Conservation, Processing and Utilization Practices of Cereal Straw as Basal Feed for Dairy Cattle in the Central Highlands of Ethiopia

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Abstract: The study was carried out to assess the current status of cereal straw management practices, challenges and opportunities to enhance its use as feed resource to dairy cattle across the crop production corridors in the central highlands of Ethiopia. Data were collected from 180 smallholder dairy farmers (85.6% male and 14.4% female-headed households) using a structured questionnaire, key informant discussion and personal observations. Chi-square and one-way ANOVA procedure of the Statistical Analysis System was used to estimate and compare qualitative and quantitative data, respectively. The average cattle herd size per household in the study areas was 14 Tropical Livestock Units (TLU), and the number of total cows and lactating cows owned per household was 4.5 heads and 2.9 heads, respectively with a higher proportion of crossbreds than local cows. *Tef*, barley, wheat and oat straws were the principal residues conserved and used to feed dairy cattle by all the farmers across the study areas. On average, about 7.4t DM of cereal crop residues were produced per household. Overall, cereal residues contribute to the level of 75% of the basal feed proportion in the late dry season which gradually declines to a lower level in the middle of the wet season. The entire respondents practice collection and storage of cereal residues out of which about 83.5% use under shelter shade loose storage system. Although the farmers use these residues for different purposes, more than 68% of the respondents reported as they use them only for feeding purposes. Moistening (61.8%) with water and salt, mixing (34.4%) with some kind of market available concentrates, molasses and local beverage residues (*atella*) and treatment (3.8%) with urea were the common processing methods used before feeding. Overall, about 91.1% of the sampled respondents reported as they encounter crop residue loss and the majority (>75%) of the loss occurs during utilization. The cluster-based farming system underway in the area created an opportunity for crop expansion with better straw yield. However, lack of processing, appropriate utilization and absence of regular training supported by practical demonstration were listed as important challenges in their descending order. Commonly, *tef*, wheat and barley straws were available in the market throughout the year via retailers. Straws are abundantly available at fair price within a few months from the time of harvest but gradually get scarce and expensive towards the wet season across the districts. From the study it was concluded that the conservation, processing and utilization practices of cereal straw as basal feed source for dairy cattle were not fully exploited. Based on the conclusion it was recommended that farmers should be better exposed to efficient crop residue conservation, treatment and utilization techniques. Further studies should be made to adopt straw densification methods utilized and appreciated in some other tropical countries.

Keywords: *Cereal straws availability, Dairy cattle, Processing, Proportion in the basal diet, Utilization*

Introduction

Inadequate nutrition is a major constraint that impacts negatively on the growth and viability of dairy cattle farming in Ethiopia (EIAR, 2017). Makkar (2018) estimated the total annual potential biomass of available feeds at 144.48 million tons. From this total amount, forages contributed to 96.6 and 92 percent of total ME and CP availability, respectively, while concentrate feeds contributed little. Based on these calculations, FAO (2018) estimated Ethiopia's national feed deficit at 21 percent as DM, 52 percent as ME and 48 percent as CP, reflecting that Ethiopia clearly lacked good quality feeds. Specifically, in the highlands of Ethiopia, the annual DM production could satisfy only two-thirds of the total DM requirements of the livestock only (Senbeto *et al*., 2010).

Cereals are dominant crops grown in all the regions of Ethiopia with varying quantities. On average, cereals cover 81.4% of the total land cultivated in Ethiopia (CSA, 2020). The smallholders produce a yearly average of 30 million tons of cereal grain which accounts for 88.5% of the total agricultural grain production in

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Ethiopia. In the mixed crop-livestock system, these crop residues provide about 50% of the total feed source for ruminant livestock which sometimes reach 80% during severe dry seasons of the year (Adugna, 2007; Adugna *et al*., 2012; Mekete *et al*., 2018).

The total crop residue annual production is increasing over years and is estimated to be 62.6 million tons at the national level (CSA, 2019). Its availability as feed for livestock is also largely affected by the seasonality of crop production which were abundantly available at the beginning of the dry season following the harvest of crops but severe shortage occurs during the late dry season (February to May) in the highlands of Ethiopia (ESAP, 2009; Mesay *et al*., 2013; Sefa, 2017). Crop residues are mainly fed to livestock during the dry season when the quantity and quality of available fodder from the natural pasture decline drastically (Tsegaye and Lemma, 2009; Getachew *et al*., 2012). However, the low protein content (<7%) and poor digestibility (< 55%) of this feedstuff makes it feeds of low nutritional value (AACCSA, 2006; Adugna *et al*., 2012; Malede and Takele, 2014; Makkar, 2018). The low constituent of crop residue in CP and *in vitro* DM digestibility necessitated supplementations with some energy and protein-rich feeds or some physical, chemical, and biological treatments in order to support satisfactory intake and digestion thereby improving the livestock performance (Solomon *et al*., 2008).

Further increased dependence on crop residues for livestock feed is also expected as more and more of the native grasslands are cultivated to satisfy the grain needs of the rapidly increasing human population in the country (Seyoum, 2007). Thus, it is worth understanding the current scenario and the upcoming trend in terms of enhancing the use of crop residues as dairy cattle feed and suggesting intervention mechanisms. Therefore, this study was designed to assess cereal crop residue seasonal availability, processing methods and utilization challenges, and opportunities for dairy cattle among smallholder farmers in the central highlands of Ethiopia.

Materials and Methods

Description of the Study Sites

The study was conducted between August to October 2020 to assess the production, conservation, processing methods and utilization of cereal crop residues for feeding dairy cattle in selected three districts in the central highlands of Ethiopia. The three districts included were located in Oromia Regional State of Ethiopia. Wolmera and Ejere are found in the west of Addis Ababa on the main road to Ambo some 30 and 41 km away, respectively. Geographically, Welmea is found at 9˚ 0' 0"'- 9º 10' 0" N latitude and 38˚ 25' 0"- 38˚ 30' 0" E longitudes. Whereas Ejere is located between 8°51'16"N to 9°14'53"N latitude and 38°15'2"E to 38°28'45"E longitude. Degem is located in the North Shewa Zone some 125 km to the north of Addis Ababa. It is situated between 8°51'16"N to 9°14'53"N and 38°15'2"E to 38°28'45"E. These districts are known for cereal crop production mainly *tef*, wheat, barley and oats. They are characterized by intensive cropping where both crops and livestock production have comparable contributions to livelihoods. As per the objective of this particular study, Welmera represents the wheat crop production belt; Ejere for *tef* and Degem was selected for representing the barley production belt.

Sampling Method and Data Collection

Districts, *kebeles* and households (HHs) were selected using multi-stage sampling techniques. In the first stage, three districts were selected following *tef*, wheat and barley production belts. The second stage involved a random selection of two *kebeles* from each district based on the availability of crossbred dairy cattle, experiences on crop residue production, conservation and utilization as dairy cattle feed. The third stage involved a random selection of households from each selected *kebeles* depending on the frame lists and information obtained from the respective district Livestock and Agriculture Development Office. Accordingly, thirty dairy farmers were randomly selected from each *kebele* with a total of 60 dairy farmers from each study district for a personal interview. The sample size was determined according to the formula given by Arsham (2007) for survey studies: N = 0.25/SE2 Where, N = sample size; SE = Standard error of dairy farms. Accordingly, by assuming a standard error of 3.73% at a precision level of 5% and 95% confidence interval, $N=0.25/(0.0373)^2 = 180$; a total of 180 dairy farmers were selected by random sampling method.

Data Analysis

Statistical package of SPSS version 20 was employed for data analysis. Chi-square and one way ANOVA procedure of the Statistical Analysis System were used to estimate and compare qualitative and quantitative data, respectively. The significant differences in mean values of the quantitative variables were tested using Duncan`s Multiple Range Test (Duncan, 1955) at a probability level of 0.05.

Results and Discussion

Household Characteristics

The household characteristics of the respondents in the study area are presented in Table 1. The overall average sex of household heads in the present study resulted in a higher proportion of male households (85.6%) than females (14.4%). This result is similar to different studies that livestock/dairy production is highly dominated by male-headed households in the cereal-based production system of Ethiopia (Daniel *et al*., 2013; Fekede *et al*., 2013; Bainesagn, 2016). The involvement of less number of female-headed households could probably be due to cultural influence that females are not encouraged to lead a family and the husband is considered as head to represent the family for a survey.

The overall average family size of the sample households in the study areas was reported 6.13 (ranges, 3-12 persons) (Table 1). Family size was not significantly different (P>0.05) across the districts. However, about 63.3% of respondents had a family size of greater than or equal to 6 persons which were lower than the previous report of 6.8 (Fekede, 2013; Endale *et al*., 2016). In agriculture-based livelihoods, large family size is required to guarantee adequate labor for the agricultural occupation. Evidence in Ethiopia suggested that a household with a large family size is more likely to adopt improved agricultural technologies (Gemechu *et al*., 2016). The large family size recorded has an advantage especially for the dairy producers to engage the labor force in different activities of dairying, which is labor-intensive operation.

The overall educational status of the respondents ranged from totally illiterate (24.4%) to the extent of diploma holders and above (1.1%). Of the total respondents, about 43.9% attended elementary school, 26.1% secondary & high school and the rest 4.4% attended preparatory levels of formal education (Table 1). No significant difference (P>0.05) was observed across the districts in education status. Overall, more than 70% of the respondents attended formal education in this study. This literacy level is higher than the report of Fekede (2013) but agrees with that of Ahmed *et al.* (2010). However, it is lower than the illiteracy level reported for household heads in most highland areas of the country (Azage *et al*., 2008; Yoseph *et al*., 2015; Bainesagn, 2016). A literate population is believed to have better access to information on improved technologies with better managerial capacity and develop more tendencies towards intensification of dairy production (Fekede, 2013; Gemechu *et al*., 2016).

Income was generated from different activities including crop production, livestock rearing, labor, private businesses and remittance (Table 1). Among these sources of income, livestock production was reported as one of the highly competent income sources in the study areas. The income from the livestock sector emanates from the selling of live animals, animal products and byproducts to the extent of dung cake marketing. Accordingly, more than half of the household income is reported to be generated from crop production (59.65±0.67) which did not differ significantly (P>0.05) across the districts. This result agrees with the study report in Fogera and Bure districts that the sale of grain is the main income source followed by livestock marketing (Azage *et al*., 2013). The overall average livestock source annual income was reported 37.08±0.52 which is consistent (P>0.05) across the districts. In line to these findings, 37 % of household income was reported to be generated from livestock in the mixed farming system (Gebremariam *et al*., 2010; Behnke and Menagerie, 2011; ATA, 2012). However, this study finding is lower than the report from Arsi Zone, Limuna Bilbilo district where the livestock covers about 39% of the livelihood income source (Mesay *et al*., 2013) but higher than the report from Dini village of Jeldu district, Melka watershed where only 28% of the household income was reported as originated from livestock and livestock products marketing (Andnet *et al*., 2014).

Table 1. Demographic characteristics and income source of the respondents in the study areas.

Variables	Ejere (n=60)	Welmera (n=60)	Degem (n=60)	Overall (n=180)	P-value
Sex of household heads					
Male (%)	90	80	86.7	85.6	0.28
Female (%)	10	20	13.3	14.4	
Family size (Mean±SE)	5.9±0.2	6.0±0.2	6.4±0.2	6.1±0.1	0.248
Educational status of household heads					
Illiterate (%)	28.3	16.7	28.3	24.4	0.419
Elementary (%)	45	51.7	35	43.9	
Secondary & high school (%)	25.0	26.7	26.7	26.1	
Preparatory (%)	0	5	8.3	4.4	
Diploma and above (%)	1.7	0	1.7	1.1	
Major sources of income for livelihoods (Mean±SE)					
Crop production	58.9±1.3	60.3±1	59.7±1.2	59.7±0.7	0.691
Livestock production	35.6±1	38.1±0.7	37.6±0.9	37.1±0.5	0.114
Labor	1.4±0.6	0	1.00±0.4	0.8±0.2	0.05
Business	3.8±1[a]	0.4±0.4 [b]	0	1.4±0.4	<0.001
Remittance	0.3±0.2[b]	1 ±0.8[a]	1.7±0.7[a]	1 ±0.4	0.033

a-b means with different letters of superscripts in the same row differ significantly at (P<0.05).

Livestock Herd Size and Structure

The average number of livestock holding per household in terms of tropical livestock unit (TLU) for the study site is shown in Table 2. Cattle are the dominant species raised by 100% of the responding households in the study areas. No significant difference (P>0.05) was observed among the districts in terms of cattle holding per household. The average cattle holding per household was 14±0.5 TLU and accounted for about 70% of the total livestock herd owned by the

households. This result is higher than the earlier reports (Senbeto *et al.*, 2010; Bainesagn, 2016; Endale *et al.*, 2016) which might be due to the progress in the scale of dairy production across the study areas emphasizing the diverse social and economic roles of cattle to smallholder farmers.

The overall average number of local and improved cattle breeds owned per household in terms of TLU in the study area was 3.3 and 10.7, respectively. Average local cattle holding per household was markedly higher ($P<0.05$) for Ejere than for Welmera and Degem districts which might indicate the intensity of crop cultivation in the Ejere district. However, no significant difference ($P>0.05$) was observed for improved types of cattle rearing across the districts. The overall proportion of indigenous cattle reared per household in this study is found lower (23.6%) than the proportion of crossbred cattle (76.4%). In contrast, a higher proportion of local breed of cattle was reported previously (Fekede *et al.*, 2013; Yoseph *et al.*, 2015). In general, the increased importance of cattle especially dairying was observed in this study which is in line to the earlier report that suggested the importance of cattle in mixed farming system of the highlands and mid-altitudes of Ethiopia (Getachew *et al.*, 1993). This shows the increased importance of dairying to the livelihoods of farmers across the study areas.

Sheep, donkeys, horse and chickens were the other important livestock species raised by a large proportion of households in the study areas. About 70.6%, 68.9% and 87.8% of the total respondents reported owning sheep, donkey, and chickens, respectively. The overall average TLU owned per household in the study area is 1.6, 0.2, 0.7, 0.6, 0.02 and 0.02 for sheep, goats, donkeys, horses, mules and chicken, respectively (Table 2). Comparable figures were also reported previously from the study undertaken in the central highlands of Ethiopia (Fekede, 2013; Endale *et al.*, 2016; Bainesagn, 2016). Comparatively, donkey (68.9%) rearing was reported more common than horses (57.8%) in the study areas. This is in line with the report of ILCA (1990) where the proportion of donkeys in the herds tends to be relatively high in mixed production systems as these animals are used for draught and transport purposes. Less attention was given to the small ruminants and chicken rearing rather more focus was on dairy production in the study area.

Table 2. Livestock and dairy cattle herd size and composition per household in the study areas.

Species	Ejere (n=60)	Welmera (n=60)	Degem (n=60)	Overall (n=180)	P- values
	Mean±SE	Mean±SE	Mean±SE	Mean±SE	
Cattle:	13.6±0.8	13.8±0.6	14.4±0.9	14±0.5	0.760
Local	3.9±0.3^{a}	3.0±0.2^{b}	2.9±0.2^{b}	3.3±0.1	0.004
Crossbred	9.8±0.6	10.9±0.6	11.4±0.9	10.7±0.4	0.251
Sheep	0.9±0.1^{c}	1.7±0.2^{b}	2.2±0.2^{a}	1.6± 0.1	<0.001
Goat	1.2±0. 4^{a}	0.3±0.2^{b}	0.3±0.2^{b}	0.6±0.2	0.022
Chicken	0.2±0.02^{b}	0.3±0.03^{a}	0.2±0.02^{b}	0.2±0.01	<0.001
Donkey	0.9±0.8^{a}	0.36±0.6^{b}	0.81±0.6^{a}	0.7±0.4	<0.001
Horse	0.8±0.09^{a}	0.79±0.08^{a}	0.33±0.01^{b}	0.6±0.05	<0.001
Mule	0	0.6±0.3	0.1±0.1	0.2±0.1	0.068
Total	**17.6± 0.8**	**17.9 ±1.0**	**18.3±0.6**	**17.9±0.5**	**0.873**
Dairy cows herd size and structure (heads)	Mean (*)	Mean (*)	Mean (*)	Mean (*)	P values
Total cows	4(1-8)	4.6(1-13)	4.7(2-9)	4.5(1-13)	0.159
Local cows	1.3^{a}(1-3)	0.7^{b}(1-5)	1.1^{a}(1-4)	1.1(1-5)	0.013
Crossbred cows	2.7^{b}(1-5)	3.6^{a}(1-13)	3.9^{a}(1-6)	3.4(1-10)	0.002
Total lactating cows	2.4^{b}(1-5)	3.1^{a}(1-9)	3.3^{a}(1-6)	2.9(1-10)	0.005
Local lactating cows	0.4^{b}(1-2)	0.6^{ab}(1-2)	0.8^{a}(1-2)	0.6(1-2)	0.017
Crossbred lactating cows	1.7^{c}(1-4)	2.8^{a}(1-13)	2.3^{b}(1-4)	2.3(1-10)	<0.001

$^{a-b}$ means with different letters of superscripts in the same row differ significantly at ($P<0.05$). (*)= Range; *TLU= Tropical livestock unit; Cattle TLU= [Cow (local=1, cross=1.8) + Oxen (local=1.1, cross=1.9) + Bull (local = 06, cross = 0.8) + Heifer (local = 0.5, cross = 0.7) + Calf (local = 0.2, cross = 0.4)], sheep/goat = 0.1, Horse = 0.8, Donkey = 0.5, Mule = 0.7, Poultry = 0.01. Source: Bekele (1991).*

The herd size and composition of dairy cows owned per household in the study areas are shown in table 2. The overall average total number of cows owned per household was 4.5 heads (ranging from 1-13 heads) which has no significant ($P>0.05$) variation across the districts. This finding is comparable with the figures previously reported by Fekede *et al.* (2013) but higher than the report of Kelay (2002) in Sululta and Degem *woredas* and Yitaye (2008) in the milk shed areas around Bahir Dar and Gondar. Out of the total respondents, 38.7% owned 1-3 heads, 48.3% owned 4-6 heads and 25% owned more than 6 heads of cows. Compared to the earlier study by Fekede *et al.* (2013), the proportion of respondents that keep 1-3 heads of herd size is reduced but these respondents keep both 4-6 and greater than 6 dairy cows are increased indicating the

progress in the scale of dairy production. Generally, 96.7% of the respondents in Ejere, 76.6% of the respondents in Welmera, 85% of the respondents in Degem, and 87% of overall respondents in the three districts owned 1-6 heads of mature dairy cows.

With regard to breed composition, crossbred cows accounted for about three fourth of the total cow's possession (Table 2). The average number of both improved (crossbred) and local breed cows owned per household was significantly different ($P<0.05$) across the districts. About 76.2% and 23.8% of the total respondents owned improved breeds of cows and local cows, respectively. This finding is different from the previous reports by Fekede, (2013) and Zewdie (2010) that the ratio of improved cow owning is higher indicating the increase in market-oriented dairy production in the area. Overall, 62.8% of the households owned 1-3 heads, 30.6% owned 4-6 heads, and 6.7% possess more than 6 heads of crossbred cows with the average being 3.4 heads (ranging from 1-13 heads). On the other hand, the average number of local cows owned per household was higher in Ejere (1.3 heads) and Degeme (1.1 heads) followed by Welmera (0.7 heads). According to the respondents, the major reasons for keeping crossbred cows were for milk production but local cows were reared to produce replacement oxen for draught power in the peri-urban crop-livestock farming system (Fekede, 2013).

Over 97.8% of the respondents owned lactating cows within a range of 1-13 heads with an overall average of 2.9 heads per household (2.4 heads in Ejere, 3.1 heads in Welmera and 3.3 heads in Degeme) which is significantly not different ($P>0.05$) across the districts. Out of the total lactating cows, 65.6% owned 1-3 heads, 30% owned 4-6 heads, and only 2.2% owned more than 6 heads of milking cows during the time of the survey. This finding is slightly higher than the report in Fogera woreda of the Amhara region (Belete *et al.*, 2010). Generally, the higher proportion of milking cows owned by the sampled respondents indicates the importance of dairying to the livelihood of smallholder farmers in the study areas.

Cereal Straw/Stover Production and Utilization as Basal Diet for Dairy Cattle

Cereal straw/stover production: The average area allocated for major cereal crop production across the districts was 3.55 ha (Table 3). The average area allocated for crop production was noted to be wider at Degem followed by Welmera and Ejere districts. The dominant cereal crops were barley, wheat, *tef* and oats production, respectively. The respective average cropland (ha) in South West Shewa, North Shewa and West Shewa (Tadessa *et al.*, 2009) was 1.6, 2.0 and 2.02 ha against the average cropland of 3.5 for Welmera, 3.3 at Ejere and 3.7 for Degem districts with the current study suggesting a significant increase cropland which might be due to reduction of grazing pasture land during the last decade (Agajie *et al.*, 2001; Tadessa *et al.*, 2009).

The estimated quantities of different cereal crop residues produced in a season per household in the study areas are shown in Table 4. Crop residue yield estimation was made by multiplying the grain yield with established conversion factors for each type of crop (Kossila, 1984; FAO, 1987). Accordingly, a multiplier of 1.5 was used for wheat, barley and *tef* (*Eragrostis tef*); 1.7 for oats and 2.0 for maize.

The total estimated quantity of cereal crop residues produced per household in a season was found to be none significant ($p>0.05$) across the districts that in Ejere (6.62 tones DM), followed by Welmera (7.03 tones DM), and Degem (8.51 tones DM). The total estimated quantity of cereal crop residues produced per household in this study is consistent with the result reported by different scholars (Solomon *et al.*, 2008; Kassahun *et al.*, 2013). However, it is lower than the report by Zewdie (2010) at Debre Birhan, Jimma and Sebeta study sites.

Table 3. Major crops and area allocated for crop production (ha/HH).

Crop	Welmera		Ejere		Degem		Overall Mean	P- value
	n	mean	n	mean	n	mean		
Tef	59	0.63^{b}	60	1.23^{a}	19	0.58^{b}	0.88±0.05	***
Barley	60	1.36^{b}	58	0.82^{c}	60	1.71^{a}	1.3±0.06	***
Wheat	60	1.44^{a}	60	1.37^{a}	60	0.72^{b}	1.17±0.06	***
Oat	54	0.28^{b}	54	0.3^{b}	58	0.5^{a}	0.36±0.01	***
Total		3.5		3.3		3.7	3.55±0.11	

*** = *Highly significant difference.*

The quantities of different crop residues produced per household in the study area depends on the farmland size allocated to each crop, grain productivities and harvest indexes of the different crops. In Ethiopia, the total annual crop residue production varies from place to place depending on the production system of the area and the type of crops grown (Tesfaye *et al.*, 2006). In this study, it was observed that cereals took dominant positions in terms of both household land allocation and crop residue production which is in line with the national scenario where cereals account for 81.5% of the total cropland coverage and 88.6% of the total grain production of the country (CSA, 2020).

Table 4. Estimated total cereal crop residue yield for specific food-feed crop produced in the study area for the year 2019/2020.

Crop type	Average grain yield (Q/ha)			CF	Average cereal straw/stover yield (Mt/HH)		
	Ejere	Welmera	Degem		Ejere	Welmera	Degem
Tef	11.5	10.5	10	1.5	1.3	0.91	0.75
Barley	16.2	19.4	28.9	1.5	1.92	1.83	4.7
Wheat	19	20.4	17.3	1.5	2.1	3.18	1.87
Oats	12.9	15	14	1.7	0.66	0.71	1.19
Maize	25.5	23.3	0	2	0.64	0.40	0
Total					6.62	7.03	8.51

CF: Conversion factors used for estimation of the amount of CRs or fibrous by-products produced from different crops (Kossila, 1984; FAO, 1987).

Cereal straw availability and proportion in the basal diet of dairy cattle: Cereal straws are available at a high level across the districts in the dry season but drops to a moderate level in the wet season except for the case of Degem where a high proportion of cereal straws are conserved to be used in the wet season (Table 5). In line with this finding crop residues were reported as the major feed resources for dairy cattle in the dry season in most mixed crop-livestock farming areas in the country (Seyoum *et al*., 2001; Adugna *et al*., 2012; Ketema, 2014). Particularly, Azage *et al.* (2013) point out that straws of *tef*, wheat and barley, and maize stover are important feed resources in the rural highland system of Bure and Fogera districts of Amhara Regional State of Ethiopia.

Cereal crop residue proportion in the roughage diet is higher up to 75% in the dry season except for the case of Degem where a higher proportion (75%) was rather used in the wet season (Table 5). This difference for Degem is due to higher natural pasture hay availability and utilization in the area. However, both Ejere and Welmera districts use at less than 50% in the wet season. The proportion of straws in the basal diet of dairy cattle in the current study is higher than the earlier report of Gryseels (1988) that about 40% of the feed was originated from crop by-products, particularly cereal straws. In contrast to the current study, overall crop residue feed contribution was reported lower than 25% in Dembi and Humbo village of Diga district of East Wollega Zone and Bokeji Negeso village of Limuna Bilbulo district of Arsi zone, Ethiopia (Mesay *et al*., 2013; Dereje *et al*., 2014). However, comparable proportion was reported from different parts of the country indicating the higher proportion utilization was mainly in the dry season (Agajie *et al*., 2001; Seyoum *et al*., 2001; Yeshitila, 2008; Adugna *et al*., 2012).

Table 5. Cereal residue source feed availability and proportion in the diet of dairy cattle in the study areas.

Variables of cereal crop residue		Dry season			Wet season		
		Ejere (n=60)	Welmera (n=60)	Degem (n=60)	Ejere (n=60)	Welmera (n=60)	Degem (n=60)
Level of availability (in %):							
	High	70	68.3	83.3	28.3	5	80
	Medium	30	28.3	16.7	48.3	68.3	20
	Low	-	3.3	-	16.3	26.7	-
	NA	-	-	-	6.7	-	-
Proportion in the basal diet:							
	NA	-	-	-	10.3	8.3	6.7
	< 25%	15	16.7	78.3	31.4	43.4	30
	26-50%	38.3	40.0	21.7	58.3	48.3	63.3
	51-75%	46.7	43.3	-	-	-	-

NA= Not available.

Cereal Straw/Stover Storage Practice

Cereal crop residue conservation practices for dairy cattle feeding in the study area are indicated in Table 6. All the respondents in the study area utilize crop residues for dairy cattle feeding. The entire respondents across the districts reported as they practice the collection and storage of crop residue. This is in agreement with the report of Ketema (2014) and Tesfaye and Charatanayuth (2007) where more than 96% and 90% of respondents collect and store crop residue in Gurage and East Shewa Zones, respectively.

According to the sample respondents, loose storage method is the only system used for cereal straw storage in the study area. Similarly, Fekede (2013) reported as 99.7% of the overall respondents in Sululta, G/jarso and Ejere districts store crop residue in loose form. Regarding storage practice, sheltered shade system (shelter/roof made from either of iron sheet, grass or plastic cover) was reported the popular way of conservation as practiced by about 83.5% of the overall respondents in the study areas. This practice is higher than the previous reports in the central highlands of

Ethiopia (Endale *et al*., 2016; Fekede and Gezahegn, 2018). However, it is comparable to the report from Burie Zuria district of Amhara Regional State where 85% of sheltered shade storage utilization was reported (Getahun and Tegene, 2019).

Table 6. Crop residue conservation practices for livestock feeding in the study area.

Straw/stover	Storage practice	Study sites			
		Ejere (n=60)	Welmera (n=60)	Degem (n=60)	Overall (N=180)
Tef	Under shelter shade (%)	80	83.3	83.7	82.3
	Open air (%)	20	16.7	16.3	17.6
Barley	Under shelter shade (%)	88.3	86.7	85	86.6
	Open air (%)	10.7	13.3	15	16.4
Wheat	Under shelter shade (%)	78.3	81.7	75	78.3
	Open air (%)	21.7	18.3	25	21.7
Oat	Under shelter shade (%)	88.1	86.3	85.9	86.8
	Open air (%)	11.9	13.7	14.1	13.2
Maize	Under shelter shade (%)	10	2.2	-	6.1
	Open air (%)	20	35.6	-	27.8

Generally, it was observed that leaving crop residue uncollected on the field and baling of crop residues prior to storage were not common practices in the study areas. However, a slight difference was reported in the case of under shade storage regarding specific crops. Accordingly, barley and oat straw under shade storage were practiced by 86.8% and 86.6% of the sampled respondents, respectively. Relatively, lower (78.3%) was reported for wheat straw under shade storage which might be due to the farmer's perceptions that it has poor nutritional value to contribute to dairy cattle productivity. The bulky nature of crop residue is the primary challenge for transporting and storing the whole crop residue produced appropriately. However, the majority of the respondents feed residues stored in the open air first to minimize the loss due to extreme weather conditions.

Cereal Straw Processing Practice

Crop residue processing and methods of processing in the study areas are indicated in Table 7. Overall, the majority (95.5%) of the sampled households in the study area reported as they use some kind of processing before offering cereal crop residues to dairy cattle. About 10.2% of the respondent households in the study areas offer *tef* straw as such as it is without undergoing any physical/chemical treatment options to their dairy cows. Moistening with water and salt were reported to be the dominant processing method (61.8%) used across the study districts. Urea treatment was rarely practiced as reported by only 3.8% of the overall sampled respondents in the study districts. Overall, about 34.4% of the respondents reported as they practice mixing with some kind of market available concentrates, molasses and local beverage residues (*atella*) for better palatability and intake. Very uniquely, chopping was reported as used for maize stalk in this study area. Compared to this result, about 70% of respondents in Debre Brihan and Sebeta (Zewdie, 2010) and 76.9% of the respondents at Melka and 100% of the respondents at Birbirsa village of Jeldu district reported practicing home mixing of crop residues with other feeds prior to feeding (Fekede *et al*., 2014). Water, salt and *atella* were the most common mixture used by 75% and 65% of the dairy farmers in Debre Birhan and Sebeta areas, respectively (Zewdie, 2010). But majority (70% at Melka and 72.7% at Birbirsa) of the respondents reported mixing *atella*, crop residues and salt at Jeldu district of Ethiopia (Fekede *et al*., 2014). Different studies still indicated as home mixing of available feed resources are a common practice among smallholder dairy producers aiming to increase intake and productivity of dairy cattle (Mesay *et al*., 2013; Andnet *et al*., 2014; Getahun and Tegene, 2019).

Regarding chemical treatments, Endale (2015) indicated as only 3.3% of respondents in Meta Robi district use urea treatment before feeding which is in line with the current report. However, in contrast to the current study, higher crop residue treatment practices were reported both in Debre Brihan, Sebeta and Bure Zuriea (Zewdie, 2010; Getahun and Tegene, 2019). On the other hand, some research results witnessed as there is no physical, chemical or biological treatment of crop residues were undertaken before feeding to dairy cattle in some parts of the country (Dagnachew *et al*., 2012; Dereje *et al*., 2014, Kasa and Saba, 2017).

Cereal Straw/Stover Utilization Practice

The diversified use of crop residue reported by sampled respondents in the study areas was indicated in Table 8. Crop residue is used for different purposes but is mainly used for feed as reported in the study area. Accordingly, all the respondents who produce *tef* straw reported as they primarily use it for feeding purpose. Whereas, 46.1% of respondents additionally use *tef* straw for construction, 0.6% for bedding and 2.8% for market purposes. The proportion of *tef* straw in the basal diet of dairy cattle ration varies in such a way that about 96.2% of the overall respondents use at a proportion greater than 51% but less than 25% was used for construction, bedding and marketing purposes.

Table 7. Crop residue processing and methods of processing in the study area.

Crop type	Study sites	CR processing			Crop residues processing methods (%)			
		N	Yes (%)	No (%)	Chopping	Moistening with water and salt	Urea treatment	Mixing with other feeds
Tef straw	Ejere	60	70	30	-	64.3	2.4	33.3
	Welmera	56	96.4	3.6	-	59.3	9.3	31.5
	Degem	16	100	-	-	66.7	-	33.3
Barley straw	Ejere	58	96.6	3.4	-	66.7	1.8	31.6
	Welmera	60	100	-	-	65	10	25
	Degem	60	100	-	-	61.7	-	38.3
Wheat straw	Ejere	60	100	-	-	65	3.3	31.7
	Welmera	60	100	-	-	55	10	35
	Degem	60	100	-	-	60	-	40
Oat straw	Ejere	39	100	-	-	70	-	30
	Welmera	36	100	-	-	50.9	9.1	40
	Degem	49	100	-	-	56.9	-	43.1
Maize stover	Ejere	33	100	--	100	-	-	-
	Welmera	46	100	-	100	-	-	-
	Degem	-	-	-	-	-	-	-

n= Number of sampled respondents.

Table 8. Diversified use of crop residues in the study areas (n=180).

Crop residues	Level	Different use of crop residues					
		Livestock feed	Construction	Soil fertility	Fuel energy	Bedding	Market
Tef	<25%	0.8	46.1	-	-	0.6	2.8
	25-50%	3.0					
	51-75%	53.0					
	76-100%	43.2					
Barley	<25%	-	28.9	20	-	6.7	0.6
	25-50%	1.7					
	51-75%	34.1					
	76-100%	64.2					
Wheat	<25%	0.6	29.4	18.9	-	29.4	1.1
	25-50%	54.4	3.9	0.6		0.6	
	51-75%	45					
	76-100%	-					
Oat	<25%	-	1.1	5.6	-	1.1	-
	25-50%	-					
	51-75%	5					
	76-100%	85					
Maize stover	<25%	25	0.6	-	10.6	-	-
	25-50%	8.9			6.1		
	51-75%	7.8					
	76-100%	-					

All HH respondents from barley producing areas reported that they use it for the feeding of their dairy cattle. Overall, about 98.3% respondents use the straw at a proportion higher than 51% in the basal diet of dairy cattle. Some reported as they additionally use it for construction (28.9%) and soil fertility amendment (20%) purpose. Few respondents still use barley straw for bedding (6.7%) of dairy cattle and 0.6% sale it for earning additional income. It is also common to use wheat straw for feed and other diversified purposes in the study area. The entire sampled respondents reported to use wheat straw for dairy cattle feeding. The majority (54.4%) of respondents reported that they use wheat straw in the proportion of 25-50% in the basal diet. Considerable number of respondents still uses wheat straw for construction (33.3%), soil fertility amendment (19.5%), bedding (30%) and market (1.1%) purpose. Relative to other cereal straws, the number of respondents that use wheat straw for other purposes than feeding were higher which might be due to lower nutritional contribution when fed without any form of treatment. Similarly, the least preference index value was reported for wheat straw in Debre Brhan, Sebeta and Jimma study areas (Zewdie, 2010). Oats straw is reported rarely used for other purposes than feed in the study area. About 85% of the sampled respondents indicated as they use oats straw in the proportion of greater than 76% in the basal diet. Maize is not a

common crop produced in the study area. Only about 16.7% of the overall sampled respondents reported to use the stover as feed for dairy cattle and its proportion is at less than 25% in the basal diet.

The extent of utilization of cereal straws as basal diet depends on its availability which further influenced by the size of land cultivated, yield obtained and availability of other alternative feed sources in the area. For instance, wheat and *tef* were reported as the major straw used to feed dairy cattle in and around Shashamane town, which is one of the potential areas for milk production in Southern Ethiopia (Girma *et al.*, 2014). In this study it is observed that farmers conserve and use the type of crop they produce both for feed and other purposes. They don't practice selling of cereal residue they had and buy other residues for replacement of what they produce.

Competitive Use of Cereal Straws

Sampled respondents in the study areas reported that they use cereal straw for animal feed, construction, soil amendment, animal bedding and sale to the market with varied proportions (Figure 1). The result of this particular study indicated that about 70%, 68% and 73% of Ejere, Welmera and Degem respondents reported to use the harvested and conserved straws for animal feed only, respectively. In line to this, FAO (2018) reported, 70% of the crop residue produced by the smallholders is used for animal feeding. Frederic *et al.* (2016) also showed that, about 95% of farmers from East and West Shewa Zones use wheat, maize, barley and *tef* residues for animal feed. Similarly, a number of field researches indicated that smallholders in Ethiopia are forced to use majority of the crop residues for animal feed with low retention on the farm for soil conservation purpose (Moti *et al.*, 2012; Dagnachew *et al.*, 2012). Generally, straws allocation for different purposes varies depending on the type of crop produced. For instance, higher proportion of maize Stover is used for fuel purpose next to animal feeding. But the allocation of cereal straw for fuel is not common and similarly maize Stover is not used for construction.

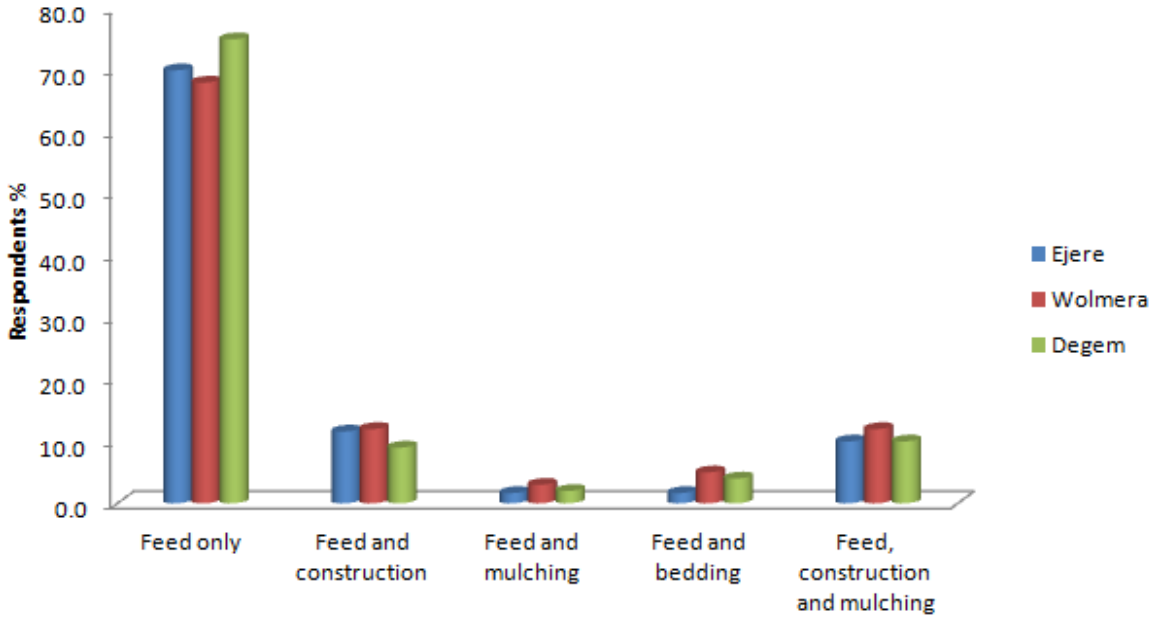

Figure 1. Multiple uses of cereal crop residue in the study area.

Cereal Straw Trading

Crop residue marketing is a common practice for farmers in the study areas to generate additional income for their livelihood. All the sampled respondents have information about the marketability of straws and their price in their locality. Similar to our findings, Azage *et al.* (2013) and Mesfin *et al.* (2014) reported that crop residue mainly cereal straws are one of the major feed resources marketed in addition to baled grass hay and green grass. The entire respondents also indicated that its availability and price fluctuate based on seasons. As indicated in table 9, *tef*, wheat and barley straws are the major cereal straws available in the local market of both Welmera and Ejere districts. Wheat and barley straws are rather reported dominantly available in the local market of Degem district. Respondents indicated that, these cereal residues are available in the market with higher quantity and fair prices for the first two to three months after crop harvest. Generally, the type and quantity of crop residue supplied to the market varies from place to place depending on the type of crop grown as determined by the agro-climatic conditions.

Majority of the dairy producer farmers reported that they don't buy or sale straws otherwise conserve and use from their own farm harvest. However, few

respondents reported to purchase in the form of stack/heap at the gate or farm of producers estimating the quantity traditionally by the size of the heap. Accordingly, it was reported that the average price goes up to 2000-2500 birr for the larger stack (estimated at 20-25 donkey back) and 35 to 45 birr per sack for wheat and barley straws in the harvest season which gets more expensive in the wet season.

Bale making that helps to facilitate easy transportation, storage and marketing of cereal residues is not a common practice across the study districts. As a result, cereal residues are available in the market mainly on donkey back and in sack. The value chain used in marketing cereal residues across the study districts is not complex. The end users directly buy from the producers in the market or at the producer's gate. However, recently retailers are emerging in the value chain where they collect crop residue from producers both at market point and farm gate to store and make it available throughout the year. Interviewed retailers reported, that they don't practice any value addition to the residues except application of appropriate storage system aiming to protect from extreme weather conditions. The business has a good return when collected in the harvest season and sold in the wet season where its demand increases in the market and the supply from producers declines.

Table 9. Marketable cereal crop residues in the study areas.

Type of cereal residues	Study Site					
	Ejere (n=60)		Welmera (n=60)		Degem (n=60)	
	n	%	n	%	n	%
Tef straw	-	-	4	6.7	-	-
Wheat straw	2	3.3	-	-	-	-
Tef and barley straw	-	-	8	13.3	-	-
Tef and wheat straw	4	6.7	5	8.3	-	-
Barley and wheat straw	-	-	4	6.7	47	78.3
Tef, wheat and barley straw	54	90	39	65	13	21.7
Total	60	100	60	100	60	100

n= Number of respondents sell crop residue.

Challenges to the Efficient Utilization of Straw as Feed

Challenges to cereal crop residue utilization in the study areas are indicated in Table 10. Processing, utilization and lack of regular training and extension linkage were reported as the top priority challenges in their descending order as reported in the study areas. Processing is the primary challenge reported by about 73% of the overall sampled respondents in the study areas. Efficient utilization is also prioritized as the second important challenge by 64.4% of the respondents as less is invested in processing or nutritional manipulation prior to feeding.

Absence of regular trainings and strong extension linkage was reported as the third important problem affecting the utilization by about 56.6% of the sampled respondents. The respondents also explained that, the so far delivered few trainings were not supported by practical demonstration with convincing pieces of evidence of improving productivity. In line with this study, Mesay *et al.* (2013) also reported that most farmers did not have access to practical training on improved feeding techniques.

Table 10. Major constraints on efficient cereal straw utilization as ranked by respondents.

List of possible challenges	Levels of challenges in number (%) (N=180)				Rank
	NP	Low	Medium	High	
Availability and cost	121(67.2)	40(22.2)	14(7.8)	5 (2.8)	6
Harvesting and transporting	67(37.2)	77(42.8)	33(18.3)	3 (1.7)	5
Storage/conservation problems	31 (17.2)	70(38.9)	66(36.7)	13(7.2)	4
Processing	1(0.6)	5(2.8)	42 (23.3)	132(73.3)	1
Utilization	-	0.6 (3.3)	116(64.4)	58 (32.2)	2
Lack of regular training and extension linkage	-	22 (12.2)	102(56.6)	54(34.4)	3

Notice: Columns of medium plus high levels of challenges were considered in ranking; NP= Not a problem.

Storage or conservation was also reported as a problem since some parts of the collected crop residues are still left outside in the open air because of the bulky nature of crop residues. Respondents indicated as all the collected cereal residues cannot be accommodated under the shade because of lack of enough storage space. However, some farmers in the study area were observed first utilizing the straws stored in the open air as a coping strategy in preventing nutrient loss that occurs in extreme weather conditions. In some cases, where the crop farm is far away from dairy cattle rearing locations, transporting also becomes an important challenge as it requires high labor and cost. Although its availability declines in the wet season,

nowadays it is possible to find cereal straws in the local market irrespective of season just because of the involvement of retailers in the business.

Conclusion

The result from this study revealed that cereal straw was the major basal feed resources available in the study areas. The utilization of crop residue extends to about 75% in the dry season which gradually declines in the middle of the main rainy seasons. Under shelter shade loose storage was found a common conservation practice in the study areas. Treatment of crop residue in the study area were moistening with salt and water (61.8%) followed by mixing with market available concentrate, molasses and homemade local beverage residues (34.3%) and few attempts of urea treatment (3.8%). From the study it was concluded that the conservation, processing and utilization practices of cereal straw as basal feed source for dairy cattle were not fully exploited. Based on the conclusion it was recommended that farmers should be better exposed to efficient crop residue conservation, treatment and utilization techniques. Further studies should be made to adopt straw densification methods utilized and appreciated in some other tropical countries.

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Conflict of Interests

The authors declare that they have no competing interests.

References

AACCSA (Addis Ababa Chamber of Commerce and Sectoral Associations) (2006). Livestock resources: potentials, constraints, and prospects for private-sector development. Final report.

Adugna Tolera (2007). Feed resources for producing export quality meat and livestock in Ethiopia: Examples from selected *woredas* in Oromia and SNNP Regional States. Ethiopia Sanitary and Phytosanitary Standards and Livestock and Meat Marketing (SPS-LMM) Program, Addis Ababa. Ethiopia. p: 77.

Adugna Tolera, Alemayehu Mengistu, Diriba Geleti, Alemu Yami & Yirdaw Woldesemayat (2012). Livestock feed resources in Ethiopia: Challenges, opportunities and the need for transformation. Ethiopian Animal Feeds Industry Association, Addis Ababa, Ethiopia.

Agajie Tesfaye, Chilot Yirga, Mengistu Alemayehu, Elias Zerfu & Aster Yohannes (2001). Smallholder livestock production systems and constraints in the highlands of North and West Shewa Zones. Ethiopian Society of Animal Production, 9th *ESAP-Proceedings*, pp: 100-111.

Ahmed Hassen, Abule Ebro, Mohammed Kurtu & Treydte, A.C. (2010). Livestock feed resources utilization and management as influenced by altitude in the Central Highlands of Ethiopia. *Livestock Research for Rural Development*, 22 (12).

Andnet Deresse, Temesgen Assefa, Zewdie Wondatir, Tibebu Seifu, Jonse Negassa, Abera Adie & Adugna Tolera (2014). Assessment of livestock production system and feed resources availability at Melka watershed, Jeldu district, Ethiopia. International Livestock Research Institute, Nairobi, Kenya.

Arsham, H. (2007). Business statistical decision science and systems stimulation Merric School of business Charles at Mount Royal, Baltimore, Maryland, 2120, University of Baltimore, UAS, p: 100.

ATA (Agricultural Transformation Agency) (2012). Livestock value chain programs. https://www.ata.gov.et/.

Azage Tegegne, Berhanu Gebremedhin, Dirk Hoekstra, Berhanu Belay & Yoseph Mekasha (2013). Smallholder dairy production and marketing systems in Ethiopia: IPMS experiences and opportunities for market-oriented development. IPMS (Improving Productivity and Market Success) of Ethiopian Farmers Project Working Paper 31. Nairobi: ILRI.

Azage Tegegne, Tesfaye Mengistie, Tesfaye Desalew, Worku Teka & Eshete Dejen (2008). Does the future hold for transhumance cattle production system in North Western Ethiopia? *Proceedings of the Conference on International Research on Food Security*, Natural Resource Management and Rural Development, University of Hohenheim, Tropentag.

Bainesagn Worku (2016). Smallholder cattle production systems and husbandry management in West Shewa Zone of Oromia Regional State, Central Ethiopia. *World Scientific News*, 53(3):178-188.

Behnke, R. & Menagerie, F. (2011). The contribution of livestock to the Ethiopian economy-part II, IGAD livestock policy initiative (LPI) working paper no. 0211, http://www.igadlpi.org/publication/docs/IGADLPI-WP-02-11-PartII.

Bekele Shiferaw (1991). Crop livestock interactions in the Ethiopian highlands and effects on sustainability of mixed farming: a case study from Ada district, Debrezeit, MSc. Thesis, Agricultural University of Norway, Oslow, Norway, p:163.

Belete Anteneh, Azage Tegegne, Fekadu Beyene & Berhanu Cebremedhin (2010). Cattle milk and meat production and marketing systems and opportunities for market orientation in Fogera *woreda*, Amhara region, Ethiopia. IPMS (Improving Productivity and Market Success) of Ethiopian Farmers Project Working Paper 19. ILRI (International Livestock Research Institute), Nairobi, Kenya, p: 65.

CSA (Central Statistical Agency) (2019). Agricultural Sample Survey Report on area and production of major crops. Statistical Bulletin, Addis Ababa, Ethiopia.

CSA (Central Statistical Authority) (2020). Report on Livestock and Livestock Characteristics. Addis Ababa, Ethiopia.

Dagnachew Lule, Wakgari Kaba, Abera Degefa, Kifle Degefa, Meseret Negash, Kindu Mekonnen, Gerba Leta & Duncan, A. (2012). Optimizing livelihood and environmental benefits from crop residues in smallholder crop–livestock systems in western Oromia: PRA case studies conducted across eight villages around Nekemte, Ethiopia. ILRI, Nairobi, Kenya.

Daniel Taddess, Mengistu Urge, Gebeyehu Goshu & Zemelak Goraga (2013). Evaluation of chemical composition and in vitro dry matter digestibility of sorghum stover ensiled with urea and effective microorganisms (EM) in West Hararghe Zone, Eastern Ethiopia. *American-Eurasian Journal Agriculture & Environmental Science*, 16 (8): 1473-1483.

Dereje Duressa, Debela Kenea, Wakgari Keba, Zelalem Desta, Gutema Berki, Gerba Leta & Adugna Tolera (2014). Assessment of livestock production system and feed resources availability in three villages of Diga district Ethiopia. ILRI, Nairobi, Kenya.

Duncan, D.B. (1955). Multiple range and multiple F tests. *Biometrics*, 11: 1-42.

EIAR (Ethiopian Institute of Agricultural Research) (2017). Livestock research strategies (2016-2030): Feeds and nutrition, rangelands and animals health, EIAR, Addis Ababa, p: 239.

Endale Yadessa (2015). Assessment of feed resources and determination of mineral status of livestock feed in Meta Robi district, West Shewa Zone, Oromia Regional State, Ethiopia, MSc Thesis, Ambo University, Ambo, Ethiopia.

Endale Yadessa, Abule Ebro, Lemma Fita & Getnet Asefa (2016). Feed resources and its utilization practices by smallholder farmers in Meta-Robi District, West Shewa Zone, Oromiya Regional State, Ethiopia. *Academic Research Journal of Agricultural Science and Research*, 4 (4):124-133.

ESAP (Ethiopian Society of Animal Production) (2009). Climate change, livestock and people: Challenges, opportunities, and the way forward. In: Zelalem Yilma and Aynalem Haile (Eds), *Proceedings of the 17th Annual conference of the Ethiopian Society of Animal Production (ESAP)*, held in Addis Ababa, Ethiopia, September 24 to 26, 2009. ESAP, Addis Ababa, p: 300.

FAO (Food and Agricultural Organization) (2018). Ethiopia: Report on feed inventory and feed balance. Rome, Italy.

FAO (Food and Agriculture Organization of the United Nations) (1987). Master land use plan, Ethiopia: Range/livestock consultancy. Report prepared for the government of the People's Democratic Republic of Ethiopia based on the work of L. Mayer, AG/ETH/82/010 Technical Report, FAO, Rome, Italy.

Fekede Feyissa (2013). Evaluation of feed resources and assessment of feeding management practices and productivity of dairy cattle in the central highlands of Ethiopia, PhD Thesis submitted to National Dairy Research Institute, Karnal-132001 (Haryana), India.

Fekede Feyissa and Gezahagn Kebede (2018). Feed availability, conservation practices and utilization in selected milk-shed areas in the central highlands of Ethiopia. *Ethiopian Journal of Animal Production*, 18 (1):1-19.

Fekede Feyissa, Adugna Tolera, Andnet Deresse, Temesgen Assefa, Diriba Geleti & Alan, D. (2014). Assessment of livestock feed production and utilization systems and analysis of feed value chain in Jeldu district, Ethiopia. ILRI, Nairobi, Kenya.

Fekede Feyissa, Shiv Prasad, Getnet Assefa, Getu Kitaw & Seyoum Bediye (2013). The status of production, conservation and utilization of natural pasture hay for feeding dairy cattle in the greater Addis milkshed, central highlands of Ethiopia. *Journal of Agricultural Research and Development*, 3 (6): 082-093.

Frederic, K., Osmowskia, J.S., Jeff, C., Alemayehu, A. & Asmelash, H.T. (2016). On the ground or in the air? A methodological experiment on crop residue cover measurement in Ethiopia, Policy Research Working Paper 7813, World Bank Group.

Gebremariam Sintayehu, Amare Samuel, Derek Baker & Solomon Ayele (2010). Diagnostic study on live cattle and beef production and marketing: constraints and opportunities for enhancing the system, Addis Ababa, Ethiopia, p: 46.

Gemechu Keneni, Milion Eshetu & Asinake Fikire (2016). Reflections on highland pulses improvement research in Ethiopia: Past achievements and future direction. Ethiopian Institute of Agricultural Research 50th Year Jubilee Anniversary Special Issue, *Ethiopian Journal of Agricultural Science*, pp: 1-16P.

Getachew Agegnehu, Angaw Tsigie & Agajie Tesfaye (2012). Evaluation of crop residue retention, compost and inorganic fertilizer application on barley productivity and soil chemical properties in the central Ethiopian highlands. *Ethiopian Journal of Agricultural Science,* 22:45-61.

Getachew Asamenew, Haile Beyene, Werkneh Negatu & Gezahegn Ayele (1993). A survey of farming systems of vertisol areas of the Ethiopian highlands. In: Tekalign Mamo, Abiye Astatke, K.L. Srivastra & Asgelil Dibabe (Eds.), Improved management of vertisols for sustainable crop-livestock production in the Ethiopian highlands. Synthesis 84 Report 1986-92. Technical committee of the joint vertisol project, Addis Ababa, Ethiopia, pp: 29-49.

Getahun Belay & Tegene Negesse (2019). Livestock feed dry matter availability and utilization in Burie

Zuria district, North Western Ethiopia. *Tropical and Subtropical Agro-ecosystems*, 22: 55-70.

Girma Chalchissa, Yoseph Mekasha & Mengistu Urge (2014). Feed resources quality and feeding practices in urban and peri-urban dairy production of southern Ethiopia. *Tropical and Subtropical Agro-ecosystems*, 17: 539 -546.

Gryseels, G. (1988). Role of livestock on mixed smallholder farms in the Ethiopian highlands. A case study from the Baso and Worena *wereda* near Debre Berhan, Ph.D. Thesis, Wageningen Agricultural University, Wageningen, The Netherlands.

ILCA (International Livestock Center for Africa) (1990). Livestock systems research manual. No.12,

Kasa Biratu & Saba Haile (2017). Assessment of livestock feed availability, conservation mechanism and utilization practices in South Western Ethiopia. *Academic research Journal of agricultural science and research*, 5 (7).

Kassahun Bekele, Hager, H. & Kindu Mekonnen (2013). Woody and non-woody biomass utilization for fuel and implications on plant nutrients availability in the Mukehantuta watershed in Ethiopia. *African Crop Science Journal*, 21: 625-636.

Kelay Belihu (2002). Analyses of dairy cattle breeding practices in selected areas of Ethiopia, Ph.D. Thesis, Humboldt University of Berlin, Germany.

Ketema Worku (2014). Assessment of dairy cattle feed resources and milk yields under smallholder farmers in Kersa Malima *woreda*, MSc. Thesis, Addis Ababa University, Bishoftu, Ethiopia.

Kossila, V. L. (1984). Location and potential feed use. In: F. Sundstol & E. Owen (Eds.), Straw and other fibrous by-products as feeds. Elsevier Science Publishers, Amsterdam, Oxford, New York, Tokyo, pp: 4-24.

Makkar, H.P.S. (2018). Support to Institutionalization of livestock feed security system in Ethiopia. VSO report to FAO.

Malede Birhan & Takele Adugna (2014). Livestock feed resources assessment, constraints and improvement strategies in Ethiopia. *Middle-East Journal of Scientific Research,* 21 (4): 616-622.

Mekete Bekele, Ashenafi Mengistu & Berhan Tamir (2018). Evaluation of livestock feed balance under mixed crop–livestock production system in the central highlands of Ethiopia. *Agriculture & Food Security*, 7:19.

Mesay Yami, Bedada Begna & Teklemedihin Teklewold (2013). Enhancing the productivity of livestock production in the highlands of Ethiopia: Implication for improved on-farm feeding strategies and utilization. *International Journal of Livestock Production*, 4 (8):113-127.

Mesfin Dejene, Seyoum Bediye, Dawit Alemu, Getu Kitaw, Aemiro Kehaliw, Getnet Assefa & Getaw Tadesse (2014). Livestock feed marketing in Ethiopia: Challenges and opportunities for livestock development. *Journal of Agricultural Science and Technology*, A (4) 155-168.

Moti Jaleta, Menale Kassie & Bekele Shiferaw (2012). Trade off in crop residue utilization in mixed crop-livestock systems and implications for conservation agriculture and sustainable land management; selected paper for presentation at the international associations of agricultural economists, August 18-24, Brazil.

Sefa Salo (2017). Estimation of feeds and fodders for livestock population of Ethiopia and mitigation of feed shortage. *Journal of Natural Sciences Research*, 7 (11). 45-51.

Senbeto Funte, Tegene Negesse & Getahun Legesse (2010). Feed resources and their management systems in Ethiopian highlands: the case of Umbulo Wacho watershed in southern Ethiopia. *Tropical and Subtropical Agro-ecosystems*, 12 (1): 47-56.

Seyoum Bediye (2007). Livestock feed potential of crop residues in Ethiopia: opportunities and challenges. In: Bayeh Mulat, Getachew Agegnehu and Angaw Tsige (Eds.), Utilization of Crop Residues, EIAR, Addis Ababa, pp: 74-100.

Seyoum Bediye, Getnet Asefa, Tilahun Abate & Dereje Fekadu (2001). Present status and future direction of feed resources and nutrition research targeted for wheat-based crop livestock production system in Ethiopia. In: P.C. Wall (Ed.), Wheat and weed: Food and Feed, Proceedings of the stakeholder workshop on improving the productivity of crop-livestock system in Ethiopia.

Solomon Bogale, Solomon Melaku & Alemu Yami (2008). Potential use of crop residues as livestock feed resources under smallholder farmers' conditions in Bale highlands of Ethiopia. *Tropical and Subtropical Agro ecosystem*, 8: 107-114.

Tadessa Daba, Getu Kitaw, Aemiro Kehaliw, Seyoum Bediye, Dereje Fekadu, Bayisa Hatew & Liyusew Ayalew (2009). Feed resource status, livestock feeding and management in the central highlands of Ethiopia. *Proceedings the 17th annual conference of ESAP*, held in Addis Ababa, Ethiopia, Sep 24-26, 2009, pp: 205-218.

Tesfaye Ashenafi & Chairatanayuth P. (2007). Management and feeding systems of crop residues: The experience of East Shoa Zone, Ethiopia. *Livestock Research and Rural Development*, 19 (3).

Tesfaye Alemu, Pornsri, C., Pravee, V. & Sayan, T. (2006). Production and utilization of crop residues in three agro ecological zones of Eastern Shoa Zone, Ethiopia. *Kasetsart Journal of Natural Science*, 40: 643-651.

Tsegaye Dereje & Lemma Tesma (2009) Livestock production systems in Darolabu, Habro and Boke districts of western Harerghe. *Proceedings of the 16th Annual Conference of the Ethiopian Society of Animal Production (ESAP)*, held on 8-10 October 2008, Addis Ababa, Ethiopia.

Yeshitila Admassu (2008). Assessment of livestock feed resources utilization in Alaba *woreda*, southern

Ethiopia, M.Sc. thesis, School of Graduate Studies, Haramaya University, Ethiopia.

Yitaye Alemayehu (2008). Characterization and analysis of the urban and peri-urban dairy production systems in the North western Ethiopian highlands, Ph.D. Dissertation, University of Natural Resources and Applied Life Sciences, Vienna, Austria.

Yoseph Mekasha, Birhanu Biazen, Azage Tegegne, Tesfaye Shewage, Tadiwos Zewdie & Asrat Tera (2015). Spatio-temporal dynamics of natural grazing lands and livestock holding in Sidama highlands of Southern Ethiopia: Implications for sustainable grazing land development. *Journal of Agricultural Engineering and Biotechnology*, 3 (3): 109-119.

Zewdie Wondatir (2010). Livestock production systems in relation with feed availability in the highlands and central rift valley of Ethiopia, M.Sc. Thesis, Haramaya University, Ethiopia.