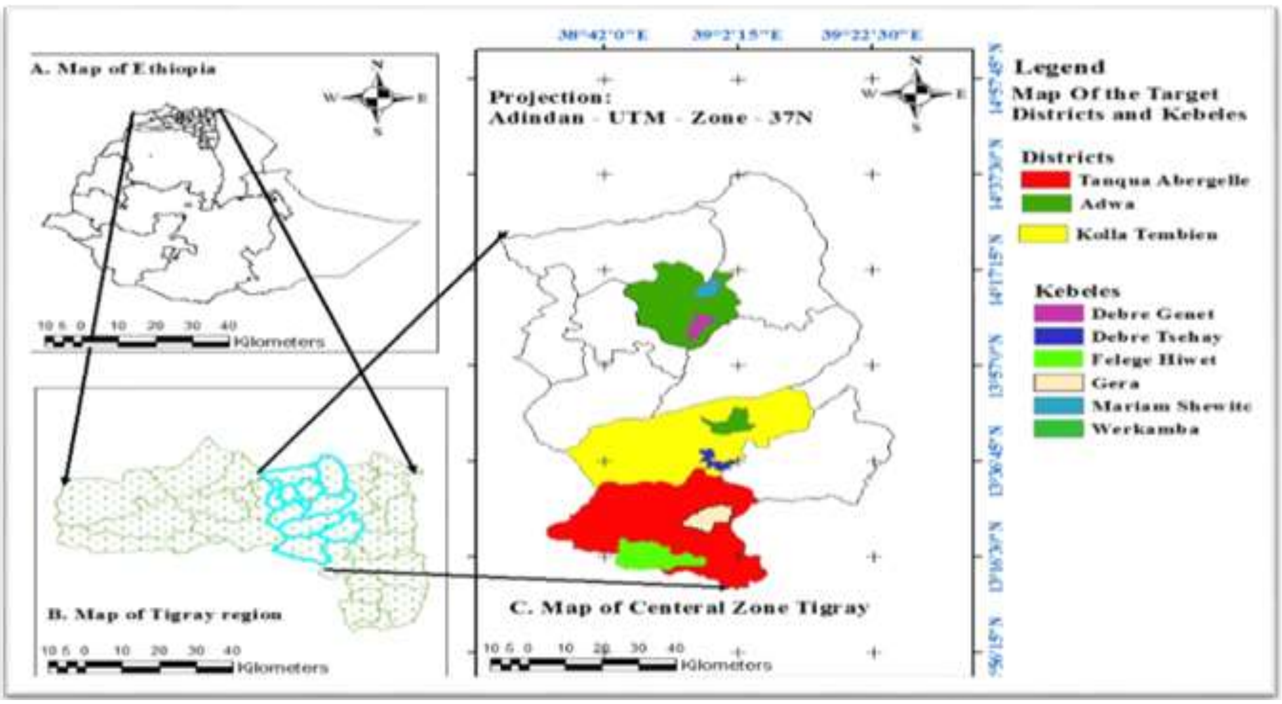

Figure 1. Map of the study area.

information resulting in inadequate utilization of the indigenous genetic resources. Due to these, a number of like the livestock population trend, distribution and marketing vary across space and time (Samson and Frehiwot, 2014).

Lack of such knowledge leads to the setting up of unrealistic breeding goals in the design of livestock genetic improvement programs and the consequence of which can put in danger the conservation of indigenous animal genetic resources (Wuletaw et al., 2006). The farmers' decision of selection criteria could be affected by breeds, production system and herd size (Thiruvenkadan et al., 2009). However, little is known about traditional breeding practices and selection criteria of sheep improvement in central zone of Tigray. Thus, this study was made to assess indigenous sheep breeding practices, selection criteria and identify trait preference of smallholder farmers in the central zone of Tigray.

MATERIALS AND METHODS

Description of study area

The study was conducted in three districts of central zone of Tigray (Tanqua Abergell, Kola-Tembien, and Adwa), showed in Figure 1.

The central zone of Tigray covers about 9741 km^2 with a total population of 786,271 cattle, 406,018 sheep, 1, 139, 452 goat, 81,468 colonies of honey bee, and 1,390,782 poultry (CSA, 2015). The elevation of the area ranges from 1332 to 2921 m. Annual rainfall varied within the range of 466 to 758 mm. Temperature ranges from 14 to 22°C. Most of the lands are cultivated with some native pasture patchy grazing bottomlands and degraded hilly sites (CSA, 2015).

Sampling procedure

Selection of the study districts and peasant association (kebeles) were done using multi-stage purposive sampling technique in consultation with zonal and district bureau of agriculture experts. Six kebeles were selected based on their suitability for sheep production, road access and willingness of the farmers to participate in the study. A total of 180 households (63 from Tanqua-Abergelle, 60 from Kola-Tembien and 57 from Adwa) were randomly sampled for the interview from within the selected and surrounding Kebeles.

Data type and methods of data collection

Data were collected from primary and secondary data sources. Primary data were collected from pretested semi-structured questionnaire and group discussions (with farmers and development agents).

Secondary data were collected from published and unpublished documents (reports of Bureau of Agricultural and Rural Development (BoARD), Minister of Agriculture (MoA) and Central Statically Agency (CSA)), research publications, journals and internet browsing.

Data for questionnaires survey

Modified questionnaires were prepared by adopting a questionnaire prepared by International Livestock Research Institute (ILRI) for survey of livestock breed and standard breed description list developed by FAO (2012). The structured questionnaires were pre-tested and administrated to collect information on existing sheep production and husbandry practices from each selected flock owners. Further information was obtained from key informants and secondary sources via interviewee and organizing group discussions. Before commencement of the actual interview with selected farmers, the questionnaires were pre-tested on a small number of selected farmers from each site. Based on the pre-tested information, questionnaires were further improved as per need.

The questionnaires were designed to collect information on: the environment in which the animals are kept (e.g. descriptors of the environment, farming system, husbandry practices, etc.); breed/types of sheep observed in the district, flock structure, population size and physical adaptive traits; main purpose and reasons for keeping the sheep population, major diseases and constraints of sheep production, breeding practice like mating type, sheep production objective, selection criteria, and culling age; and reproductive performance like age of sexual maturity, lambing interval, lamb crop (number of lambs born per ewe life span).

Data management and analysis

After data were collected and entered into the computer for analysis, preliminary data analysis like homogeneity test, normality test and screening of outliers were employed before conducting the main data analysis. Household survey (questionnaire) data were analyzed using districts as fixed effect.

Questionnaire data:

Data collected through questionnaire were subjected to descriptive statistics using Statistical Package for Social Sciences (SPSS 20.0 for windows, release 20.0 2011) and Chi-square was employed to test for the independence between the categorical variables. F-test was applied when required to test the statistical significance. Indices were calculated for ranked data to provide ranking of the reasons of keeping sheep, sheep breeding objective, ram and ewe selection criteria. Indices were calculated as Index = Sum of (3 × number of household ranked first + 2 × number of household ranked second + 1 × number of household ranked third) given for an individual reason, criteria or preference divided by the sum of (3 × number of household ranked first + 2 × number of household ranked second + 1 × number of household ranked third) for overall reasons, criteria or preferences according Musa et al (2006). The rate of inbreeding from effective population size for a randomly mated population was calculated as Ne = (4 Nm Nf) / (Nm + Nf); where Ne = effective population size, Nm = number of breeding males and Nf = number of breeding females. The rate of inbreeding coefficient (F) was calculated from Ne as ΔF = 1/2Ne (Falconer and Mackay, 1996).

RESULTS AND DISCUSSION

Purpose of sheep keeping

Small ruminants play a significant role in the life of man whether in the rural or urban areas in different ways. As indicated in Table 1, the primary reason for keeping sheep from first to third rank in Tanqua-Abergelle and Kola-Tembien were the same even though the index value for each purpose was different. According to the leading farmers purpose for keeping sheep in Tanqua-Abergelle and Kola-Tembien districts were sources of manure, cash income followed by insurance for risk (rural banking) with the index value of 0.38, 0.35, 0.12 and 0.39, 0.38, and 0.16 rank, respectively. However, cash income, sources of manure and insurance for risk with index value of 0.44, 0.27 and 0.21 rank, respectively in Adwa district.

Obviously, sheep keeping in most part of Ethiopia is primarily to generate income sources. However, the result of the present study (Tanqua-Abergelle and Kola-Tembien) shows keeping sheep was primarily towards manure production. This might be due to the reason to compensate the price of inorganic fertilizer. Similar to this result, Zelealem et al. (2012) also reported in Tanqua-Abergelle and Ganta-Afeshum districts that sheep were primarily kept for manure production. According World Bank Report (2008), the cultivated land of Tigray is characterized with vast land degradation and loss of soil fertility with subsequent loss of productivity and the use of organic fertilizer especially animal manure is inevitable and has been practiced since times in history.

Regarding milk production consumption except sheep keepers in Tanqua-Abergelle district, none of the respondents from Kola-Tembien and Adwa districts reported utilization of sheep and goat milk; this might be as a result of low cultural acceptance. Similar to this finding, Edea et al. (2012) also reported that sheep milk consumption in Southern part of Ethiopia, in Adiyo Kaka and Horro districts were not common. Because of cultural taboo, even in Tanqua-Abergelle district, drinking raw sheep and goat milk for women are not allowed unless, processed in the form of cheese, butter and yogurt. The reason stated by the female respondents for not drinking raw sheep and goat milk was that it was a cultural taboo, that is, drinking raw sheep and goat milk increases female sexual desire. Similar finding was reported for the same district (Desta et al., 2013).

Sheep flock structure

Classes of sheep flock structure by district (Number and Mean ±SD) are presented in Table 2. The average sheep population over each age and sex categories in Tanqua-Abergelle district was significantly (p<0.0001) higher than Kola-Tembien and Adwa districts of the same age categories. From the total flocks size, the percentage of female greater than one year (breeding ewes) accounted for 38.5, 35.9 and 38.7% in Tanqua-Abergelle, Kola-Tembien and Adwa districts, respectively. The corresponding value for male is greater than one year which accounted for 8.6, 10.4 and 9.4%, respectively. The results of present finding is in line with the result of previous work done by Mohamed et al. (2014) and Abera et al. (2014) for native sheep types in North Wollo zone, Northern Ethiopia, Habru and Gubalafto districts and in Selale Area, Central Ethiopia, Debre Libanos and Wuchale districts where the sheep flock structure was dominated by breeding ewe at 34.4, 37, 48.43 and

Table 1. Ranking of sheep production objectives by districts.

Objective	Tanqua-Abergelle				Kola-Tembien				Adwa			
	R2	**R2**	**R3**	**I**	**R1**	**R2**	**R3**	**I**	**R1**	**R2**	**R3**	**I**
Sale cash income	24	24	14	0.35	28	22	8	0.38	38	17	3	0.44
Meat for home use	0	2	12	0.04	0	2	11	0.04	0	3	18	0.07
Manure as fertilizer	33	21	4	0.38	31	21	7	0.39	17	15	11	0.27
Milk	4	3	7	0.07	0	0	0	0	0	0	0	0
Hide for home use	2	0	4	0.03	0	0	5	0.01	0	0	0	0
Insurance for risk	0	13	19	0.12	1	15	23	0.16	2	22	21	0.21
Ceremonies (gift wedding)	0	0	3	0.01	0	0	6	0.02	0	0	4	0.01

Index = Sum of (3 for rank 1 + 2 for rank 2 + 1 for rank 3) for particular production objective divided by sum of (3 for rank 1 + 2 for rank 2 + 1 for rank 3) for all objective.

Table 2. Average sheep flock structure in surveyed households in the study areas.

Sheep classes by age and sex	Tanqua-Abergelle [N (63)]			Kola-Tembien [N (60)]			Adwa [N (57)]		
	n	**Mean ± SD**	**%**	**n**	**Mean ± SD**	**%**	**n**	**Mean ± SD**	**%**
ML <6months	134	2.21 ± 0.7^{a}	10.6	119	1.98± 0.6^{b}	11.9	87	1.49± 0.7^{c}	9.4
FL<6months	191	3.13 ± 0.8^{a}	15.1	155	2.58± 0.9^{b}	15.5	171	2.87 ± 0.7^{b}	18.5
ML from 6month to one year	132	2.19± 0.7^{a}	10.5	94	1.57 ± 0.6^{b}	9.4	77	1.29 ± 0.9^{c}	8.3
FL from 6month to one year	211	3.46 ± 0.9^{a}	16.7	169	2.82± 0.7^{b}	16.9	144	2.44 ± 0.9^{c}	15.6
M> than 1year	108	1.79± 0.7^{a}	8.6	104	1.73± 0.7^{a}	10.4	87	1.46± 0 .9^{b}	9.4
F> than1year	486	7.97 ± 1.1^{a}	38.5	359	5.97 ± 1.5^{b}	35.9	358	6.12 ± 0.2^{b}	38.7
Total	1262	20.8±4.9	100	1000	16.7±5	100	924	15.7±4.3	100

^{a,b,c}Values with different subscript are significant at (p<0.000) level, N=number of respondents, n=number of animal, SD=standard deviation, %=percentage of animals by sex and age group, ML=male lambs, FL=female lambs, M=male, F=female.

49.89%, respectively. Therefore, sheep composition and sheep holding per household might be affected by production objective and demand, requirement of breeding female, feed availability and the occurrence of disease and natural calamities. This is because of male greater than one year is frequently sold whenever cash is needed in the household. Therefore, here intervention is needed to control negative selection to improve the reproductive and productivity of sheep particularly for males because farmers usually sell in good body condition (which may have good genetic makeup) to get high price. The ratio of ram to ewe in the study districts (Tanqua-Abergelle, Kola-Tembien and Adwa) was 1:4.5, 1:3.5 and 1:4.1, respectively. This ratio is higher than the normal range which is about 1:35 though it varies based on several aspects including age and mating experience of the ram and feed availability (Susan, 2011).

The result from the study areas showed, with such ratio rams have maximum contact with ewes and ewe lambs and mate them efficiently without missing any estrus. A sex ratio similar to the present study had been reported in different part of Ethiopia. For example a sex ratio in Abergelle and Keffa and Benchmaji which were 1:4.87 and 1:5.21 (Tajebe et al., 2011; Dejene, 2010), but higher than 1:8.03, 1:8.3 and 1:17.4 reported for Debre Libanos, Wuchale, Menz and Afar (Mohamed et al., 2014; Getachew et al., 2010).

Feed resources and grazing management

Available feed resources for sheep, seasonal fluctuations, coping mechanisms and management type for grazing and herding of sheep in study area is presented in Table 3. Based on the finding in the present study, the main source of feed for sheep throughout the year were natural pasture from the communal range land, grazing on fallow lands and crop residue (35, 31.1 and 27.8%), respectively. In comparison, Kola-Tembien and Adwa districts had better in feed availability than Tanqua-Abergelle district. Locally available feed like local beverage (‘*Hatela*’ by product of ‘*tela*’) and mineral like common salt (’*Chew*’) supplementation were also common in Kola-Tembien and Adwa districts. Majority of the respondents above 75% in the study areas reported that there was seasonal fluctuation in feed availability and apply different coping mechanisms to cope with the feed shortage.

From the total respondents, 58.7% in Tanqua-Abergelle and 38.7% in Kola-Tembien explore feed resources

Table 3. Feed resources for sheep, seasonal fluctuation and coping mechanisms during feed shortage in the study areas as reported by respondents (%).

Feed resources	Tanqua-Abergelle		Kola-Tembien		Adwa		Overall		χ2	P-value
	N	%	N	%	N	%	N	%		
Natural pasture	28	44.4	21	35	14	24.6	63	35	15.8	0.015
Crop residues	8	12.7	9	15	33	58.9	50	27.8		
Fallow lands	27	42.9	26	43.3	3	5.3	56	31.1		
Locally available like 'Hatela' and salt	0	0	4	6.7	7	12.3	11	6.1		
Seasonal fluctuation of feed availability										
Yes	61	96.8	55	91.7	44	77.2	160	88.9	11.0	0.004
No	2	3.2	5	8.3	13	22.8	20	11.1		
Coping mechanisms when feed shortage happen										
Purchasing feed	10	15.9	22	36.7	33	58.9	65	36.1	46.5	0.000
Moving to search feed and water	37	58.7	23	38.3	1	1.8	61	32.7		
Destocking	16	25.4	15	25	23	40.4	54	30		

*P<0.05 significant, χ^2=person chi square, N (%)=number of respondent in percentage.

(move their flock to distant area) (Tekezie basin) during the dry season to search feed and water. However, in Adwa district, 58.9% of the respondents reported that they purchased feed while, the rest 40.4% of the respondents were forced to sell their sheep when there is feed shortage. This result is in agreement with that of Nigussiea et al. (2015) who reported mixed crop-livestock production system, Jijiga, Shinile and east Hararghe zones, in Eastern Ethiopia.

Herding practice

Management in relation to grazing and herding were significantly (p<0.001) different across the study districts (Table 4). The degree of tethering practiced in the study area varied highly from district to district and this might result in animal population density per household. In agreement to the present study, Alemayehu et al. (2015) reported that tethering practiced vary across season and across districts of Dawuro zone and Konta special Wereda in Southern region of Ethiopia. About 68, 60 and 45% of the respondents in Tanqua-Abergelle, Kola-Tembien and Adwa districts mixed their flock with other flocks during grazing and watering. In line with the current result, Nigussiea et al. (2015) reported that mixing of sheep flocks of several households was practiced by most of the sheep owners in both mixed crop-livestock 70.0% and agro-pastoral 55.6% production system.

Indigenous knowledge of sheep breeding and management practices

Breeding male

Most of the respondents in the surveyed districts 93.7, 91.46 and 86% in Tanqua-Abergelle, Kola-Tembien and Adwa districts, respectively had their own indigenous breeding ram. In contrast to this result, Abera et al. (2014) reported that above 23 and 50% native sheep keepers in Gubalafto and Habru lacked breeding rams types in North Wollo zone, Northern Ethiopia.

Above 70% sources of breeding ram in all the study districts were from own flock. The purpose of keeping ram was mainly for breeding purpose as 77.8, 42 and 44% in Tanqua-Abergelle, Kola-Tembien, and Adwa districts, respectively. This finding substantiated the finding of Getachew et al. (2010) who reported 65.5 and 3.5% sheep keepers in Menz breed ram for breeding purpose and socio-cultural benefits, respectively. In all the study districts, natural and uncontrolled mating system was practiced throughout the year. It is difficult to introduce controlled breeding as communal herding is practiced during grazing and watering. This finding is inconsistent with the result of Tajebe et al. (2011), Zelealem et al. (2012), and bera et al. (2014) who reported that mating system within the flock and between the flock in Abergelle, Gubalafto and Habru sheep population were uncontrolled. All sheep populations were pure indigenous (Table 5).

Trait preference for selection of breeding ram and ewe

Selection criteria for breeding ram

Prior to prioritizing, the beneficiaries were asked to list the traits used as selection criteria for both ram and ewe breeding. Ranks of beneficiaries' selection criteria for breeding rams are present in Table 6. Tail type, body size and pedigree with index value of 0.24, 0.22, 0.21 and 0.30, 0.23 and 0.12 were the major selection criteria for

Table 4. Percent of respondents used different management type for grazing and herding of sheep in the three districts.

Parameter	Tanqua-Abergelle N (%)		Kola-Tembien N (%)		Adwa N (%)		Overall N (%)		χ^2	p-value
Grazing management										
Free grazing	20	31.7	10	16.7	5	8.8	35	19.4		
Herding	42	66.7	37	61.7	30	52.6	109	60.6	28.6	0.000
Tethering	1	1.6	13	21.7	22	38.6	36	20.0		
Herding										
Within sheep flock										
Lambs are separate	52	82.5	32	53.3	14	24.6	98	53.3	42.1	0.000
All classes of sheep	11	17.5	28	46.7	43	75.4	82	46.7		
Sheep flock is herded										
Together with cattle	27	42.9	18	30	31	54.4	76	42.2		
Together with goat	36	57.1	28	46.7	23	40.4	87	48.3	29.14	0.000
Sheep separately	0	0	14	23.3	3	5.3	17	9.4		
Way of herding										
Only one HH run as a flock	20	31.7	23	38.3	31	54.4	74	41.1	5.83	0.054
More than one HH run as a flock	43	68.3	37	61.7	26	45.6	106	58.9		

*P<0.05 significant, χ^2=person chi square; N (%)=number of respondents in percentage, HH=Household head.

Table 5. Breeding management in the study districts.

Parameter	Tanqua-Abergelle		Kola-Tembien		Adwa	
	N	%	N	%	N	%
Ram possession						
Having one ram	6	9.52	11	18.13	19	33.33
Having More than one ram	53	84.13	44	73.33	30	52.63
Having no ram	4	6.35	5	8.33	8	14.04
Purpose of keeping breeding ram						
For breeding only	49	77.8	42	70	44	77.2
For fattening	-	-	-	-	13	22.8
For breeding and socio -cultural vale	14	22.2	18	30	0	0
Sources of breeding ram						
From own flock	48	76.2	47	78.3	40	70.2
Neighboring	9	14.3	10	16.7	10	17.5
Purchased from market or farm	6	9.5	3	5	7	12.3

N = Number of respondents, %=percentage of respondents.

breeding rams reported by the respondents in Tanqua-Abergelle and Kola-Tembien districts, while tail type, coat colour, and pedigree with index value 0.24, 0.19 and 0.13 were ranked in its order, respectively in Adwa district. Besides libido, body conformation and drought resistance were also considered as selection criteria for breeding ram but less emphasis was given by the respondents in all study districts.

Most of the respondents in Tanqua-Abergelle and Kola-Tembien districts gave more emphasis for the first two top traits (tail type and body size) which might be related with the purpose of keeping sheep, while in Adwa district tail type and coat color were given more emphasis for selection of breeding ram, which might be related with market price and preference attraction.

Selection criteria for breeding ewe

As indicated in Table 7, tail type, body size and pedigree in Tanqua-Abergelle and Kola Tembien with index value 0.24, 0.22, 21 and 0.30,23 and 12 were major selection criteria for breeding female ranked first, second and third, respectively, while tail type, coat color and pedigree with

Table 6. Trait preference for selection breeding rams in the study districts.

Trait	Tanqua-Abergelle				Kola-Tembien				Adwa			
	R1	R2	R3	I	R1	R2	R3	I	R1	R2	R3	I
Appearance	0	5	1	0.02	3	9	7	0.10	4	5	7	0.09
Coat colour	5	9	4	0.10	0	2	1	0.01	11	11	10	0.19
Growth rate	7	1	5	0.07	2	8	5	0.08	4	5	3	0.07
Libido	1	5	10	0.06	4	4	9	0.08	8	3	7	0.11
Tail type	14	18	11	0.24	24	9	15	0.30	16	10	13	0.24
Pedigree	15	13	7	0.21	7	6	8	0.12	3	14	9	0.13
Body Size	18	10	10	0.22	17	12	7	0.23	0	6	0	0.04
Resistance to diseases	2	2	15	0.07	3	10	0	0.08	11	3	5	0.13

Index = Sum of (3 for rank 1 + 2 for rank 2 + 1 for rank 3) for particular trait divided by sum of (3 for rank 1 + 2 for rank 2 + 1 for rank 3) for all traits.

Table 7. Trait preference for selection breeding ewe in the study districts.

Trait	Tanqua-Abergelle				Kola-Tembien				Adwa			
	R1	R2	R3	I	R1	R2	R3	I	R1	R2	R3	I
Growth rate	5	3	0	0.06	1	1	1	0.02	0	1	4	0.02
Mothering ability	3	9	8	0.09	4	14	9	0.14	3	8	1	0.08
Age at first sexual maturity	5	8	10	0.11	10	8	15	0.17	10	11	9	0.18
Lamb weight	6	12	8	0.13	11	13	12	0.20	12	7	10	0.18
Lambing interval	5	5	11	0.10	10	5	6	0.13	11	3	8	0.14
Tail type	15	1	5	0.14	10	4	3	0.11	13	3	3	0.14
Resistance to diseases	3	3	3	0.05	3	1	3	0.04	5	4	1	0.07
Milk yield	11	4	3	0.12	0	1	0	0.01	0	0	0	0
Longevity	3	4	3	0.05	4	4	1	0.06	3	4	5	0.06
Body confirmation	1	4	3	0.04	2	2	1	0.03	0	7	1	0.04
Coat colour	6	2	5	0.07	5	1	8	0.07	0	6	6	0.05
Pedigree	0	8	4	0.05	0	6	1	0.04	0	3	9	0.04

Index = Sum of (3 for rank 1 + 2 for rank 2 + 1 for rank 3) for particular trait divided by sum of [3 for rank 1 + 2 for rank 2 + 1 for rank 3] for all traits.

an index value 0.24, 0.19 and 0.13 were reported first, second and third, respectively in Adwa district.

Effective population size and level of inbreeding

The observed ram to ewe ratio in Tanqua-Abergelle, Kola-Tembien and Adwa districts of sheep flock population may be sufficient if we consider only the capacity of male to female. But as revealed in the study districts, uncontrolled utilization of breeding rams born within the flock for mating, lack of awareness about inbreeding and small flock size, may lead to accumulation of inbreeding and decreased genetic diversity (Falconer and MacKay, 1996; Jainer et al., 2001; Kosgey, 2004). However, communal herding practiced by the sheep keepers in all the study districts obtained in this study allows females to mix with males from other flock and this can minimize the risk of inbreeding (Jaitner et al., 2001) by increasing the effective population size.

Effective population size (Ne) and the rate of inbreeding coefficient (ΔF) calculated for the sampled sheep flock of Tanqua-Abergelle, Kola-Tembien and Adwa districts considering the existing flock size and inbreeding practiced are presented in Table 8. When sheep flock of a household were not mixed, ΔF for sheep in Tanqua-Abergelle, Kola-Tembien and Adwa were 0.085, 0.093 and 0.11, respectively. The value was higher than the maximum acceptable level of 0.063 (Armstrong, 2006). For Tanqua-Abergelle sheep, Ne was higher than the Ne of the other two districts, but ΔF was higher (0.11) for Adwa sheep. However, the present results were smaller than what had been reported for Tocha, Mareka and Konta, which were 0.17, 0.20, and 0.18, respectively by Alemayehu et al. (2015).

Reproductive performance

Average reproductive performance (Mean±SD) of the

Table 8. Effective population size and level of inbreeding when flocks of sheep are not mixed in Tanqua-Abergelle, Kola-Tembien and Adwa districts.

District	When flocks are not mixed			
	Nm	Nf	Ne	ΔF
Tanqua-Abergelle	1.79	7.97	5.85	0.085
Kola-Tembien	1.73	5.97	5.37	0.093
Adwa	1.46	6.12	4.72	0.11

Ne = Effective population size; ΔF = coefficient of inbreeding. Nm = number of male; Nf = number of female.

Table 9. Average reproductive performance (Mean±SD) of indigenous sheep population in the study districts.

Traits	Tanqua-Abergelle [N (63)]	Kola-Tembien [N (60)]	Adwa [N (57)]	Overall [N (180)]
Average age male giving serves (year)	$1.71{\pm}2.5^{a}$	$1.51{\pm}0.49^{b}$	$1.95{\pm}0.66^{a}$	2.97±0.8
Age of male sexual maturity (months)	$7.43{\pm}0.76^{a}$	$6.67{\pm}0.91^{b}$	$6.64{\pm}0.95^{b}$	6.93±0.95
Age of female sexual maturity (months)	$9.16{\pm}0.82^{b}$	$8.75{\pm}1.34^{a}$	$8.63{\pm}0.81^{a}$	8.86±1.04
Female age at first lambing (months)	$15.12{\pm}1.17^{b}$	$14.87{\pm}0.87^{a}$	$14.58{\pm}0.91^{a}$	14.86±1.01
Lambing interval (months)	$7.81{\pm}0.83^{a}$	$7.57{\pm}0.97^{a}$	$7.65{\pm}0.82^{a}$	7.68±0.88
Life span lamb crop (number)	$10.73{\pm}2.3^{a}$	$10.35{\pm}1.89^{a}$	$8.77{\pm}1.38^{b}$	9.98±2.08

N=Number of respondent, SD= standard deviation, value with different subscript are significant (p<0.05), values with the same subscript are non-significant (p<0.05)

studied sheep population in Tanqua-Abergelle, Kola-Tembien and Adwa districts are presented in Table 9. Reproductive performance such as age of sexual maturity for both sexes, average life crop, age at first lambing and male giving service sampled sheep in Adwa district were significantly (p<0.05) smaller than the sampled sheep of Tanqua-Abergelle district, but comparable with Kola-Tembien sampled sheep, while lambing interval across the three districts had not shown significant (p>0.05) difference. The mean age of at first lambing of ewes in months was 15.12±1.17, 14.87±0.87 and 14.58±0.91, respectively for Tanqua-Abergelle, Kola-Tembien and Adwa districts, respectively. The present result in the study districts mean age of at first lambing was comparable with the previous work done on other sampled sheep population in different parts of Ethiopia. For example, age of at first lambing for Raya-Azebo, Tahtay-Adiyabo and Tsegede was 15.2±0.2, 15.5±0.2, 14.1±0.3 months, respectively (Zelealem et al., 2014). The reported average ages of lambing for semi-arid and sub-humid sub-Saharan countries were 16.9 and 16.2 months, respectively (Otte and Chilonda, 2002). This indicates that the sheep breeds in the current study area have acceptable age range for breeding though they are late compared with temperate breeds that reach puberty at the age range of 5 to 12 months (Susan, 2011).

However, this finding should be dealt carefully since there are many other factors affecting the age of sexual maturity and the age at first lambing. Lambing interval of the sampled female sheep in Tanqua-Abergelle, Kola-Tembien and Adwa districts were 7.81±0.83, 7.57±0.97 and 7.65±0.82 months, respectively, which is within the ranges of the previous work done reported by Hailemariam et al. (2013) for Gamogofa zone 7.34±0.13 months. Almost all respondents in all the study districts reported that overall the reproductive performance of the animal is not fixed rather it depends on the feed availability of the area and management of growing ram lambs and ewe lambs.

Conclusions

Within a given household, ewes greater than one year accounted for the largest proportion 38.5% in Tanqua-Abergelle, 35.9% in Kola-Tembien and 38.7% in Adwa district, while male greater than one year accounted for the smallest proportion of 8.6% in Tanqua-Abergelle, 10.4% in Kola-Tembien and 9.4% in Adwa district. The primary reason for keeping sheep in Tanqua-Abergelle and Kola-Tembien from first to third rank was for manure as fertilizer, besides cash income and insurance for risk (rural banking). In Adwa district, income generation ranked first, using manure as fertilizer ranked second and insurance for risk ranked third for the purpose of keeping sheep. Natural pasture, fallow lands and crop residues were the main source of feed for sheep throughout the year in all the study districts and transhumance was identified in Tanqua-Abergelle and Kola-Tembien. Most of the sheep keepers in the study districts emphasize traits tail type and coat colour type as selection criteria for breeding rams. The major sheep diseases hindering sheep productivity and survivability frequently encountered in the study area were pasteurellosis, pest des petit ruminants, anthrax, sheep and goat pox, foot and mouth diseases and mange mites.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The author dully acknowledged Tigray Agricultural Research Institute for the budget and necessary materials support. The farmers in the three districts of Central Zone of Tigray are also acknowledged for their cooperation during data collection.

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