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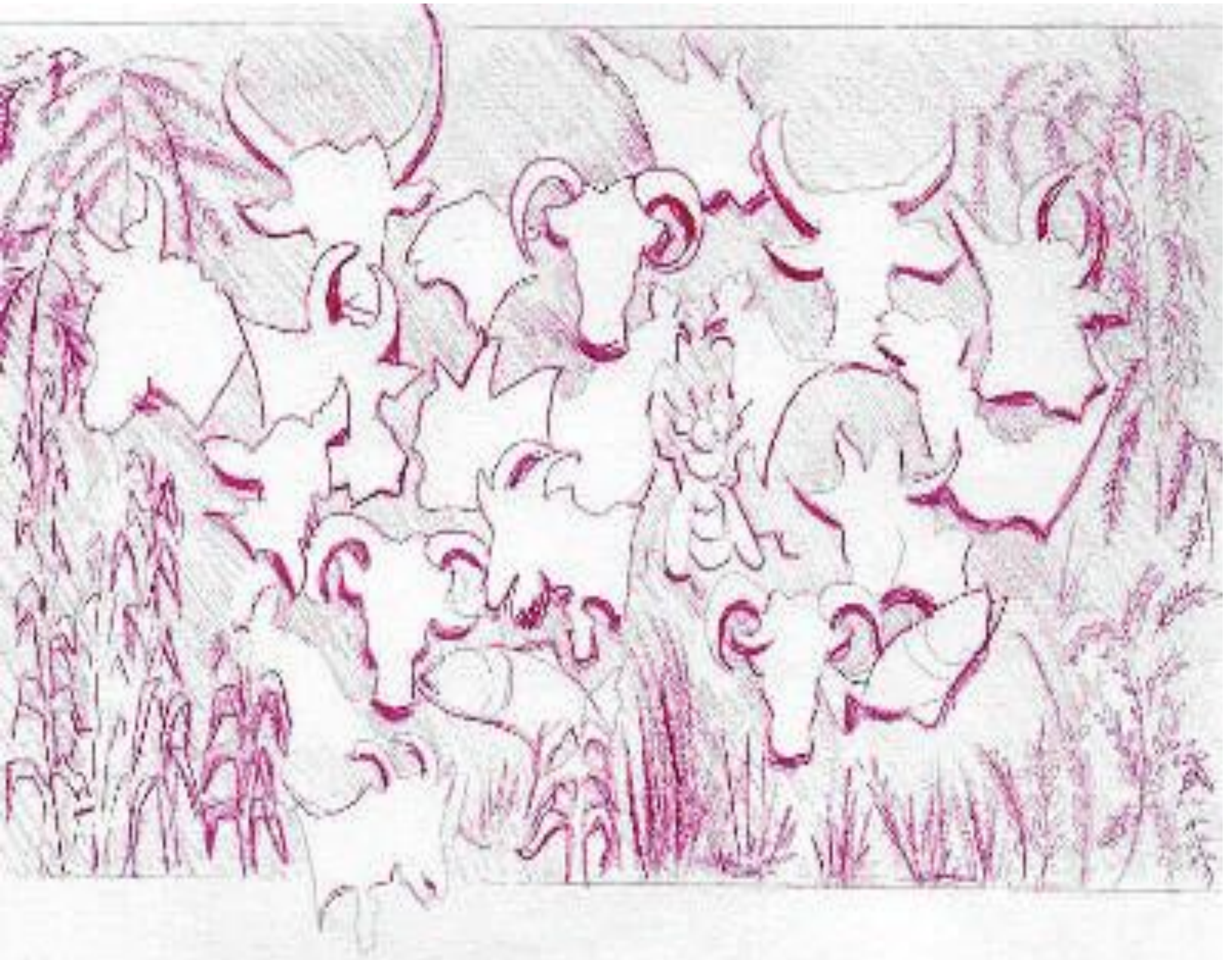

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An Official Journal of the Ethiopian Society of Animal Production (ESAP)

Aims and Scope: The Ethiopian Journal of Animal Production is a peer reviewed journal publishing original basic and applied research articles, short communications, technical notes, and review articles dealing with livestock and livestock related issues. Although the journal focuses on livestock production in Ethiopia, papers from similar agro-ecological regions of the world are welcomed.

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Farmers' Perception of Dairy Cattle Reproductive Performance in the Central Highlands of Ethiopia

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ABSTRACT

This study was designed to assess the perception of dairy farmers regarding reproductive performance (age at first calving and calving interval) of dairy cattle using data collected in the central highlands of Ethiopia. The study covered two zones of Oromia (Special Zone around Finfinne and North Shewa) and one zone of the Amhara region (North Shewa). The multistage sampling technique was employed to select the sample households (farmers) using purposive and random sampling techniques. A total of 564 crossbreeds and 152 local zebu cattle from 289 randomly selected dairy farmers were examined. The data collection was done using a structured questionnaire. Both descriptive and inferential statistics were used to analyze the data. The logistic regression model was also used to identify factors affecting farmers' recognition of dairy cattle delayed conception. The result revealed that the mean lactation length for crossbreed and local zebu cows was 299 and 284 days, respectively. The mean calving interval of crossbreed cows was 19.19 months for delayed cows and 12.4 for normal cows implying 6.79 months delay, compared to the optimal calving delivery. On the other hand, the average calving interval of local zebu cows was 24.03 months for delayed cows and 14.53 for normal cows showing 9.53 months delay. The study also pointed out that 28% of the sample farmers recognize delayed conception of their cows/heifers for which disease was one of the main reasons as they perceived. The respondents reported that poor feeding, management, and genetic setup are other problems that contributed to the problem. The result revealed that the delayed conception rate for the local zebu cows was 26% while it was 32% for the crossbreed cows. The delayed conception rate was also 36% and 25% for local zebu and crossbreed heifers, respectively. The result of the logistic regression model also exhibited that access to dairy extension services, family size, number of cows, distance to veterinary clinics, and access to expert advice affect the recognition of dairy cattle conception performance positively and significantly. The finding suggests emphasizing effective extension services and knowledge distribution to create awareness of dairy cattle's reproductive performance for the proficient intervention of the problem.

Keywords: calving interval; crossbreed; delayed conception; lactation length; local zebu

INTRODUCTION

Poor reproductive efficiency of dairy animals includes increased calving intervals and delay age at first calving. This poor reproductive performance sometimes said to be infertility has become a leading expensive health issue in the dairy industry (Falvey and Chantalakhana, 1999; Lucy, 2001; Hare *et al.*, 2006). According to Falvey and Chantalakhana (1999), infertility is a reduced ability or temporary inability to reproduce which is different from sterility (a complete and permanent inability to reproduce). Infertility has both direct and indirect effects throughout the farm system. Poor fertility reduces genetic gain, increases veterinary costs, decreases milk production, disrupts the pattern of milk production, cuts calf sales, and increases the cost of artificial insemination (AI). The problem of poor reproductive performance finally leads to increased calving interval and involuntary culling which contributes to economic loss (FAWC, 2009; Laven, 2018). The causes of delayed conception are many and can be complex (Arthur, 1982). However, infectious and non-infectious are the two main possible causes of delayed conception in dairy cattle. Non-infectious causes of infertility include nutrition, management, and genetic, and stress (Mayne *et al.,* 2003; Christine and Soren, 2010). On the other hand, the infectious causes of infertility are that resulted from bacteria, viruses, and protozoa (Falvey and Chantalakhana, 1999). The presence of diseases may be subclinically present but are still capable of quickly reducing the fertility on a cattle farm. In addition to a reduced chance of conception, increased embryonic mortality, and/or abortion percentage, these diseases also result in suboptimal milk productions (Mayne *et al.,* 2003).

Recognizing the delayed conception of dairy cows is used to identify different interventions to overcome the reproductive inefficiency of cow/heifer (Mayne *et al*., 2003). Among others, the use of good herd recording procedures, medical treatment, nutritional intervention, and the use of efficient AI techniques are some of the interventions proposed for infertile cows/heifers.

The Ethiopian highlands possess a high potential for dairy development. This area occupies the central part of Ethiopia and covers over 40% of the country's area. In the central highlands, the agricultural production system is predominantly subsistence smallholder mixed farming, with crop and livestock husbandry typically practiced within the same management unit. As mentioned before, the livestock sector in general, and the dairy subsector, in particular, is constrained by different factors and delayed conception is one. Although the contribution of dairy products to the livestock sector as well as to the agricultural sector at large is considerably high in the highland farming system, limited information is available on the level of delayed conception of dairy farms. This information gap is exacerbated by the dearth of empirical findings on the awareness and perception level of the dairy producers in the area. Thus, this study was conducted to assess dairy farmers' perception of delayed conception of dairy cattle under peri-urban and smallholder dairy production systems of the central highlands of Ethiopia, to identify their perception regarding causes of delayed conception and investigate factors affecting farmers' recognition of dairy cattle reproductive performance in the study areas.

METHODOLOGY

Study area

The study was conducted in three zones, Special Zone around Finfinne and North Shewa zone of Oromia National Regional State and North Shewa zone of Amhara Regional State. Oromia Special Zone Surrounding Finfinne (Addis Ababa) is found in the central part of the Oromia Regional State, surrounding the capital city-Addis Ababa. It consists of six districts namely Akaki, Berek, Mulo, Sebeta-Awas, Sululta, and Welmera, and eight major towns. The major food crops produced in the zone are cereals, pulses, oilseeds, and other crops such as vegetables, fruits, root crops, and stimulants are also grown. The area is the major milk shed of the country. Different dairy improved technologies and practices have been generated and disseminated by Holeta Agricultural Research Center for the area including improved dairy cattle. Welmera is a district sampled for this study.

North Shewa-Oromia zone: The zone shares common boundaries with the East Shewa zone to the southeast, west Shewa zone to the southwest, and Amhara National Regional State to the north, northeast, and Finfinne special zone in the south. Teff, wheat, barley, maize, sorghum, horse beans, field peas, lentils, chickpeas, vetch, Niger seed, rapeseed, and linseed are the most widely cultivated crops in the zone. Livestock rearing is a common agricultural activity in the zone. The area is also a prominent milk supplier to Addis Ababa city. Two districts namely Degem and Debrelibanos districts were selected for the study.

North Shewa-Amhara zone: The agroecology is predominantly highland with few areas of midland. Most parts of the zone are hilly or mountainous, but there are some plains. The economy of the zone is highly dependent on agriculture in which livestock rearing makes an important contribution to household incomes. The area is known for its moderately good productivity and is considered to be self-sufficient in grain. Teff, beans, wheat, and pulses are ranked in importance in terms of cash earned from sales. Sheep, cattle, poultry, and a few goats and equines are the livestock kept in the area. The source of animal feed is pasture and crop residues. Livestock possession, particularly oxen holding, and cultivated land area are the main determinants of wealth. Crop pest and diseases, shortage of rain, and livestock diseases are the main hazards which affect crop and livestock. Sale of more labor and livestock, sale of more firewood and trees, and use of carry-over stock are coping strategies variously of households during bad times (NSW, 2007). Basona Werana and Angolelana Tera districts of the zone were selected for the study.

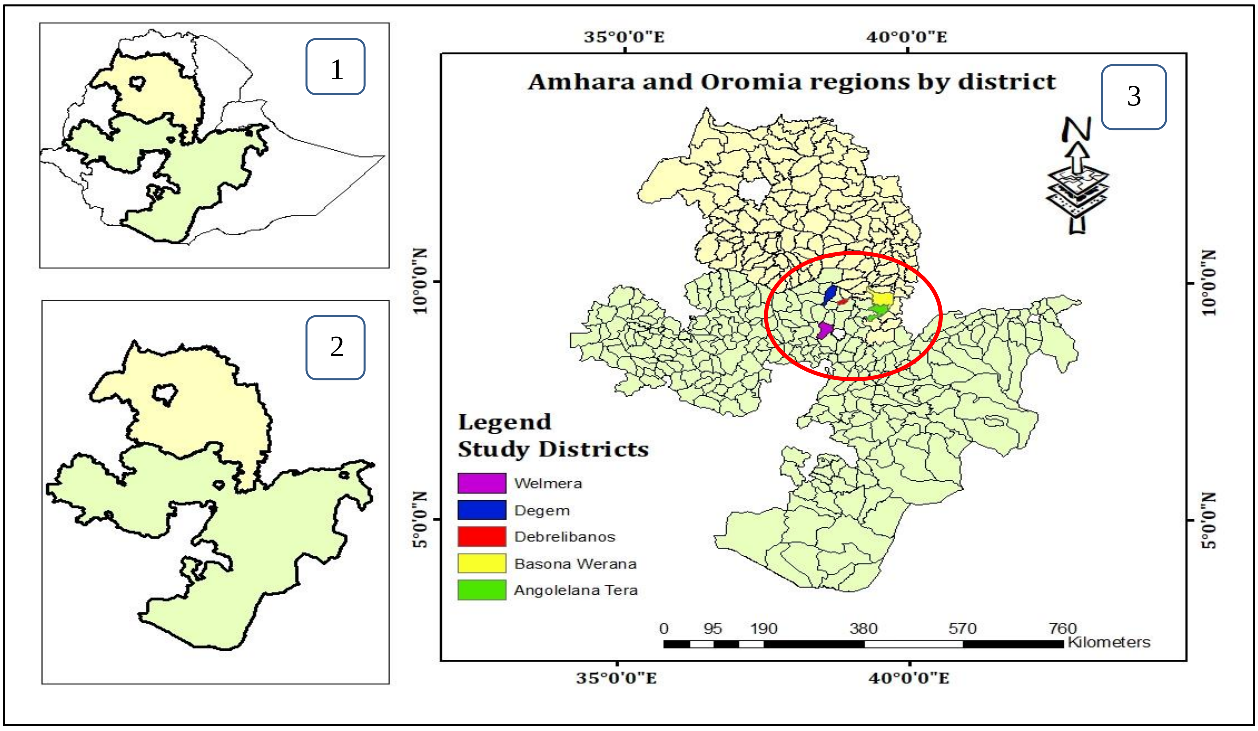


Figure 1: Map of the study areas

Sampling procedure

A multi-stage sampling technique was employed to select the sample from a population for the study which involved both purposive and random sampling techniques. First, regions, zones, and districts were purposively selected based on the importance of the dairy sector and dairy investment trends. Then, kebeles were picked randomly. Finally, dairy farmers/households were randomly selected from the sampling frame/list of farmers that exist at the Peasant Association (PA) level to select a total of 298 dairy farmers that were allocated to each district based on the proportion to the population size.

A total of 289 dairy farming households were interviewed from Oromia and Amhara national regional states. About 60% of respondents were from Oromia and the rest 40% were from the Amhara region. A total of 564 crossbreeds and 152 local zebu cattle were examined. Districts, the proportion of the households, and the number of peasant associations selected from each district are presented in Table 1 below.

Table 1: Study areas and proportion of selected households

Zones	Districts	Number of households	The proportion of households (%)	Number of PAs
Finfinne Special zone	Walmara	52	18	3
North Shewa Oromia	Degem	60	20	2
	Debrelibanos	66	22	2
North Shewa Amhara	Basona Werana	60	20	2
	Angolelana Tera	60	20	2
Total		298	100	11

Data collection and analysis

Data on reproductive performance was collected using a structured questionnaire administered to sampled farmers. The questionnaire was filled using computer-aided personal interviews (CAPI) designed by Census Survey Processing System (CSPro) software. Before implementing the actual survey, the questionnaire was pretested in non-sampled villages. The pretest was not only used to test the appropriateness of the tool in collecting the required data, but also to evaluate the trained enumerators on the capability of administering the questionnaire. Information related to dairy production, reproduction, and utilization was gathered from the respondents. Farmers' perception of dairy cattle's conception performance was also assessed. Furthermore, socio-demographic, institution, and economic features of the sample households were also collected. The collected data were cleaned, organized, and analyzed using Stata version 12.1 software. Both descriptive and inferential statistics were used to analyze the data. The logistic regression model was used to identify factors affecting farmers' recognition of dairy cattle's poor reproductive performance.

For the farmer to recognize or not to recognize dairy cattle poor conception performance, a reaction threshold of different factors affects (Hill and Kau, 1973; Pindyck and Rubinfeld, 1998). As such, at a certain value of stimulus below the threshold, no recognition is observed while at the critical threshold value, a reaction is stimulated. This is modeled as:

$Y_I = \beta X_i^* + \mu_i$ …………………………………………………………………… (1)

Where Yi is equal to one (1) which stands for recognizing poor conception performance and zero (0) otherwise and X* represents the combined effects of the independent variables (Xi) at the threshold level.

The above binary probability model involves the estimation of the probability of recognition of a given conception problem (Y) as a function of independent variables (X). The probability of recognizing and non-recognizing is also modeled as:

$prob(Y_i = 1) = F(\beta' X_i)$ ………………………………………………………… (2)

$prob(Y_i = 0) = 1 - F(\beta' X_i)$ ………………………..…………………………… (3)

Where Y_i is the observed response for the i^{th} observation of the response variable Y and X_i is a set of independent variables associated with the i^{th} individual, which determines the probability of recognizing (P). The function, F may take the form of a normal, logistic, or probability function. The empirical model for the logit model estimation is specified as:

$z_i = \log\left(\frac{p_i}{1-p_i}\right) = \alpha + \beta' X_i + \varepsilon_i$………………………………………………… (4)

Where X_i is the combined effect of X explanatory variables that enhance or prevent farmers to recognize poor conception performance in their dairy cattle and $\log\left(\frac{p_i}{1-p_i}\right)$ is the log-odds in favor of farm households' probability of recognition of dairy cattle poor conception performance.

Category of cattle reproductive performance

A crossbreed cow is said to be reproductively poor if and only if its calving interval is above 14 months. On the other hand, crossbreed heifer is called reproductively poor if the age at first calving of the heifer is 36 months. Hence, the age at first calving for the normal crossbreed heifers' ranges between 25 and 36 months in normal condition. Otherwise, it is considered reproductively poor (37 months and above) as suggested by Falvey and Chantalakhana (1999) and Mulugeta and Belayeneh (2013). The calving interval for local zebu cow is between 12 and 19 months and the age at first calving for the local zebu heifers ranges between 36 and 48 months. If these conditions are not fulfilled, they are considered reproductively poor.

RESULTS AND DISCUSSION

Characteristics of the sample households

The descriptive result showed that 95% of the respondents were male-headed and the rest 5% were female-headed households. The overall mean age of the household head was 45 years with a standard deviation of 12 years. The result also showed the highest education level in the Finfinne special zone and the lowest in the north Shewa-Amhara zone with the overall mean of 3.93 years which is statistically significant at a 10% significance level. The mean dairy farming experience was 11.64 years which is statistically different among study zones at a 5% significance level. The mean family size was 6.08 which is the highest in the North Shewa-Oromia zone and the lowest in the North Shewa-Amhara zone (Table 2).

Table 2: Sociodemographic characteristics of the respondents

Particulars	Finfinne Special Zone (n=52)	North Shewa Oromia (n=126)	North Shewa Amhara (n=120)	Overall (n=298)	*P-value*
	Mean ±SD	Mean ±SD	Mean ±SD	Mean± SD	
Age of HH head	46.10 ±12.9	43.48±12.1	46.74±12.4	45.23±12.4	0.108
Education of HH head	4.58 ±4.1	4.22±3.5	3.33±3.5	3.93±3.6	0.062*
Farming experience (yrs.)	10.44 ±13.6	15.42±10.5	14.93±11.6	14.36±11.6	0.027**
Labor force	3.06 ±1.7	3.07±1.8	3.11±1.7	3.09±1.7	0.972
Total family size	6.06 ±2.1	6.21±2.6	5.94±2.2	6.08±2.3	0.667

*** p<0.01, ** p<0.05, * p<0.1
HH: Household

The sample farmers of the north Shewa-Oromia zone owned significantly the largest land size compared to the other zones. The mean landholding in the study area was 3.33 hectares. Large land for hay, grazing land, and improved forage land was allocated by the farmers of the North Shewa Oromia region where relatively larger total land exists. A large proportion of land for livestock feed was allocated at the North Shewa-Oromia zone and a low proportion at Finfinne special zone. The area is also known for commercial hay production and supply. The mean land allocated to feed was 28% of the total area which is significant at α=0.05 (Table 3).

Table 3: Land ownership of the respondents

Land size in hectares	Oromia Special Zone Around Finfinne (n=52)	North Shewa Oromia (n=126)	North Shewa Amhara (n=120)	Overall (n=298)	P-value
	Mean± SD	Mean± SD	Mean± SD	Mean± SD	
Total land owned	2.88±1.99	3.68±1.80	3.16±1.71	3.33±1.82	0.012**
Homestead land	0.18±0.09	0.44±0.78	0.22±0.12	0.31±0.53	0.001***
Cropland	1.77±1.31	1.99±1.24	2.01±1.23	1.96±1.25	0.498
Forest/tree land	0.20±0.52	0.07±1.65	0.12±0.21	0.11±0.28	0.014**
Grazing land [A]	0.44±0.79	0.49±0.57	0.48±0.63	0.48±0.64	0.877
Hay grassland [B]	0.23±0.71	0.39±0.60	0.23±0.26	0.29±0.52	0.029**
Forage land [C]	0.03±0.09	0.24±0.40	0.13±0.22	0.16±0.31	0.000***
Cattle feed [A+B+C]	0.70±0.63	1.12±0.89	0.84±0.77	0.93±0.90	0.031***
% allocated to feed	24	30	27	28	0.046**

*** p<0.01, ** p<0.05, * p<0.1

Dairy farmers' access to services

The accessibility of different livestock service providing institutions was also assessed in this study. The result revealed that the proportion of the sample household's access to artificial insemination (AI) service was 82% which is the highest in the North Shewa Amhara zone and the lowest in Finfinne special zone. The overall access to experts' advice regarding dairy cattle management was 81%. Moreover, the North Shewa-Oromia zone is more accessible to AI services. Finfinne special zone is less accessible to both AI services and experts' advice (Figure 1).

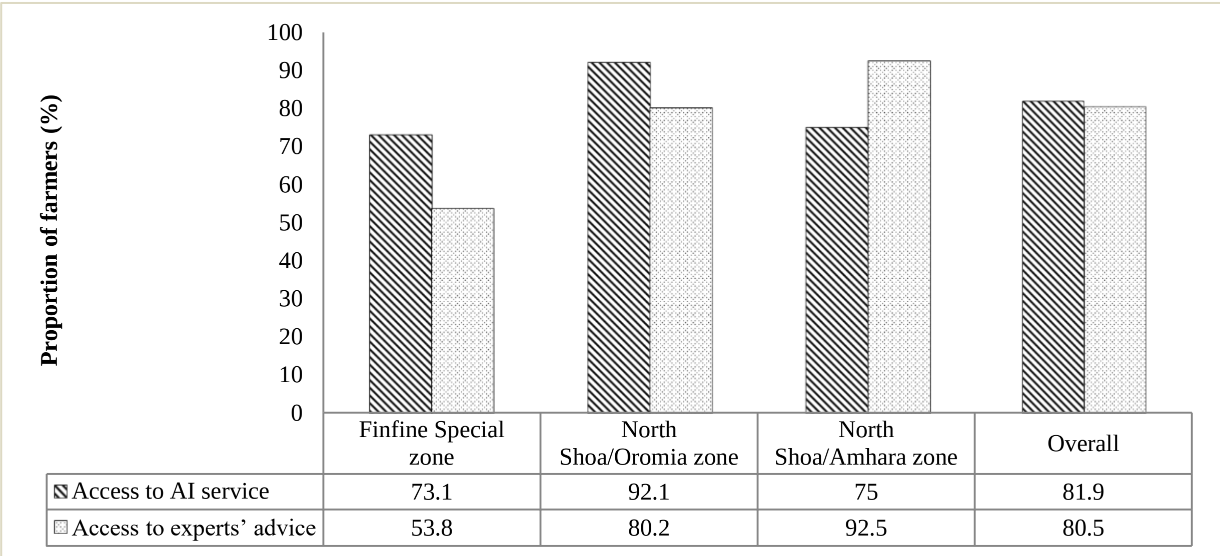


Figure 1: Farmers' access to AI and experts' advice

The result also shows that 50% and 30% of dairy farmers had access to dairy extension services and training on dairy cattle management, respectively. Farmers of North Shewa-Oromia have more access to both dairy extension services and training. However, Finfinne special zone dairy farmers have lower access to both extension service and training (Figure 2).

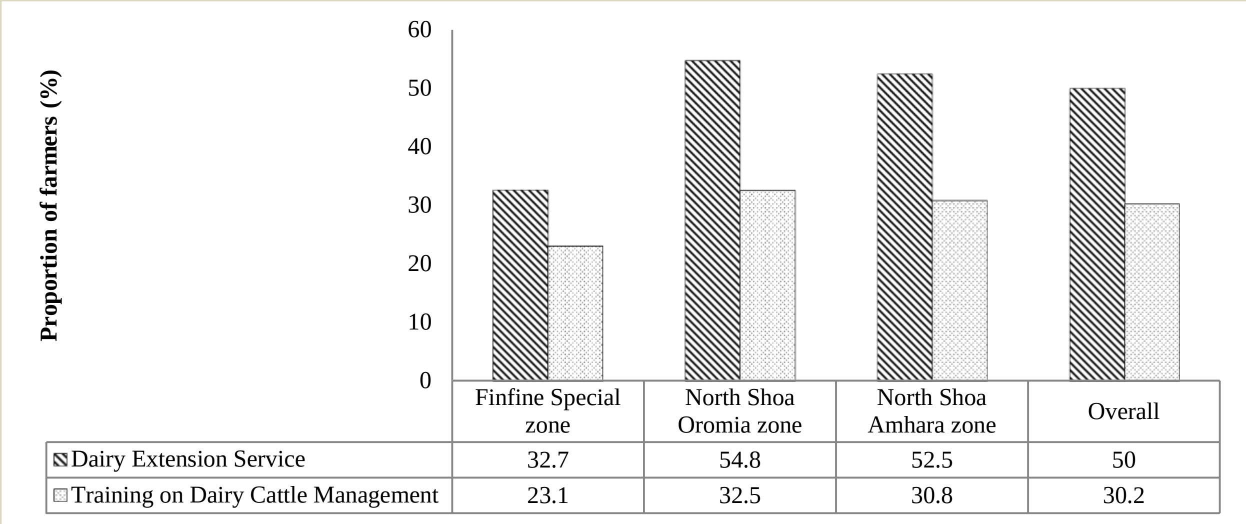


Figure 2: Access to extension service and training

Livestock production and productivity

Livestock ownership

The result of the survey showed that households' livestock holding is low which realized the mixed farming feature of the area. The mean crossbreed and local zebu dairy cattle holding are statistically different in number among the study zones. The mean number of lactating cows was 1.66 which is highest in the north Shewa-Oromia zone (1.71) and lowest in the North Shewa-Amhara zone (1.55). The mean livestock holding was 10.12 TLU (Tropical livestock units) (Table 4).

Table 4: Livestock ownership of the sample households in the study zones

Livestock	Finfinne Special Zone (n=52)	North Shewa Oromia (n=126)	North Shewa Amhara (n=120)	Overall (n=298)	P-value
	Mean± SD	Mean± SD	Mean± SD	Mean± SD	
Crossbreed cows	0.98±1.27	2.37±1.73	1.75±0.78	1.88±1.43	0.000***
Local cows	1.73±2.05	0.36±0.89	0.50±0.78	0.65±1.24	0.000***
Crossbreed heifers	0.48±0.87	0.96±0.88	0.71±0.77	0.78±0.85	0.001***
Local heifers	0.65±0.97	0.14±0.43	0.15±0.48	0.23±0.61	0.000***
Crossbreed oxen	0.29±0.75	1.18±1.28	1.35±1.03	1.09±1.16	0.000***
Local oxen	2.17±1.45	0.92±0.94	0.88±0.98	1.12±1.11	0.000***
Crossbreed bulls	0.33±0.86	0.52±1.49	0.37±0.69	0.42±1.12	0.464
Local bulls	0.50±1.02	0.09±0.35	0.12±0.48	0.17±0.58	0.000***
Crossbreed calves	0.81±1.14	1.16±1.11	1.26±0.90	1.14±1.04	0.032**
Local calves	0.87±1.03	0.17±0.46	0.28±0.62	0.33±0.70	0.000***
Lactating cows	1.71±1.26	1.75±0.96	1.55±0.82	1.66±0.97	0.243
TLU	10.64±6.54	9.58±4.90	10.48±4.48	10.12±5.07	0.276

*** p<0.01, ** p<0.05, * p<0.1

Dairy cattle productivity

The productivity of cows in the study zones was also assessed. The results showed that mean milk for crossbreed cows was 8.04 liters/day, which is highest at the north Shewa-Amhara zone and lowest at Finfinne special zone. For local zebus, the highest milk yield was observed at north Shewa-Oromia and the lowest was observed at Finfinne special zone with a mean of 2.82 lit/day. The result showed significant local zebu milk yield differences among the study zones at α=0.1 (Table 5). Recent empirical studies showed that the average daily milk yield of exotic cows was 8.78 and 5.83 for the urban and peri-urban areas, respectively. On the other hand, the average daily milk yield of local cows was 2.56 and 1.87 for the urban and peri-urban areas, respectively (Gebrekidan *et al.*, 2012). The study conducted by Dayanandan (2011) also revealed that the mean daily milk production of crossbred cows was found to be 8.7 liters in the central highlands of Ethiopia.

Table 5: Milk yield of cows in the study areas

Daily milk yield (lit/day)	Finfinne Special Zone (n=52)	North Shewa Oromia (n=126)	North Shewa Amhara (n=120)	Overall (n=298)	P-value
	Mean± SD	Mean± SD	Mean± SD	Mean± SD	
Crossbreed Cow	7.68±2.81	7.98±3.25	8.23±2.58	8.04±2.96	0.550
Zebu/Local Cow	2.38±1.52	3.27±1.24	3.26±1.73	2.82±1.61	0.050*

*** p<0.01, ** p<0.05, * p<0.1

Feeding regime

Farmers in the study zones were using two main feeding regimes namely open grazing and stall feeding. Most of the farmers at each study zones are using stall feeding and open grazing. On average 74% of sample farmers were using both open grazing and stall feeding together. The use of both feeding regimes together was reported highest at the North Shewa Amhara zone and lowest at the North Shewa Oromia zone. On the other hand, it was reported that the highest proportion of farmers practiced open grazing at Finfinne special zone and while stall feeding was reported the highest at North Shewa Oromia zone (Figure 3).

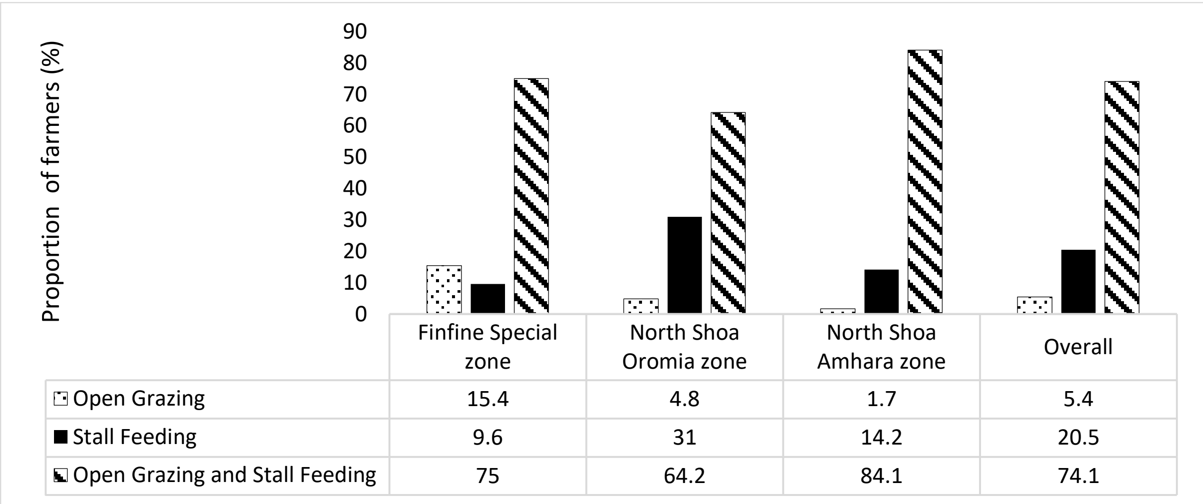


Figure 3: Feeding regime on the study zones

Dairy cattle reproduction

Lactation length, age at first calving, calving interval, breeding methods, and conception rate were the most common dairy cattle reproductive and milk production traits examined in this study. Major findings on these reproductive and milk production traits are reported in the following sub-sections.

Lactation length

Lactation length in the study zones was seen both for crossbreed and local zebu cows. The result showed that the mean lactation length for crossbreed cows was 9.96 months (299 days) which is the highest in the North Shewa-Amhara zone and the lowest in Finfinne special zone with a statistically significant difference among the study zones. The lactation length of the local zebu cattle is relatively lower than that of crossbreed cows with a mean of 9.46 months (284 days) which is also the highest in the North Shewa Amhara zone and the lowest in the North Shewa-Oromia zone. There was a significant difference between lactation length of crossbreed and local dairy cows in the North Shewa Oromia zone and North Shewa Amhara regions. However, the overall mean comparison result exhibited no significant difference between the lactation length of crossbred and local cows with a mean of 9.84 months (Table 6). The lactation length reported in this study is relatively higher than the study conducted by Gebrekidan *et al.*, (2012) which reported the average lactation length of the local, cross, and exotic breed being 6.5, 7.48, and 8.82 months, respectively.

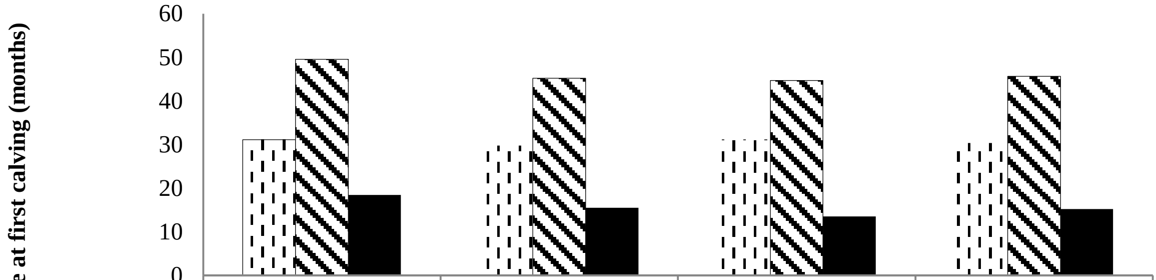
Table 6: Lactation length of dairy cows in the study areas

Lactation length in months	Finfinne Special Zone (n=52)	North Shewa Oromia (n=126)	North Shewa Amhara (n=120)	Overall (n=298)	P-value
	Mean± SD	Mean± SD	Mean± SD	Mean± SD	
Crossbreed Cow	9.11±1.98	9.68±1.69	10.63±2.12	9.96±1.97	0.000***
Zebu/Local Cow	9.50±2.69	8.17±1.75	9.96±2.47	9.46±2.54	0.124
Overall	9.33±2.23	8.99±1.71	10.11±2.33	9.84±2.13	
P value	0.459	0.031**	0.048**	0.392	

*** p<0.01, ** p<0.05, * p<0.1

Age at first calving

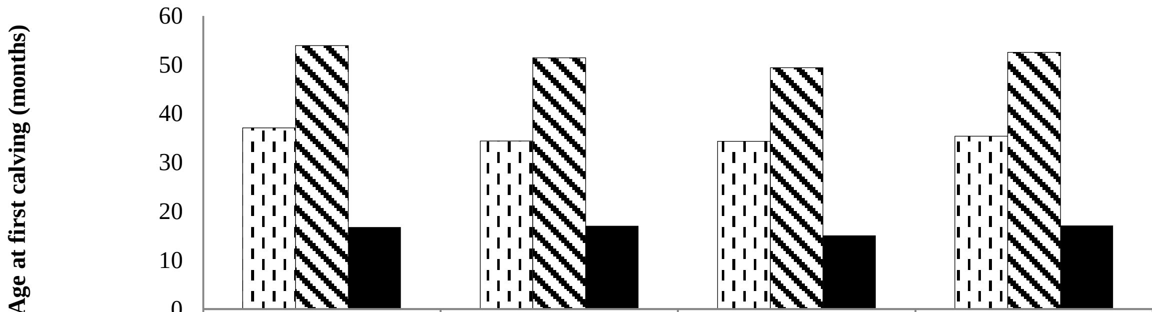
Age at first calving affects the reproductive performance of heifers. The result of the survey showed the mean age at first calving for fertile crossbreed heifers was 30.39 months and while it was 45.62 for delayed heifers implying the overall mean difference/delay of 15.23 months between them. However, there is a variation in ages at the first calving among the study zones with the highest and the lowest at Finfinne special zone and North Shewa-Amhara zone, respectively (Figure 4).



	Finfine Special zone	North Shoa/Oromia zone	North Shoa/Amhara zone	Overall
Normal Heifers	31.12	29.75	31.18	30.39
Delayed Heifers	49.55	45.24	44.72	45.62
Difference	18.43	15.49	13.54	15.23

Figure 4: Age at first calving for crossbreed heifers in the study areas

Age at first calving for local zebu heifers also showed that the overall mean for fertile heifers was 35.39 months whereas it was 52.52 months for the delayed heifers implying the average difference of 17.13 months. However, there is a variation among the study zones with the highest and the lowest recorded at the North Shewa-Oromia zone and North Shewa-Amhara zone, respectively (Figure 5). Long first calving interval results in fewer numbers of calves and less milk yield in the lifetime of the cow. Besides, farmers also incur unnecessary costs of carrying these unfertile heifers until they become productive and generate milk. The overall estimated average age at first calving was found to be 40.9 months, of which 47.16 months for local cows, and 37.95 months for crossbreed cows (Mulugeta and Belayeneh, 2013).

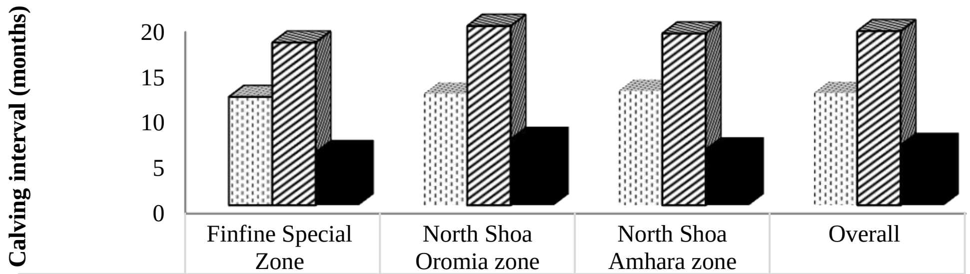


	Finfine Special zone	North Shoa/Oromia zone	North Shoa/Amhara zone	Overall
Normal Heifers	37.06	34.38	34.31	35.39
Delayed Heifers	53.86	51.42	49.37	52.52
Difference	16.79	17.04	15.05	17.13

Figure 5: Age at first calving for local zebu heifers in the study areas

Calving interval

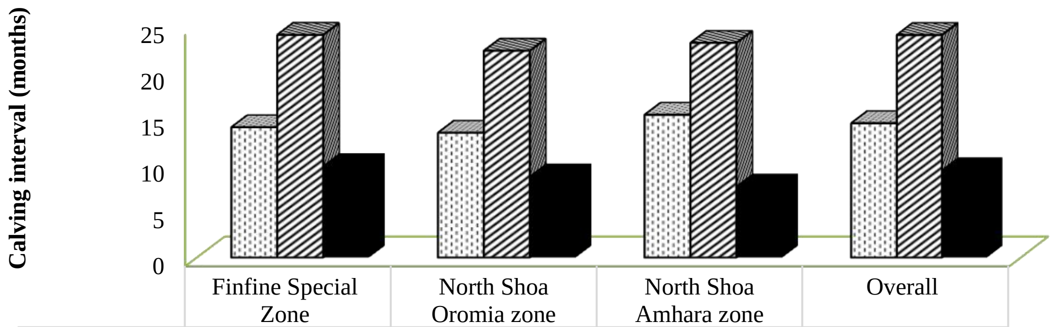
Calving interval is the most important trait which affects the reproductive performance of the dairy cows. The mean calving interval of crossbreed cows was found to be 12.4 months for fertile cows and 19.19 for delayed cows which showed 6.79 months delay. However, there is a variation in calving interval among the study zones with the smallest delay at Finfinne special zone and the largest delay at the North Shewa-Oromia zone (Figure 6).



	Finfine Special Zone	North Shoa Oromia zone	North Shoa Amhara zone	Overall
Normal cows	11.96	12.32	12.64	12.4
Delayed cows	17.94	19.76	18.93	19.19
Difference	5.98	7.44	6.29	6.79

Figure 6: Calving interval of crossbreed cows in the study areas

The calving interval of the local zebu cows also revealed that the overall mean calving interval of 24.03 months for the delayed and 14.5 for the fertile cows implying the delay of 9.53 months. For local zebu cows, the highest delayed months were observed at Finfinne special zone while the lowest was in the North Shewa-Amhara zone (Figure 7). This result is almost similar to the previous studies conducted by Mulugeta and Belayeneh (2013) which shows the mean calving interval of local and crossbreed dairy cows was 23 months (24.94 months for local cows and 22 months for crossbred) indicating more delayed calving interval in local cows.

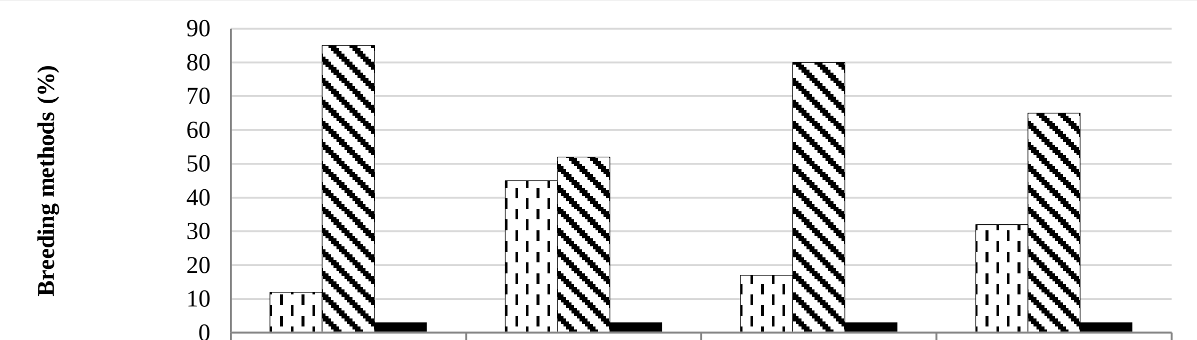


	Finfine Special Zone	North Shoa Oromia zone	North Shoa Amhara zone	Overall
Normal cows	14.07	13.47	15.41	14.5
Delayed cows	24.05	22.33	23.18	24.03
Difference	9.98	8.86	7.77	9.53

Figure 7: Calving interval of local zebu cows in the study areas

Breeding methods

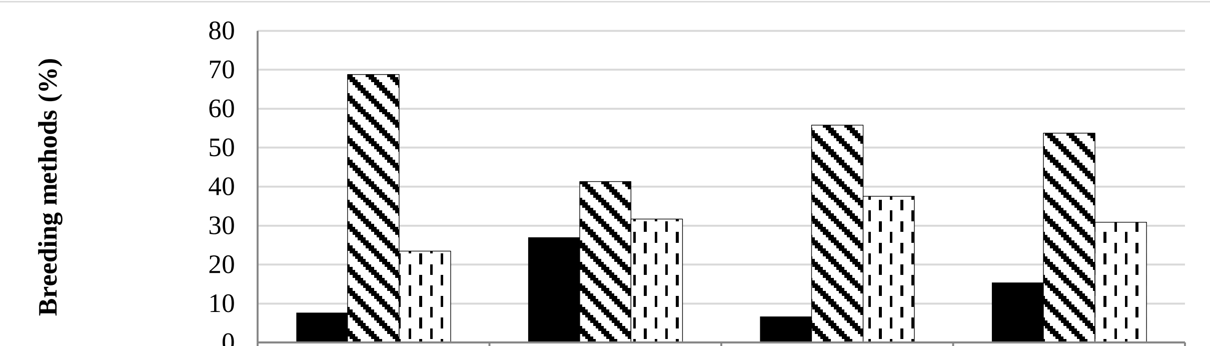
Farmers are practicing the different breeding methods for both crossbreed and local zebu cows and heifers. Most dairy farmers in study areas use crossbreed bulls followed by AI to breed crossbreed cows and heifers. Artificial insemination (AI) is highly used in the North Shewa Oromia zone (45%) with an overall mean of 32% (Figure 8).



	Finfine Special zone	North Shoa Oromia zone	North Shoa Amhara zone	Overall
AI	12	45	17	32
Crossbreed Bull	85	52	80	65
Local Bull	3	3	3	3

Figure 8: Breeding system for crossbreed cows/heifers in the study areas

The result showed that the majority of farmers use crossbreed and local bulls to breed local cows and heifers. Relatively better use of AI for local cows was observed North Shewa Oromia zone (27%). The overall mean of AI use in the study areas was 15% (Figure 9).

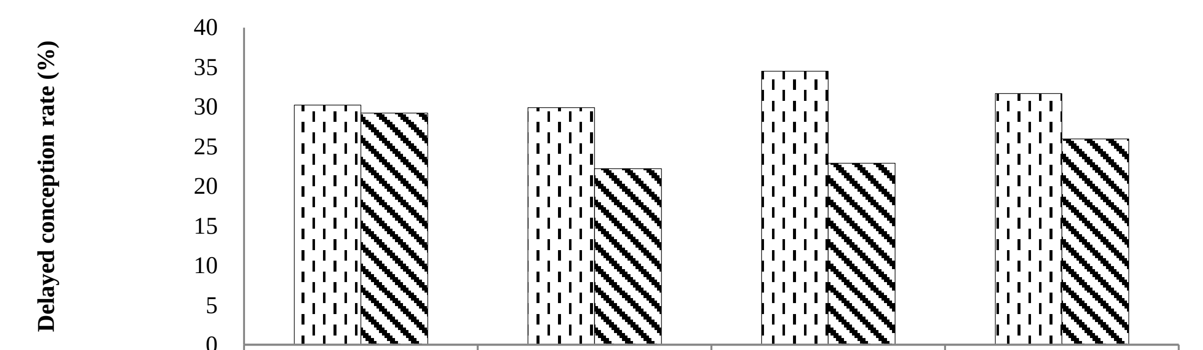


	Finfine Special zone	North Shoa Oromia zone	North Shoa Amhara zone	Overall
AI	8	27	7	15
Crossbreed Bull	69	41	56	54
Local Bull	24	32	38	31

Figure 9: Breeding system for local zebu cows/heifers in the study areas

Dairy cattle fertility and reproductive status

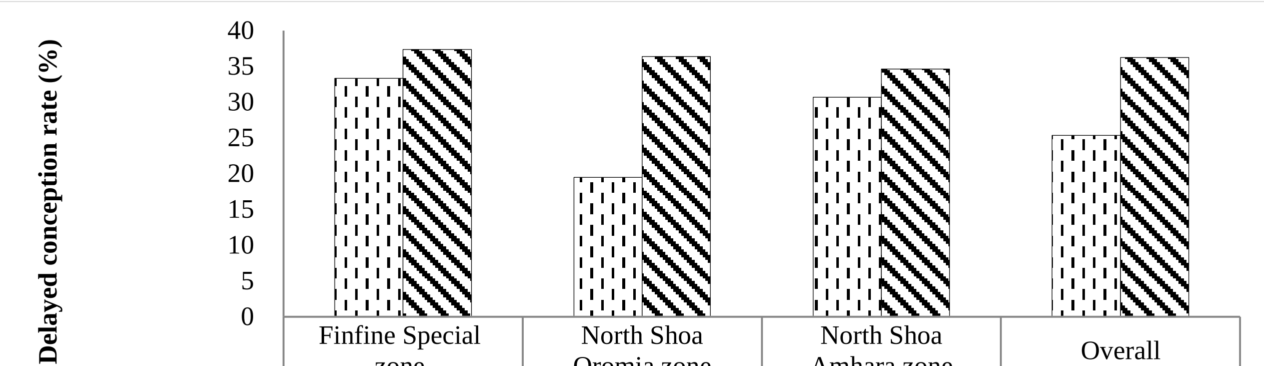
The study assessed the delayed conception status of both local and crossbreed dairy cows and heifers, respectively. The results showed that the mean poor reproductive performance rate of the local zebu cows was 26% and vary among the study zones. For instance, local zebu cows had a higher poor reproductive performance rate at Finfinne special zone than at North Shewa. This might be because Finfinne special zone dairy farmers have less access to AI and poor reproductive performance rate test. The poor reproductive performance rate of crossbred cows was larger (35%) at the North Shewa Amhara zone than the overall average of 32% (Figure 10).



	Finfine Special zone	North Shoa Oromia zone	North Shoa Amhara zone	Overall
Crossbreed Cows	30	30	35	32
Local Cows	29	22	23	26

Figure 10: Proportion of animals (cows) with delayed conception

The reproductive performance of local zebu heifers also revealed that the mean delayed conception rate was 36% with a high rate at Finfinne special zone and a low rate at the North Shewa Amhara zone. Higher (33%) poor reproductive performance of crossbred heifers was reported at Finfinne special zone and the lowest (19%) at the North Shewa Oromia zone. The mean poor reproductive performance rate of crossbreed heifers was 25% (Figure 11).



	Finfine Special zone	North Shoa Oromia zone	North Shoa Amhara zone	Overall
Crossbreed Heifers	33	19	31	25
Local Heifers	37	36	35	36

Figure 10: Proportion of animals (heifers) with delayed conception

Farmers' perception of delayed conception

Dairy farmers' perception of the poor reproductive of their cows has an important implication to reduce its effects. The study result shows that 34% of North Shewa-Amhara zone farmers recognized the poor reproductive performance of their cows. On the contrary, only 19% of the farmers of the Finfinne special zone recognized the poor reproductive performance with the overall mean of 28% (Figure 12), indicating a lower level of farmers' perception of the poor reproductive performance of their cows.

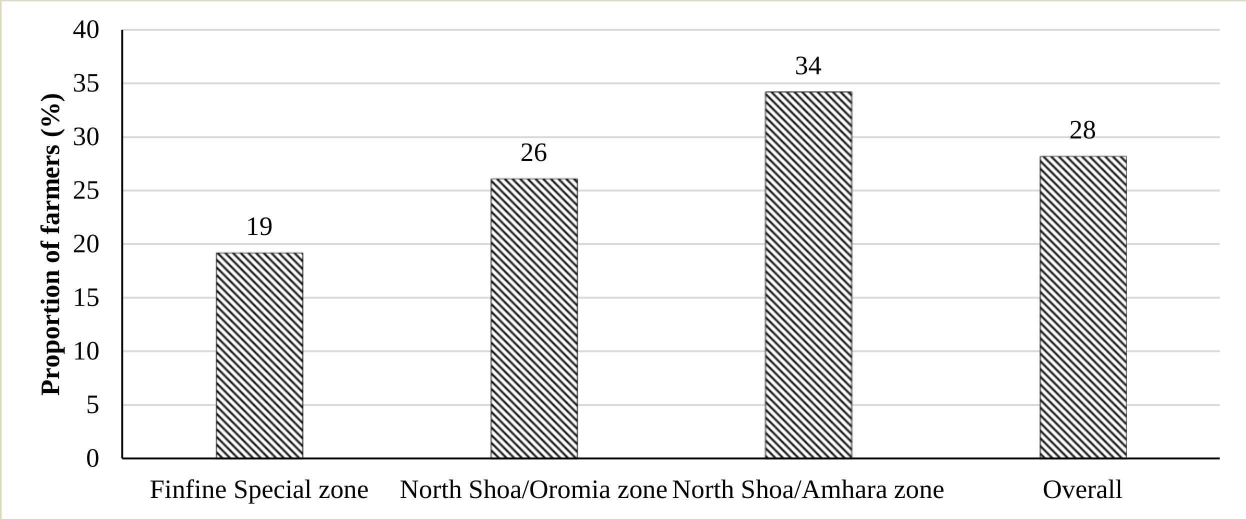


Figure 12: Farmers' recognition of delayed conception

Farmers make a different decision after they recognize the delayed conception of their cows. Based on the survey result, 66% of the farmers reported that they did nothing with the infertile/reproductively poor cows/heifers. However, there is a variation among the study zones regarding the farmers' decision to do nothing with the infertile cows. For instance, most of the sample farmers (84%) did nothing while 8%, 6%, and 2% decided to cull, followed medical treatment, and practiced home treatment in Finfinne Special zone. On the other hand, the decision made to cull was the highest in the North Shewa-Oromia zone and the lowest in Finfinne special zone. Overall, the decision made to cull infertile cattle was 16% implying that culling due to delayed conception was not common in the study areas. About 13% of farmers were provided medical treatment and very few of them reported to treat delayed conception at home. The trend and experience of medical treatment for delayed conception were the highest in the North Shewa-Amhara zone (17%) and the lowest in Finfinne special zone (Figure 13).

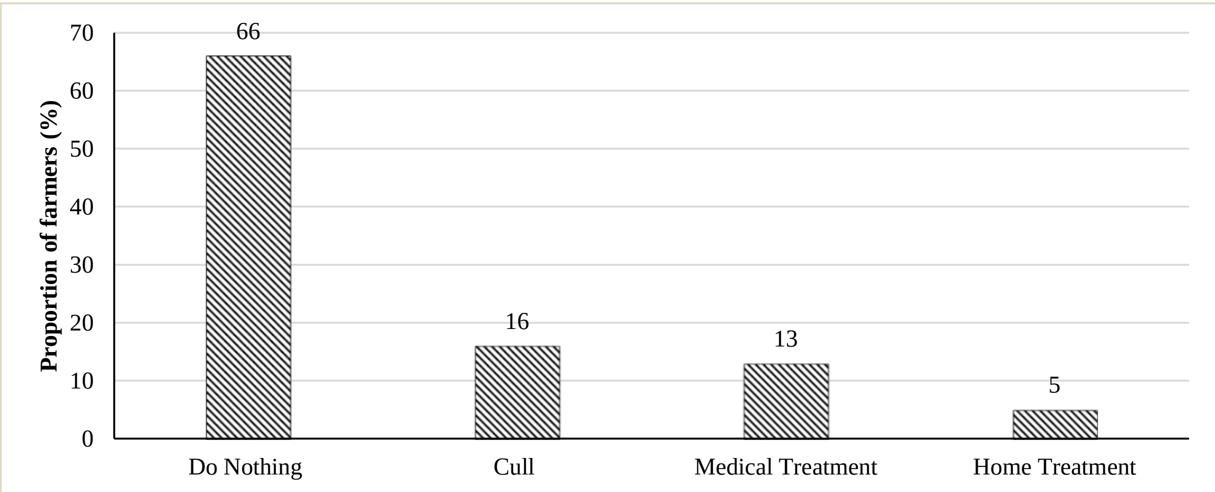


Figure 13: Farmer's decision on infertile/reproductively poor cows/heifers

Farmers' perception of the cause of poor reproductive performance has also been assessed in this study. The result revealed that 81% of the farmers in the study zones believed that disease was the main cause. Besides, they also reported that poor feeding, management, and genetic problem were also the major causes of poor reproductive performance. However, there is a variation among the study zones regarding the causes. For example, sample farmers of the Finfinne special zone reported poor feeding, genetic problem, and management as the most important causes. On the other hand, farmers of North Shewa-Oromia and North Shewa-Amhara zone reported disease, poor feeding, and management as the three major causes of delayed conception in dairy cows and heifers (Figure 14).

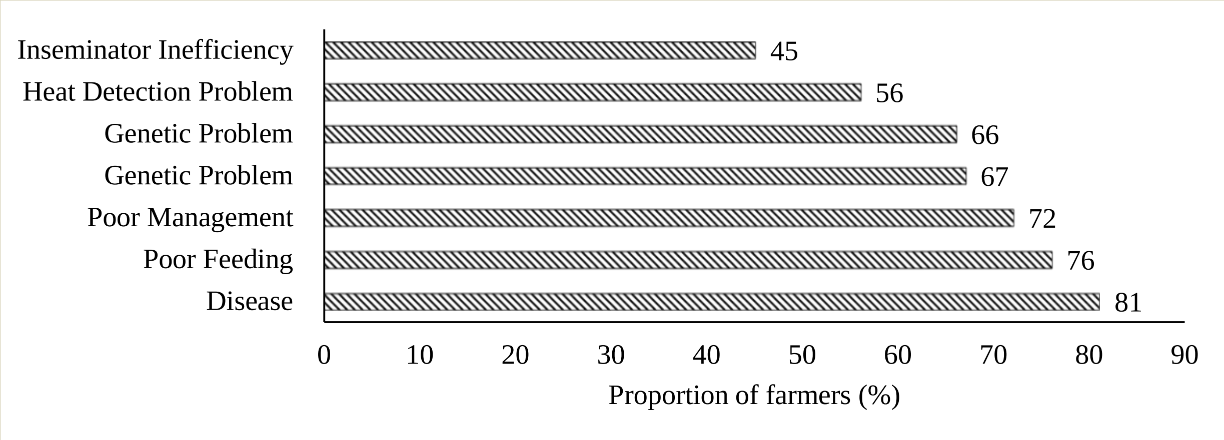


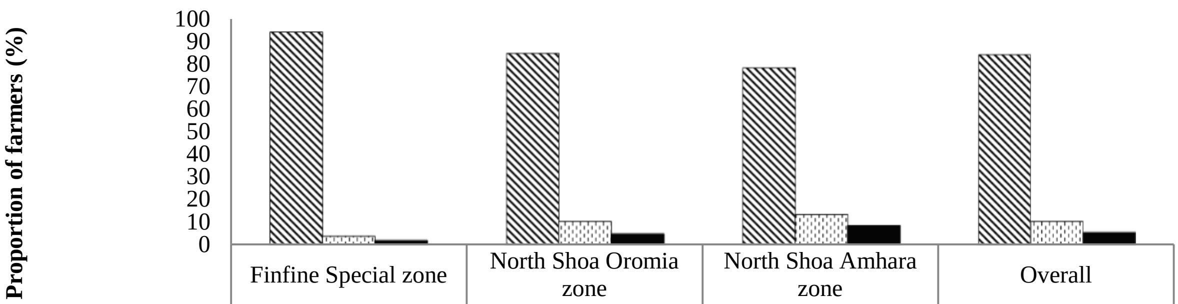
Figure 14: Farmers' perception of the cause of delayed conception

Dairy farmers have a long period of culling experience of their unproductive cattle due to different reasons. The result showed that 21% of the sample households culled their cows due to old age. As the age raises, the productivity declines and farmers decide to cull to avoid carrying costs. The second important reason for culling was reported (16% of sample farmers) to be poor production/productivity. Besides, feed shortage, inadequate space for cattle, and conception delay were also reported as some of the reasons for the culling of cows and heifers. There is a variation among the study zones in terms of the reason why they culled their cows. For example, age and feed shortage was the main reason for culling at Finfinne special zone while both delayed conception and age (old) were at the north Shewa-Oromia zone. Furthermore, about 26% of the sample farmers at the North Shewa-Amhara zone used age as the main reason for culling cows (Table 7).

Table 7: Reasons for culling dairy cow/heifer (proportion of respondents)

Farmer's list of reasons for culling	Finfinne Special Zone (n=52)	North Shewa Oromia (n=126)	North Shewa Amhara (n=120)	Overall (n=298)
Inadequate space	12	12	12	12
Feed shortage	17	15	12	13
Poor reproductive performance	10	16	8	11
Old age	29	17	26	21
Other health problem	0	8	5	5
Poor production	15	8	15	16
Financial requirement	10	9	13	11
Delay in conception	7	15	9	11

It was indicated that the selling price of infertile cows/heifers is low as compared to normal and fertile cows/heifers. More than 67% of the sample farmers reported that they sold the infertile cows at a lower price as compared to the fertile ones. In general, farmers' decisions made on infertile cows revealed that about 84% of respondents did not cull the cows/heifers even if the cattle are infertile. The decision made not to cull was the highest at Finfinne's special zone (94%) and the lowest at the North Shewa-Amhara zone (78%). Furthermore, some 10% of the sample households culled and replaced and the rest 5% culled and but not replaced the cows. Culling and replacing were reported to be the highest in the North Shewa-Amhara zone (13%) and the lowest in Finfinne special zone (Figure 15).



	Finfine Special zone	North Shoa Oromia zone	North Shoa Amhara zone	Overall
Do not cull	94.3	84.9	78.4	84.2
Cull and replace	3.8	10.3	13.3	10.4
Cull and no replace	1.9	4.8	8.3	5.4

Figure 152: Farmers` decisions on replacing cows/heifers with poor reproductive performance

Factors affecting farmers' recognition of dairy cattle infertility

Different factors were considered to observe factors affecting farmers' recognition of the poor reproductive performance of their dairy cattle. Region dummy (Amhara) is positively associated with the knowledge of recognizing the infertility problem in their dairy cows. On the other hand, male-headed households are more likely to judge cattle reproductive performance. The coefficient of the marginal effect of the male was 0.129 which implies that being male increases the recognition of poor reproductive performance by 12.9%. The reason could be that males know and evaluate the cattle's performance during rearing and feeding. Dairy extension service and expert advice had a positive impact on the dairy farmers' knowledge to recognize infertility (delayed fertility) of milking cows. This is due to farmers' exposure to awareness and knowledge during extension and expert contact. Family size was positively associated with the dairy farmers' knowledge to recognize infertility in Ethiopia. This is because, in large families, there is a higher probability of overlooking dairy cows including heat detection and following-up the herd. Furthermore, their level of understanding and recognizing the infertility problem in their herd can be higher in a larger family.

The number of cows was positively associated with dairy cattle reproductive performance evaluation. This implies specialization in dairy farms and hence frequent follow-up to their dairy cows. As a result, their level of recognizing infertility problem in their dairy farm is higher than those who are not specialized in dairy farms. Another important result is the distance to veterinary clinics measured in kilometer. The result indicated that dairy farmers who have located a far distance from the veterinary clinic had a higher probability of recognizing the infertility problem in their dairy farms (Table 8). Meena *et al.* (2012), in their study in India, indicated a positive and significant correlation between knowledge of cattle reproductive performance and age, milk production, extension contact, and credibility of the information source.

Table 8: Factors affecting farmers' recognition of dairy cattle infertility: a result of logistic regression

Variables	Coefficient	SE	dy/dx	SE
Household head sex [Male]	0.740	0.508	0.129*	0.072
Access to dairy extension [Yes]	0.605***	0.179	0.122***	0.035
Region [Amhara]	0.376*	0.202	0.077**	0.041
Household head age in years	-0.004	0.009	-0.001	0.002
Household education in years	-0.022	0.026	-0.005	0.005
Total family size	0.082*	0.045	0.017*	0.009
Dairying experience	0.003	0.009	0.001	0.002
Total number of cows	0.202**	0.094	0.041**	0.019
TLU in livestock number	0.019	0.029	0.004	0.006
Training on dairy cattle management	-0.269	0.190	-0.054	0.037
Distance to veterinary clinics in km	0.108**	0.047	0.022**	0.010
Access to expert advice	0.961***	0.275	0.170***	0.040
Use of AI	-0.112	0.195	-0.023	0.040
Constant	-4.551***	0.756		

Number of observations = 289
Pseudo r^2 = 16.403
Chi-square = 70.783
Prob > chi2 = 0.000
*** p<0.01, ** p<0.05, * p<0.1

CONCLUSIONS AND IMPLICATION

The study was conducted to evaluate farmers' perception of dairy cattle reproductive performance in the central highlands of Ethiopia. Based on the study results, the mean calving interval of crossbreed cows was 12.4 months for fertile cows and 19.19 for delayed cows, implying a difference of 6.79 months. The calving interval of local zebu cows was 24.03 months for delayed cows and 14.53 for normal cows with a difference of 9.53 months. The mean age at first calving for normal crossbreed heifers was 30.39 months and 45.62 for delayed heifers. Farmers perceived that disease is the main cause of delayed conception. Poor feeding, poor management, and genetic problem were also reported as other causes of poor reproductive performance. The proportion of crossbred and local zebu cows with poor reproductive performances in the study areas were 26 and 32%, respectively. Similarly, 36% local zebu heifers and 25% crossbred heifers were reported to have delayed conception rate in the areas. Based on these findings, the following recommendations have been proposed.

- Emphasis must be given to effective extension services and knowledge transfer to improve awareness on dairy cattle reproductive performance followed by proficient intervention to tackle the problem. Awareness must also be created among the farmers regarding the causes of delayed conception in dairy cattle. Moreover, farmers should be trained on proper heat detection and overall management of the animal.
- It is necessary to have a record to revisit cattle fertility, reproduction, and production status. The record-keeping practice among the farmers should be developed to maintain scorecards which would assist the producer, planner, and researcher in discerning the characteristics, fertility, and performance of animals for future planning and improvement of production.

- Further research is required at a wider scale integrated with clinical diagnoses that enable to generalize about the findings and help policymakers to design appropriate dairy development interventions.

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Evaluationof Management Levels and Performance of Crossbred Dairy Cattle Demonstrated to Smallholder Farmers in the Central Highlands of Ethiopia

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ABSTRACT

Astudy was conducted in three districts (Dirre Inchinni, Walmara and Ada'a Berga) of West Shewa Zone of Oromiya National Regional State to evaluate the management levels, and production and reproductive performance of dairy cattle on smallholder farms. A total of 90 households (Dirre Inchinni-15, Walmara-47 and Ada'a Berga-28) having at least one crossbred dairy cattle were purposively selected and individually interviewed. The sample respondents had an average experience of 7.16 (range 4.93-12.78) years in dairy production. Theyon averaged owned 1.71 milking cows, 1.40 dry cows, 1.62 pregnant cows, 1.37 heifers and 1.46 calves. The average milk yield at first parity was 9.61 litters (L)/cow/day ranging from 8.54-10.50 L/cow/day. There was variation ($P<0.05$) in milk yield among the districts with the highest (10.50 L/cow/day) recorded at Ada'a Berga. The longest lactation length (10.27 months) was reported at Dirre Inchinni with no significant difference ($P>0.05$) among the districts. The average number of service per conception was 2.0, ranging from 1.93 at Ada'a Berga to 2.18 at Walmara. The average age at first calving was 30 months with a narrow range of 28.80 to 30.20 months. Similarly, calving interval ranged between 13.23 to 14.81 months with a mean of 14.26 months. Most (92.9, 46.7 and 80.2%) of the respondents in Ada'a Berga, Dirre Inchinni and Walmara, respectively, were using artificial insemination for breeding their animals. Dairy cattle were housed in separately constructed houses according to majority of the respondents. About 75.6% and 96.7% of the respondents respectively produce improved forages and purchase supplementary feeds for their dairy animals.River was reported to be the main source of water for animals mainly during the dry season. In general, the farmers in the study area apply improved dairy cattle management practices with better daily and lactation milk yield, and reproductive performance of the animals as compared to other areas with less crossbred dairy animals. Thereforeit is recommended to share the experience of the farmers in the study area to other farmers and implement intensive trainings to make the dairy sector more productive.Finally, it would be necessary to conduct cost-benefit analysis or analysis of production costs to clearly understand the contribution of dairy farming tothe livelihood of smallholder farmers.

Key words: Crossbred, Management, Production, Reproduction performance

INTRODUCTION

Although indigenous Zebu cattle are more adapted to tropical environment, their capacity for milk production is usually low. Selection for high milk production within indigenous cattle would require a long-term genetic improvement program. To meet the ever-increasing demand for milk, milk products and their contribution to economic growth, genetic improvement through crossing of the indigenous with exotic cattle has been proposed as one of the options (Aynalem *et al.,* 2009). In Ethiopia, crossbred cattle mainly cross of zebu with Holstein-Friesian cattle have been used for milk production for decades (Niraj *et al*., 2017). However, fertility rate of crossbred, high grade and pure breed exotic dairy cattle suffered from poor reproduction performance, poor conception rate, long post-partum anestrous and calving interval (Madalena *et al.*, 1990).These lower reproductive performances could be related to genetic, environment and management factors. Management factors such as accuracy of heat detection, use of proper insemination techniques, proper semen handling, and appropriate herd health policies can directly influence the reproductive performance of a dairy herd (Fikre, 2007).

The success of dairy production in general and crossbreeding program in particular needs to be monitored regularly by assessing the productive and reproductive performance under the existing management system. In Ethiopia, the poor genetic potential accompanied with substandard feeding, poor healthcare and management practices are the main contributors to low productivity of dairy cattle. Hence, there is a need to periodically evaluate the reproductive and productive performance of dairy cattle and factors affecting their performance. Information is limited about the performance of dairy cows in smallholder urban and peri-urban dairy farms in the tropics, particularly in Ethiopia (Lobago *et al*., 2007).

A large number of smallholder dairy farmers are operating in the central highlands of Ethiopia due to the proximity to different organizations working on dairy research and development. On-farm participatory verification of improved dairy cattle production packages has started since 2000 as a result more than 315 crossbred dairy cows were demonstrated to 10 districts including the study areas (Kefena *et al.*, 2016). However, market opportunities for their products, information on management levels, productive and reproductive performance of crossbred dairy cattle demonstrated to smallholder farmers, were not well assessed and documented. Therefore the objectives of this study were to evaluate the management levels and production and reproductive performances of dairy animals demonstrated to smallholder farmers.

MATERIALS AND METHODS

Description of study areas

The study was conducted in Dirre Inchinni, Walmara and Ada'a Berga districts which are located in West Shewa Zone of Oromia National Regional State. West Shewa Zone was selected based on the number of crossbred dairy animals demonstrated and the experiences of the farmers in managing dairy animals. Dirre Inchinni is located at a distance of 40 km from Ambo (the capital of West Shewa Zone) with an annual rainfall ranging between 1000to 1400 mm. Average minimum and maximum daily temperatures are 8.8^0 C and 21.6^0C, respectively (PSEP, 2011).

Walmara district is located at 9°00'N latitude, 38°30'E longitude withan altitude of 2400 m above sea level (masl). It is 34 km west of Addis Ababa and hasan average annual rainfall of 1055 mm, average relative humidity of 60.6% and average maximum and minimum daily temperature of 22.2°c and 6.1°c, respectively (HARC, 2010).The area is a typical mixed crop-livestock production system, where small-scale dairying based on crossbred animals is commonly practiced.

Ada'a Berga district is located in the central highlands of Ethiopia at $9^0$16'N latitude and $38^0$23'E longitude, 70 km west of Addis Ababa and 35 km North West of Holetta town on the main road to Muger. It lies at an altitude of 2500 masl. It is characterized by cool sub-tropical climate with the mean annual temperature and rainfall of 18^0c and 1225 mm, respectively (HARC, 2010).

Table 1: Districts participated in dairy technology transfer and number of farmers participated in the program up to 2015.

Districts	**Number of participant farmers**
Walmara and Ejere	142
Dandi	49
Jeldu	38
Ambo and Guder	25
Weliso	12
Dirre Inchinni	33
Kersa Malima	10
Ghoa Tshion	6
Total	**315**

Source: Kefena *et al*. (2016)

Sampling method and data collection

Among the districts of West Shewa zone, three districts (Ada'a Berga, Dirre Inchinni and Walmara) having relatively large number of crossbred dairy animals were purposively selected. From each district, two peasant associations (PA) were selected. A total of 90 households (Dirre Inchinni-15, Walmara-47 and Ada'a Beraga-28) having at least one crossbred dairy cowwere purposively selected and individually interviewed. Data was collected in formal survey using pre-tested structured questionnaires which includes: - household characteristics, local and crossbred cattle holding size, production and reproductive performance of crossbred animals, feeding, feed availability and types, housing, marketing and diseases affecting crossbred dairy animals. Secondary data were also collected from livestock and fishery development office, and other documented sources.

Statistical analysis

Qualitative and quantitative data sets were analyzed using Statistical Package for Social Sciences (SPSS, Version 20).

RESULTS AND DISCUSSION

Land holding and land use pattern

The overall average land owned by a household (hh) in the study areas was 2.93 hectares(ha) with the range of 2.60-4.04 ha (Table 2). The average land allocated for crop production varied from 1.68 to 2.23 ha while that of grazing land was in the range of 1.02 to 1.27 ha. In general, the sample households in the study districts allocated about 1.82 ha (42.12%) for crop production and 1.14 ha (26.38%) for grazing. Contrary to this study, Gezahegn *et al.*(2016) reported the average land allocated for crop production, grazing, hay making and improved forage production in Bench-Maji, Sheka and Majang zones was in the order of 1.95, 0.39, 0.13 and 0.14 ha, respectively. The variation in land allocation for different purposes in these districts might be due to differences in the land holding size of the respondents.

Table 2: Land holding and land use pattern in the study areas (ha)

Land allocation for different purposes	Districts				Sig. Level
	Ada'a Berga	Dirre Inchinni	Walmara	Overall Mean	
Total land owned	2.95±0.72 (28) *	4.04±2.05(15)	2.62±1.56 (46)	2.93±1.49 (89)	***
Crop land	1.68±0.58(26)	2.23±1.29(15)	1.76±1.21(47)	1.82±1.08(88)	NS
Grazing land	1.27±0.58(22)	1.14±0.84(14)	1.02±0.22(26)	1.14±0.55(62)	NS
Land for hay making	0.95±0.15(20)	1.11±0.33(9)	1.07±0.26(14)	1.02±0.24(43)	NS
Land used for other purposes	0.70±0.20(5)	0.83±0.25(6)	1.29±0.48(7)	0.97±0.42(18)	**

* =numbers in the parenthesis are number of respondents

Number of local and crossbred cattleowed by respondents

Number of local cattle

The average number of local cattle owned by the sample households 1.39 milking cows, 1.62dry cows, 1.64pregnant cows, 2.22 heifers and1.27 calves (Table 3). In agreement to this finding, Gezahegn *et al.* (2016) reported that the mean number of cows, heifers, female calves and male calves in the order of 3.3, 2.3, 1.5 and 1.7, respectively. Similarly Mezgeb *et al.* (2016) reported the mean numbers of cows, heifers > 12 months, heifers 6-12 months and female caves in Arsi-Bale zones were 2.49, 1.82, 1.52 and 1.48, respectively.

Table 3: Local cattle holding of the sample respondents

Types of local cattle	Districts			
	Ada'a Berga	Dirre Inchinni	Walmara	Overall Mean
Milking cows	1.00±0.00 (10) *	1.87±0.99 (8)	1.39±0.77(18)	1.39±0.76(36)
Dry cows	1.33±0.57(3)	2.17±0.75(6)	1.42±0.90(12)	1.62±0.86(21)
Pregnant cows	1.00±0.00(2)	1.67±0.57(3)	1.78±1.30(9)	1.64±1.08(14)
Heifers	1.00±0.00(8)	4.20±3.56(5)	2.21±1.36(14)	2.22±2.02(27)
Calves	1.08±0.28(12)	1.40±0.54(5)	1.44±0.52(9)	1.27±0.45(26)
Oxen	1.90±0.30(20)	2.0±1.04(12)	2.78±1.33(46)	2.22±0.89(78)

*= numbers in the parenthesis are number of respondents

Number of crossbred cattle

Respondents in the study districts had 7.16 (range 4.93-12.78) years of experience in improved dairy production. There was significant variation (P<0.05) in the experience of the respondents in improved dairying which could be attributed to the difference in time of distribution of crossbred heifers to farmers. As shown in Table 4, the average ownership of improved cattle by the sample households include1.71 milking cows, 1.40 dry cows, 1.62 pregnant cows, 1.37 heifers and 1.46 calves. According to Mulisa *et al.* (2011) the number of lactating cows, pregnant cows, heifers and calves owned per household around Bishoftu town was 1.29, 0.9, 0.84 and 0.64, respectively. In agreement to the present study, Million *et al. (*2015) reported that the mean number of dairy cows and calves owned per household in Walmara district was 2.6 and 1.6, respectively. Similarly, Solomon (2016) also reported a dairy herd structure of pregnant cows (0.69), lactating cows (1.2), heifers (1.1) and calves (1.3) for smallholder farmers around Debrebrhan town.

Table4: Crossbred cattle holding of the sample respondents

Crossbred cattle	Districts			
	Ada'a Berga	Dirre Inchinni	Walmara	Overall Mean
Milking cows	1.44±0.69(27) *	1.54±0.87(13)	1.97±1.25(37)	1.71±1.05(77)
Dry cows	1.00±0.00(4)	1.33±0.51(6)	1.60±0.96(10)	1.40±0.75(20)
Pregnant cows	1.62±0.80(21)	1.23±0.43(13)	1.79±0.86(29)	1.62±0.79(63)
Heifers	1.60±0.75(20)	1.33±0.50(9)	1.20±0.57(25)	1.37±0.65(54)
Calves	1.26±0.65(19)	1.13±0.35(8)	1.69±0.85(29)	1.46±0.76(56)

*= numbers in the parenthesis are number of respondents

Production performance of crossbred dairy animals in the study areas

Daily Milk Yield (DMY)

The milk production performance of crossbred dairy cows is presented in Table 5. The average milk yield at first parity was 9.61 L/cow/day with the range of 8.54-10.50 litters/cow/day. There was significant difference (p< 0.05) in milk yield among districts with the highest (10.50 L/cow/day) at Ada'a Berga district. This difference in milk yield among districts might be due to differences in the management of the animals and exotic blood level of the animals. The average daily milk yield during second and third parties were 9.80 and 8.76 L/cow, respectively. Similar to this finding, Kumar *et al.* (2014), Yohannes *et al.* (2015) and Sena *et al.* (2014) reported a milk yield of 9.87, 9.43 and 9.91 L/day/cow from crossbred dairy cows in Gonder, Walmara and Debretabor, respectively. Contrary to the present study, Gebrekidan *et al.* (2012), reported lower (6.8 L) daily milk yield from crossbred dairy animals in central zone of

Tigray. Zenebe *et al.* (2016) reported relatively higher (11.48 L) daily milk yield from crossbred dairy cows in Addis Ababa and Bishoftu towns. In another study, Dessalegn (2017) reported a daily milk yield of 11.6 and 10.8 L from crossbred dairy cows in Bishoftu and Akaki, respectively. The variation in milk yield in different areas is mostly due to differences in management of the animals, resource availability, experiences of the farmer and blood level of the animals.

Lactation Length (LL)

The mean lactation length of crossbred dairy cowsin the study areas was 9.64 months (Table 5). The longest lactation length (10.27 months) was reported at Dirre Inchinni and there was non-significant difference (p>0.05) across the districts. Similar to this finding, Sena *et al.* (2014) and Dessalegn *et al.* (2016) reported 9.1 and 9.2 months of lactation length for crossbred dairy cows in Debretabor and Bishoftu towns, respectively. Contrary to the current finding, Yohannes *et al.* (2015) reported a higher lactation length of 14.4 and 12.96 months for crossbred dairy cows in Walmara and DirreInchinni districts, respectively. This difference in lactation length in the same districts at different times might be due to lack of record keeping experience by the farmers. On the other hand Gebrekidan *et al.* (2012) reported lower (7.6 months) lactation length for crossbred dairy cows in central zone of Tigray.

Table 5: Milk productivity (L/cow/day) and lactation length (months) of crossbred dairy cows in the study areas

Crossbred cattle		Districts				Sig. Level
		Ada'a Berga	Dirre Inchini	Walmara	Overall Mean	
Lactation length		8.75±3.40	10.27±1.98	9.98±3.09	9.64±3.07	NS
Daily milk yield by parity	First	10.50±2.79	8.5z4±2.22	9.38±2.49	9.61±2.61	**
	Second	10.08±2.62	8.50±1.28	10.05±2.58	9.80±2.47	NS
	Third	8.29±2.12	7.86±1.79	9.61±3.66	8.76±2.93	NS
	Fourth	-	7.08±2.13	11.29±5.05	8.55±3.90	NS
	Fifth	-	6.62±2.50	6.00±2.00	6.47±2.34	NS

Reproductive performance of Crossbreed dairy cows in the study districts

Service per Conception (SPC)

The mean number of service per conception in the study districts was 2.0, with the highest (2.18) at Walmara and the lowest (1.93) at Ada'a Berga (Table 6). In agreement to this finding, Debir (2016), Zenebe *et al.*(2016), Niraj *et al.*(2017) and Wondossen *et al*. (2018) reported 1.8,1.96, 1.8 and 2.18 SPC for crossbred dairy cows in Sidama Region, around Addis Ababa, in and around Bishopftu (Debre Zeit) and in south western Ethiopia, respectively. Moreover, Hunduma (2012) and Sena *et al.* (2014) also reported that the mean number of service per conception for crossbred cows was 1.56 and 1.52, respectively.The differences in number of service per conception could be attributed to differences in management practices such as proper heat detection and timely insemination.

Age at First Calving (AFC)

The mean age at first calving in the study districts was 30 months with the range of 28.80-30.20 months. This valueislower than the value (36.96 months), (34.8 months), (35.3 months), (35.7 months) and (39.3 months) reported by Gebrekidan *et al.* (2012), Hunduma (2012), Alemselam *et al.* (2015), Yohannes *et al.* (2015) and Debir (2016), respectively. Contrary to this study, lower age at first calving was reported by Meseret *et al.* (2014) and Dessalegn *et al.* (2016).

Calving Interval (CI)

The mean calving interval of dairy animals in the study areas was 14.26 months and ranged from 13.23-14.81 months (Table6). The present finding is in agreement with Hunduma (2012); Sena *et al.* (2014); Alemselam *et al.* (2015) and Dessalegn *et al.* (2016) who reported a calving interval of 12.25 months in Ethiopia, 12.88 months in Debretabor, 13.2 months around Mekele and 13 months in Bishoftu town, respectively. Contrary to this findings a higher calving interval of 17.4 months in central zone of Tigray, 17.1 months in Sidama, 14.36 months in and around Addis Ababa, 15.22 months around Debre Zeit and 20.19 months in south western Ethiopia was reported by Gebrekidan *et al.* (2012); Debir (2016); Zenebe *et al.* (2016); Niraj *et al.* (2017 and Wondossen *et al*. (2018), respectively.

Table 6: Reproductive performance of crossbred dairy cows in the study areas

Reproductive traits	Districts			
	Ada'a Berga	Dirre Inchinni	Walmara	Overall Mean
Service per conception(N)	1.93±0.94(28)	2.00±0.84(15)	2.18±1.05(47)	2.07±0.98(90)
Age at first calving (M)	28.80±0.94(28)	30.00±0.71(15)	30.20±2.31(47)	30.00±1.78(90)
Calving intervals (M)	13.23±2.31(28)	14.47±2.13(15)	14.81±3.54(47)	14.26±3.05(90)

*M=Months N=Number of respondents

Dairy cattle breeding and culling practices

Table 7 presents the kinds of mating and culling practices of dairy cattle in the study areas. About 92.9, 46.7 and 80.2% of the respondents in Ada'a Berga, Dirre Inchinni and Walmara, respectively were using artificial Insemination (AI) for breeding their animals. In agreement to this, Million *et al.* (2015); Mekuria (2016) and Abadi *et al.* (2017) reported that 92%, 72.1% and 56.67% of respondents, respectively, use AI for breeding. This indicates that majority of dairy farmers use AI mostly because of high cost of managing breeding bulls and/or availability of AI service in the areas. On the other hand,large proportion(53.3%) of the respondents in Dirre Inchinni were using nature mating (controlled) for breeding their animals mostly due to lack or shortage of AI facilities. In agreement to this, Mulisa *et al.* (2011) and Abadi *et al.* (2017) reported that 46.4 and 43.33% smallholder dairy farmers in Bishoftu and Adigrat, respectively use breeding bulls for mating their dairy animas.

According to the present study old age, low milk yield and infertility of the animals were the criteria used for culling dairyanimals from the herd (Table 7). However, even if the cows produce low amount of milk, the respondents in all the study districts tend to keep their cows till they become too old due to shortage or high price of replacement dairy heifers.

Table 7: Animal breeding and culling practices in the study areas (% age of respondents)

Practices		Districts		
		Ada'a Berga	Dirre Inchinni	Walmara
Mating system used for crossbred dairy cows	Natural mating	7.2 (2)*	53.3 (8)	19.2 (9)
	Artificial Insemination	92.9 (26)	46.7 (7)	80.2 (38)
Criteria used for culling crossbred dairy cows	Old age	61.5 (16)	60.0 (9)	50.0 (22)
	Low milk production	34.6 (9)	33.3 (5)	20.5 (9)
	Infertility	3.8 (1)	6.7 (1)	11.4 (5)
	Sickness	-	-	18.2 (8)

*= Number of respondents

Calf rearing practices

Calf rearing practice in the study areas indicated that calves are weaned at an average age of 5.2 months and within the range of 4.64-6.27 months (Figure 1). The weaning age at Walmara district was the lowest (4.67 months), which could be attributed to the better awareness of farmers in selling milk. About 74.1, 66.7 and 64.3 % of the respondents in Ada'a Berga, Dirre Inchinni and Walmara districts, respectively, use partial suckling for feeding their calves (Figure 2). Since higher percentage of respondents practice partial suckling, it is not possible to know the amount of milk a calf consume so this is a good indication of lack of awareness of respondents about calf feeding so this could be improved through training.

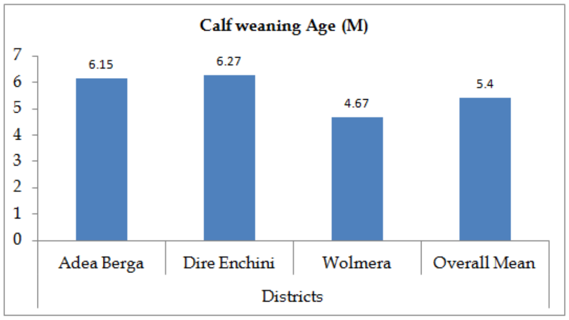


Figure 1.Calf weaning age in months

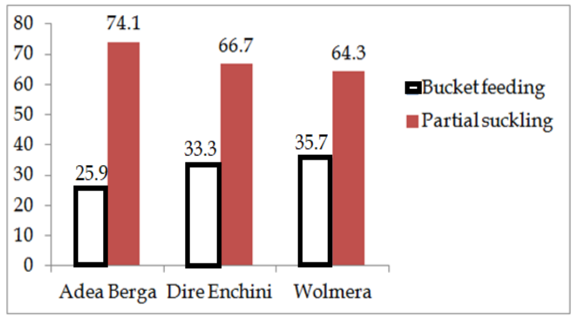


Figure 2.Milk feeding practice for calves

Housing and materials used for housing

Most respondents at Ada'a Berga, Dirre Inchinni and Walmara were housing their animals in separately constructed houses (Table 8). This indicates that most of the respondents have the awareness of keeping the animals in separately constructed houses which is contributing for human health by reducing the transmission of zoonotic diseases. In agreement to this finding, Gezahegn *et al.* (2016) reported that81.2% of respondents was keeping their animals in separately constructed houses. Similarly, Mezgeb *et al.* (2016) reported that majority of dairy farmers Arsi (66.3%) and West Arsi (61.2%) zones were housing their animals in separately constructed houses. As shown in Table 8, majority of the respondents in Ada'a Berga, Dirre Inchinni andWalmara were using corrugated iron sheet roofed house for their animals. This indicate that most of the respondents in the study areas had the awareness of keeping the animal in appropriate housestoprotect their animals from rain, wind and any other environmental stress. Only few (15.6%) and (13.3%) of the respondents in the study areas use grass thatches and plastic sheets as housing materials, respectively.

Table 8: Housing and materials used for housing dairy animals in the study areas (% age of respondents)

Housing and housing materials		Districts			Overall mean
		Ada'a Berga	Dirre Inchinni	Walmara	
How do you house your animals	Adjoining house	3.6	-	8.5	5.6
	Separately constructed	96.4	100	80.9	88.8
	Together with households	-	-	10.6	5.6
Housing materials used (Roof type)	Grass thatches	25	6.7	12.8	15.6
	Iron sheet	46.7	93.3	78.7	71.1
	Plastic sheet	28.6	-	8.5	13.3

Improved forage production and concentrate supplementation

About 75% and 96% of the respondents in the study areas respectivelyreported to produce improved forages and purchase supplementary feeds for their dairy animals (Table 9). In contrary to this finding, Endale *et al.* (2016) and Gezahegn *et al.* (2016) reported that 74.4% and 95% of the sampled households in Meta Robi district and Bench Maji, Sheka and Mejenger zones did not produce improved forage crops. Relatively large land holding of the respondents, proximity to different organizations working on dairy and experience of the farmers on daring might have contributed for better awareness of farmers to produce improved forage crops on their land in the study districts.

As shown in Figure3, about 75% of the respondents purchase both oil seed cakes and wheat bran, 14.4% purchase wheat bran alone and 7.8% of the respondents purchase only oil seed cakes to supplement their animals. Generally, the respondents in the study areas provide concentrates and improved forages with better nutritive value than natural pasture in order to keep their animals healthier and produce more milk.

Table 9: Improved forage production and concentrate supplementation practices

Feed production and supplementations		% of respondents
Do you grow improved forages	Yes	75.6
	No	24.4
Do you buy any feed supplements	Yes	96.7
	No	3.3

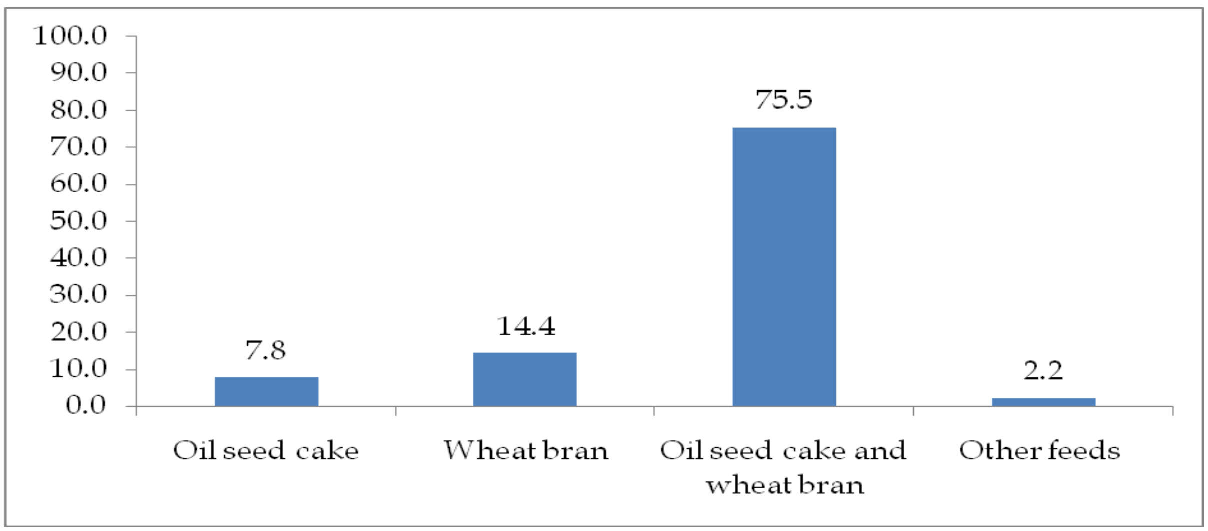
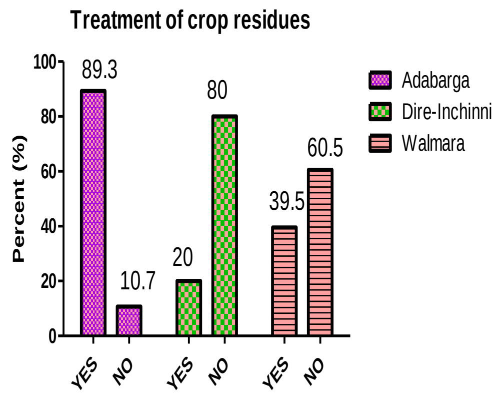


Figure 3: Feed ingredients used for supplementing dairy cattle in the study areas

Crop residues utilization practices

Majority of the respondents in Ada'a Berga, Dirre Inchinni and Walmara use crop residues for feeding dairy cattle. This indicates that the availability of other feed sources was limited. In agreement to this study, Endale *et al.* (2016) reported that the proportion of crop residues as animal feed (76.72%) was higher as compared to other feed types in Meta Robi district. Yeshitila *et al*. (2008) also reported crop residues alone accounted for 78.72% of livestock feed supply. However, the nutritive value of crop residues is very low for dairy cows. To improve the nutritive value and palatability of crop residues, more than 49% of the respondents reported practicing treatment using molasses or salt (Figure 4).



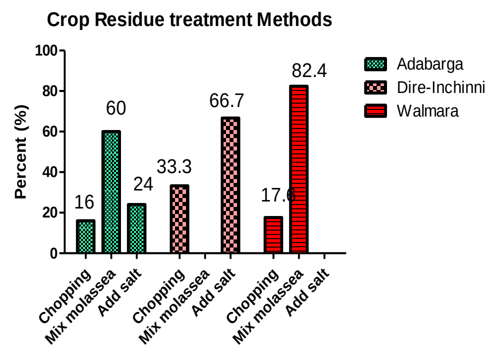


Figure 4. Crop residue treatment practices   Figure 5. Crop residue treatment methods

Source of water

Most respondents in Ada'a Berga (39.3%), Dirre Inchinni (66.7%) and Walmara (44.7%) districts use river as major source of water for dairy animals during the dry season (Table 10). In agreement to this finding, Gezahegn *et al.* (2016); Kasa *et al.* (2016) and Mezgeb *et al.* (2016) reported that 94.7, 75.4-96.5 and 79.5% of surveyed dairy farmersuse river as source of water for their animals in Benchi Maji, Sheka, Mejenger, Jimma and Ilu Aba Bora and Arsi Bale zones, respectively. Most respondents in Ada'a Berga, Dirre Inchinni and Walmara provide water to their dairy animals by transporting water from its source. Significant numbers of respondents in all districts providewater by transporting which significantly contribute in reducing the energy and time spent by the animal in searching water from longer distance.

Table 10: Sources of water and ways of availing waterto dairy animals (% of respondents)

Water availability and source		Districts			Overall mean
		Ada'a Berga	Dirre Inchinni	Walmara	
Sources of water during dry seasons	River	39.3 (11)*	66.7 (10)	44.7 (21)	39.3 (21)*
	Pond	32.1 (9)	-	23.4 (11)	32.1 (9)
	Pipe	28.6 (8)	33.3 (5)	31.9 (15)	28.6 (8)
How do you avail water for your animals	Transportation	66.7 (19)	53.3 (8)	92.9 (44)	66.7 (19)
	Track the animals to water point	33.3 (9)	46.7 (7)	7.1 (3)	33.3 (9)

* = Number of respondents

CONCLUSIONS

The reported performance of crossbred dairy cattle in the study area was encouraging with better daily and lactation milk yield, age at first calving, calving interval and number of services per conception. This improved performance might be due to intensive training of farmers, closer supervision by researchers during demonstration, proximity of the area to research and development organizations for support and above all the experience of the farmers in dairying. Thus, experience sharing among farmers, intensive trainings and closer supervision by researchers and extension staff should be targeted to make the dairy sector more productive. Finally, production cost analysis should be carried out to clearly understand the contribution of dairy farming to the livelihood of smallholder farmers.

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Application of Multivariate Analysis on Morphometric Traits to Characterize the Sheep Populations Reared in the Central Rift Valley of Ethiopia

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ABSTRACT

The study was conducted in Adam-Tullu Jiddo-Kombolcha (ATJK), Bora, Asasa and Kofele districts situated at the Central Rift Valley of Oromia, to describe the morphological diversity of sheep populations by applying multivariate analysis. Morphometric traits were taken from 523 ewes of various age groups. The traits scored were live weight (LW), body length (BL), height at withers (WH), heart girth (HG), height at rump (RH), chest depth (CD), chest width (CW), rump length (RL), rump width (RW), head length (HL), head width (HW), ear length (EL), canon circumference (CC), canon length (CL), tail length (TL), tail circumference (TC) and neck length (NL). Results revealed that district had a highly significant effect on most traits except RL, RW, and HL. The age effect was also significant for all traits except CC, CL and TC. The sheep of Kofele had the highest LW, BL and TL values while those of the Asasa showed the lowest RH, and WH being the shortest amongst the studied sheep populations. The highest WH was noted in Kofele sheep being the tallest ($p<0.01$) from Asasa and Bora sheep. The longest EL was observed in Asasa and Kofele sheep being higher ($p<0.01$) than those of ATJK and Bora. Most morphometric traits increased with advancing age. Body length, TC, CW, TL and LW were identified as the most discriminating variables to differentiate the four district sheep populations. All Mahalanobis distances were significant ($p<0.01$) being the shortest between sheep of ATJK and Bora (0.76) while the longest was observed between those of Asasa and Bora (3.60). Three canonical variables (CAN) were determined of which CAN1 and CAN2 accounted for 69.0 and 27.0% of the total variations, respectively. The CAN1 loaded highly for RH while CAN2 weighted for CD. About 72.3%, 68.6%, and 64.7% of original sheep were correctly classified into their respective source population of Asasa, Kofele and Bora districts. However, only 36.4% of the original ATJK sheep were assigned into their respective population while the remaining being misclassified to other sheep populations. The present work revealed that characterization of indigenous livestock based on morphological traits using a multivariate analysis is a viable option in regions where molecular tools are inaccessible. We recommend initiation of a community-based breeding program for sustainable utilization and conservation of Kofele sheep.

Keywords: Central rift valley; districts; indigenous sheep; morphometric traits; multivariate analysis

INTRODUCTION

Sheep rearing is one of the most important means of livelihood and food security for majority of the rural population, especially in developing countries. Given its proximity to the Arabian Peninsula, Ethiopia is considered as a genetic corridor for the introduction of livestock species including sheep to the African continent (Muigai and Hanotte, 2013). There are 14 traditional sheep populations and nine identified sheep breeds (Gizaw *et al.* 2007) and with a population of 39.89 million heads of sheep out of which about 70.3 and 29.7% are females and males, respectively (CSA, 2019/20).

The 14 Ethiopian sheep populations are broadly categorized according to their tail phenotypes as thin tailed (one breed), fat-tailed (11 populations), and fat-rumped (two populations) (Gizaw*et al.*, 2007). The short fat-tailed population mainly inhabits the sub-alpine regions; long fat-tailed sheep are predominant in mid- to high-altitude environments; and fat-rumped sheep are distributed in dry lowland areas (Gizaw *et al.*, 2007).Study conducted by Edea *et al.* (2018) using a high-density genome-wide SNP analyses on five local sheep revealed that Ethiopian sheep populations are roughly clustered according to their geographic distribution and tail phenotype. Accordingly, short fat-tailed,long fat-tailed and fat-rumped sheep are distributed in very cool high altitude, mid to high-altitude, and arid low-altitude, respectively. Recent study based on genome-wide scans of Bonga sheep revealed the existence of several candidate regions spanning genes that were not reported before in prolific sheep (Tera *et al.*, 2019).

Indigenous livestock biodiversity serve as apoolfor genes that confer disease resistance, specific product qualities likefatty acid composition or milk composition, resistance todraught and high temperatures. Indigenous sheep in Ethiopia play multifarious roles including sources of income, meat, skin, and coarse fleece. They provide an economic buffer in the event of crop failures especially under marginal productivity under low and erratic rainfall, severe land erosion, frost, and water logging regions. In some areas such as the cool alpine and arid lowlands where crop production is not a viable economic option, sheep production is a sole choice for sustainable livelihood of the rural community. Improvement of sheep productivity through proper husbandry and breeding is needed to meet the increasing demand of dietary protein from animal products.It is thus necessary to first explore the genetic potential of the existing sheep genetic resources at national, regional and/or district level through well designed characterization studies (FAO, 2012).

The first step of the characterization of local genetic resources is based on the knowledge of variation in the morphological traits (FAO, 2012). Linear body measurement traits have been suggested as objective measures of body conformation in sheep, which mainly influences market value of meat sheep in traditional markets (Gizaw *et al.*, 2008). In this regard, characterization studies based on morphological traits has contributed to the designing of viable breeding and conservations programs for sustainable utilization of the indigenous livestock genetic resources. Multivariate analyses of morphological traits have been reportedas suitabletools in assessing the genetic variations within and between populations and can effectively discriminate different population ecotypes when all measured morphological variables are considered simultaneously (Härdle and Simar, 2015). These kinds of studies are commonly reported in small ruminant animals such as goats and sheep in many countries of the world (Yakubu and Ibrahim, 2011; Dudusola *et al.*, 2019).

In Ethiopia, characterization of animal genetic resources has largely been limited to description of production systems and phenotype classification of traditional breeds using simple statistical tools such as correlation and regression analysis (Getachew *et al.*, 2009; Melesse *et al.*, 2013; Taye *et al.*, 2016; Tesfay *et al.,* 2017). In a recent study, Wagari *et al.* (2020) reported the existence of new sheep ecotype in western part of Ethiopia by applying multivariate statistical tools. However, to the authors' knowledge, no recent information is available in the literature on the morphological characterization of the indigenous sheep populations of the study area by applying a multivariate analysis. Moreover, morphological distances between sheep populations in the study areas have not been yet established which could serve as a possible basis for genetic improvement and conservation programs. The current study was therefore conducted to describe the indigenous sheep populations of four districts reared in the central rift valley of Oromia based on their morphometric traits by applying multivariate statistical tools.

MATERIALS AND METHODS

Site selection and sampling procedures

The study was conducted in four districts drawn from East Shewa and West Arsi zones of Oromia, Ethiopia. First, the relevant second hand information was gathered from Agriculture and Rural Development office of livestock. Based on the collected information, multi-stage purposive sampling techniques were applied to select the representative districts, kebeles and households. In the first stage, four districts namely Adam-Tullu Jiddo-Kombolcha (ATJK) and Bora from East Shewa zone, and Asasa, and Kofele from West Arsi zone were identified and selected purposively based on their potential for sheepproduction. In the second stage, based on distribution of sheep population, 3 kebeles from each district (total of 12 kebeles) were selected purposively. In the final stage, the households within kebeles who possess at least three matured sheep of both sexes and had long enough experiences in rearing sheep, were randomlyselected based on the proportional to the population size of the selected kebeles. Collectively, 523 ewes were sampled from the four districts. The agro-climatic characteristics of the studied districts and number of sampled ewes are provided in Table 1. The owner's recall method along with dentition classes (pairs of permanent incisors, PPI) were used to estimate the ages of sheep. Thus, sheep with 1PPI, 2PPI, 3PPI and 4PPI were classified in the age groups of yearling, 2-year-old, 3-year-old and 4-year-old, respectively (Ebert and Solaiman, 2010).

Table 1. Agro-climatic characteristics and sample size of households and sheep across each district

Districts	GPS coordinates	Altitude (m.a.s.l)	Agro-ecology coverage	Annual Rainfall(mm)	Sampled ewes
ATJK	07° 55'N, 39°45'E	1643	90% LL, 10% ML	700	89
Bora	08°39′ N, 39°50′ E	1880	85% LL, 15% ML	800	85
Kofele	07° 00' N, 38°45'E	2695	90% HL, 10% ML	2500	178
Asasa	07°06′ N, 39°12′ E	2367	65% ML, 35% HL	1970	171

ATJK = Adam-Tullu Jiddo-Kombolcha; LL = lowland <1500 m a.s.l;
ML = midland =1500-2300 m a.s.l; HL = highland >2300 m a.s.l

Data collection procedures

Data were scored on 17 morphometric traits following the descriptor list of FAO (2012) for phenotypic characterizations of sheep. Accordingly, the following traits were measured: live weight (LW), body length (BL), height at withers (WH), heart girth (HG), height at rump (RH), chest depth (CD), chest width (CW), ramp length (RL), rump width (RW), head length (HL), head width (HW), ear length (EL), canon circumference (CC), canon length (CL), tail length (TL), tail circumference (TC) and neck length (NL). Wooden made ruler fitted with sliding height bars were used to measure withers height. The LW was taken using a suspended weighing scale with 100 kg capacity by placing each animal in self-devised holding harness. All other linear measurements were taken in the morning before sheep were released for grazing by using measuring tapes made of textile material. Measurements were also restricted to healthy and non-pregnant sheep.

Data analysis

After double-checking for any types of errors or outliers, data were subjected to GLM procedures of Statistical Analysis System (SAS 2012, ver. 9.4)to analyze quantitative variables to determine effects of class variables (district and age) and their interactions. When F-test declared significant, multiple least square means were then compared with Tukey-Kramer test. The degree of morphological similarity or divergence among the indigenous sheep populations was determined using the multivariate analysis.

Dendrogram was constructed based on distances between the sheep populations of the four districts using the average linkage method of the hierarchical cluster analysis to group the flocks into their morphological similarity. Moreover, the stepwise discriminant analysis was applied using the STEPDISC procedure to determine the morphometric traits that have the most discriminating power to separate the studied sheep populations. The relative potential of the morphometric variables in discriminating the foursheep populations was assessed using the level of significance, F-statistic and partial R^2.

The canonical discriminant analysis was then performed on the identified traits with the highest discriminating power using the CANDISC procedure to compute the squared Mahalanobis distances between class means, univariate (ANOVA) and multivariate (MANOVA) analysis, canonical variables with eigenvalues, standardized canonical coefficients and canonical structures. The TEMPLATE and SGRENDER procedures were used to create a plot of the first two canonical variables in a scatter graph for visual interpretation. The discriminant analysis of the DISCRIM procedure was also conducted to determine the classification of sheep into their source populations using the quadratic discriminant function for unequal covariance matrices within classes after conducting the Bartlett's homogeneity test. The cross-validationoption was finally applied to evaluate the accuracy of the classification with a minimum bias. All multivariate analyses were performed using the Statistical Software of SAS (2012, ver. 9.4).

RESULTS

Effect of district and age on morphometric traits

Leastsquare means of morphometric traits, as well as the significance of the district and age effects, are presented in Table 2. The effect of district was highly significant for most traits studied except RL, RW, and HL. Accordingly, the Kofele sheep had higher LW, BL and TL values than the other populations. The Kofele sheep were further characterized withhigher HG than ATJK and Asasa sheep populations. The Asasa sheep had the lowest BL, CC, and TCas compared with other sheep populations. They had also the lowest RH, and WH values compared with Bora and Kofele sheep being the shortest amongst the studied sheep populations. The highest HW was noted in sheep of Kofele, which differed ($p<0.01$) from those of Asasa and Bora. The longest EL was observed in Asasa and Kofele sheep being higher ($p<0.01$) than those of ATJK and Bora. The effect of age was also significant for all traits except CC, CL and TC. Accordingly, most of the morphometric traits increased with the advancing age of the sheep. The interaction effect was significant for HG, WH, BL, CD, RL, HL, EL, and CL.

Table 2. Least square means of the morphometric traits as affected by district and age (N = 523)

Traits	Districts (D)				Age (A)				Sources of variation		
	ATJK	Asasa	Bora	Kofele	1PPI	2PPI	3PPI	4PPI	D	A	D*A
Live weight	26.0^{b}	25.9^{b}	25.9^{b}	28.1^{a}	23.6^{d}	25.2^{c}	27.8^{b}	29.0^{a}	<0.001	<0.001	0.689
Heart girth	70.0^{b}	68.6^{bc}	70.2^{ab}	71.5^{a}	67.0^{d}	68.9^{c}	71.6^{b}	72.8^{a}	<0.001	<0.001	0.006
Height at withers	61.9^{ab}	61.2^{b}	62.4^{a}	62.7^{a}	61.1^{c}	61.9^{bc}	62.3^{ab}	62.9^{a}	<0.001	<0.001	0.009
Body length	62.0^{b}	59.4^{c}	62.2^{b}	63.9^{a}	60.3^{c}	61.2^{bc}	62.6^{ab}	63.5^{a}	<0.001	<0.001	0.018
Height at rump	63.5^{ab}	62.5^{b}	63.9^{a}	64.3^{a}	62.9^{b}	63.2^{b}	63.9^{ab}	64.3^{a}	<0.001	0.006	0.101
Chest depth	30.4^{ab}	29.3^{c}	30.2^{bc}	31.1^{a}	29.1^{c}	30.1^{bc}	30.6^{b}	31.3^{a}	<0.001	<0.001	0.004
Chest width	17.6^{ab}	17.9^{a}	17.2^{b}	17.9^{a}	17.0^{b}	17.9^{a}	17.7^{a}	18.0^{a}	0.007	0.001	0.295
Rump length	19.6	19.5	19.4	19.7	19.1	19.6	19.6	19.8	0.082	0.097	0.024
Rump width	17.0	16.6	17.2	16.9	16.4^{b}	17.1^{ab}	17.0^{ab}	17.1^{a}	0.108	0.007	0.620
Head length	16.5	16.4	16.7	16.4	16.2^{b}	16.4^{ab}	16.6^{ab}	16.8^{a}	0.884	<0.001	0.002
Head width	10.9^{ab}	10.6^{b}	10.6^{b}	11.1^{a}	10.4^{b}	10.8^{ab}	11.0^{a}	11.1^{a}	0.004	<0.001	0.194
Ear length	11.2^{b}	11.7^{a}	11.2^{b}	11.9^{a}	11.0^{b}	11.4^{ab}	11.7^{a}	11.8^{a}	0.007	<0.001	0.059
Canon circumference	6.99^{a}	6.56^{b}	6.93^{a}	6.79^{a}	6.83	6.93	6.72	6.79	0.002	0.902	0.007
Canon length	12.3^{a}	11.9^{b}	12.4^{a}	12.1^{ab}	12.1	12.2	12.2	12.2	0.004	0.732	0.445
Tail length	32.6^{b}	32.7^{b}	31.7^{b}	34.8^{a}	29.6^{c}	34.9^{a}	33.0^{b}	34.2^{ab}	<0.001	<0.001	0.003
Tail circumference	16.8^{a}	14.4^{b}	17.0^{a}	16.6^{a}	16.0	16.1	16.0	16.6	<0.001	0.233	0.098
Neck length	22.6^{ab}	22.4^{b}	22.6^{ab}	23.2^{a}	22.2^{b}	22.3^{b}	23.0^{ab}	23.3^{a}	0.006	<0.001	0.633

$^{a-d}$Means with different superscript letters between columns across districts and age are significant; ATJK = Adam-Tullu Jiddo-Kombolcha

Results of multivariate analysis

The dendrogram (Figure 1) showed two clusters: cluster one identified Asasa sheep as an independent group and cluster two includes all other sheep with two sub-clusters in which Bora and ATJK grouped in one while those of Kofele in the other.

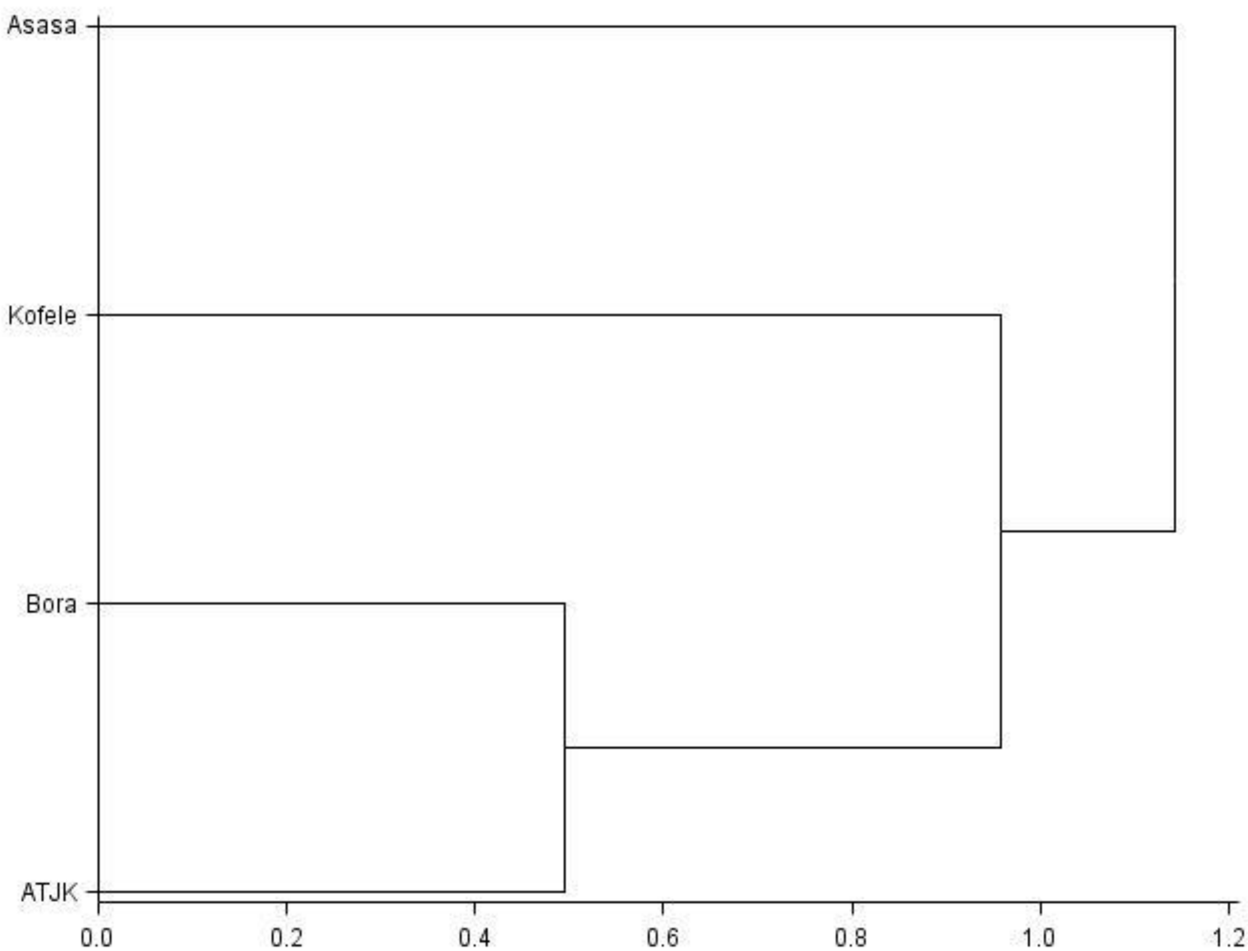

Figure 1. Dendrogram based on average linkage distances among the indigenous sheep populations of the four districts by using 15 morphometric traits (ATJK = Adam-TulluJiddo-Kombolcha district)

Seventeen quantitative variables were subjected to the STEPDISC procedure and fifteen were identified as the best discriminating variables in stepwise selection summary (Table 3). Wilk's lambda test confirmed that all the selected variables had significant ($p<0.001$) contribution to discriminate the total population into separate groups. Among them, BL, TC, CW, TL and LW were identified as the most discriminating variables to differentiate the four sheep populations.

Table 3.Selection summary of morphomteric traits using the stepwise discriminant analysis

Variables entered	Partial R^2	F Value	Pr > F	Wilks' Lambda	Pr < Lambda	ASCC	Pr > ASCC
Body length	0.149	29.60	<.0001	0.850	<.0001	0.050	<.0001
Tail circumference	0.072	13.15	<.0001	0.789	<.0001	0.071	<.0001
Chest width	0.057	10.24	<.0001	0.744	<.0001	0.088	<.0001
Tai length	0.037	6.52	0.0002	0.716	<.0001	0.100	<.0001
Live weight	0.034	5.88	0.0006	0.692	<.0001	0.110	<.0001
Chest depth	0.048	8.35	<.0001	0.659	<.0001	0.122	<.0001
Rump width	0.034	5.86	0.0006	0.637	<.0001	0.132	<.0001
Head length	0.027	4.65	0.0032	0.620	<.0001	0.139	<.0001
Height at rump	0.033	5.69	0.0008	0.599	<.0001	0.147	<.0001
Height at withers	0.025	4.32	0.0051	0.584	<.0001	0.154	<.0001
Ear length	0.023	3.85	0.0096	0.571	<.0001	0.160	<.0001
Canon length	0.023	3.84	0.0098	0.558	<.0001	0.167	<.0001
Head width	0.021	3.57	0.0141	0.546	<.0001	0.173	<.0001
Canon circumference	0.015	2.46	0.0623	0.537	<.0001	0.176	<.0001
Heart girth	0.015	2.52	0.0569	0.530	<.0001	0.180	<.0001

ASCC = average squared canonical correlation

All the fifteen variables were subjected to canonical discriminant analysis using the CANDISC procedure. The univariate statistics confirmed that each quantitative variable in sampled populations is a significant ($p<0.01$) contributor to the total variation (data not shown). The hypotheses that assumes districts' means are equal in the populations were tested using multivariate statistics and was rejected by Wilk's Lambda (F-value = 7.77, $p<0.001$).

Table 4 shows significant Mahalanobis distances between flocks based on morphometric measurements sorted by mean distances. All Mahalanobis distances were significant ($p<0.001$) being the shortest between ATJK and Bora sheep (0.76) followed by that of ATJK and Kofele (0.79). On the other hand, the longest distances was noted between Asasa and Bora (3.60) followed by that of Asasa to Kofele (2.61). The third longest distance was observed between Bora and Kofele sheep (1.76).

Table 4.Mahalanobis distances and significant levels among the sheep populations of the four districts based on morphometric traits

Districts	ATJK	Asasa	Bora	Kofele
ATJK	0	1.88***	0.76**	0.79***
Asasa		0	3.60***	2.61***
Bora			0	1.76***
Kofele				0

*** = $p<0.0001$; ** = $p<0.001$; ATJK = Adam-TulluJiddo-Kombolcha

The canonical discriminant analysis further derived a linear combination of the variables that has the highest possible multiple correlation with the groups (Table 5). The variable that is defined by the linear combination is the first canonical variable (CAN1). The process of extracting CAN2, CAN3, etc.that is needed for the separation purposes will be repeated until the number of canonical variables equals the number of classes/groups minus one. In the present study, there were four districts (ATJK, Asasa, Bora and Kofele), thus there would be 4 − 1 = 3 possible CANs(CAN1, CAN2 and CAN3) needed for separation purposes. This is evident in Table 5 where CAN1 and CAN2 explained 69.0% and 27.0% of the total variation, respectively being highly significant (p<0.0001). The third CAN (CAN3) accounted for only 4% of the total variation and its contribution to the total variation was insignificant (p = 0.3919). The correlation between CAN1 and the sheep populations sampled from the four districts was relatively high (0.568), with the canonical variables being highly significant (p<0.0001).Moreover, the respective eigenvalues foe CAN1 and CAN2 were 0.524 and 0.205, which together accounted for 0.729 (96.3%) of the cumulative variance.Table 5 further displayedthe likelihood ratio test rejecting the hypothesis that the current canonical correlation and all smaller ones are zero, except CAN3.

Table 5. Summary of canonical correlations, eigenvalues and likelihood ratios

Functions	Canonical correlations	Eigenvalues			Likelihood ratios	Approximate F-value	Pr>F
		Eigenvalue	Proportion	Cumulative			
CAN1	0.568	0.524	0.69	0.69	0.530	7.77	<0.0001
CAN2	0.387	0.205	0.27	0.96	0.807	3.98	<0.0001
CAN3	0.098	0.028	0.04	1.00	0.973	1.06	0.3919

CAN1 = canonical variable 1; CAN2 = canonical variable 2; CAN3 = canonical variable 3

Figure 2 shows a plot built with the first two canonical variables illustrating the relationships between sheep belonging to the four districts. The plot clearly showed that CAN2 discriminates between the Asasa sheep in one group while the CAN1 best discriminates among the ATJK and Bora sheep populationsin another group. The Kofele sheep fall between the two canonical variables (CAN1 and CAN2). Nevertheless, a noticeable overlapping has been observed among the three sheep populations suggesting morphological similarity among them.

As indicated in Table 6, the first canonical variable CAN1 loaded highly for RH, TC, and BL with canonical discriminant function scores of 0.765, 0.661 and 0.565, respectively. On the other hand, the CAN2 loaded for CD, TL, HW, CW, LW and ELwith canonical discriminant function scores of 0.530, 0.479, 0.462, 0.306, 0.287 and 0.255, respectively. Results of canonical structures were also in line with that of total standardized canonical coefficients in which BL, TC and RH dominated CAN1, while TL, LW, CD, HW, EL and CW showed the largest influence on CAN2 with comparable values of canonical structures.

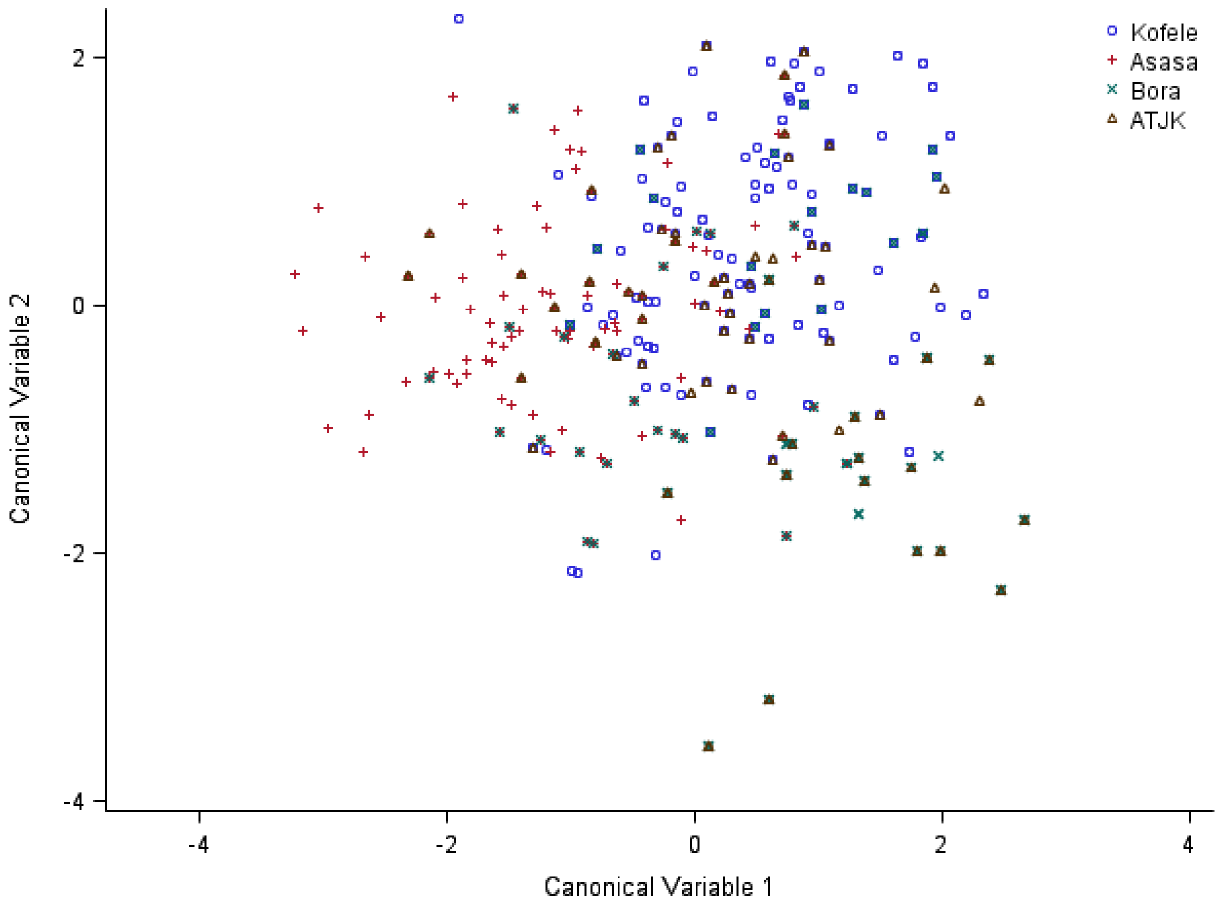

Figure 2. Canonical representation of the central rift valley sheep populations across the four districts based on morphometric traits

Discriminant analysis assumes that the individual group covariance matrices are equal (homogeneity within covariance matrices) and by default it uses the linear discriminant function for classification unless specified otherwise. In the current discriminant analysis, equality of covariance matrices within groups was tested using Bartlett's test of homogeneity for all traits and was significant (χ^2 = 926; p<0.0001). Thus, the null hypothesis that assumes all four covariance matrices within the sheep populations are equal was rejected (Table 7). Based on these results, the appropriate discriminant function to be applied for the classification of the four sheep populations would be the quadratic discriminant function.

Table 6.Standardized canonical coefficients and canonical structures based on morphometric variables of indigenous sheep populations sampled from four districts

Variables	Standardized canonical coefficients		Canonical structures	
	CAN1	CAN2	CAN1	CAN2
Live weight	-0.589	0.287	0.208	0.465
Heart girth	0.256	-0.470	0.331	0.285
Height at withers	-0.531	0.226	0.315	0.233
Height at rump	0.765	-0.292	0.410	0.216
Body length	0.565	0.405	0.595	0.370
Chest depth	0.465	0.530	0.415	0.412
Chest width	-0.574	0.306	-0.098	0.365
Rump width	0.103	-0.483	0.231	-0.131
Head length	-0.365	-0.194	0.012	0.001
Head width	0.006	0.462	0.155	0.403
Ear length	-0.246	0.255	-0.118	0.396
Canon circumference	0.258	-0.234	0.323	-0.020
Canon length	-0.005	-0.417	0.277	-0.060
Tail length	0.177	0.479	0.077	0.509
Tail circumference	0.661	-0.102	0.593	-0.0013

Most important variables (WEIGHT) within the CAN1and CAN 2 are indicated with bold CAN1 = canonical variable 1; CAN2 = canonical variable 2;

Table 7. Test for the homogeneity of covariance matrices

Districts	Covariance matrix rank	Log of covariance determinant	Overall homogeneity test results
ATJK	15	11.6	$\chi^2 = 926$
Asasa	15	11.2	DF = 360
Bora	15	9.42	P-value = <0.0001
Kofele	15	12.3	
Pooled within districts	15	13.3	

ATJK = Adam-Tullu Jiddo-Kombolcha

As presented in Table 8, 72.3% of Asasa sheep were correctly classified into their respective group with 12.7, 8.43 and 6.63% being misclassified to ATJK, Bora and Kofele sheep populations, respectively. Likewise, 68.6% of Kofele sheep were correctly assigned to their source population while the remaining 11.1, 14.0 and 6.40 being misclassified to ATJK, Asasa and Bora sheep populations, respectively. The quadratic discriminant function was also able to differentiate the Bora sheep from others with 64.7% correct classification into their original source population with the remaining 3.53, 15.3 and 16.5% being misclassified to ATJK, Asasa and Kofele sheep populations, respectively. On the other hand, only 36.4% of the original ATJK sheep were correctly classified into their respective population while the majority (about 63.6%) of the remaining being misclassified to the other sheep populations. Overall, 60.5% the sheep populations were correctly assigned to their source population using the quadratic discriminant function with 15 variables.

Table 8. Percent of individual sheep classified into source populations and cross-validation of the classification using morphometric variables (values in brackets are number of sheep)

Districts	ATJK	Asasa	Bora	Kofele	Total
Classified					
ATJK	36.4 (32)	15.9 (14)	27.3 (24)	20.5 (18)	88
Asasa	12.7 (21)	72.3 (120)	8.43 (14)	6.63 (11)	166
Bora	3.53 (3)	15.3 (13)	64.7 (55)	16.5 (14)	85
Kofele	11.1 (19)	14.0 (24)	6.40 (11)	68.6 (118)	172
Error count rate	0.636	0.277	0.353	0.311	0.395
Priors	0.250	0.250	0.250	0.250	
Cross-validated					
ATJK	22.7 (20)	19.3 (17)	29.6 (26)	28.4 (25)	88
Asasa	18.7 (31)	60.2 (100)	11.5 (19)	9.64 (16)	166
Bora	14.1 (12)	21.2 (18)	45.9 (39)	18.8 (16)	85
Kofele	18.6 (32)	14.5 (25)	9.30 (16)	57.6 (99)	172
Error count rate	0.773	0.398	0.541	0.424	0.534

ATJK = Adam-Tullu Jiddo-Kombolcha

The classification accuracy of the discriminant analysis was further cross-validated and indicated an overall 46.6% success rate. The error-count estimates gave the proportion of misclassified observations in each group being highest in ATJK sheep and lowest in Asasa. Accordingly, 19.3, 29.6 and 28.4% of ATJK sheep were misclassified to Asasa, Bora and Kofele, respectively (Table 8). The overall rate of error count estimate for the classification was 39.5% while it was 53.4% for cross-validation method. It would be worthwhile to note that the cross-validation method achieves a nearly unbiased estimate but with a relatively large variance.

DISCUSSION

Morphometric traits as affected by district and age

District showed a significant ($p<0.001$) effect on all quantitative traits except RL, RW, and HL. The observations are consistent with the reports of Wagari *et al.* (2020) for sheep populations of western part of Ethiopia. The Asasa sheep were characterized by short height as measured by their WH and RH (both represent height), with the body being close to the ground, which might correspond to their adaptation to mountainous terrains. Moreover, the Asasa sheep were described by small body size as measured by their BL, CC, and TC values being the lowest compared with the other sheep populations. Sheep of Kofele district were the heaviest possessing the longest body size as measured by their LW and BL, respectively. This may suggest that the productivity of Kofele sheep related to its adaptation to the highland altitudes, an environment that favors sheep keeping. The longest EL was observed in Asasa and Kofele sheep, which is consistent with the observations of Wagari *et al.* (2020), who reported a similar value (11.8 vs. 11.9 cm) for Guduru sheep reared in western part of Ethiopia. Abdallah and Omar (2017) reported EL values for Awassi ewes ranging from 19.5 to 22.3, which is almost twice as long as the ear length of the Ethiopian sheep reported here. Ear length has been related to the adaptation potential of small ruminant animals in a specific production environment such as exposure to extreme heat stress conditions (Elbeltagy *et al.*, 2016).

The overall average LW for all districts (26.5 kg) in the present study is similar to that of Wagari *et al.* (2020) who reported 26.4 kg for female sheep populations from Dendi, Guduru and MidaKegn districts of western Ethiopia. Melesse *et al.* (2013) also reported similar LW, WH and BL values for female sheep populations reared in five administrative zones of southern Ethiopia. However, the same authors reported lower HG for the same sheep than observed in the average values of the current study. Likewise, Wagari *et al.* (2020) reported higher HG, WH, BL and RH values for female sheep than observed in the average of values these traits. Taye *et al.* (2016) also reported higher HG, WH, and RH for Doyogena female sheep compared with the average values of the current study. The manifestation of such variations in the indicated quantitative traits in the literature might be attributed to differences in the management practices among the communities and availability of feed and water resources. The indigenous sheep populations are also mostly bred at low selection intensity, and might be subject to high natural selection pressure resulting in considerable variations among indigenous livestock populations with respect to the expression of the morphometric traits.

Except CC, CL and TC, other morphometric traits significantly increased with the age of the sheep suggesting that these traits were little influenced by season (wet and dry season) which is mainly characterized by the availability of feed resources among others. This observation is consistent with those of Mohammed *et al.* (2018) and Wagari*et al.* (2020) who reported increase of all measured morphometric traits with the age of the sheep reared in North Eastern and western parts of Ethiopia, respectively. Yakubu (2013) reported a significant effect of age on all the morphological characters except for EL.Edea*et al.* (2009) and Taye *et al.*(2016) reported a non-significant effect of age on TC of local sheep, which is in good agreement with current finds. The interaction of district with age showed a significant effect for HG, WH, BL, CD, RL, HL, EL, and CL which suggests that some districts influence the development of these traits with the age of the sheep. In this regard, Kofeleagro-climate, which is dominated by high elevation, appeared to favor the sheep productivity for most of the studied morphometric traits. Moreover, the significant interaction effects of district by age may indicate the separate rankings of the sheep populations under ages investigated.

Multivariate analysis of morphometric traits

The stepwise discriminant analysis identified fifteen significant discriminatory traits (to discriminate among the sheep populations of the four districts) with BL, TC, CW, and TL showing the highest discriminating power. These identified morphomtetric traits in the studied sheep could be utilized as references to develop future conservation and breeding strategies. These observations are consistent with the reports of Abdallah and Omar (2017) who reported similar traits that had discriminating power in differentiating the Awassi female sheep breed in three regions. Most of these traits were also significant contributors to discrimination among geographical regions in Spanish Assaf (Legaz *et al.*, 2011) and Ethiopian (Melesse *et al.*, 2013) indigenous sheep breeds.

The application of cluster analysis identified two clusters in which cluster one displayed the Asasa sheep as a separate independent group and cluster two embraces all other sheep with two sub-clusters in which sheep of Bora and ATJK grouped in one and those of Kofele in the other. The grouping of Bora and ATJKsheep populations collectively under one sub-cluster could be explained by the fact that these two ecotypes tend to have comparable values in most of the morphometric traits. Moreover, both sheep populations share similar geographical terrains that cover most (over 80%) of the lowland regions of the studied districts (Table 1). This observation indicates the existence of genetic similarity among sheep populations due to gene flow caused by the exchange of flocks through common market outlets. Moreover, the shortest Mahalanobis distance was noted between sheep of ATJK and Bora districts further confirming their genetic similarity.

On the other hand, the cluster analysis indicated that the Asasa sheep were separately groupedfar away from the threesheep populations, which could be explained by the fact that this sheep population tend to have the shortest height and the smallest body size, which apparently differentiated them into a separate group. Besides, this observation has been further supported by the results of the Mahalanobis distances in which the Asasa sheep had the longest distances (ranging from 1.88 to 3.60) with the other three sheep populations. Separate grouping is an indication that the sheep populations of the Asasa district may possess different morphometric qualities and characteristics that might be attributed mainly to geographical origin of the ecotypes. Differences in the origin of farm animals could influence phenotypic response based on potential for additive genes controlling the quantitative traits (Mulyono *et al.*, 2009).

Most of the discriminating variables in the present study are similar to those reported by Wagari *et al.* (2020) for sheep of western Ethiopia, that of Abdallah and Omar (2017) for Awassi sheep of Palestine, and Yunusa *et al.* (2013) for Nigerian sheep populations. Canonical discriminant analysis finds linear combinations of the quantitative variables that provide maximal separation between classes or groups. Determining the morphological distances will help to comprehend the genetic diversity of the indigenous animal populations and enable to initiate suitable breeding programmes that are useful for the conservation of the animal geneticresources.

The Wilks' Lambda, which presents the ratio of within-group variability to total variability on the discriminating variables, is an inverse measure of the importance of the discriminant functions (Huberty and Olejnick, 2006). In the present study, the value of Wilks' Lambda for the sampled population was 0.53 (53.0%), which indicates that almost half (47.0%) of the variability in the discriminator variables was because of the differences between the sheep populations rather than variation within the population. In this regard, the discriminant analysis carried out provided complementary information in which about 59.7% of the individual sheep were correctly classified to their source population, which indicates the existence of genetic heterogeneity of sheep populations across populations for those variables included in the discriminant analysis. However, only about 36.0% of the original ATJK sheep were correctly classified into their respective population while the majority (about 74.0%) of the remaining being misclassified to the other sheep populations. This observation may suggest a strong intermingling of the ATJK sheep with the other ecotypes with almost similar misclassification rates (15.9to 27.3%) across the three districts (Table 8). In agreement with the current findings, Yakubu and Ibrahim (2011) reported on Nigerian indigenous sheep population that 41.2% of Uda sheep were misclassified as Yankasa sheep and 35.4% of Yankasa as that of Uda sheep.

The Mahalanobis distance is the most commonly used distance measure for quantitative traits of livestock breeds. All the Mahalanobis distances in the current study were significant which is consistent with the findings of Birteeb *et al.* (2013) and Wagari *et al.* (2020) for Northern Ghana sheep and western Ethiopia sheep, respectively.The significant differences among distances indicated that differences among sheep populations are important for the classification process. It also signifies theexistence of variations among the quantitative traits of the studied populations. The longest Mahalanobis distance occurred between Asasa and Bora sheep populations (3.60) possibly due to geographical isolation of these herds, consequently limiting the flow of genes across generations. The shortest Mahalanobis distance observed between ATJK and Borasheep populations may suggest that that they share similar phenotypic similarities, which might have been resulted from non-selection, continuous inbreeding, and admixture among these populations due to migration or ram exchange programs over several generations. Moreover, geographic proximity may have facilitated gene flow between the ATJK and other populations particularly to that of Bora sheep.

Yakubu and Ibrahim (2011) reported a Mahalanobis distance of 1.79 between Uda and Yankasa sheep, which is consistent with the current results observed between Bora and Kofele sheep (1.76). The Mahalanobis distances between Asasa and Kofele sheep populations in the current study are comparable to those reported by Wagari *et al.* (2020) among Dendi and Guduru sheep; but were much lower than those reported by Abdallah and Omar (2017) for Awassi sheep. Such large variations might arise in the methods applied for computing the Mahalanobis distances. For example, pairwise distances computed using canonical discriminant analysis might be different from the one analyzed using the discriminate function that produces squared Mahalanobis distances (Abdallah and Omar, 2017). Moreover, the number of samples used in the discriminant analysis would influence the outcome of the Mahalanobis distances being higher in smaller sample size than in larger (Melesse *et al.*, unpublished data).

It is apparent that for the total traits used in this study both canonical variables were adequate to explain the total variation (96.0%), indicating large reduction in sample space, with little loss (4.0%) to explain the total variation. Most of studies dealing with goats suggested that canonical analysis could minimize sample space with a loss of similar to this value (Jimcy *et al.* 2011; Arandas *et al.*, 2017).In a study conducted by Traoré *et al.* (2008) for Burkina Faso sheep and Legaz *et al.* (2011) for Spanish Asaf sheep, all the canonical variables extracted were found to be significantly different and are consistent with the current results. In the present study, CAN1 and CAN2 explained 69.0% and 27.0% of the total variation while the third CAN (CAN3) accounted for only 4% of the total variation being its contribution insignificant ($p = 0.3919$). Therefore, the third CAN does not contribute much significantly in the discrimination process as compared to that of CAN1 and CAN2. The current observations are lower than that of Wagari *et al.* (2020) who reported that the first canonical variable accounted for 80.6% of the variation for sheep of western part of Ethiopia. On the other hand, Ogah (2013) reported 59.7 and 40.3% of the total variation for CAN1 and CAN2, respectively, which is lower than found in the present study. The observed variations for each canonical variable in the literature might be due to differences in genetic makeup of the sheep studied and management practices applied by different countries.

The standardized canonical coefficients indicated the partial contribution of each variable to the discriminant function, controlling for other attributes entered in the equation. The first canonical variable CAN1 loaded highly for RH, which is in good agreement with the observations of Birteeb *et al.* (2013) and Wagari *et al.* (2020) who reported RH as a principal trait to differentiate the Sahel from the Djallonke sheep and the four local sheep populations in western Ethiopia, respectively. The CAN2 highly loaded for CD as important discriminant variable among other traits. Results of canonical structures were also in line with that of total standardized canonical coefficients. Wagari *et al.* (2020) also reported a strong influence of EL and WH on CAN1 that differs from the present observation. Age, genetic make,and production environments of the givensheep populations might be responsible for differences reported by various authors.

Overall, 60.5% the sheep populations were correctly assigned to their source population using the quadratic discriminant function with 15 morphometric variables, which indicates the existence of heterogeneity among the sheep populations across districts for those variables included in the discriminant analysis. Nevertheless, the overall average correct classification for sampled populations was relatively low with high proportion of misclassification rates. The large number of misclassified individuals was particularly observed in ATJK sheep,which indicates a higher degree of intermingling with the other sheep ecotypes. The existence of genetic variation within and between populations is essential for the populations to adapt to frequently changinglocal climate and to respond to artificial selection successfully (Toro *et al.*, 2011).

Wagari *et al.* (2020) correctly classified 71.2% of Dandi sheep to their genetic group, which is similar to those of Asasa sheep in which 72.1% of them were assigned to their original group. The same authors also reported the classification of 69.2% of MidaKegn sheep into their genetic group, which is consistent to the present study where68.6% of Kofele sheep were correctly assigned to their source group. About 60.3% (semi-arid), and 38.5% (dry subhumid) of indigenous goats of Limpopo province in South Africa were correctly allocated into their original agro-ecological zone by Selolo *et al.* (2015), which is comparable with the current findings for Bora and ATJK sheep populations (with the respective values of 64.7 and 36.4%). The classification of Bora and ATJK sheep into their source population was also in good agreement with those of Yakubu and Ibrahim (2011), who reported that 61.5% and 33.5% of Balami and Uda sheep breeds were assigned to their source population.

Animal genetic resources in developing countries like Ethiopia are components of biological diversity, which play a significant role in meeting the food requirement of these nations where the effect of climate change has been a major challenge to the main stay of the rain fed agriculture. Between-breed diversity has beentraditionally considered as a major criterion to be taken into account when setting priorities for conservation of domestic animal breeds. In the present study, both Asasa and Kofele sheep have shown significant deviations from each other as well as from the other two sheep populations. The Kofele sheep were particularity superior in most of economic important traits including LW, BL, HG and CD.

CONCLUSIONS

District and age had a significant effect on most of the morphometric traits studied. The highest live weight, height at withers and body length was noted for Kofele sheep being the tallest among the other sheep with a large body dimension. Sheep of ATJK and Bora were clustered together while those of Asasa were grouped distantly. Among the studied morphometric traits, body length, tail length and circumference, chest width, and live weight were identified as the best discriminating variables to differentiate the four sheep populations. All pairwise Mahalanobis distances were significant being the shortest between sheep of ATJK and Bora districts and the longest among those of Asasa and Bora. The CAN1 and CAN2 explained 69.0% and 27.0% of the total variation, respectively. The CAN1 highly loaded for rump height while CAN2 for chest depth with the respective discriminant function scores of 0.765 and 0.530. Most of the sheep populations were correctly assigned into their districts of origin except those of ATJK. However, the canonical discriminant analysis has showed a visible overlapping among the four district sheep populations indicating the existence of morphological homogeneity among them. The current findings further revealed that the Kofele sheep were particularity found to be superior in most of economic important traits and would be justifiable to consider this unique ecotype in a community-based breeding program as a conservation strategy for its sustainable utilization.

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Conflict of interest

Authors declared that there is no conflict of interests.

Authors' contribution: AW prepared the proposal; collected all data in the field; entered all data to spread sheet; prepared the first draft manuscript. AM reviewed the proposal; supervised the field research activity; run all statistical analysis; prepared the final manuscript.

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Dry Matter Intake and Feed Conversion Efficiency of Pure Jersey Calves Reared on Two Whole Milk Feeding Systems

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ABSTRACT

Setting economically better level of milk for calves rearing is essential in dairy farming. The objective of this study was to evaluate feed intake, growth and feed conversion efficiency of pure Jersey calves at Adea Berga Research Station, Ethiopia. A study on rearing Jersey calves (males and females), utilizing two systems of whole milk feeding was conducted on 29 calves. Calves were fed colostrums from birth up to 4 days of age and assigned to either Holeta Research Center feeding standard set for crossbred calves (feeding 260 litres whole milk per calf from birth up to weaning) as Treatment 1, and 10% calf body weight level as Treatment 2. Calf starter and hay) were offered from two weeks of age. Daily whole milk consumption, feed intake and fortnightly body weights were recorded. Feed samples were collected and analyzed for chemical compositions. Data were analyzed using SAS version 9, 2004. Calves in Treatment1 consumed higher amount of whole milk during early life than those in Treatment 2. However, Calves in Treatment 2 consumed higher amount of whole milk than calves in Treatment 1 after seven weeks of age. Daily dry matter intake of calves was higher for calves reared under Treatment 2. Calves reared under Treatment 2 had higher growth rate starting at 7 weeks of age. Calves in Treatment 2 attained significantly ($P<0.05$) higher body weight at 6th months of age as compared to calves in Treatment 1. Calves in Treatment 2 had higher feed conversion efficiency (gain: feed) than calves in Treatment1. Thus it can be noted that for better growth performance of Jersey calves, feeding whole milk at the rate of 10% body weight is recommended.

Key words: milk level, calf starter, feed intake, body weight

INTRODUCTION

Calf rearing is one of the most important husbandry practices used as a basis for sustainability and productivity of the dairy farm. The overall target of raising dairy calves is accelerating growth and lowering mortality. In order to achieve these targets proper calf rearing practices and health care are very important.

The appropriate level of whole milk feeding for dairy calves has the potential to increase growth rates during the pre-weaning period (Kamiya *et al*, 2009 and Uys *et al*, 2011), to reduce time needed to reach a necessary body weight and attain age at first service early (Davis *et al*, 2006) and improve milk yield at first calving (Moallem *et al,* 2010 and Soberon *et al*, 2012). Disadvantages of providing more whole milk include reduced solid feed intake during the milk feeding period (Uys *et al*, 2011 and DePassille *et al*, 2011) and slower rumen development (Khan *et al*, 2007a,b). Bascom (2002) discussed that Jersey and Guernsey calves may have higher maintenance energy requirements and thus require a more energy-dense diet than calves of the Holstein or Ayrshire breed, as indicated by the breed differences in milk composition.

Jersey calves are unique due to their smaller frame size and lighter birth weights. Due to their smaller size, it is feasible to assume that Jersey calves might require more energy per unit of BW (Body Weight) for maintenance, because they have a greater body surface area per unit of BW, as indicated by their metabolic bodyweight, and thus are likely to use more energy to maintain their body temperature. Davis and Drackley (1998) recommend that milk replacer powder should contain between 18 and 24% CP (Crude Protein). However, the appropriate level of CP in the diet depends on the level of intake and energy supplied (Davis and Drackley, 1998). Calves consuming high levels of DM (as a percentage of BW) or high-energy diets require more dietary protein for lean tissue growth than calves on low energy or restricted levels of intake. Calves consuming milk or milk replacer at or near *ad lib* intake require a higher level of protein relative to energy than calves fed a restricted level of milk or milk replacer. This indicates maintenance energy requirement of Jersey calves may have been higher per unit of metabolic BW than Holstein calves and that NRC (2001) equations for maintenance energy may not be appropriate for Jersey calves.

Jersey calves are being raised at Adea Berga Research Center which is located in West Shewa Zone, Oromia Region, Ethiopia as a replacement for pure Jersey herd. Adea Berga Research Center was governmental dairy state farm before it was transferred to EIAR. It was established to support milk supply to Addis Ababa market. This herd has been also serving as genetic pool to recruit best sire for semen collection which has been used by National Artificial Insemination Center (NAIC). In addition, there will be a possibility to adopt and practice raising pure Jersey cattle by private holders in the near future because of high fat content of milk from Jersey breed, which is suitable for manufacturing cheese and other milk products. However, Jersey calves at Adea Berga have been raised by feeding unlimited amount of whole milk. There is no clear whole milk feeding guide to implement regular practice. However, unpublished data indicates each calf consume 669 litres of whole milk and weaned at 6 months of age. This type of calf rearing incurs extra cost of milk and labor. Therefore, generating technologies that support rearing of Jersey calves especially in early life is crucial both for profitable farming and productive life span of the animals. The objective of this study was to evaluate DM consumption, growth and feed conversion efficiency of pure Jersey calves reared on two whole milk feeding systems.

MATERIALS AND METHODS

Location

The stud**y** was conducted at Adea Berga Research Station, West Shewa Zone of Oromia Region, Ethiopia, which is located 70 km west of Addis Ababa. The center lies within 9^{o}16’N and 38^{o}23’E and has an altitude of 2500m a.s.l. It has an annual mean temperature of 18^{o}C and annual mean rainfall of 1225mm (HARC, 2010).

Experimental Design

The experimental design was RCBD with two treatments (blocked by calf sex), using 8 replicates. Originally, it was planned to use 16 male and 16 female Jersey calves (32 Calves for the experiment). Thirty two Jersey calves were randomly assigned to experimental treatments right after birth. However, three calves have died and their data was excluded from analysis. Data from twenty nine calves were used for statistical analysis.

Two treatments consisting standard check (whole milk feeding standard practiced by Holeta Research Center, in which calves are fed colostrums over 4 days, and expected to consume 260 litres of whole milk over 94 days), (Table 1) and 10% calf body weight whole milk feeding levels (as recommended by Amaral-Phillips, *et al*, 2006) daily were used as treatments 1 and 2 respectively. Calves on both treatment groups were weaned at 98 days of age.

Table 1. Calf whole milk feeding standard of Holeta Research Center (litres)

Calf Age range (days)	A.M.	P.M.	Total/day	Days on milk
0-4	colostrum	colostrum	colostrum	4
5-15	1.5	1.5	3.0	11
16-43	2.0	2.0	4.0	28
44-63	1.5	1.5	3.0	21
64-85	1.0	1,0	2.0	21
86-98	0.5	0.5	1.0	13

Daily whole milk consumption**,** feed intake, and fortnightly body weights were measured and recorded. Animal weighing scale was used to measure calf body weights. Growth rate of calves was computed by regression analysis of fortnightly body weights, body weight as dependent and age as independent variable. Daily body weight gain was calculated as predicted final weight minus predicted initial weight divided by age of the calf. Feed conversion efficiency was calculated by dividing mean daily weight gain by mean daily feed DM intake. Data were analyzed using least square mean procedure of SAS system (SAS, 2004).

Experimental animal management

Calves were housed in separate well ventilated calf room. The floor is concrete with suitable drainage system. Each calf was kept in separate calf box with feed trough for hay feeding. Plastic buckets were used for watering and feeding calf starter.

Concentrate feed mixture with estimated 0.73 Mcal DE/Kg energy and 18 % CP was formulated to be supplemented to the calves. Calf starter used was a mixture of 73% wheat bran, 26% *noug* cake 1% Calcium Carbonate. Hay harvested from natural pasture from Adea Berga Research Center was used as roughage source. Hay feeding commenced starting at first week of age, while calf starter feeding was commenced starting at two weeks of age. Calves were offered dry feed at the rate of 3% body weight on DM basis. Calf starter and hay were offered only once every morning after weighing feed refusals of last day's feeding. Concentrate: roughage ratio of 30:70% was used to feed the calves. The amount of calf starter and hay offered was adjusted weekly.

Calves were watered *ad lib* both in the morning and afternoon in pails starting at one week of age. Calf room was cleaned twice per day every morning and in the afternoon. Oat straws were used as bedding material. The bedding was changed twice per day after cleaning urine and faces. Calves were allowed to exercise for an hour daily outside their rearing room every morning.

Feed sample collection and laboratory analysis

Feed samples (calf starter and hay) were collected daily and bulked. The bulked samples were thoroughly mixed and sub sampled for laboratory analysis. Dried feed samples were clipped and ground using Wiley Mill to pass 1 mm sieve. Samples were analyzed for Dry Matter (DM), Ash, and CP using standard procedure (AOAC, 1990). Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) were determined according to the procedure described by Van Soest, and Robertson (1985). Two-stage technique of Tilley and Terry (1963) was used to determine In-vitro Dry Matter Digestibility (IVDMD) of the feedstuff.

RESULTS

Chemical compositions of calf starter and hay used in the study are presented in Table 2.There were no significant ($p > 0.05$) differences between treatments in feed chemical compositions. Whole milk consumptions of calves in the study are presented in Fig 1. Calves in Treatment1 were fed higher amount of whole milk from day 5 up to 7 weeks of age as compared to calves in Treatment 2. However, calves grouped in Treatment 2 had consumed higher amount of whole milk as compared to calves in Treatment 1 from 7 weeks of age up to weaning.

Table 2. Chemical composition of feeds used in the study

Chemical component	Calf starter		Hay		CV%	R^2
	Given	Left	Given	Left		
DM (%)	92.0±0.21	92.1±0.21	92.6±0.19	92.8±0.22	0.63	0.35
CP (% DM)	19.3±0.32	19.2±0.32	4.5±0.30	4.7±0.34	7.62	0.99
ADF (% DM)	19.4±1.47	19.0±1.47	34.6±1.38	35.7±1.57	15.3	0.81
NDF (% DM)	23.8±2.68	23.7±2.68	52.2±2.53	50.3±2.87	20.2	0.80
IVDMD (%)	87.3±0.98	87.7±0.98	58.9±0.92	59.3±1.04	3.76	0.97

Hay consumption of calves over the period of six months is presented in Fig 2. Daily hay consumption was increasing with advancing age in both treatment groups. However, calves reared under Treatment 2 had relatively higher hay intake as compared to calves reared on Treatment 1.

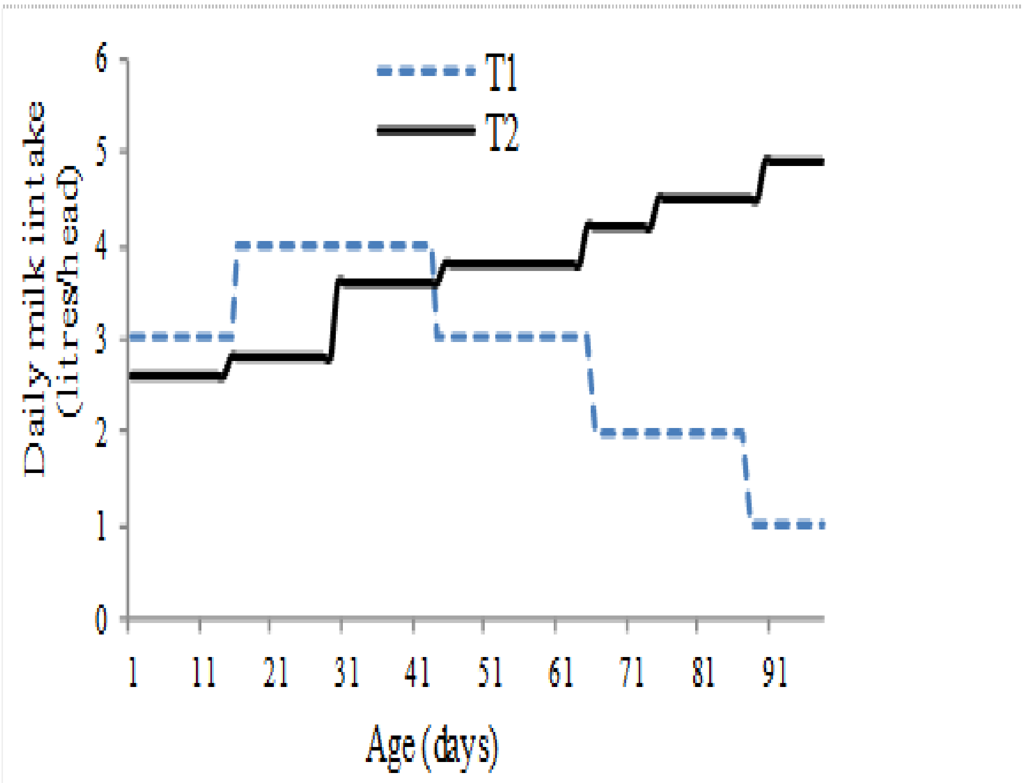

Figure 1. Whole milk intake of calves

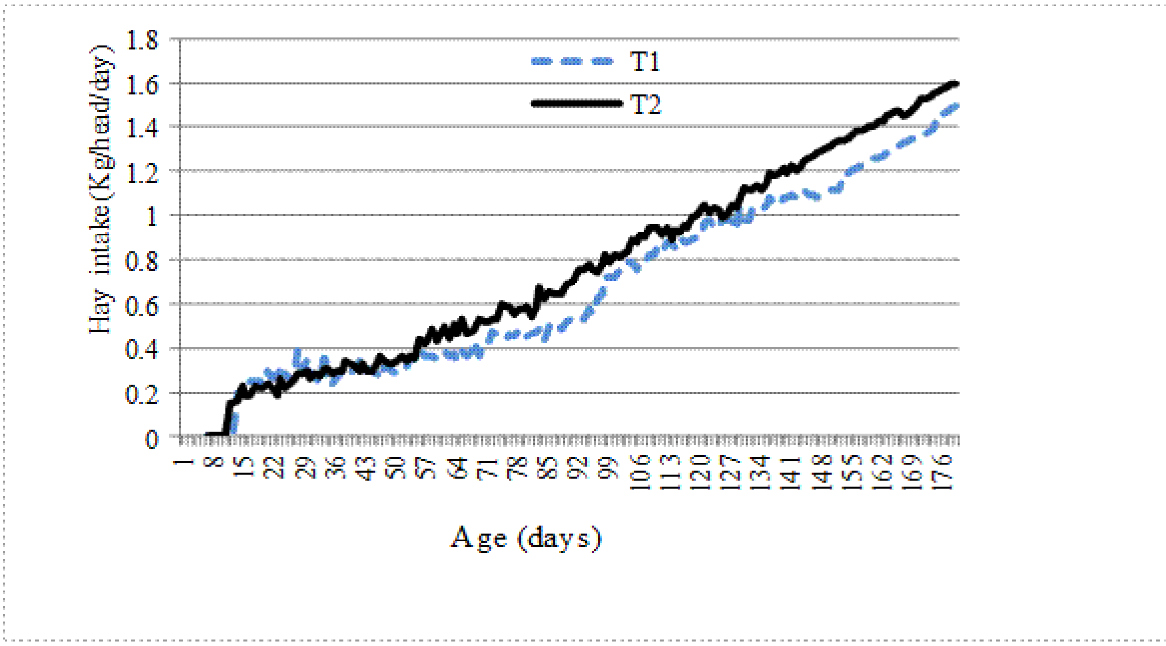

Figure 2. Mean daily hay intake

Daily calf starter intake was also surging with advancing age in all calf groups (Fig 3). During initial rearing age both groups had similar intake levels which showed disparity trend with advancing age. Calf starter intake was higher for calves in Treatment 2 thereafter. Daily calf starter intake was almost similar for both groups towards the end of the rearing period.

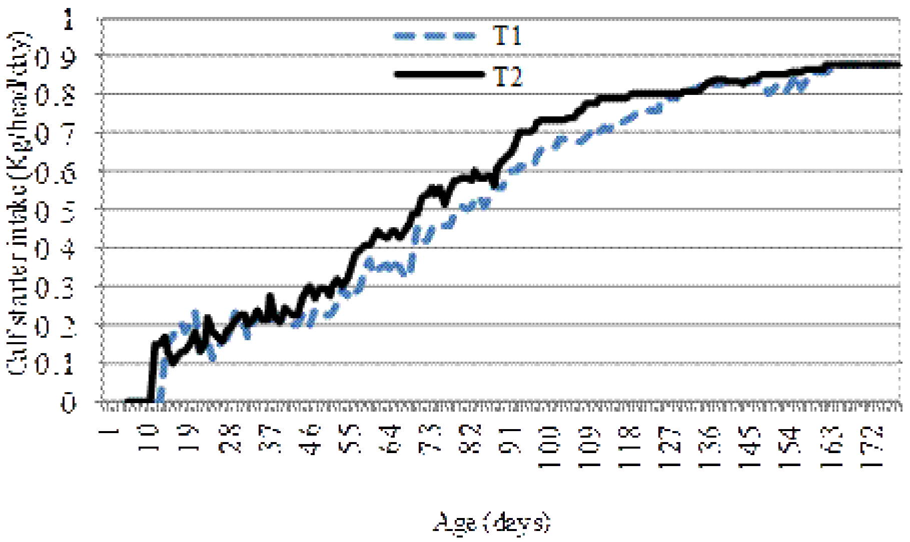

Figure 3. Mean daily calf starter intake

Daily total Dry Matter (DM) intake of calves was generally higher for calves reared under Treatment 2 as compared to calves in treatment 1 (Fig 4). Daily total DM intake was similar for calves in Treatments 1 and 2 during early calf life. However, total DM intakes between treatments showed variation after two months of age, where both groups showed linear increasing trend.

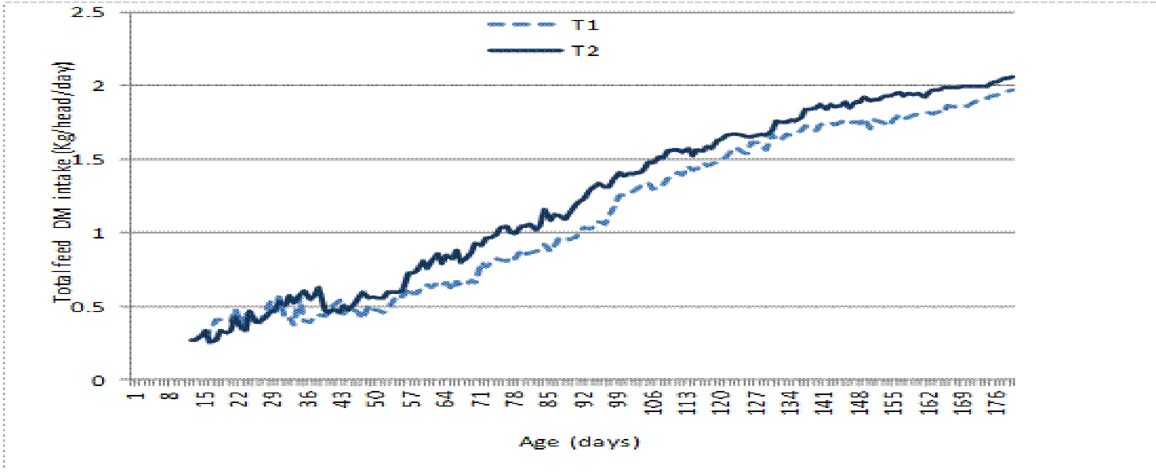

Figure 4. Daily total DM intake of calves

Body weight of calves attained at 3 and 6 months of age are presented in Table 3. Calves reared under Treatment 2 had significantly ($p < 0.05$) higher body weight at 3rd and 6th months of age as compared to calves reared under Treatment 1. Similarly, male calves had significantly ($p < 0.05$) higher bodyweight than females at 6 months of age. Least square mean calf daily weight gains during pre and post weaning periods are presented in Table 4. Daily body weight gains of calves were not significantly different ($p > 0.05$) between Treatments. However, daily weight gains of calves in Treatment 2 indicated higher growth trend during pre-weaning and post weaning rearing periods.

Calf sex had marked ($p < 0.05$) effect in daily weight gains during post weaning and overall rearing periods. There was no significant difference ($p > 0.05$) between male and female calves in daily weight gain during pre-weaning period but male calves grew significantly higher ($p < 0.05$) than female counterpart during post-weaning period.

Table 3. Least square mean calf body weights at different ages (Kg)

Variables	Number	Birth	Three Months	Six Month
Overall mean	29	22.93	51.52	63.23
Treatments				
1	14	22.93±0.58	49.57±1.96^{b}	61.99±2.20^{b}
2	15	22.92±0.56	53.53±2.07^{a}	63.35±2.20^{a}
Calf sex				
Males	15	23.07±0.56	51.93±1.9	64.71±1.92^{a}
Females	14	22.79±0.58	51.16±2.14	60.63±2.53^{b}
CV		9.42	14.27	11.34
R^2		0.005	0.08	0.09

Least square means with the same superscripts within rows are not significantly different (p>0.05)

Table 4. Least square mean daily weight gain of calves (g)

Variables	Number	Birth to 3months	3-6 months	Birth to 6 months
Overall mean	29	318.25	156	238.48
Treatments				
1	14	296.83±0.02	146.24±0.02	235.07±0.01
2	15	339.29±0.02	169.34±0.02	242.90±0.01
Calf sex				
Males	15	321.00±0.02	170.37±0.02[a]	244.90±0.01[b]
Females	14	315.30±0.02	145.21±0.02[b]	233.07±0.01[b]
CV%		24.75	53.7	21.73
R^2		0.08	0.05	0.02

Least square means with the same superscripts within rows are not significantly different (p>0.05)

Calves reared under Treatment 2 had higher feed conversion efficiency (gain: feed ratio) as compared to calves reared under Treatment 1. However, feed conversion efficiency of calves in both rearing groups was higher at early age which diminished post weaning (Fig 5).

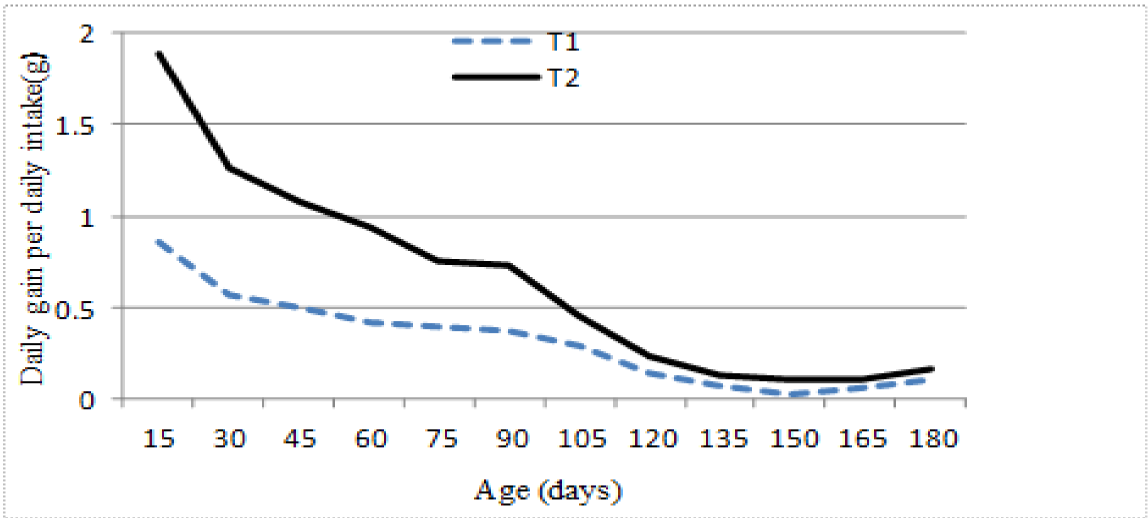

Figure 5. Feed conversion efficiency (DM basis) of calves

DISCUSSION

Crude protein (CP) value (4.48%) of hay used in this study was too low relative to usual CP values of hay harvested from natural pasture. Calves require best quality hay with 8 to 14% CP, which was designated as good to excellent (Radunz, and Schriefer, 2011). Stimulation of growth by increasing dietary CP has been reported previously in calves (Gerrits *et al*, 1996). Hay quality at Adea Berga Research Center is usually harvested late after maturity due to the fact that, the hay field is too marshy during September and October to let in farm machineries for mowing. This may have contributed to lower CP available for the calves to support whole milk and calf starter. Thus, since the same hay was used for all calves in both experimental groups, its effect was expected similar for both groups.

Whole milk intake of calves was declining as age advanced up to weaning for calves in Treatment 1 due to the feeding system that gradually reduces whole milk level up to weaning, while it was rising opposite to this trend for calves in Treatment 2. In Treatment 1 the amount of whole milk was presented as predetermined, while it was based upon calf body weight change in Treatment 2.Therefore, weaning was gradual in Treatment 1, while it was abrupt in Treatment 2. Both practices may also have their own impact on calf feed intake and growth performances. The total amount of whole milk consumed was slightly higher for calves in Treatment 2 (360 litres) as compared to those in treatment 1(260 litres), resulting in higher growth rate in agreement with previous study on dairy calves fed milk replacers containing different amounts of CP at two feeding rates (Bartlett *et al*, 2006). However, disadvantages of providing more milk include reduced solid feed intake during the milk-feeding period (Terre et al., 2007) and slower rumen development (Khan et al., 2007a, b) have been reported.

At early age calf starter and hay intakes were minimal and therefore calves mostly depend upon whole milk. Hay and calf starter intakes of calves was rising smoothly as age advanced, due to the fact that calves' rumen development with advance in age leading to full transformation from liquid to dry feeds.

Body weight change of calves showed disparity starting at three months of age. This indicates whole milk feeding levels were effective to show body weight variation after three months of age. Calves in treatment 2 significantly gain more weight (4 kg at 3 months and 1.3 kg at 6 months age) than those in treatment 1. This is partly due to consumption of more milk. Calves grouped in treatment 1 consumed 260 litres of whole milk; while those grouped under treatment 2 consumed 310 litres per head from birth up to weaning. Similar to our finding, Appleby et al. (2001) and Diaz et al. (2001) noted that higher weight gains of calves fed more milk. Body weight variations between male and female calves became prominent at six months of age, indicating physiological growth variation due to sex starts from six months of age. Similarly, male calves were significantly heavier than females by 4.74 kg at 6 month weight and 4.48 kg at weaning age (Bayou *et al*, 2016).

Feed conversion efficiency (gain: feed) for calves in Treatment 2 was higher than that of calves in Treatment 1, indicating higher body weight gain of these calves on lower amount of dry feed. The lowest feed conversion efficiency of calves grouped in Treatment 1 indicates they didn't utilize the CF more efficiently than calves grouped in Treatment 2 as reported earlier (Nat *et al*, 2016). Earlier studies also showed gain: feed was greater for calves fed at 1.75% of BW daily than for calves fed at 1.25% of BW daily and increased in a quadratic manner as CP was increased, with greatest efficiencies observed for calves fed milk replacer (based on whey protein concentrate, dried whey, lard, and tallow) with 22% CP (Bartlett *et al*, 2006). Feed conversion efficiency in both treatment groups was declining as age advanced, indicating calves had accelerated growth at early age but had slow growth rate with advancing age. Additionally calves had low amount of dry feed intake at early age and survived on whole milk which was not accountable in computing feed conversion efficiency.

CONCLUSION

Pure Jersey calves fed whole milk at 10% body weight and weaned at 98 days of age had higher feed intake, growth rate feed conversion efficiency as compared to Holeta Research Center whole milk feeding system designed for crossbred calves. These calves had lower feed dry matter intake and expected to have better productive performance in their later age due to their higher metabolic efficiency. Therefore, the slightly higher milk consumption per rearing life as compared to calves reared on HRC standard (310 liters' versus 260 liters) can be economically offset in later age. That means calves can reach productive age (slaughter weight for males and age at first calving for female calves) at early age so that cost due to additional milk compensated and more income generated in lifetime.

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Feed Resource Bases and Farmers' Perceived Uses of Grain Legume Haulms in the Mixed Crop-Livestock Farming System of Ethiopia

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ABSTRACT

Survey was conducted from January 2016 to March 2016 to assess feed resource bases and grain legume haulms use practices in the mixed crop-livestock farming system of Ethiopia. Three districts (Ada'a, Sinana and Damot-Gale) were selected purposively based on their accessibility and intensity of crop production from the mixed farming areas. Then, single visit formal survey was conducted to collect data from 90 purposively selected grain legume producers. The collected data were analyzed using descriptive statistics in SPSS software. The results revealed significant difference ($P<0.05$) among study districts in livestock holding per household and overall mean livestock holding was 5.86±0.42 TLU per head. Except grazing land, total land size and land allocated for different uses were significantly ($P<0.05$) different among the districts. The results showed that crop residues (33.3%, consisting of cereal residues 23.8% and legume haulms 9.5%), natural pastures (22.6%), stubble grazing (18.1%), non-conventional feeds (11.7%, composed of Enset leaves, farmyard weeds, poultry litter, grain screening), cut and carry forages (8.3%), agro industrial byproducts (5.3%) and hay (0.7%) were the feed resources available in the three districts. The main use of grain legume haulms was as source of livestock feed (76.3%) and about 89.8% of the interviewed farmers reported increasing trends of using haulms as a livestock feed in the studied districts. Mixing of haulms with cereal straws during feeding and conservation of the haulms for dry period use were practiced by 62.2% and 60.1% of the respondents, respectively.To boost the role of grain legumes production in the mixed crop-livestock production system of Ethiopia, smallholder farmers' need to be supported technically and institutionally with promotion of technologies which have potential to improve grain human and haulm animal nutrition traits.

Key words: Crop-livestock farming, Grain legume, Haulms

INTRODUCTION

Mixed crop-livestock farming system dominated the highlands of Ethiopia and maintains about 85% of human population (Aklilu*et al*., 2014). Nearly two thirds of the ruminant livestock population of the country is also found in this farming system (Alemneh, 2003). This production zone is suitable for cultivation of diverse crops and rearing of different livestock species for various ends by smallholder farmers (Birhan and Adugna, 2014).

In this zone crop and livestock production are highly interdependent and complementary (Bogale *et al*., 2009). Livestock play a crucial role in crops cultivation through provision of draft power, organic fertilizer (manure), and cash availability for purchase of agricultural inputs whereas crops provide in return inputs for livestock production in the form of crop residues (Powell *et al*., 2004). In this way the two systems are integrated with each other through crop residues and draught power.

Despite such opportunities, inadequate feed supply and low quality of available feeds is the main bottleneck that hinders the development of livestock in the mixed farming system (Duguma *et al*., 2013; Birhan and Adugna, 2014; Defar, 2018). With the rapid conversion of grazing lands into cultivation, crop residues are increasingly becoming the major sources of feed for livestock. Estimation made in different parts of the country show that the contribution of crop residues is more than 50% of the annual feed dry matter (Abera *et al*., 2014; Defar, 2018).

The utilization of crop residues as an ultimate year round feed source is limited due to their low nutritive value and considerable fluctuation in availability with the season of the year. Grain legume haulms have relatively better nutritional values such as protein and metabolazable energy contents and digestibility than cereal straws and stovers (Lopeze *et al*., 2005). Grain legume haulms produced in Ethiopia can be categorized under medium quality roughages depending on their crude protein content (Tolera, 2008). Thus, grain legume haulm is a good option in ruminant feeding.

Grain legumes are the second largest crops produced next to cereals in Ethiopia and annually around 1.6 million hectare of land is planted to grain legumes (CSA, 2015). The intensity of legume haulms use as livestock feed is determined based the quantity of crop residue produced on the farm which is a function of land size allocated to cultivated legumes (Akinola *et al.,* 2015). The lower legume haulms utilization for animal feeding in Ethiopia may be associated with smaller annual production of the legume residues due to the smaller land allocation for these crops by smallholder farmers (Gebrehiwot and Mohammed,1989; Bogale *et al.,* 2008) and lower straw yielding potential of legume crops as compared to cereals (Lopez *et al.*, 2005). As stated by Akinola *et al*. (2015), awareness of the farmers on the nutritional values of legume haulms can determine the extent of utilization in livestock feeding which could be mentioned in Ethiopian scenario also. Therefore, assessment and documentation of farmers' perception and current practices of grain legume haulms uses along the major feed resources available in the mixed crop-livestock farming areas of Ethiopia is important for more integration and exploitation of grain legume haulms in livestock feeding.

MATERIAL AND METHODS

Description of the Study Areas

The study was conducted in the N2-Africa project target districts in the mixed farming system of Ethiopia. N2 Africa project with a theme of 'Putting nitrogen fixation to work for smallholder farmers growing legumes in Africa' was a project implemented in Ethiopia in partnership with ILRI. Goal of the project was increasing inputs from nitrogen fixation (by targeting technologies for legume production in farming systems). N2 Africa was had also a strong interest in looking at integration of legume production with livestock by advising and collaborating on aspects relating to the use of legume crop residues for animal feeding across different African countries including Ethiopia. Common bean, faba bean, soybean, chickpea and forage legumes were the target legumes of the project in Ethiopia.

Accordingly Ada'a and Sinana districts from Oromia Regional State and Damot-Gale district from South Nations Nationalities and People Regional State were used for the survey (Figure 1). Ada'a, Sinana and Damot-Gale districts are located in the altitude range of 1500-2250, 2000-2500 and 1501-2950 m.a.s.l, respectively. Ada'a district receives mean annual rainfall 877.2 mm and has annual temperature of 12.4-26.6 ^{0}C. Sinana district has bimodal rainfall (900-1150mm) with two main cropping seasons. Annual mean temperature in Sinana district varies 15-18 ^{0}C. The annual average rainfall and temperature of Damot-Gale district are 1200-1300mm and 12-26^{0}C, respectively. Major grain legumes cultivated in Ada'a district are chickpea, faba bean, field pea, lentil and grass pea. Chickpea and haricot bean is widely grown by smallholder farmers of Damot-Gale district whereas faba bean, field peas and lentil are the main grain legumes widely produced in Sinana district.

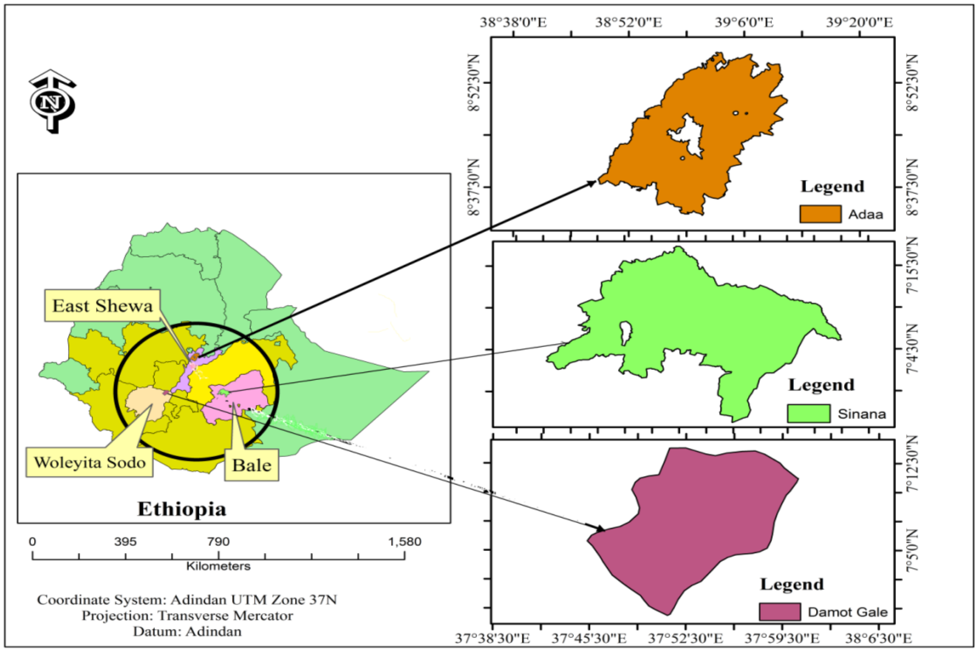

Figure 1: Map of study area

Selection of Respondents and Data Collection

The three survey districts (Ada'a, Sinana and Damot-Gale) were selected purposively based on their accessibility and intensity of crop production. A total of 90 grain legumes producers (28 from Ada'a and Sinana districts, each and 34 from Damot-Gale district) were selected and used as source of data. Sampling technique used was purposive which targeted only households who grown grain legumes by excluding households who do not cultivate grain legumes. Then selected grain legumes producers interviewed individually using single-visit-formal survey method (ILCA, 1990). Data were collected on socio-economic characteristics, livestock holding and feed sources, landholding and land use pattern, type of grain legumes grown in earlier year, household level uses of legume haulms, haulm management practices, trends in use of grain legume haulms for livestock feeding etc.

Calculation of Livestock Holding in Tropical Livestock Unit (TLU)

Livestock holding of the surveyed households was calculated in TLU using conversion factors developed by Janke (1982). Accordingly, conversion factors of ox/bull=1, cow=0.7, heifer= 0.5, calf =0.2 sheep/goat=0.1, horse = 0.8, donkey = 0.5 were used.

Data Analysis

The collected data were analyzed using Statistical Package for Social Science (SPSS, Ver.16). Descriptive statistics (percentage, mean and standard error) were used to present the survey result. Data on household age, livestock and land holding, and land use pattern were subjected to general linear model (GLM) of SPSS for analysis of variance to declare significant variation among districts at the P value of <0.05. In case of significant difference in means among districts, Duncan Multiple Range Test was used to locate mean separation. Model used was: $Y_{ij} = \mu + T_i + eij$; Where: Y_{ij} = the j^{th} observation in the i^{th} district level, μ = overall mean, T_i = districts effect and eij = random error. Index mean was calculated in Microsoft Excel as shown below and multiplied with hundred to get aggregate value for ranking of feed sources and uses of grain legumes haulms in the study areas.

$$\text{Index mean} = \frac{\Sigma[(n \times \text{no of R for 1st rank}) + (n-1 \times \text{no of R for 2nd rank}) + \ldots + (1 \times \text{no of R last})]}{\Sigma[(n \times \text{total R for 1st rank}) + (n-1 \times \text{total R for 2nd rank}) + \ldots + (1 \times \text{total R for last})]}$$

Where: R=number of response, n=value given for the factor, no=number

RESULTS

Household Characteristics

The demographic characteristics of the sampled households are presented in Table 1. Majority of the respondents were male headed households (95.6%). The overall mean age of the household heads was 42.6±0.9 years, with a range of 39-68 years. There was significant difference (P<0.05) among districts in mean age of the household heads which was 39.3±1.06, 43.6±1.87 and 45.5±1.70 years at Damot-Gale, Ada'a and Sinana districts, respectively. About 62.2% and 17.8% of the respondents attended primary (grade 1-8) and secondary (above grade 8) school education, respectively (Table 1). About 12.2% of the respondents also had the ability to read and write (obtained through basic/traditional education), while the remaining 7.8% were illiterate.

Table 1: Basic households' characteristics of surveyed farmers

Descriptors		Ada'a (N=28)	Sinana (N=28)	Damot-Gale (N=34)	Overall (N=90)
Age	Years (Mean ±SE)	43.6 (1.9)^a	45.5 (1.7)^a	39.3(1.1)^b	42.6 (0.9)
Sex (%)	Male	92.1	100	94.1	95.6
	Female	7.1	-	5.9	4.4
Educational status (%)	Illiterate	10.7	7.1	5.9	7.8
	Basic education	25	10.7	2.9	12.2
	1-8 grade	64.3	71.4	52.9	62.2
	Above grade 8	-	10.7	38.2	17.8

^{abc} Mean values with different superscript within the rows are significantly different at P<0.05

Livestock, Land Holding and Land Use Patterns

Livestock holding of the households was assessed based on the ownership of cattle, sheep, goats, donkey and horse. The survey result showed that the overall mean livestock holding of the smallholder farmers in the study area was 5.86±0.42 TLU per household. The average livestock holding per household was significantly higher ($P<0.05$) in Ada'a district (8.63±0.61 TLU) than the other two districts. Significantly lower ($P<0.05$) livestock holding was observed in Damot-Gale district (3.04±0.56 TLU) while it was an intermediate in Sinana district (Table 2).

The overall average total land holding per household in the study area was 2.10±0.13ha (Table 2). Total land (3.24±0.14 ha) and cultivated land (2.57±0.12 ha) holding per household in Sinana district was higher ($P<0.05$) than Ada'a (2.52±0.14 ha total land and 2.02±0.12ha cultivated land) and Damot-Gale (0.81±0.13 ha total land and 0.53±0.11 ha cultivated land) districts. Land allocated for grain legumes production in Ada'a district (0.95±0.07ha) was higher ($P<0.05$) than Sinana (0.21±0.07 ha) and Damot Gale (0.24±0.06ha) districts. Common food legumes (pulse crops) grown by smallholder farmers in the surveyed districts are shown in Figure 2. The result showed that farmers from Ada'a district with medium cultivated landholding from studied districts integrated more numbers of food legumes in their cropping activity.

The average grazing landholding per household was very small and not significantly different ($P>0.05$) among the study districts. The overall mean grazing land owned per household in the study area was 0.12±0.02 ha (Table 2). Moreover, land allocated for cultivated fodder per household was significantly different ($P<0.05$) among the surveyed districts. The average farm size (0.11±0.02ha) allocated for fodder production per household in Sinana district was significantly larger than the remaining two districts. Whereas in proportion, 0.99%, 4.28% and 3.68% of cultivated land is allocated to fodder production by farmers at Ada'a, Sinana and Damot-Gale districts, respectively.

Table 2: Mean livestock holding and land holding and land use patterns of the farming households

Particulars	Ada'a	Sinana	Damot-Gale	Overall	SL
	Mean (±SE)	Mean (±SE)	Mean (±SE)	Mean (±SE)	
Livestock holding (TLU)	8.63 (0.61)^a	6.51 (0.61)^b	3.04 (0.56)^c	5.86 (0.42)	***
Total land (ha)	2.52 (0.14)^b	3.24 (0.14)^a	0.81 (0.13)^c	2.10 (0.13)	***
Cultivated land (ha)	2.02 (0.12)^b	2.57 (0.12)^a	0.53 (0.11)^c	1.63 (0.11)	***
Land allocated for pulses (ha)	0.95 (0.07)^a	0.21 (0.07)^b	0.24 (0.06)^b	0.45 (0.05)	***
Grazing land (ha)	0.14 (0.03)	0.11 (0.03)	0.10 (0.03)	0.12 (0.02)	Ns
Land allocated for cultivated fodder (ha)	0.02 (0.02)^b	0.11 (0.02)^a	0.04 (0.01)^b	0.06 (0.01)	***

^{abc} Mean values with different superscript within the rows are significantly different at $P<0.05$, SL: significant level, ns: not significant.

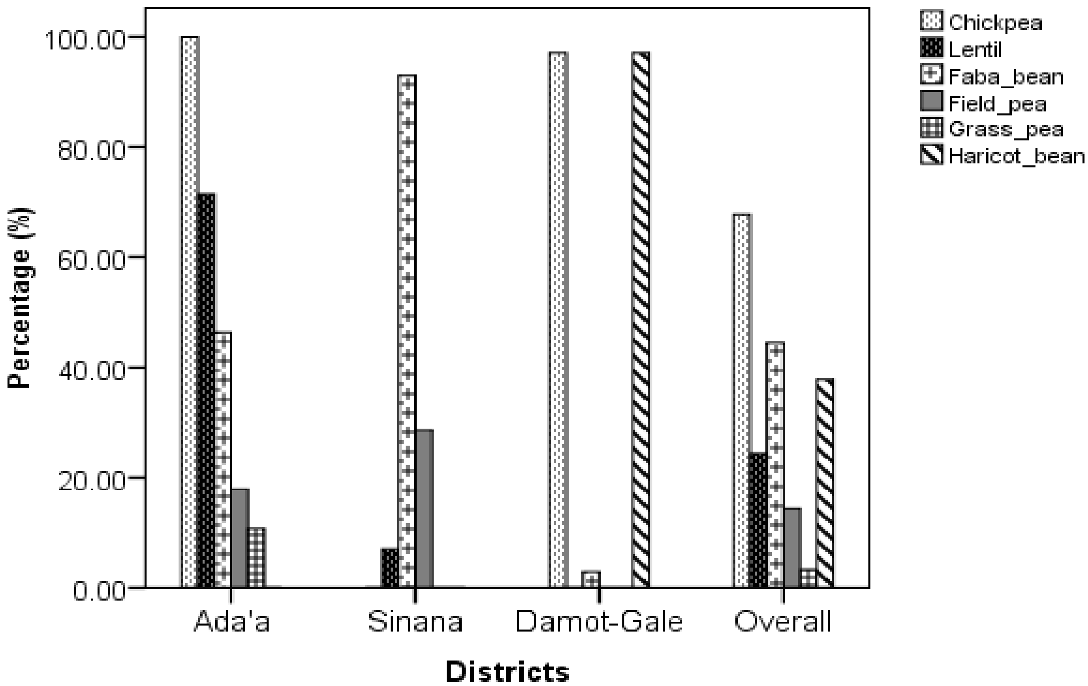

Figure 2: Percentage of respondents growing common legumes in the surveyed districts

Major Household Feed Sources in the Study Area

The major feed resources prioritized by the sampled households according to their perceived contribution to total feed supply in the study area are presented in Table 3. The result showed that cereal residues (23.8%), natural pasture (22.6%), stubble grazing (18.1%), other feeds (11.7%), legume haulms (9.5%), cut and carry forages (8.3%), agro-industrial by products or concentrates (5.3%) and hay (0.7%) were the major feed resources utilized by smallholder farmers in the study area. Similar to the aggregate bases, feeds obtained from the farming system which consists of cereal residues, legume haulms and stubble grazing were reported to be the most commonly used by all surveyed farmers across all districts.

In the study areas, about 72.2% of the households reported feed shortage as first important constraint of livestock production. According to the current study feed scarcity occurred over different periods of the year. Majority (73%) of the households reported that they experienced feed shortages in the dry season of the year (Figure 3A), whereas the remaining 25.0% and 1.6% of the respondents reported feed shortage to be a critical challenge during wet season and throughout the year, respectively. The farmers of all study districts adopted different coping strategies in time of limited feed availability (Figure 3B). The major coping strategies identified in the present survey includes efficient utilization of crop residues (32.8%), use of different farm and home by-products (29.7%), use of purchased feed (18.8%) and exploration of other alternative like moving animals where better grazing (including stubble grazing) is available during the day time and obtaining from fellow farmers (18.7%).

Table 3: Major feed resources available in the surveyed districts

Feed Resources	Proportion of respondents (%)			Overall
	Ada'a	Sinana	Damot Gale	
Cereal residues	29.3	24.0	18.2	23.8
Legume haulms	10.0	6.0	12.6	9.5
Natural pasture	19.6	19.8	28.2	22.6
Stubble grazing	17.1	27.2	10.0	18.1
Cut and carry forage	2.9	12.9	9.1	8.3
Agro-industrial by products	5.4	2.3	8.2	5.3
Hay	1.8	0.0	0.3	0.7
Others feeds**	13.9	7.8	13.2	11.7
Total	100.0	100.0	100.0	100.0

**: Lists of other feeds include weed plants collected from farms, *Enset* leaves (pseudo banana) and different household by products and grain screenings

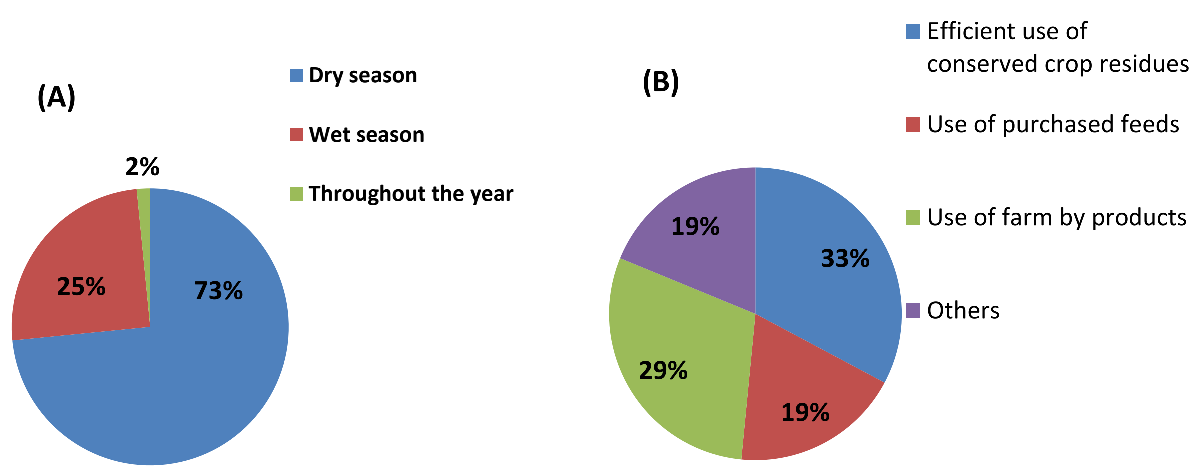

Figure 3: Time of feed scarcity (A) and farmers' coping strategies (B) in the study areas

Uses of Grain Legume Haulm in the Study Area

Grain legume haulm has multiple uses for the smallholder farmers of the study area (Table 4). The farmers prioritized and ranked the importance of grain legumes haulm in their area based on the amount of residues allocated for different alternative uses. Regardless of the variations among the districts, the result showed that primary use of grain legume haulm in the study areas was reported to be as source of feed (76.3%) and followed by source of household fuel (11.6%), for mulching and compost making (8.7%). About 7.8% and 2.4% of legume haulms produced sold by households to generate additional income in Ada'a and Damot Gale districts, respectively.

Table 4: Household prioritized use of grain legume haulms in the surveyed districts

Uses of haulms	Proportion of respondents (%)			Overall
	Ada'a	Sinana	Damot Gale	
Feed source	64.7	80.0	84.1	76.3
Domestic fuel	19.0	7.3	8.5	11.6
Mulching/bio-fertilizer	8.6	12.7	4.9	8.7
For sale/income generation	7.8	0.0	2.4	3.4
Total	100	100	100	100.00

Table 5: Trends of haulm use as feed and reasons for the increasing trends in using as livestock feed in the survey districts

Variables	Indicators	Proportion of respondents (%)			Overall
		Ada'a	Sinana	Damot Gale	
Trend of haulms use as feed	Increasing	90	79.3	100	89.8
	No change	4	13	0	5.7
	Don't know	6	7.7	0	4.6
	Total	**100**	**100**	**100**	**100.0**
Reasons for increasing	Feed shortage and lack of other option	59.1	72.2	48	59.8
	Improved awareness of nutritional advantage	22.7	27.8	33.4	28.0
	Increased annual production	18.2	0	18.6	12.3
	Total	**100**	**100**	**100**	**100.0**

Majority (89.8%) of the sampled households stated that the trend of haulm utilization in livestock feeding is increasing from time to time (Table 5). There are many factors that triggered a rapid shift to legume haulm use as livestock feed source in the mixed crop-livestock farming areas. Shortage of livestock feed and lack of other options, better awareness on the nutritional advantages of legume haulms than cereal residues and increased annual production of grain legume haulm are the three main drivers prioritized by the respondents for the increasing interest in including grain legume haulm in livestock diets.

Table 6: Grain legumes haulm feeding methods, time of feeding and storage methods in the surveyed districts

Variables	Feeding practices	Proportion of respondents (%)			Overall
		Ada'a	**Sinana**	**Damot Gale**	
Haulm feeding method	Mixed with cereal straws	64	66.7	55.9	62.2
	Feed alone	28	33.3	32.4	31.2
	Mixed with other supplements	8	0	11.8	6.6
	Total	**100**	**100**	**100**	**100.0**
Time of haulm use as feed	During dry season	28	66.9	85.3	60.1
	Throughout the year	44	27.1	11.8	27.6
	During wet season	24	0	2.9	9.0
	Immediately after harvesting	4	6	0	3.3
	Total	**100**	**100**	**100**	**100.0**
Haulm storage methods	Traditional heap/stack without shelter	100	4.8	28.5	44.4
	House constructed from locally available materials	0	62.7	17.6	26.8
	House with plastic or tin roof	0	26.5	4.5	10.3
	Home side	0	0	25	8.3
	Not practiced conservation	0	6	4	3.3
	Others (like use of old sacks)	0	0	20.4	6.8
	Total	**100**	**100**	**100**	**100.0**

The survey showed majority of the respondents (62.2%) feed grain legumes haulms to livestock by mixing with cereal straws and, 31.2% and 6.6% of them feed haulm to livestock alone and by mixing with other supplement, respectively (Table 6). According to the respondents, mixing of grain legume haulms with cereal straws and concentrates are mainly done to improve intake of the haulm. In the study area, grain legume haulm mainly collected and used during dry period of the year by 60.1% of the households. Proportion of the farmers used grain legume haulms throughout the year, during wet season and immediately after harvesting and threshing accounts about 27.8%, 8.9% and 3.3% respectively. In district bases, largest proportion of the respondents of Sinana (66.9%) and Damot Gale (85.3%) districts used legume haulms during dry period of the year, whereas in Ada'a district about 44% of the respondents fed their animals on grain legume haulm throughout the year. Conservation method of crop residues including grain legumes haulms has considerable impacts on both quality and quantity of the residues. Majority (96.6%) of the respondents used different haulm conservation and storage techniques (Table 6). In Ada'a district all (100%) the respondents replied that they store haulm in traditional stack without shelter and mainly they put the haulm inside the stack and covered outer parts of the stack with cereal straws. Haulms storage in shelter constructed from locally available materials was practiced by 62.7% of the farmers in Sinana district. About 28.5%, 25% and 20.4% surveyed farmers of Damot Gale district practiced use of traditional heap without shelter, home side and old sacks for storage of legume haulms, respectively.

DISCUSSION

Landholding and Land Use Pattern

The household land holding observed in Sinana and Ada'a districts was above the national average (1.77 ha) and Oromia region average (1.98 ha) rural land holding (ERSS, 2013). The average total land holding (0.81 ha) of the households recorded in Damot Gale district is comparable with the average rural land holding in the South Nation Nationality and People region (0.88 ha) but below the national data (ERSS, 2013). The land holding (0.81ha total land and 0.53ha cultivated land) of the households observed in Damot-Gale district is comparable with 0.6 ha reported in Wolayta Area (Aliyi, 2013) and 0.7 ha in Umbulo-Watershed of Southern Ethiopia (Funte *et al*., 2010). Consistent to current report in Damot Gale district, decreasing trend of average land holding of the household to about 0.25-1ha could be due to very high population density in Wolayta zone as reported by Ayele (2008).

Differences were observed among the districts in the proportion and area of land used per household for grain legume production (Table 2). About 47.03%, 45.3% and 8.17% of cultivated land was allocated for grain legumes production in Ada'a, Damot-Gale and Sinana districts, respectively. Unlike farmers from Ada'a and Damot-Gale districts, farmers of Sinana district give more priority for production of cereal crops than grain legumes. This might be due to increased trends of using mechanized crop harvester in wheat production and availability of more productive modern wheat varieties suitable for agro-ecology of the area. This is in agreement with the result of Abate *et al*. (2012), which showed that the farming system of Sinana district to be a predominantly mixed cereal-livestock type.

The grazing land holding of the households was very small and comparable among surveyed districts (Table 2). The overall mean grazing land holding (0.12 ha) per household in the study area was comparable with the findings reported in central highlands of Ethiopia (Tsegaye *et al*., 2008) and Umbulo-Wacho watershed of Southern Ethiopia (Funte *et al.*, 2010). The current study indicated that grazing land holding is smaller than the reports of Bosana, Meta-Robi and Halaba districts of mixed farming area (Hassen 2006; Kocho, 2007; Yadessa, 2015), respectively. The small grazing land holding per household indicated in the present study may be due to continuous conversion of productive grazing land to crop fields. In the highlands of Bale where mixed farming is dominantly practiced conversion of grazing land to cropland is estimated to be 99.22% over 29 years period from 1986 to 2014 (Defar, 2018). As noted by Mengistu (2004) the current available grazing land in Ethiopian highlands is limited to the areas which have no farming potential.

The relatively higher share of cultivated forage from the total farm land in Damot-Gale, the district with the smallest total land holding per household, negates the notion that shortage of land is the main barrier to adoption of cultivated forage production. This calls for more in-depth research to identify and address barriers to adoption of improved forage production and use. Smallholder farmers in Sinana area were reported to grow oat and maize fodder for livestock feeding. Abate *et al*. (2012) reported experience of smallholder farmers in Sinana district who have been growing fodder oat and maize solely for livestock feeding purpose. The continuous distribution of fodder oats varieties adaptive to the area by Sinana Agricultural Center and the presence of two favorable cropping seasons for fodder production might be positively contributed in better adoption of cultivated forage by smallholder farmers of Sinana district. In Damot-Gale district sampled households were also reported to have established Desho and Elephant grasses on the border of their farm field to serve dual purposes *i.e*. soil conservation and feed source.

Livestock Holding and Feed Resources

Livestock holding of the households of the surveyed districts was assessed based on the ownership of cattle, sheep, goat and equines. The overall average livestock holding of 5.86TLU per household in the study areas was much closer to the figures reported earlier in the mixed farming areas of BasonaWorana district of North Shewa, highlands of Blue Nile basin and highlands of Bale (Hassen, 2006; Eba, 2012; Defar, 2018), but lower than the figures reported by Kocho (2007) in Halaba and Yadessa (2015) in Meta-Robi districts. Significantly smaller livestock (3.04 TLU) holding reported in Damot-Gale district might be associated with limited land holding of the households in the area. The mean livestock of farmers in Damot-Gale district is comparable with the figure reported in Umblo-Wacho watershed of Southern Ethiopia (Funte *et al*., 2010).

Different feed resources were available in the study areas with different levels of contribution. The major feed resources in the study areas are cereal residues and legume haulms followed by natural pastures and stubble grazing. The current findings on the available feed resources in the study districts is in agreement with the results reported earlier in similar agricultural production system of Ethiopia (Zewdu *et al*., 2014; Yadessa, 2015; Defar, 2018; Asmare and Mekuria, 2019).

However, the contribution of each types of feed to annual household feed demand fluctuates with the season of the year. According to the current study, feed shortage was a major constraint of livestock production in in the study areas which is in agreement with the finding reported earlier in the mixed farming system of Ethiopia (Duguma *et al.*, 2013; Yadessa, 2015; Zewdu *et al.*, 2014; Defar, 2018). Dry season was a critical period of feed scarcity in the study areas and different coping strategies is adopted by smallholder farmers of all study districts to feed their animals during feed scarcity. Consistent to current study Duguma and Greet (2016) and Funte *et al*. (2010) reported that smallholder farmers have their own experience of using various available options to feed their animals when they faced limited feed availability.

Grain Legumes Haulm Use Practices

Farmers of all study districts used grain legume haulms for various purposes. The majority of the respondents in Ada'a, Sinana and Damot Gale districts reported that the primary use of grain legume haulm was as feed for livestock. The finding is in agreement with research result reported in the highlands of Ethiopia (Alkhtib *et al.*, 2014). In the study area the haulm refusals from feeding systems have alternatives uses like bio-fuel, fertilizer and compost making. Additionally, sale of haulm is an alternative source of income for the households in the study area. The amount of crop residues (including grain legume haulm) allocated for other purposes rather than livestock feeding in mixed farming systems is very small (Hassen, 2006; Alkhtib *et al*., 2014).

An increasing trend of grain legume haulms use as feed resource was reported by the respondents, which is in agreement with the findings of Alkhtib *et al.* (2014) who reported increasing trends of grain legume haulm use as livestock feed by smallholder farmers in the highlands of Ethiopia. Various studies (Akinola *et al*., 2015; Valbuena *et al*., 2015) indicated that many interacting factors determine farmers' decision to use crop residues for various alternatives. As identified in the current study, livestock feed shortage and lack of other options, improved awareness on the nutritional advantages of legume haulms than cereal residues and increased annual production of grain legume haulms are the main factors contributing for the increasing interest of farmers in including grain legume haulms in livestock diet.

CONCLUSION

The farming households of the study areas mainly used grain legume haulms as source of livestock. The use of grain legume haulm as livestock feed has been steadily increasing over the past few years in the study area due to feed shortage and lack of other options, better awareness of their nutritional quality and increased annual production of annual grain legumes. Generally, in the mixed farming systems of Ethiopia, both grain and haulms of grain legumes have significant importance for the livelihood of the farming households. Thus, agricultural technologies such as new cultivars and agronomic packages which have potential to improve grain and haulm attributes of grain legumes should be a priority in the area.

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Materials and methods: The techniques and procedures of the research, the conditions under which the study was conducted and the experimental design are described under this heading. Relevant details about the animal should be given and the statistical design should be described briefly and clearly. Data should be analyzed and summarized by appropriate statistical methods; authors should examine closely their use of multiple comparison procedures. A measure of variability, e.g., standard deviation or standard error must be provided when reporting quantitative data. If standard methods of investigation and analysis are employed appropriate citation suffice.

Results: The summary of major findings and assessments of the investigation are given in this section. The results can be presented using tables, illustrations and diagrams.

Tables: Tables are numbered consecutively in arabic numerals (e.g., Table 1) and should bear a short, yet adequately descriptive caption. Avoid using vertical and/or horizontal grid lines to separate columns and/or rows. Metric units are clearly to be shown, abbreviated in accordance with international procedure. Footnotes to tables are designated by lower case which appear as superscripts in appropriate entries. Tables should be compatible with column width viz. 140 mm, and should be presented on separate sheets, and grouped together at the end of the manuscript. Their appropriate position in the text should be indicated and all tables should be referenced to in the text.

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Figures: Figures should be restricted to the display of results where a large number of values are presented and interpretation would be more difficult in a Table. Figures may not reproduce the same data as Tables. Originals of figures should preferably be A4 size, of good quality, drawn or produced on good quality printer and saved in a separate file. There should be no numbering or lettering on the originals. Numbering and lettering, which must be kept to an absolute minimum, should be legibly inserted on the copies. Vertical axes should be labelled vertically. A full legend, describing the figure and giving a key to all the symbols on it, should be typed on a separate sheet. The symbols preferred are: ▲,■ ○ ■, but + and x signs should be avoided. Figures should be numbered consecutively in arabic numerals (e.g., Figure 1), and refer to all figures in the text.

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Discussion: The reliability of evidence (result), comparison with already recorded observations and the possible practical implication is discussed.

Conclusion: Authors are encouraged to forward conclusion (two to three brief statements) from the study summarising the main findings and indicating the practical implications of the findings.

Acknowledgements: Should be briefly stated following the conclusion.

References: Cite references by name and date. The abbreviation et al should be used in the text where more than two authors are quoted. Personal communications and unpublished work should be cited in the text only, giving the initials, name and date. They should not appear in the list of references. All references should be listed alphabetically. References should be selected based on their relevance and the numbers should be kept to a minimum. Journal names should be abbreviated according to the World list of Scientific Periodicals.

Examples

Journal article:

Zerbini, E., Gemeda, D., Tegegne, A., Gebrewold, A. and Franceschini, R. 1993. The effects of work and nutritional supplementation on postpartum reproductive activities and progesterone secretion in F1 crossbred dairy cows in Ethiopia. Theriogenology 40(3):571-584.

Crosse, S., Umunna, N.N., Osuji, P.O., Tegegne, A., Khalili, H. and Tedla, A.. 1998. Comparative yield and nutritive value of forages from two cereal-legume based cropping systems: 2. Milk production and reproductive performance of crossbred (Bos taurus x Bos indicus) cows. Tropical Agriculture 75 (4):415-421.

Article by DOI

Negewo, T., Melaku, S., Asmare, B. and Tolera, T. 2018. Performance of Arsi-Bale sheep fed urea treated maize cob as basal dietand supplemented with graded levels of concentrate mixture. *Tropical Animal Health and Production*. https://doi.org/10.1007/s11250-018-1544-4

Book

Steel, R.G.D. and Torrie, J.H. 1960. Principles and Procedures of Statistics. McGraw-Hill Book Co., Inc., New York.

Chapter in a Book

Zerbini, E., Gemeda, T., Gebre Wold, A. and Tegegne, A. 1995. Effect of draught work on the metabolism and reproduction of dairy cows. In: Philips, C.J.C. (ed.), Progress in Dairy Science. Chapter 8. CAB International. pp. 145-168.

Paper in Proceedings

Gebre Wold, A., Alemayhu, M., Tegegne, A., Zerbini,E. and Larsen, C. 1998. On-farm performance of crossbred cows used as dairy-draught in Holetta area. Proceedings of the 6th National Conference of the Ethiopian Society of Animal Production (ESAP), May 14-15, 1998, Addis Ababa, Ethiopia, pp. 232-240.

Thesis/Dissertation

Trent, J.W. 1975. Experimental acute renal failure. Dissertation, University of California

Online document

Tekle, D., Gebru, G. and Redae, M. 2018. Growth performance of Abergelle goats fed grass hay supplemented with pigeon pea (*Cajanus cajun* (L.) Millsp) leaves. *Livestock Research for Rural Development. Volume 30, Article #149.* Retrieved August 2, 2018, from http://www.lrrd.org/lrrd30/8/desta30149.html

Cartwright, J. 2007. Big stars have weather too. IOP Publishing PhysicsWeb. http://physicsweb.org/articles/news/11/6/16/1. Accessed 26 June 2007

Abbreviations

Follow standard procedures.

Units

All measurements should be reported in SI units. (e.g., g, kg, m, cm)

Table 1. The following are examples of SI units for use in *EJAP*

Quantity	Application	Unit	Symbol or expression of unit
Absorption	Balance trials	Grams per day	g d^{-1}
Activity	Enzyme	Micromoles per minute per gram	µmol min^{-1} g^{-1}
Area	Land	Hectare	ha
	Carcass	Square centimetre	cm^{2}
Backfat	Carcass	Millimetres	mm
Concentration	Diet	Percent	%
	Blood	Gram per kilogram	g kg^{-1}
		International unites per	IU kg^{-1}
		kilogram	mg dL-^{1}
		Milligram per 100 mL	Mequiv L^{-1}
		Milliequivalents per litre	
Density	Feeds	Kilogram per hectolitre	kg hL^{-1}
Flow	Digesta	Grams per day	g d^{-1}
	Blood	Milligrams per minute	mg min^{-1}
Growth rate	Animal	Kilogram per day	kg d^{-1}
		Grams per day	g d^{-1}
Intake	Animal	Kilograms per day	Kg d^{-1}
		Grams per day	g d^{-1}
		Grams per day per kg bodyweight0.75	g d^{-1} kg$^{-0.75}$
Metabolic rate	Animal	Megajoules per day	MJ d^{-1}
		Watts per kg bodyweight	W kg^{-1}
Pressure	Atmosphere	Kilopascal	KPa
Temperature	Animal	Kelvin or degree Celsius	K or ^{o}C
Volume	Solutions	Litre	L
		Millilitre	ML
Yield	Milk production	Litres per day	L d^{-1}
Radioactivity	Metabolism	Curie or Becquerel	Ci (=37 GBq)

Units with two divisors should be written with negative indices (e.g., kg ha^{-1} yr^{-1}). The use of solidus (/) should be reserved for units written in full (e.g., mole/kilogram) or to separate a physical quantity and unit (e.g., yield/ha). Units should be chosen so that the numeric component falls between 1 and 10 or 1 and 100 when using one or two significant figures, respectively (e.g., use 31.2 mg than 0.0312 g).

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