Animal and Veterinary Sciences
2024; 12(1): 31-36
http://www.sciencepublishinggroup.com/j/avs
doi: 10.11648/j.avs.20241201.14
ISSN: 2328-5842 (Print); ISSN: 2328-5850 (Online)

Management, Utilization and Chemical Analysis of the Available Crop Residue Feed Sources in the Case of South Tigray, Ethiopia

Chala Edea[1], Shambel Taye[1, *], Atsbaha Hailemariam[1], Angesom Taye[2], Efrem Asallefew[2], Haftom Miglas[2]

[1]Debre Zeit Agricultural Research Center, Bishoftu, Ethiopia

[2]Mehoni Agricultural Research Center, Maichew, Ethiopia

Email address:

olyaadshambel@gmail.com (Shambel Taye)

[*]Corresponding author

To cite this article:

Chala Edea, Shambel Taye, Atsbaha Hailemariam, Angesom Taye, Efrem Asallefew et al. (2024). Management, Utilization and Chemical Analysis of the Available Crop Residue Feed Sources in the Case of South Tigray, Ethiopia. *Animal and Veterinary Sciences*, *12*(1), 31-36. https://doi.org/10.11648/j.avs.20241201.14

Received: December 12, 2023; **Accepted**: January 3, 2024; **Published**: January 23, 2024

Abstract: A study was conducted to assess the available crop residue feed sources, and its' management, utilization and chemical analysis in southern zone of Tigray, Ethiopia. A survey of 109 representative sample households (hh) was carried out properly. Structured questionnaires, field observations, and group discussions were used to gather data from sampled households. Moreover, chemical composition and in vitro dry matter digestibility (IVDMD) of crop residue was determined. The majority of the respondents indicated that there is no enough crop residue availability in the area which indicates scarcity of enough crop residue mainly associated with drought. The types of crop residue available in the study location were: maize stock, teff straw, sorghum straw, barley straw, wheat straw, pea straw, bean and lentil straw. But the major were; sorghum straw, maize stock and teff straw in terms of production. Majority of the farmer were ranked teff straw as most preferable feed resource followed by barely and sorghum for their cattle feeding. This is associated with smoothness, palatability, best for milk and suitability. The crop residue treatment practices mentioned were chopping/soaking (27%), chopping/threshing (16%) and urea treatment (7.34%) while the rest 40.37% do not practice crop residue treatment mainly because of lack of awareness. Majority of the respondents store the crop residue and the ways of storage were stacked outside (54.13%), stacked under shade (16.51%), and baled under shade (29.36%). Salt, local beverage, by product (Atela) and fodder were the mentioned supplements feed resources. Salt was reported as sole supplemental feed resource by majority of respondents (55.05%). The major constraints of crop residue mentioned were termite and mould, hence proper storage is crucial to avoid feed loss. Teff and wheat straw crop residue crude protein content were ranged from 7.90 to 4.79%, respectively. The highest invitro dry matter digestibility was noted in maize straw while the lowest was in sorghum. Moreover, awareness should be given to farmers on means of storage, treatment and processing of crop residues to improve shelf life and nutritive values of the crop residues.

Keywords: Barely Straw, Crop Residue, Feed, Ethiopia, Teff Straw

1. Introduction

In Ethiopia livestock obtained feed mostly from crop residues, natural pastures, improved forage and pasture, by products of agro-industry and agricultural residues fibrous [3]. The agro-ecology, crop type, accessibility, and production method all affect how much of these feed resources are used [4, 16] and due to inadequate management practices and the ongoing expansion of crop cultivation into grazing areas, natural pasture's contribution is occasionally decreasing [3, 10]. The proportion of crop leftovers used as livestock feed is rising as a result of crop farming's ongoing expansion. In Ethiopia's highlands, crop leftovers make up

roughly 50% of the total feed source for ruminant livestock on average. This percentage can reach 80% during the year's dry seasons [2], and it continues to rise as more and more of the native grasslands are cultivated to meet the grain needs of rapidly growing human population. rapidly growing population's grain needs [4]. In each livestock production activity, feed is the primary input and the main expense component, making up between 60 and 70 percent of the entire production costs [3]. Based on a multitude of research and evaluations [3, 6, 10, 24]. it is clear that the primary barrier impeding Ethiopia's livestock production is a lack of feed supply. Insufficiency of feed in terms of quality and quantity is considered to be critical among the constraints of livestock in the country and this is exacerbated by the expansion of cropping land, urbanization and industrial development, all of which results in proportional decrease in grazing land [6]. Feed shortage is indicated as a factor responsible for the lower reproductive and growth performance of animals especially during the dry season [13]. A lack of feed resources is also caused by the progressive decline in average farm sizes as a result of growing human populations, the expansion of degraded lands that can no longer support pastures or annual crops, and the encroachment of cropping land onto formerly grazing areas as well as less fertile and more easily erodible lands [5].

Farmers in Ethiopia, southern Tigray region are smallholders engaged in a mixed crop-livestock system. Livestock-crop integrated farming system is dynamic and complex with numerous interacting factors. Productivity and sustainability of the system depends on appropriate decisions on the resource allocations on to the different sectors and efficient use of the available resources. For the most efficient use of currently available feed resources and enhance livestock production and productivity, understanding of possible feed supply and utilization strategies would be needed. Regarding crop residue availability and utilization practices in the study area, there is a dearth of information. Therefore, the objective of this study was to assess the availability, management, utilization and chemical analysis of the available crop residues used in southern Tigray of Ethiopia.

2. Materials and Methods

2.1. The Study Area

The study had two phases; a survey and laboratory analyses. The survey was conducted in two agroecology (highland and lowland area) districts of southern Tigray, Ethiopia. The study area was geographically located at 12015'and 13041'north latitude and 380 59'and 390 54'east longitude, at an altitudinal range of 930 – 3925 masl. Long term meteorological data indicate that the area receives 400 to 912 mm of mean annual rainfall with mean daily temperature ranges between 9 to 32ºC. The zone comprises five Woredas (Raya Azebo, Raya Alamata, Ofla, Enda mehoni, and Alage) of which the former two (Alamata and Raya azebo) lies in the lowland area whereas the three are high altitude areas. The study was addressed both agro ecologies. As per the baseline survey study indicated that cattle were the predominant (55.1%) in the area followed by sheep (22.4%), goats (15%), equine (5.2%) and camels (2.3%). This showed that ruminants account a great value in the area.

2.2. Sampling Techniques

A cross-sectional field survey was used to collect the data, and rigorous sample procedures were followed. Before moving to the official survey employing focused group discussion and structured questionnaires, a reconnaissance survey was done to gain an overview of the research area and identify representative study sites. Based on the country's agro-ecological classification, the study geographical area was divided into highland and lowland agro ecologies. Based on accessibility and representative, four kebeles were specially selected for each agroecology. Using a systematic random selection technique, households from each kebele were selected from lists of households that development agent (DA) had made available. Ultimately, 109 households from both agro-ecologies were chosen and interviewed.

2.3. Data Collection and Chemical Composition Analysis

Respondent households were interviewed with a structured questionnaire to get information on crop residue management strategies such as collection, storage, processing, and animal feeding of crop residues, as well as the barriers to implementing such activities. Fields farmers were scoured for samples of various major crop residues. The crop residue samples were chosen based on the types of crops that are commonly grown in those places. As a result, the crop residues of maize, sorghum, wheat, barley, teff, peas, beans, and lentil samples were well mixed before sub-samples of 0.5 kg were dried in a forced draught oven at 65^0C for 72 hours until constant weight. The dry materials were then pulverized with a whiley mill until they passed through a 1 mm sieve. The dry matter, organic matter, and total nitrogen contents of feed samples were assessed using standard [7] procedures, as were the crude ash (CA, 550oC for 3 hours) and ether extract (EE), and crude protein was calculated as N x 6.25. The Neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were calculated using the [23] method on an ANKOM Fibre Analyzer 220 (ANKOM Technology 05/03, Macedon, NY, USA). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) values are stated with residual ash included. Solubilization of cellulose with H_2SO_4 yielded lignin (ADL). Van Soest and Robertson [5] method was used to calculate invitro dry matter digestibility (IVDMD).

2.4. Data Analysis

SAS version 9.0 was used to analyses the data. The Tukey pair wise comparison approach was used to compare means with significant differences at P 0.05. For qualitative data,

descriptive statistics were used with the statistical package for social sciences version 17.0 [19]. For data analysis, the following analysis of variance model was utilized. Analysis of variance model was used for data analysis.

$$Y_i = \mu + l_i + e_{ij},$$

where; Y_i = quantity of feed available
μ = overall mean
l_i = the effect of the ^{i}th ecology and e_{ij} = random error

3. Results and Discussion

3.1. Available Crop Residue in Study Areas

The key crop residues used in study areas were comprises teff, sorghum, maize, wheat, barley, Pea, Bea and lentils straw) (Table 1). As indicated in Table 1, the availability of crop residues varied according to the type of crops grown across the two agro-ecologies. More sorghum, maize stocks, and teff straw were generated in lowland agroecology (P0.05) than in highland agroecology, with higher production of corresponding crop residues, which depends on the appropriateness of the agro-ecology for production of specified crops. The highlands, on the other hand, generated much more (P<0.01) wheat and barley straw than the lowlands. Pea, bean and millet straw were accessible only in high land areas of study zones. In the overall agricultural crop residues produced per household were more in the highland (10.231.36 ton/hh) than in the lowland (8.4171.25 ton/hh). The entire amount crop residues produced in both agro ecologies were comparable to the 9.0 ton /hh reported for Bale zone at Sinana and Dinsho sub districts [18]. Similarly, its equivalent with crop residue produced in central Refit Valley of Ethiopia at Adami Tullu Jiddo Kombolcha districts which estimated 9.79 ton per household [8].

The result showed that the majority of the respondents indicated that there is no enough crop residue availability in the area which indicates that scarcity of enough crop residue mainly associated with drought season especially in the lowland which less crop available than high land areas. This may be due to many of crop varieties were cultivated in highland area than lowland area. However, most of the respondent farmers (51.4%) in the study areas were uses two cropping seasons. Relatively lowland agro ecology respondent were uses numerous cropping season than highland agroecology. This may be due to low land agro ecology had irrigation facility and not only depend on rain fed cropping.

Table 1. *Amount of crop residue produced in the study areas in the ton/hh.*

Agro ecology	Teff	Barley	Maize	Wheat	Sorghum	Pea	Bean	Millet	Total
Low land	1.94±0.36	0.332±0.23	2.86±0.12	0.24±0.08	3.417±0.44	-	-	-	8.41±1.36
High land	1.32±0.25	1.21±0.6	0.83±0.47	2.72±0.82	0.91±0.21	1.27±0.1	1.47±.0.1	0.5±0.	10.23±1.21
Total	3.26±0.05	1.542±0.18	3.69±0.40	2.96±0.87	4.327±0.05	1.27±0.51	1.47±0.2	0.50	9.32

Table 2. *Major crop residue available in the study areas.*

Crop residue type	Agro ecology		Total	Chi square test
	Lowland	High land		
Teff, sorghum, maize	47	24	71	0.45
Wheat, barley	4	28	32	
Pea, bean and lentils	-	6	6	
Total	51	58	109	

Table 3. *Cropping season.*

	Times	low land	Highland	Total	Chi square test
How many cropping seasons do you have	1.00	15	36	47	0.281
	2.00	34	22	56	
	3.00	2	-	5	
Total		51	58	109	

Teff straw placed highest rank in both agro-ecological zones due to its smoothness, fineness, and palatability by farmers. It is vital to understand whether farmers prefer one type of crop residue over another when it comes to feeding different ruminants efficiently and effectively with crop residues. Respondent farmers in the study zones have long known the order in which available crop residue should be ordered. With this knowledge, they can save the most tasty and controllable agricultural crop residues and feed it to their cattle. The present report was substantially identical to that of Sinana Dinsho districts, where farmers select soft, fine, and easy-to-manage crop residue for conservation and use [18]. Also, the present study confirms the report of Gurmessa et al. [11] who reported teff and barley straw were chosen by cattle because of being soft, fine and less rain damage during rainy season.

Table 4. *Types of crop residue favorably selected by cattle in the study areas.*

Type	Agro ecology		Total
	Lowland	Highland	
Sorghum	1	-	1
Maize	1	-	1
Tef	49	46	95

Type	Agro ecology		Total
	Lowland	Highland	
Wheat	-	1	1
Barley	-	8	8
Pea	-	-	
Bean	-	-	
Lentil	-	-	
Total	51	58	109

3.2. Conservation Practices

The present crop residue conservation practices in the study areas are shown in Table 5. It was discovered that the methods for collecting grain from the crops and storing it depended on both the crop type and the technique of collection. Little seeded crops called teff, wheat, and barley are brought to a homestead area threshed in order to separate the grain from the straws. The crop leftovers were then gathered into a heap and placed around the homestead. Typically, the heap is surrounded with locally accessible materials, especially prickly tree and shrub branches, to provide protection against stray animals. Straws can be kept in an open field or beneath a tree cover. As indicated in table 5, the majority of the respondents conserved their crop residue stacked outside and followed by baled under shade.

Table 5. *Practice of crop residues storage.*

Problems	Agro ecology		Total	Chi square test
	Lowland	High land		
Stacked under shade	7	11	18	0.02
Stacked outside	25	34	59	
Baled under shade	19	13	32	
Total	51	58	109	

3.3. Crop Residue Processing Methods

The common methods for processing and treating agricultural crop residues in the present study locations are shown in Table 6. Processing techniques that were often used at the study locations included cutting, soaking, and urea treatments. The majority of interviewed participants from the highlands (44.8%) and lowlands (35.3%) do not cuts crop residues for animal feeding. According to survey respondents, soaking dry crop residue in water and/or dissolved salts is more common in the highlands and lowlands 25.8 and 23.5 %, respectively. The majority of respondents from both agro-ecological zones do not treat crop residues chemically. Processing and treating crop residues enhance their availability, digestibility, and consumption, according to numerous reviews and previous studies [9, 12, 21].

Table 6. *Crop residues processing/treatments practices.*

Processing methods	Agro ecology		Total	Chi square test
	Lowland	High land		
Chopping/threshing	8	8	16	0.00
Soaking/spraying	12	15	27	
Chopping and spraying	9	5	14	
Urea treatment	4	4	8	
No processing	18	26	44	
Total	51	58	109	

3.4. Crop Residue Supplements

The use of chemical substances like feed additives to enhance crop residue's nutritional value and palatability seems to be unusual in both agro ecologies. Supplements for animals occasionally include salt, leaves from trees and shrubs, and by-products of the local beverage industry (*atela*). The majority of lowland (49.0%) and highland 60.0%) and the total households surveyed said they used salt (55.0%). On the other hand, practically the majority of respondents had no experience of feeding agro-industrial by products.

Table 7. *Supplementations types of crop residues.*

Supplement methods	Agro ecology		Total	Chi square test
	Lowland	High land		
Local beverage (*atela*)	7	8	15	0.02
Salt	25	35	60	
Fodder, tree and shrub leaves	7	3	10	
Atela and salt	12	12	24	
Total	51	58	109	

3.5. Constraints of Crop Residues

The results of major crop residue problems in the study areas are shown in table 8. The result obtained indicated that, the major constraints of crop residue mentioned were termite and mould, hence proper storage is crucial to avoid feed loss.

Table 8. *Major crop residue problems.*

Problems	Agro ecology		Total	Chi square test
	Lowland	High land		
Mould due to rain fall	10	17	27	0.00
Termite	17	11	28	
Termite and mould	11	25	36	
No problems	13	5	18	
Total	51	58	109	

3.6. Nutrient Composition of Selected Crop Residues

In the table 9 shown that the results of the proximate composition of key crop residues used in the study areas. Tef straw had the greatest crude protein (CP) percentage among crop residues, followed by pea straw, with a range of 7.78% (teff straw) to 4.77% (wheat straw). Sorghum, maize, wheat, and barley straws, which are often used as animal feed, had CP (4.77-6.09%) content that was less than the essential level required (7%) for rumen microbial function in ruminants, and the rest had levels that were higher than the critical level required by animal [23]. This demonstrates that supplementing

with a protein source is required for reasonable livestock production in the study area, particularly during the dry season when livestock rely mostly on standing hay and crop residues. The current findings are remarkably in line with other scholar's findings on the CP content of cereal crop residues [11, 18]. Table 9 shows that the ash concentrations of various crop residues differ significantly. Wheat residue had the highest ash concentration (13.89%), whereas maize straw had the lowest ash percentage (7.57%). There was a notable variation in the neutral detergent fiber (NDF) content of the various crop residues; the highest (75.68) NDF content was reported in wheat straw, which was followed by teff and barley straws, and the lowest (61.14) in lentil straw. The neutral detergent fiber content of legume haulms and maize straw was lower than that of wheat and barley straw; the lower NDF content of lentil could be attributed to its content of less fibrous parts (head and flower) of the crop. Fibrous feeds with a neutral detergent fiber content of less than 45% were classified as high quality, those with 45–65% were categorized as medium quality, and those with more than 65% neutral detergent fiber content were classified as low-quality roughages [17]. The majority of crop residues reported in this study, with the exception of pea, lentil, and maize, can be classified as low-quality roughages based on their neutral detergent fiber content. Unless supplementation and chemical and/or physical treatment are applied, these roughages may limit the amount of feed that animals can consume and how well they perform in production and reproduction outputs. Legumes, peas and maize are all classified as medium quality. The current study findings shows that the ADF value from various crop residue types ranged from 59.98 to 44.81%, with Faba bean haulm providing the greatest value and maize providing the lowest.

Average ADL content of crop residues ranged from 5.5% to 12.5%, with a significant difference ($P<0.001$) observed. This is consistent with the lignin content of the majority of crop residues, which [15] reported to range from 5 to 20%. According to recent findings, the residues from cereal crops typically had a lower ADL concentration than residues from pulse crops. Lignin is the single most significant factor lowering the digestibility of forages [23]. The observed elevated levels of fiber are thought to have a negative correlation with the rate of organic matter fermentation, microbial cell yield per unit of fermented organic matter, and propionate: acetate ratio in fermentation products. Thus, in order to increase the feeding value of low-quality agricultural crop residues, supplementing and treatment are required.

In vitro dry matter digestibility (IVDMD) values were found to be highest (59.55) in maize stover and lowest (42.69) in sorghum. The IVDMD found in this investigation for the various crop residues was within the range of reports from [18]. Crop residues considered to be of low quality are those whose digestibility is less than 50% [14]. The only wheat and sorghum IVDMDs were below 50% that are more digestible are the others. As a result, if there is a protein supplement available, they may be a viable source of animal feed.

ME concentration of crop residues ranged from 6.41MJ/kg DM (sorghum) to 9.21MJ/kg DM (maize). This is greater than the 5.6 MJ/kg DM average for crop residues gathered in western Ethiopia that as reported by [10]. The critical threshold of 7.5 MJ/kg DM required [14, 20] is almost similar to the total mean ME content of 7.53 MJ/kg DM reported in the present reports, and it could meet the optimal requirement for livestock for production and maintenance activity.

Table 9. *Invitro dry matter digestibility (IVDMD) and Chemical composition of crop residues collected from different selected crop types.*

Parameters	Pea	Sorghum	maize	Lentil	bean	teff	Wheat	Barley	SE
DM	91.22^{cd}	92.22^{bc}	90.64^{d}	90.85^{d}	90.50^{d}	93.18^{b}	94.57^{a}	90.20^{d}	0.61
CP	7.78^{a}	5.75b^{c}	6.09^{b}	7.61^{a}	7.64^{a}	7.85^{a}	4.77^{a}	5.52^{c}	0.24
ASH	9.26^{c}	7.58^{e}	7.57^{e}	9.16^{c}	8.04^{d}	12.58^{b}	13.89^{a}	9.18^{c}	0.14
ADF	59.61^{a}	45.57^{e}	44.81^{f}	46.77^{d}	59.92^{a}	46.46^{d}	52.46^{b}	48.12^{c}	0.19
NDF	61.62^{g}	67.31^{e}	63.31^{f}	61.14^{g}	68.43^{d}	72.56^{b}	75.68^{a}	70.27^{c}	0.35
ADL	12.55^{a}	5.50^{e}	6.00^{d}	11.34^{b}	12.41^{a}	5.43^{e}	6.14^{d}	8.34^{c}	0.12
IVDMD	50.37^{c}	42.69^{e}	59.55^{a}	50.08^{c}	50.31^{c}	50.48^{c}	48.71^{d}	56.79^{b}	0.57
ME	8.28^{b}	6.41^{c}	9.21^{a}	6.74^{c}	6.85^{c}	7.30^{c}	7.06^{c}	8.36^{ab}	0.51

$^{a-g}$ Means within a row with different superscripts differ significantly ($P<0.05$). NDF = neutral detergent fiber, ADF = acid detergent fibers, ADL = acid detergent lignin, IVDMD = invtro dry matter digestibility, ME= metabolizable energy, DM= dry matter, CP= crude protein

4. Conclusion and Recommendation

One of the major feed sources for farming livestock in study areas is crop residues and the major common crop residues available were maize, teff, wheat, and sorghum. The availability of respective type of crop residues varied based on the difference in agro ecologies of studied areas. Crude protein content of crop residues was below the critical crude protein (CP) level required for effective rumen microbial function. Similarly, crop residues were low in invitro dry matter digestibility (IVDMD), whereas their fiber content was high enough to limit feed intake. Most of crop residues were wasted mainly because of improper storage mechanism and incapability to collect residues. Mould formation followed by termite attack was the main storage problem mentioned. Thus, the crop residues require some degree of physical treatment and supplementation, to improve the quality of the roughages and to support optimum animal performance. Livestock extension workers need to train and demonstrate the farmers how to implement the proven crop residue feeding value improvement techniques such as physical treatment, supplementation and urea treatment to increase production and productivity of the livestock.

Acknowledgments

We are really grateful to Ethiopian Institute of Agricultural Research (EIAR) for their financial assistance. The authors also acknowledge experts from the study area Agricultural office for their assistance in data collection.

ORCID

Shambel Taye: https://orcid.org/0000-0002-2113-6340
Chala Edea: https://orcid.org/0000-0002-5185-9646

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] Adugna, A. 1999. Three essays in international trade and peasant agriculture. Columbia University.

[2] Adugna T, 2007. Feed resources for producing export quality meat and livestock in Ethiopia (Examples from selected Woredas in Oromia and SNNP regional states.

[3] Adugna T, 2012. Potential for Development of Alternative Feed Resources in Ethiopia. An Assessment Report prepared for ACDI/VOCA. Addis Ababa Ethiopia. pp20.

[4] Ahmed H, Abule E, Mohammed K, Tredate A. 2010. Livestock feed resources utilization and management as influenced by altitude in central highlands of Ethiopia. Livest Res Rural Dev 2(12): 125–132.

[5] Alemayehu, M. 2005. Feed Resources Base of Ethiopia: Status Limitations and opportunities for integrated development. Proceedings of the 12th Annual Conference of the Ethiopian Society of Animal Production (ESAP) held in Addis Ababa, Ethiopia, August 12-14, 2004. Addis Ababa, 410 p.

[6] Alemayehu M, 2006. Pasture and Forage Resource profiles of Ethiopia. pp 19. Ethiopia/FAO. Addis Ababa, Ethiopia.

[7] AOAC. 2000. Official methods of analysis of AOAC international, 17th edn. AOAC International, Md., USA.

[8] Dawit A, Ajebu N, Sandip B. 2013. Assessment of feed resource availability and livestock production constraints in selected Kebeles of Adami Tullu Jiddo Kombolcha District, Ethiopia. African Journal of Agricultural Research. Vol. 8(29), pp. 4067-4073.

[9] Devendra, C. 1991. Technologies currently used for the improvement of straw utilization in ruminant feeding systems in Asia. In: Proceedings of the NRI/MARDI Workshop on the Utilization of Straw in Ruminant Production Systems, 7-11 October 1991, Malaysian Agricultural Research and Development Institute, Kuala Lumpur, pp. 1-8.

[10] Dirriba G, Mekonen H, Ashenafi M, Adugna T. 2013. Herbage yield, species diversity and Quality of Native grazing land vegetation under Sub humid climatic conditions of Western Ethiopia. E3 Journal of Agricultural Research and Development Vol. 2(4). Pp. 096-100.

[11] Gurmessa K, Tolemariam T, Tolera A, Beyene F, Demeke S. 2015. Feed resources and livestock production situation in the Highland and Mid altitude areas of Horro and Guduru district of Oromia regional state, western Ethiopia. Sci Technol Arts Res J 4(3): 111-116.

[12] Han, I. and Garret, W. 1986. Improving the dry matter digestibility and voluntary intake of low-quality roughage by various treatments: A review. *Korean Journal of Animal Science* 28: 89-96.

[13] Legesse G. 2008. Productive and economic performance of small ruminants in two production systems of the highlands of Ethiopia. PhD Dissertation, University of Hohenheim, Stuttgart, Germany.

[14] Owen E. and Aboud A. 1988. Practical problems of feeding cop residues, pp. 133-156. In: Reed J D, Capper B S and Neate P J H (editors). Plant breeding and the nutritive value of crop residues. Proceedings of a workshop held at ILCA. LCA, Addis Ababa, Ethiopia.

[15] Qingxiang M. 2002. Animal Production based on Crop Residues Chinese experiences. Food and Agriculture Organization of the United Nations.

[16] Seyoum B, Getinet A, Abate T, Dereje F. 2001. Present status and future direction of feed resources and nutrition research targeted for wheat-based crop livestock production system in Ethiopia. In: Wall PC (ed) Wheat and weed: food and feed. Proceedings of two-stakeholder workshop on improving the productivity of crop livestock production in wheat-based farming system in Ethiopia, Addis Ababa, Ethiopia, pp 207-226.

[17] Singh, G. and Oosting, S, 1992. A model for describing the energy value of straws. *Indian dairyman*.

[18] Solomon B, Solomon M, Alemu Y. 2008. Potential use of crop residues as livestock feed resources under smallholder farmers' conditions in bale highlands of Ethiopia. Tropical and Subtropical Agroecosystems, Vol. 8, num. 1, 2008, pp. 107-114.

[19] Statistical Packages for the Social Sciences (SPSS) 1999 Cary, North Carolina, USA.

[20] Sundstol, E and Owen, E. (eds). 1984. Straw and other Fibrous By-Products as Feed. Elsevier, Amsterdam. By Achi Patrick Neyu.

[21] Tsiege yohannes H. 1998. The nutritive value of Tef straw and its response to chemical treatment with alkali. Short communication. SINET Ethiop. J. sci., 21(1): 145-151, 1998.

[22] Van Soest, P. and J Robertson. 1985. Analysis of Forages and Fibrous Foods. A Laboratory Manual for Animal Science 613. Comel University, Ithaca. New York, USA. 202p.

[23] Van Soest P. 1994. Nutritional Ecology of the Ruminant, second ed. Cornell University Press, Ithaca, NY. pp. 177.

[24] Yayneshet T. 2010. Feed Resources Availability in Tigray Region, Northern Ethiopia, for Production of Export Quality Meat and Livestock. Ethiopia Sanitary & Phytosanitary Standards and Livestock & Meat Marketing Program (SPS-LMM) Texas A&M University System. pp87.