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Crop Residue Nutritional Improvement and Utilization in Ethiopia: A Review

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Abstract: The contribution of crop residues as ruminant feed is becoming the major interactions between crop and livestock production system in Ethiopia. The quantity of crop residue production is increasing over periods and dominating the basal diet feed resources especially in the mixed crop livestock system. However, it seems difficult to bring the required animal production and productivity transformation using such a poor quality feed resources unless nutritional improvement techniques are implemented. So far, attempts have been made in Ethiopia to increase the efficiency of crop residue utilization through applying different treatment options like chemical, biological treatments and supplementation with legume forages. Regarding chemical treatment, fertilizer grade urea is dominantly evaluated and found doubling the CP content of the straw by retention of ammonia nitrogen to the straw. Application of biological improvement options like treatment by effective micro organisms also showed high possibility of improving the nutritional quality of fibrous feeds. Legume forages with high protein content have also a paramount contribution as a supplement to high fiber feeds substituting the expensive concentrate feed source in the country. Despite the effort in demonstration and dissemination of these nutritional improvement technologies, their adoption and utilization in the farming system has been very much limited. However, evidences showed that crop residues will continue to be the major source of basal feed for ruminants especially in a mixed crop-livestock system for the future. Therefore, it is not optional to focus on demonstration of these proved technologies at hand and put an effort for generation, adoption, evaluation and demonstration of more relevant technologies which have better economical reward and technically fit to the livestock production systems in the country.

Key words: Crop Residue・Chemical Treatment・Biological Treatment・Supplementation with Legumes

INTRODUCTION

Inadequate feed supply both in terms of quantity and quality is the major constraint affecting livestock production in Ethiopia. CSA [1], put crop residue contribution on the second position among livestock feed resources in Ethiopia. Contrary to crop residue, the contribution of natural pasture as feed resource is declining over periods due to the conversion of large proportion of grazing land to arable land to coup up with the increasing demand for food crop in the country [2, 3]. As a result, crop residue is gradually substituting the grazed feed resources in the country [4, 5]. Recently, the annual production of major crop residues are estimated to about 63 million metric tons in Ethiopia out of which cereal crop residue takes the lead in most crop livestock system of Ethiopia [6, 7].

Although crop residue biomass yield is increasing, its feed value is highly constrained by its poor nutritional character to provide animals with sufficient energy, protein and minirals [8]. Following the straw upgrading initiations adopted in Africa at early 1980s [9]. Ethiopia lately adopted these treatment options to improve the nutritional quality of crop residues in the country. Research findings of these efforts indicated as urea treatment had increased crude protein (CP), energy content, straw intake, growth rate and the milk yield in Ethiopia [10-14]. Moreover, feeding urea treated straw reduces the need for concentrate supplementation through increased nitrogen content, improved palatability and digestibility helping animals to maintain weight during seasons of feed shortage [15]. However, the success of application of chemical and biological methods at on farm level has been low because of

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several reasons including lack of knowhow, economic constraints, skill and lack of commitment among the end users [16].

Protein-N sources such as oilseed cakes and those of animal origin are produced in limited quantities and are beyond the economic reach of most of the small-holder farmers in Ethiopia [17]. As alternative supplementation with high quality protein containing forage legumes have been found improving the feeding value of poor quality crop residues and pastures, especially for resource poor small holder farmers that able to share land for forage growth [18].

Therefore, this review paper summarizes the major research findings generated with respect to the different techniques used for improving the nutritional values of crop residues.

Crop Residue Biomass Production in Ethiopia: Crop residue production in Ethiopia is estimated from the grain yield of particular crops produced using the conversion factors recommended by FAO [19]. Production of crop residues have been increasing in the country with conversion of more pasture land to arable land leading to a gradual substitution of grazed feed resources by crop residues [4, 5]. For instance, the annual production of some major crop residue is increasing over periods from 28.2 million tons in 2007/08 to 62.5 million tons in 2018/19 in Ethiopia (Table 1). This increment might be due to increase in cultivated land size, utilization of some productive crop varieties and increase in farm inputs utilization by crop producers in the country. In terms of abundance, maize stover is the highest (39%), followed by stovers of sorghum (22%), wheat straw (16%) and *teff* (15%) in Oromia region which is the leading region in overall food crop production in Ethiopia [20]. Majority (80%) of crop residue production in the country is from Oromiya, Amhara and the SNNPR regional states which also account for higher number of the total ruminant population in the country [20].

The availability of crop residue is closely associated to the farming system, the type of crops produced, seasons of the year, intensity of cultivation and distribution of the rain fall [21]. In 2019/20 main crop production season, about 12.9 million hectares are covered by grain crops i.e. cereals, pulses and oilseeds, from which a total volume of about 335, 199, 823.90 quintals of grains are obtained [1]. The same report indicated as 81.46% of the total cultivated land and 88.52% of the volume of grain yield were covered by cereals.

Crop Residue Collection and Conservation Trained in Ethiopia: The actual quantities of crop residues available for livestock feeding is reduced by cost of collection, transport, storage, processing facilities, seasonality and other alternative use of the residue [23]. The longer crop residue remain uncollected in the field, its nutritive quality declines affected by over drying, wind damage and shattering. Aftermath grazing in the crop fields also allows selective grazing of plant parts causing substantial wastage of the residue by trampling that accounted to about 50% loss [24].

The intensity of collection and method of storage varies from place to place and across production systems in the country. In East Shoa Zone of Ethiopia, majority of the farmers were reported as they do not collect crop residue and few still partially collect [25]. The same study reported as majority (75.55%) of the respondents use open air storage system and only few (0.25%) use different shade facilities. In contrast, the findings in the central highlands of Ethiopia indicated as all farmers practice collection of crop residue except few (7.69%) were still practice partial collection [26]. The same report also indicated as less number of respondents (12.1%) store the collected crop residue under shade system that more (61.88%) were store in the open air. In contrast to the previous reports [27] described as there is no crop residue left uncollected on crop field and about 72.5% of respondents use shade for storage whereas 27.5% store in the open air in the central highlands of Ethiopia. However, the storage method and duration still alters the nutritional value of crop residue mainly when stored under open air system for prolonged duration [28]. The same author reported as CP, IVOMD and ME contents of both teff and wheat straws showed consistently decreasing, while the fiber fractions showed consistently increasing trends with prolonged storage durations under both storage methods. Generally, these studies indicated as there is a progress in crop residue collection and storage system over periods recognizing the increasing importance of this feed resource in the livelihood of the livestock farming community.

Competitive Use of Crop Residues in Ethiopia: In Ethiopia, crop residue is used not only for livestock feed but construction, soil fertility amendment, fuel and as a source for cash income [29]. Retention of crop residue for soil fertility amendment, construction and fuel energy source are the most competent that needs high consideration in the country [20]. Hailu and Fekede [30] reported as the undergoing intensive cultivation and

Table 1: Estimated total amount of residues produced annually from the major crops

	Residue production (10^3MT)					
Crop	2007/08*	2008/09*	2009/10*	2010/11*	2017/18**	2018/19**
Teff	4489.4	4542.0	4769.1	5225.2	15850.2	16210.4
Barley	2032.2	2279.1	2625.7	2555.0	2463.6	2121.0
Wheat	3471.1	3806.5	4613.5	4283.5	3714.4	3870.5
Maize	8249.5	8651.6	8573.8	10969.5	16791.8	18985.5
Sorghum	6647.8	7010.9	7428.2	9899.7	15507.8	15073.1
Finger millet	1076.0	1120.6	1048.4	1269.7	3092.5	3106.9
Oat	62.2	72.7	56.1	80.9	63.2	36.2
Rice	92.7	92.8	134.1	117.5	120.8	137.5
Pulses	2139.3	2357.6	2269.0	2343.8	2978.6	3011.3
Total	28260.8	29933.8	31517.7	36744.8	60582.7	62552.5

Source: [6*, 7**, 21*]

Table 2: Competitive use of crop residue straw/stover in Oromiya regional states of Ethiopia

Crop residue straw/stover	Feed for livestock	Soil fertility	Roof or wall making	Fuel
Teff	70	-	30	-
Barley	60	10	30	-
Wheat	50	10	40	-
Maize	60	-	-	40
Sorghum	50	-	10	40
Finger millet	70	-	30	-
Oats	50	10	40	-
Rice	50	10	-	40
Horse bean	60	40	-	-
Field pea	60	40	-	-
Haricot bean	70	30	-	-
Chick pea	80	20	-	-
Lentils	80	20	-	-

Source: [20]

overgrazing of the cultivated land without considering conservation has exposed the natural resources (soil) for degradation. Retention of crop residue on crop field plays a major role in adding organic matter to the soil and improves the quality of the seedbed to protect the soil surface from damage by sun, rain drops, wind and other mechanical pressure [31]. With these all advantages in conserving soil, it will be mandatory for crop producers not to completely remove residues from crop fields in the expense of reducing the amount available for feed purpose.

Crop residue consumption for fuel energy also shares a significant amount affecting its availability for use as animal feed and soil amendment in the highlands of Ethiopia [32]. For instance, from the total production of about 22.4 million tons in 2012/13 production year, about 60% (10.3 million tons) is used for fuel purpose [33]. Increased firewood scarcity, poor efficiency in use of available biomass fuel resources and limited access to alternative modern energy sources have generally contributed to the ever increasing demand for crop residues as fuel at the expense of application for soil fertility amendment and feed to livestock [34, 35]. Generally, recent report from FAO [20] indicated as about 70% of the annually produced crop residue is used to feed ruminant animals and the other shared for other competent uses. Beside the lion share used for livestock feed, more share of the cereal straws goes for roof or wall making and the stovers used for fuel energy but the pulse crop residues were mainly left on the crop field for incorporation in to the soil (Table 2).

Chemical Composition of Major Crop Residues Used for Feed in Ethiopia: Chemical composition is the determinant factor for nutritive value of crop residues. Efficient utilization of crop residue remain a challenge because of its low intake, less digestibility, high fiber content, poor in crude protein, minerals and vitamins (Table 3). The chemical composition and in-vitro digestibility of crop residues is highly influenced by the type of crop [7]. Majority of crop residue crude protein contents are lower (20–60 g of crude protein/kg DM) than the threshold

Table 3: Chemical composition (g/kg DM) and *in vitro* dry matter digestibility (g/kg DM) of major animal feed source straws

Crop residues	DM *	Ash*	CP**	NDF**	ADF**	ADL*	IVDMD**
Barley straw	931	83	38	813	595	63	434.5
Wheat straw	929	72	32	781.5	513	79	487
Teff straw	924	71	52	765	447	77	519
Maize stover	931	84	45	753	439	56	575
Sourgum stover	912	63	48	707	480	132	511
Faba bean straw	925	87	72	705.5	631	111	588
Field pea straw	919	60	75	583	397	179	649
Haricot bean straw	925	87	61	671	492	111	587

DM = dry matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; ADL = acid detergent lignin; IVDMD = *In Vitro* DM
Source: [29*, 7**]

Table 4: Effect of urea treated crop residue on digestibility, intake and milk yield of dairy cows

Straw type	Parameters	Untreated	Treated	Increase	Source
Wheat	TDM Intake/day	5.11	5.53	0.42	[12]
	Digestibility g/Kg DM	311	435	124	
	Milk yield (lt/day)	8.12	8.99	0.87	
	Net return/cow/day birr	48.9	52.5	3.6	
Teff	DM Intake kg /day/cow	10.1	10.18	0.08	[13]
	Milk yield (lt/day)	5.46	6.22	0.76	
	Net return/cow/day birr	68.25	76.22	7.97	
Rice	DM Intake Kg/day/cow	2.17	2.42	0.25	[42]
	Digestibility %	30.8	52.3	21.5	
	Milk yield (lt/day)	1.20	2.36	1.16	
	Net return/cow/day birr	4.20	6.82	2.62	
Rice	DM Intake Kg/day/cow	6.34	7.98	1.64	[43]
	Milk yield (lt/day)	2.34	2.4	0.06	
	Net return/cow birr	132.79	194.25	61.46	

Table 5: Effect of chemical treatments of crop residue on feed intake, digestibility and body weight change in sheep

Straw	Chemical used	Measurements	Untreated	Treated	Increase	Source
Maize stover	Urea	DM intake (g/d)	238.3b	400.7a	162.4	[44]
		Digestibility %	61b	67a	6	
		ADG (g/day)	45.1b	62.8a	17.1	
Maize	Urea	DM intake (g/d)	768	979	211	[45]
		CP Digestibility %	42	71	29	
		ADG (g/day)	32.2	63.3	31.1	
Sesame straw	Urea	DM Intake (g/day)	1323	1034	289	[46]
		Digestibility %	42.6	62.2	19.6	
		ADG g/day	29.3	67.4	38.1	
	Lime	DM Intake (g/day)	1034	957	-77	
		Digestibility %	42.6	50.3	7.7	
		ADG g/day	29.3	36.5	7.2	
	Urea-lime mixture	DM Intake (g/day)	1034	995	-39	
		Digestibility %	42.6	58.1	15.5	
		ADG g/day	29.3	51.3	22	
Wheat straw	Urea	DM Intake (g/day)	715	750	35	[47]
		ADG g/day	86.5	101.8	15.3	

required for maintaining the N balance of an animal in the positive side [29]. Its fibre content is also greater than 700 g/kg DM, low in metabolizable energy (<7.5 MJ/kg dry matter) and low in mineral nutrients, low to moderate digestibility (<30–45% organic matter digestibility) [36]. Most of the residues are also deficient in fermentable carbohydrates, reflected by the relatively low organic matter digestibility [37]. Among cereal crop residues, the crude protein content of teff straw is higher than wheat straw and close to that of barley straw and native hay [38]. By-products of food legumes have relatively higher crude protein and lower total fiber content as compared to cereal crop residues (Table 3). Quantitatively, the lower CP content of crop stubbles than that of straw is due to the low leaf to stem ratio of the crop stubbles.

Crop Residue Chemical Treatment Status in Ethiopia: Crop residues shall continue to be the major source of feed for herbivore especially in mixed crop-livestock integrated system for the years to come [29]. Feeding crop residue without treatment is a common practice among majority of the smallholder livestock producers in Ethiopia. However, this approach contributes less for animals to get the required amount of nutrients because of its high fibre content, low intake and digestibility. Although various chemical treatments have been used to improve digestibility and intake of fibrous feeds, fertilizer grade urea received the major focus by scientists in Ethiopia [10-13, 39, 40]. The findings of these studies indicated as urea treatment reduces the fiber contents of low quality feed and supply nitrogen to rumen microbes that can be used to synthesis microbial protein (Table 4).

Seyoum [29] reported that irrespective of the type of crop residues treated, crude protein content of urea treated straw could be improved by about 5.5% and digestibility by 8.4%. Similarly, the urea treatment of wheat straw under local conditions raised the CP content by 5% and *in vitro* OMD by 10% [11]. The results obtained at Ethiopia condition is in line with the result from tropical countries that urea-treated straw increased feed intake by 10 to 15 percent, growth rate of calves by 100 to 150 g/day and milk yield by 0.5 to 1.5 litres/day [41].

Likewise of cattle feeding, small ruminant feeding on crop residue is a common practice in Ethiopia. Different studies indicated as chemical and biological treatment of crop residues has improved the feed intake, digestibility and growth performance of sheep in Ethiopia (Table 5).

Crop Residue Biological Treatment Status in Ethiopia: Among the biological treatment methods, effective microorganism (EM) is one of the most evaluated for improving feed quality in Ethiopia (Table 6). The method get research attention in Ethiopia to overcome the economic challenge of the urea molasses applicability that contributed for less adoption of the technology at on farm condition [48]. The effective microorganisms treated barley straw based diet supplemented with a dairy concentrate amounting to and/or above 0.3kg, lt^{-1}, d^{-1} improved the milk yield [48]. Aemiro [49] also reported that EM treated feed supplementation had a positive effect on growth performance of F1 crossbred Boran-Friesian calves. The comparative evaluation study made on rice straw treated by urea and EMO fed to local Fogera cows resulted in higher daily dry matter intake (8.52 kg/cow), higher daily weight gain (27.7 g/day), higher daily milk yield (2.82 l/day) and highest net income and marginal return rate (MRR) (82.6 and 194%), respectively. This study recommended the feeding of EMO treated rice straw for it was found efficient both biologically and economically as compared to urea treated rice straw [43]. In general, the microbial ensiling technique gives an opportunity to successfully improve the nutritional content of large amount of crop residues at a time. The studies undertaken showed that microbial ensilage of crop residues increased daily gains, feed intake and feed conversion and decreased feed cost per unit gain in growing ruminants (Table 6).

Crop Residue Supplementation with Leguminous Fodders Status in Ethiopia: Leguminous forage crops which are rich in protein and usually high in digestibility have been found beneficial as a supplement to improve intake and digestibility of crop residues. Different research output had been demonstrated the positive effect of supplementation of legume forages leaf meals on performance in ruminant livestock [51-53]. Supplementation of graded levels of *Leucaena leucocephala* leaf hay up to 300 g/head/day to Ethiopian highland sheep fed a basal diet of chickpea haulm improved body weight gain performance of sheep than those supplemented with concentrate mix. Similarly, maize stover supplemented with different levels of *Desmodium intortum* and *Macrotyloma axillare* has resulted in body weight gain of Ethiopian sheep [54, 55]. Denbela *et al.* [56] also had observed higher average daily gain performance for Woyto-Guji goats fed on basal diet of haricot bean haulms and supplemented with *Lablab purpureus* meal than those supplemented with concentrate meal formulated in combination of wheat bran and noug cake. Mosi and Butterworth [57] found that addition of 20-25% *Trifolium tembense* hay to teff straw increased feed intake of sheep by 20-30%. In another study Butterworth and Mosi [58] reported that where hay from *Trifolium* is supplemented to residues of teff, oat, wheat and maize at the rate of 30% by weight, dry-matter digestibility was increased by about 10 percent units as compared to straws alone. Generally, it is concluded that the use of legume fodder supplementation to crop residue increase feed intake by about 20 to 30% [59, 60]. Farmers generally accept supplementation as an initial move to increase milk output or to fatten cattle or sheep [61]. From the study conducted so far, supplementation of crop residue with

Table 6: Effect of EM_2 treated crop residue on digestibility, intake and milk yield of dairy cows

Straw type	Parameters	Untreated	Treated	Increase	Source
Barley	DM Intake Kg /day/cow	7.65	9.73	2.08	[40]
	Digestibility %	39.91	51.17	11.26	
	Milk yield (lt/day)	6.02	6.54	0.52	
Barley	DM Intake Kg/day/cow	4.86	6.62	1.76	[10]
	Digestibility g (%)	37.02	45.32	8.3	
	Milk yield (lt/day)	6.02	6.54	0.52	
	Net return/cow birr				
Barley	Total DMI kg/day	9.93	6.20	3.73	[50]
	Average milk yield, kg/cow/day	4.98	2.65	2.33	
	Net profit/cow/day, ETB	49.05	39.24	9.81	
Rice	DM Intake Kg/day/cow	6.34	8.52	2.18	[43]
	Milk yield (lt/day)	2.34	2.82	0.48	
	Net return/cow birr	194.25	234.93	40.6	

legume forage could serve as alternative CP supplement for crop residues based feeding and improves the biological performance and economic feasibility of the experimental animals. However, the overall lower adoption rate for available quality forages in the country highly affects its wider application in Ethiopia.

Tree legumes in the tropics are well adapted to harsh environments and produce a substantial amount of good quality forage rich in protein, vitamin and minerals. They are reliable sources of protein supplements to roughage and cereal crop residues in most areas where conventional concentrate feeds are not available or accessible. Tagasaste forage has high CP and in vitro organic matter digestibility. It has also higher rates of degradation compared to other tropical browse trees such as *Leucenea* species which normally have an advantage of increasing total dry matter (DM) and nutrient intake for better performance of animals [62, 63].

CONCLUSION

Crop residue production in the country is increasing over time as more pasture land is being converted to arable land led by increase in population, urbanization and food demand in the country. In addition lack of access to other alternative feed resources, land shortage and non affordability of processed feed sources forced the farmers to stick on crop residue utilization as a feed for livestock especially in dry season of the year. The existing scenario indicates as the demand for feed and fodder will increase rapidly in the coming decades, encouraging more intensive land use for grain crop production which further increases crop residue production. However, crop residue ability to provide animals with the required nutrient is limited due to its high fibre and low nitrogen, minerals and vitamin contents. This will be aggravated by poor crop residue management practices during collection, storage and utilization with no or les application of nutrient improvement technologies. Results of the various research works conducted in different parts of the country indicated as fertilizer grade urea and effective micro organisms are having a potential of improving the nutritive value of these fibrous feeds. However, its adoption by smallholder farmers is less due to lack of good control over the processes and adequate facilities. In addition to application of different nutritional improvement techniques, better to give more emphasis to the selection of cultivars high both in grain yield and straw quality so as to efficiently serve the existing integrated crop livestock farming system of the country.

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