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Chemical Composition and Digestibility of Major Feed Resources in Mixed Farming System of Southern Ethiopia

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Abstract: This study was conducted to identify and document nutritive values of major feed resources in southern Ethiopia. A total of 58 feed samples (13 grasses, 17 crop residues, 18 indigenous browses and 10 root and horticultural crops) were collected using a total of 90 household participants and 96 key informants for vernacular name identification. The samples were analyzed in triplicates for ash, crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF) and in-vitro dry matter digestibility (IVDMD). The results indicated that the mean CP contents of natural pasture (NP), crop residues (CR), indigenous browses (IB) and root and horticultural (FF) crops were 8.38%, 5.77%, 16.40% and 15.53%, respectively, while the corresponding values for IVDMD were 57.20%, 46.05%, 61.16% and 65.69%. The NDF values of NP, CR, IB and FF were 60.86%, 75.97%, 33.01% and 38.98%, respectively, whereas the corresponding ADF values were 40.71%, 45.16%, 28.87% and 27.83%. The CP values were positively correlated with IVDMD (r=0.492) while negatively correlated with NDF (r=0.69) and (r=0.62) ADF. The results indicated that fodder tree leaves and root and horticultural crops have considerable potential for strategic supplementation of poor quality roughages. Further studies in animal trials have to be warranted to substantiate their supplementary value and level of inclusion in animal diet.

Key words: Natural pasture · Indigenous browse · Roughage · Nutritive value · Mixed farming · Southern Ethiopia

INTRODUCTION

Limited feed supply and poor quality of the available feeds are the major constraints for optimal livestock productivity in tropical and sub-tropical countries [1-2]. These regions are characterized by irregular rainfall and thus livestock have to survive on persistent shortage of feed resources of low nutritional value for most part of the year [1, 3]. During the dry periods, poor quality feeds and inadequate nutrition has been reported to be one of the most important constraints for livestock production in Ethiopia across all ecological zones. In addition, degradation of lands due to uncontrolled and excessive use of communal grazing lands of undulated topography in the highlands and erratic rainfall in semi-arid areas has further reduced the availability of feed resources [1, 4]. Furthermore, protein content of the grasses and herbaceous plants declines during the dry season, leading to prolonged periods of under-nutrition of livestock reared under such environmental conditions [5].

To improve ruminant nutrition, efforts have been made in Ethiopia through exploration of the indigenous feed resources and introduction of improved genotypes [6]. However, the introduction of exotic species has been less successful mainly due to adaptability, agronomic problems and land shortages. Thus, indigenous plant species are contributing the largest proportion of the livestock feed across all agro-ecological zones of Ethiopia [6]. However, their chemical composition is variable due to variations in soil type, topography and other

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environmental factors [3]. These factors also affect the forage yield, quality (intake and digestibility) and animal grazing behavior [1] suggesting the need to acquire detailed information in terms of nutritive values [7], soil type and climatic changes. Information on nutritional characterization of locally available feed resources at country level is inadequate and where available the values are variably documented [8]. The great diversity, variability and nutritional values of feeds in the southern region in particular have not yet been investigated and their feeding value is largely unknown. Hence, this study was undertaken to identify and document chemical composition and dry matter digestibility of major feed resources in the region for efficient utilization of indigenous and locally available feed resources.

MATERIALS AND METHODS

Description of the Study Areas: Wolaita, Dauro, Hadiya and Guraghe zones are found from arid to highland agro-ecological zones. This study was conducted in sub-humid eco-zones of the central south region. The areas are located at 6°51'N, 37° 47'E (Wolaita), 7° 2'N, 37° 56'E (Dauro), 7°43'N, 37° 5'E (Hadiya) and 7° 58'N, 37° 56'E (Guraghe). The altitude of the area ranges between 1500m in Wolaita to 2950m above sea level in Guraghe while rainfall ranges from 1000-1855 mm. The areas are characterized by crop-livestock mixed farming systems, the Hadiya and Guraghe sites predominately produce wheat and barley, respectively. The contribution of grasses from natural pasture ranged between 21.6-29.2%, crop residues (41.9 to 69.4%), indigenous browses (2.81-6.10%) and root and horticultural crops (3.4-20.8%) as major feed resources of the areas.

Household Sampling and Feed Sampling and Preparation: Multi-stage random and purposive sampling techniques were used to select peasant associations (PA's), target villages and households. We selected representative peasant associations (PA's) purposefully by their proximity to roads, accessibility of infrastructure and livestock holding in each district. All livestock holders who have at least 5 years experiences of livestock rearing and feeding were registered at villages randomly selected. Based on the heterogeneity level of the area, we decided to sample 50households from Wolaita and Guraghe (25 from each) and 40 households from Hadiya and Dauro (20 from each) and a total of 90 households were selected. Structured and semi-structured questionnaires were used to collect the information. Group discussions were held at eight villages (two from each district) using 12 key informants from each zone and a total of 96, were participated for identification of vernacular names of the feeds.

Selection of feed types or plant species was done based on information provided during group discussion regarding their relative abundance in the area and their consumption by grazing and/ or browsing ruminants. Grasses and herbaceous legumes were sampled as described by Shenkute *et al*. [7]. Crop residues and edible leaves and twigs were sampled during the dry season (November to May) while grasses and root and horticultural plant parts were sampled during the wet season (August-October). Crop residues were collected on their actual production calendar of crops and period of availability as identified during the previous survey. Sampling of browses were taken during the dry season, because this is the period of the year when these plants may be more important for browsing and even non-browsing animals used to browse this time due to feed shortage. Leaves, thin twigs (young stems) and some flowers (when existing) were clipped with scissors from the herbage (aerial part of the plants) and were labeled. After plant sampling, the same feed samples were bulked together and thoroughly mixed and further sub-sampled. Feed samples were sun-dried until transported to laboratory and then dried at 65°C for 72 hours and milled and then stored in tightly stoppered individual plastic containers until analysis. Identification of different grass and browse species were undertaken following the guide provided in the Flora of Ethiopia [9]. For samples whose scientific names were not properly identified, specimen were prepared in a duplicate, pressed between news paper and one of the specimens was sent to the herbarium of Addis Ababa University while the other one was left in Areka Agricultural Research Center.

Determination of Chemical Analysis and *In-vitro* Dry Matter Digestibility: The various feeds evaluated in this study were grouped into different major classes. All analyses were done in triplicates. The dry matter (DM), ash and nitrogen contents in the samples were analyzed following the methods of AOAC [10]. Nitrogen was determined using the micro-Kjeldahl method (10). The CP content was calculated by multiplying nitrogen content with a factor of 6.25. The neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were analyzed according to Van Soest *et al.* [11].

Rumen fluid was collected from three cannulated Boran bull fed medium quality mixed-hay diet and prepared aneroebically using standard procedures while the culture media was prepared as described in Goering and Van Soest [12]. DM loss was calculated as the difference between the DM weight of the sample at the start of the incubation and the weight of residue DM remaining at the end of the incubation period as stated by Tilley and Terry (13). All measured concentrations were expressed on a dry matter basis.

Data Analysis: The data were analyzed using the SAS statistical package [14], using ANOVA procedures, within and across plant species as fixed effects and error as random effects. When the F-test showed significant differences, Tukey's test was used to separate the individual means. Pearson correlation coefficient was compared to understand the relationship among ash, DM, CP, ADF, NDF and IVDMD. Figure was drawn using Sigmaplot [15].

RESULTS AND DISCUSSION

Chemical Composition and In-vitro Dry Matter Digestibility of Major Feeds

Natural Pasture: Nutritional value of feed samples from natural pasture is given in Table 1. The crude protein (CP) content of the grass species varied widely, ranging from 1.42% to 18.95%. The highest CP content was found in '*andropogon gayanus var. polycladus* and the lowest in *Cymbopogon excavates,* both sampled from the Wolaita site.

Generally, nutritive value of the grasses evaluated in this study, is poor mainly due to poor pasture management, land fragmentation and degradation, overgrazing and overstocking. Soil type, plant species and maturity stage are also factors contributing for the reported low nutritive value of the feeds. Poor nutritional quality of forages from open grazing lands obtained in this study is consistent with other reports of the country [6-8, 16, 22]. The CP contents obtained in our study are in the ranges reported for rangeland grasses by Faiz *et al*. [17]. The minimum allowance level of crude protein level in the feed daily ration is 7% for tropical feed species and 8.5% for temperate species [16]. Most feeds sampled from natural pasture of the current study are below this critical CP level. Feeds with CP content less than 7% inhibits voluntary feed intake and microbial activity, resulting in poor digestibility [16]. The Napier (*p. purpureum)* specie is among the widely distributed improved grasses, with higher biomass yield, but had lower CP content. This confirms reports of Shenkute *et al*. [7] who observed species of inedible grasses like *P.schimperi (4.53% CP content)*, dominating (30%) in the top-land overgrazed areas of the mid rift valley. The general deterioration in nutritive values of grasses from the rangelands is likely due to overstocking induced trampling, loss of palatable and nutritious species and loss of soil fertility [7, 18].

The ADF content of feed samples ranged from 21.97% to 55.04% while NDF varied between 32.2 to 78.0% on DM basis. The grass species like *Hyparrhenia rufa, Cynodon dactylon and C. excavates* had high NDF and ADF. The lowest NDF content was found in *O. abyssinica* and the highest in *E. floccifola* (Table 1). The IVDMD values of the feed samples of natural pasture ranged from 31.7% of *Eluesine floccifola* to 74.26% of *Andropogon gayanus*. The gradual domination of the grasslands by *E. floccifola (*low digestibility values*)* and other inedible grasses indicates the deterioration of veld condition and loss of palatable, edible and nutritious species from the area. Our study confirms previous studies undertaken in different parts of the country under similar agro-ecological zones [6, 8, 18, 20] and other tropical countries [23, 17]. Fiber and protein are chemical fractions that have been most closely associated with intake and digestibility [16]. The poor nutritive values of grasses and their lower degradability results in low intake and feed utilization and thereby reduced performances of animals [17, 22].

Crop Residues: As indicated in Table 2, chemical composition and invitro dry matter digestibility value of crop residues varied greatly within and among species and across the districts. The CP content of crop residues ranged from 2.01% DM in *H. vulgare* straw to 13.91% DM in *Eragrotis tef,* the former contained ($p<0.05$) lower CP compared to other crop residues. Most of the crop residues are low in CP contents, the majority possessed CP value of below 8% in DM basis. The highest NDF content (93.05% DM) was found in *H. vulgare* and the lowest (33.97% DM) in *P. sativum*. The ADF content ranged from 31.52% DM in *P. sativum* to 62.91% DM basis of *H.vulgare*. The mean in-vitro dry matter digestibility value of the crop residues is 46.05% (Table 3). *Pisum sativum* had higher ($p<0.05$) digestibility value while *T. aestivum* possessed the lowest ($p<0.05$). The IVDMD varied from 23.28% in *T. aestivum (*Hadiya site) to 69.18% in *P. sativum* in Wolaita site, with great variability within and among species and across sites of the zones.

Table 1: Chemical composition (% in dry matter basis) of forage from the key grass species from natural pasture of the central south region, Ethiopia

		Percentage of nutrient proportions					
Site	Scientific name (*)	DM	Ash	CP	NDF	ADF	IVDMD
Wolaita	*Sign level*	ns	**	***	**	**	***
	Cyndon dactylon	92.67^{bA}	10.49^{cdC}	13.6^{bB}	64.33^{gE}	37.84^{dB}	68.14^{cB}
	Scripus corynobosus	92.29^{bcA}	5.62^{fD}	2.28^{f}	71.55^{fD}	51.37^{bAB}	48.47^{gD}
	Pennisetum purpureum	95.05^{aA}	9.42^{cdCD}	4.91^{deC}	73.02^{efC}	45.97^{c}	57.62^{fC}
	Eluesine floccifola	92.00^{bcA}	15.24^{aA}	6.29^{dD}	87.66^{aA}	53.39^{abA}	31.7^{kE}
	Andropogon gayanus var p.	92.44^{bcA}	12.95^{bB}	18.95^{aA}	61.32^{hF}	29.12^{fC}	74.26^{aA}
	Cymbopogon excavates	92.66^{bA}	6.09^{fD}	1.42^{fE}	76.92^{bcB}	52.76^{abAB}	44.27^{hiD}
	Sign level	-	-	-	-	-	-
Dauro	*Eluesine floccifola*	94.03^{a}	6.48^{ef}	2.35^{f}	77.99^{b}	54.63^{ab}	43.53^{i}
	Sign level	*	**	***	****	**	**
Hadiya	*Eluesine floccifola*	94.25^{aA}	8.4^{deB}	1.58^{fD}	35.69^{jC}	21.97^{gC}	63.58^{eB}
	Oxythenanthera abyssinica	94.51^{aA}	8.63^{deB}	10.6^{cB}	32.17^{kC}	23.73^{gC}	63.92^{deB}
	Sporobolus fimbriatus	91.5^{cB}	11.39^{bcA}	17.87^{aA}	57.61^{iB}	32.69^{eB}	70.58^{bA}
	Hyparrhenia rufa	92.6^{bcB}	6.81^{efC}	3.32^{efC}	74.39^{deA}	51.37^{bA}	46.11^{hC}
	Cynodon dactylon	91.7^{bc}	10.44^{cd}	12.65^{b}	63.84^{g}	32.17^{ef}	66.08^{cd}
	Sign level	-	-	-	-	-	-
Guraghe	*Eluesine floccifola*(^{4})	92.06^{bc}	5.46^{f}	2.52^{f}	75.62^{cd}	55.04^{a}	35.83^{j}
Overall	Mean	93.06	9.47	8.38	61.86	40.71	57.20
	SE	0.58	1.22	1.14	1.11	1.91	1.32
	P-value	<.012	<.001	<.0001	<.0001	<.0001	<.0001

^{abc} means across sites and ^{ABC} means within site in the same column for each parameter with different superscripts differ at indicated P level, ns, non-significant, P<0.05, **p<0.01, ***p<0.001, ****p<0.0001

Table 2: Chemical composition (% in DM) of crop residues sampled from the central south region, Ethiopia

			Percentage of nutrient proportions					
Site	Scientific name (*)	Parts sampled	DM	Ash	CP	NDF	ADF	IVDMD
Wolaita	Sign level		**	***	****	****	****	****
	Zea mays (crossbred)	Cob, straw & stover	94.03^{abcA}	8.03^{efgC}	7.44^{bcAB}	73.44^{gD}	44.85^{gD}	55.22^{bB}
	Triticum aestivum	Straw	94.00^{abcA}	9.59^{cdB}	$4.14e^{fgC}$	82.08^{dB}	54.54^{cB}	38.99^{eE}
	Hordeum vulgare	Straw	94.10^{abcA}	9.01^{cdefBC}	2.72^{hgC}	85.67^{cA}	58.69^{bA}	31.60^{dD}
	Sorghum bicolor	Straw & stover	90.05^{eB}	7.54^{fgA}	8.29^{abB}	73.63^{gC}	41.13^{iC}	56.49^{bB}
	Eragrotis teff	straw	91.34^{deB}	12.17^{bC}	6.41^{cdA}	77.65^{efD}	46.86^{fE}	50.99^{cC}
	Pisum sativum	Straw	93.41^{abcA}	12.04^{bA}	8.34^{abA}	48.06^{hE}	31.52^{jF}	69.18^{aA}
Dauro	Sign. Level		*	**	***	****	****	**
	Triticum aestivum	Straw	93.68^{abcA}	9.92^{cB}	2.01^{hB}	93.05^{aA}	62.91^{aA}	43.62^{fA}
	Hordeum vulgare	Straw	93.84^{abcA}	8.23^{defgC}	2.71^{hgB}	90.82^{bB}	59.73^{bB}	42.79^{fA}
	Eragrotis teff	straw	90.05^{eB}	13.91^{aA}	8.97^{aA}	73.09^{gC}	42.36^{hC}	37.92^{gB}
Hadiya	Sign level		***	*	*	****	****	****
	Zea mays(local var.	Cob, straw & stover	91.30^{deB}	9.6^{cdA}	4.78^{efC}	72.11^{gC}	49.49^{eC}	51.19^{eB}
	Triticum aestivum	Straw	94.94^{aA}	7.1^{gB}	5.39^{deBC}	84.44^{cA}	54.05^{cA}	23.28^{jD}
	Hordeum vulgare	Straw	94.90^{abA}	7.1^{gB}	5.39^{deBC}	84.44^{cA}	54.05^{cA}	29.49^{iC}
	Eragrotis teff	straw	92.67^{cdB}	$8.58^{cdefgAB}$	6.48^{cdAB}	78.98^{eB}	52.16^{dB}	50.72^{eB}
	Sorghum bicolor	Straw & stover	87.20^{fC}	8.23^{defgAB}	7.32^{bcA}	77.87^{efB}	53.5^{cA}	54.79^{cdA}
Guraghe	Sign level		*	ns	**	***	***	****
	Hordeum vulgare	Straw	93.03^{bcdA}	$9.54c^{deA}$	3.5^{fghB}	85.32^{cA}	54.13^{cA}	28.47^{iC}
	Sorghum bicolor	Straw & stover	87.86^{fB}	8.37^{defgA}	7.02^{bcA}	76.92^{fB}	52.14^{dB}	54.39^{dB}
	Pisum sativum	Straw	94.40^{abcA}	8.47^{cdefgA}	7.23^{bcA}	33.97^{iC}	23.59^{kC}	63.68^{bA}
Overall	Mean		92.4	9.26	5.77	75.97	45.16	46.05
	SE		0.97	0.79	0.84	1.04	0.66	1.13
	P-value		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

^{abc} means across sites and ^{ABC} means within site in the same column for each parameter with different superscripts differ at indicated P level, ns, non-significant, P<0.05, **p<0.01, ***p<0.001, ****p<0.0001

Table 3: Chemical composition (% in DM basis) of indigenous browses in the central south region, Ethiopia

			Percentage of nutrient proportions					
Site	Scientific name (*)	Parts sampled	DM	Ash	CP	NDF	ADF	IVDMD
Wolaita	Sign level		ns	**	***	****	***	****
	Eucalyptus spp.(1)	Leaves	94.53^{abA}	9.53^{defgC}	8.75^{kC}	12.9^{kD}	32.4^{deC}	25.33^{gC}
	hyphaene thebaica(1)	Leaves	94.49^{abA}	8.07^{ghijD}	8.13^{kC}	31.66^{hC}	21.89^{mD}	63.07^{cdefB}
	Cordia Africana(1)	Leaves & twigs	94.47^{abA}	11.83^{bB}	23.7^{aA}	38.67^{cdB}	36.5^{bB}	68.85^{abA}
	Vernonia amygdalina(1)	Leaves	94.45^{abA}	13.39^{aA}	16.61^{fB}	45.89^{aA}	40.98^{aA}	71.25^{aA}
	Sign level		ns	*	**	***	***	ns
Dauro	*Eucalyptus spp*.(2)	Leaves	94.65^{abA}	7.35^{jC}	11.16^{ijC}	28.49^{jC}	20.7^{mC}	61.59^{fB}
	hyphaene thebaica(2)	Leaves	94.41^{abA}	9.39^{defghB}	10.4^{jC}	34.72^{fB}	25.88^{jkB}	65.09^{cdeA}
	Syzygium guineense(2)	Leaves	94.48^{abA}	9.18^{defghiB}	12.85^{ghB}	33.78^{fgB}	26.95^{ijB}	64.77^{cdeA}
	Erythrina Abysinica(2)	Leaves & twigs	94.47^{abA}	11.20^{bcA}	8.58^{fghijBC}	20.4^{dA}	11.97^{hiD}	37.09^{deA}
Hadiya	Sign level		ns	*	***	***	***	***
	Eucalyptus spp(3)	Leaves	94.50^{ab}	32.15^{ghB}	34.05^{cA}	24.9^{klE}	63.84^{cdefAB}	63.84^{cdefA}
	Cofffee Arabica(3)	Leaves	94.65^{ab}	10.61^{bcdA}	22.1^{bcB}	34.35^{fA}	32.07^{eA}	63.27^{cdefA}
	Cordia Africana(3)	Leaves	94.70^{ab}	9.24^{defghi}	20.88^{cdBC}	31.23^{hiBC}	28.06^{ghiBC}	64.87^{cdeA}
	V. amygdalina (3)	Leaves & twigs	94.70^{ab}	9.37^{defghAB}	21.53^{bcdBC}	30.99^{hiBC}	28.44^{ghB}	65.07^{cdeA}
	Erythrina Abysinica (3)	Leaves	94.71^{ab}	9.25^{defghiABC}	20.44^{dC}	30.72^{hiBC}	27.71^{hiBC}	64.87^{cde}
	Olinia rochetiana(3)	Leaves	94.60^{ab}	7.82^{ijC}	11.46^{ijD}	29.62^{ijCD}	22.06^{mD}	62.67^{efA}
	Ricinus communis(3)	Leaves	94.9^{a}	8.64^{efghijBC}	24.34^{aA}	27.94^{jD}	26.77^{ijC}	6.93^{hB}
Guraghe	Sign level		ns	*	**	**	****	ns
	Erythrina Abysinica(4)	Leaves & twigs	94.70^{abA}	9.91^{cdefA}	22.3^{bA}	31.87^{hA}	30.14^{fA}	65.89^{bcdA}
	Hagenia Abyssinia (4)	Leaves	94.78^{abA}	7.92^{ijB}	18.12^{eC}	28.28^{jB}	23.78^{lB}	62.83^{defA}
	Betula papyrifera(4)	Leave & twigs	94.81^{abA}	8.21^{ghijB}	20.29^{dB}	28.21^{jB}	24.8^{klB}	63.28^{cdefA}
	Mean		94.55	9.68	16.40	33.01	28.87	61.16
	SE		0.33	0.77	0.79	1.10	0.80	1.62
	P-value		<0.7	<.0001	<.0001	<.0001	<.0001	<.0001

^{abc} means across sites and ^{ABC} means within site in the same column for each parameter with different superscripts differ at indicated P level, ns, non-significant, P<0.05, **p<0.01, ***p<0.001, ****p<0.0001

In the highland crop-livestock mixed production system, the importance of crop residues for livestock feed is well recognized, particularly during dry and light rain season. Study conducted by Adugna [24] in the neighboring sites indicated that crop residues play a considerable role for livestock in areas with small land holding. In spite of their substantial importance in dry season, however, the current results indicated that the CP contents are minimal, ranging from 3.3 to 13.3%, majority of them are below the critical CP level. This results confirm earlier reports that indicates crop residues are poor in their nutritional content [25, 26] although there are great variations of nutritive value within and among species. The CP content obtained for *T. aestivum* and *H. Vulgare,* is particularly lower than the previous reports [8]. The IVDMD values of major residues concur with reports of Solomon *et al*. [1]. Due to long lag times and slow fermentation, straws and stovers limit intake and utilization [21].

Indigenous Browses: There were great variations among and within species of browses sampled from different sites (Table 3). The mean CP content of the indigenous browse species is 16.4%, ranging from 8.13% DM in *hyphaene thebaica* to 24.34% in *Rucinus communis* tree leave. Most of the browse species had high CP content and the majority containing above 15% in DM basis. The highest NDF content (45.89% DM) was found in *V. amygdalina* and the lowest (12.9% DM) in tree leaves of *Eucalyptus spp.*

The ADF content ranged from 20.7% in tree leaves of *Eucalyptus spp* to 40.98% DM in *V. amygdalina* in Wolaita site. The IVDMD values of indigenous browses varied markedly, ranging from 6.93% in *R.communis* in Hadiaya site to 71.25% in *V.amygdalina of* Wolaita site; however, the general trends of IVDMD values are comparable across the sites.

Indigenous browses have higher CP content compared to grasses and crop residues sampled in this study. This confirms previous reports that indicated higher CP contents of indigenous browses in Ethiopia [1, 6, 20, 22] and other tropical countries [2, 26]. Aynalem and Taye [27] have shown that the levels of CP ranged from 18.62 to 24.44% among indigenous browses with minimum level in *Buddleja polystachya* and higher values for *Vernonia amygdalina,* which is comparable to the current study. The nutritive value of indigenous browses of the current study is also comparable with results of Njidda and Ikhimioya [26] who have reported DM, CP ADF and IVDMD values of 95.05%, 16.02%, 26.15% and 61.87%, respectively, for the indigenous browses of North-eastern Nigeria. The CP content of browse species in the current study is higher than the minimum threshold level of 7% CP required for optimum rumen function and feed intake in ruminant livestock [16]. In this study, the indigenous browse species such as 'Wanza' *(C. africana*), 'Korch' *(E. abyssinia*), 'kosso' (*V. amygdalina*) and 'Grawa'(*V. amygdalina*) contained more than 15% CP on DM basis and this level is usually sufficient to support animal growth and production. With the exception of *V. amygdalina (45.89%)*, most of the browse species evaluated in this study contained less than 45% NDF and thus according to Singh and Oosting [28], they can be regarded as a good quality roughages. The *Ricinus communis* leaves possessed an exceptionally low IVDMD value and thus the species may be categorized under inedible feedstuffs. The variation in IVDMD of the browse species in the current study is mainly a reflection of differences in their chemical composition [1, 20].

Feed Samples from Root and Horticultural Dual Purpose Crops: The chemical composition and digestibility of some root and horticultural crops is given in Table 4. There were great variations in nutritive values within and among the species and across the sites. The mean CP content of these feeds is 15.5% and is higher compared to grasses and crop residues, likely due to these dual purpose crops were sampled at a green stage. The residual fertilizer N left in the plant biomass might have also contributed for the higher CP content. The lowest CP was obtained in *S. officinarum L. (*common name, sugarcane*)* and the highest in *I. batatas L.* (common name, sweet potato). Except *E. vetricosum (*common name, enset*)* and sugarcane, most of the feeds in this category had high CP contents, usually above 15% in DM basis. The vines of sweet potato contain ($p<0.05$) higher CP than most of the feeds mentioned under this category except the clones of enset in Wolaita zone.

Dual purpose root and horticultural crops are widely produced in the central south region of Ethiopia. However, the nutritive value of these feeds has been hardly reported. Earlier studies [29] on enset and *C. esulenta* (common name, Taro) are limited to agronomic and food value analysis. This study may help to expand the database in the region by documenting nutritional values of these feeds for livestock feeding. The leaves, stems and corm/tuber of these crops are commonly used for livestock feed, particularly during the dry season. The leaves and pseudo-stems of enset possessed CP content as high as 21.9%.

The pseudostem of enset contain ($p<0.05$) higher proportion of NDF content and IVDMD compared to other feeds (Table 4). The ADF content ranged from 6.8% in taro to 32.1% in sweet potato. Taro had ($P<0.05$) lower ADF content than other feeds. The IVDMD values ranged from 56.1% in enset pseudo-stem of Hadiya to 69.2% in enset leaves and stem of Wolaita site. Majority of these root and horticultural crops feeds have the IVDMD value of above 60%. The low IVDMD in enset pseudo stem could be attributed to its relatively higher contents of cell wall components. The positive correlation of CP with IVDMD indicates feeds with higher CP contents could supply an adequate protein base for microbial growth and improves digestibility.

Taro is a root crop reported for its higher productivity (as high as 900ql fresh yield/ ha) under better agronomic management [29]. Enset and taro are used as energy and protein supplements for ruminant animals, particularly during the dry season. In the south eastern parts of the region, sweet potato vines are used for feeding of goats [30]. The same author has shown that the CP value of sweet potato is 6.53%, which is lower than the values recorded in our study. Antia *et al.* [31] reported higher CP (24.85%) contents for leaves of sweet potato in Pakistan, which is comparable to the values recorded in the current study. There is a positive correlation between CP and IVDMD. This means that in the availability of CP, better digestibility could be obtained. This concurs with other findings by Solomon *et al*. [1] for northern Ethiopia and Njidda and Akhimioya [26] for indigenous feeds and browses in Nigeria.

Comparison among Major Feed Classes and Correlations Between Nutritive Values: As illustrated in Fig 1, the chemical composition and dry matter digestibility of the major feeds showed great variations. Natural pasture and crop residues possessed ($p<0.001$) higher amount of NDF, with low digestibility values. The CP and IVDMD values

Table 4: Chemical composition (% DM basis) of root and horticultural crops in central south region, Ethiopia

			Percentage of nutrient proportions					
Site	*Scientific name(*)*	Parts sampled	DM	Ash	Cp	NDF	ADF	IVDMD
Wolaita	*Sign level*		**	*	***	***	***	*
	E.vetricosum	Leave and stem	94.43^{bB}	12.08^{aA}	21.9^{aA}	38.74^{cdB}	36.43^{aA}	69.23^{aA}
	C.esulenta	Leave, tuber	97.5^{aA}	3.6^{bB}	12.60^{eB}	48.8^{bA}	6.8^{dC}	66.87^{bB}
	S. officinarum L.	Leaves & top	94.24^{bB}	10.33^{aA}	8.68^{fC}	39.94^{cB}	28.81^{bcB}	66.54^{bcB}
Dauro	*Sign level*	-	-	-	-	-	-	-
	C. esulenta	Leaves	94.56b	9.43^{a}	16.01^{cd}	33.31^{f}	27.39^{c}	65.15c
Hadiya	*Sign level*		***	ns	***	***	ns	***
	I. batatas L.	Leaves & vine	94.5^{bA}	10.61^{aA}	22.1^{aA}	34.35^{efC}	32.07^{bA}	66.97^{aA}
	E. vetricosum	Pseudo-stem	87.7^{cB}	8.5^{aA}	9.54^{fD}	54.09^{aA}	27.54^{cB}	56.06^{dB}
	E.vetricosum	Leaves	94.5^{bA}	10.09^{aA}	17.51^{bcB}	33.95^{fBC}	29.26^{bcAB}	66.18^{bcA}
	Musa spp.	Leave and stem	94.43^{bA}	10.26^{aA}	14.0^{deC}	35.61^{eB}	29.35^{bcAB}	66.43^{abA}
Guraghe	*Sign level*		ns	ns	*	**	ns	ns
	E.vetricosum	Leaves	93.45^{bA}	10.91^{aA}	14.22^{deB}	37.97^{dA}	31.47^{bA}	67.43^{bcA}
	E. vetricosum	Leave and stem	94.59^{bA}	10^{aA}	18.75^{bA}	33.05^{fB}	29.16^{bcA}	66.03^{bcA}
Overall	Mean		93.99	9.58	15.53	38.98	27.83	65.69
	SE		1.09	1.95	1.25	0.77	1.92	0.86
	P-value		<.0001	<.0039	<.0001	<.0001	<.0001	<.0001

^{abc} means across sites and ^{ABC} means within site in the same column for each parameter with different superscripts differ at indicated P level, ns, non-significant, P<0.05, **p<0.01, ***p<0.001, ****p<0.0001

Table 5: Correlation coefficients of chemical composition and vitro dry matter digestibility of major feeds in central south region, Ethiopia

	DM	Ash	CP	NDF	ADF	IVDMD
DM	1					
Ash	-0.099	1				
CP	0.320^{**}	$.369^{**}$	1			
NDF	-0.497^{**}	-.107	$-.692^{**}$	1		
ADF	-0.351^{**}	-.112	$-.616^{**}$	0.907^{**}	1	
IVDMD	0.151	$.271^{*}$	$.492^{**}$	$-.535^{**}$	$-.590^{**}$	1

* Level of significance at p< 0.05 levels, ** p< 0.01 level

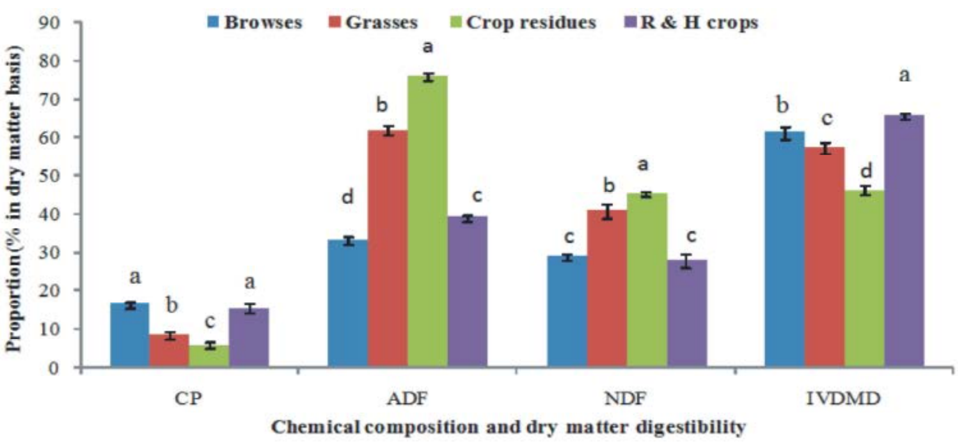

Fig. 1: Proportion nutritive values of major feed classes in the central south region, Ethiopia. Error bars represent the standard error of the mean. **P<0.01, *** P<0.001

of indigenous browses and roots and horticultural crops were (p<0.001) higher than the values obtained from natural pasture and crop residues. On the other hand, grasses from natural pasture contain (p<0.001) lower CP and IVDMD compared to crop residues. Similarly, grasses contain higher NDF and ADF compared to indigenous browses and roots and horticultural crops. Crop residues possessed (p<0.001) higher NDF and ADF compared to grasses, indigenous browses and non-conventional food and feed crops. The results are in agreement with other reports [24, 22, 29]. The correlation between the different parameters of the nutritive value of the major feeds is given in Table 5. The results indicated that CP was positively correlated ($r = 0.37$; $P<0.01$) with ash and ($r=0.49$, $p<0.01$) IVDMD, respectively, while negatively correlated ($r= 0.69$, $p<0.01$) with NDF and ($r=0.62$, $p<0.01$) ADF. There is a strong positive correlation ($r=0.91$, $p<0.01$) between NDF and ADF components of the feeds. The findings are in agreement with other reports [2, 20, 25, 27].

The majority of feed samples from natural pasture and crop residues possessed CP content, (essential nutrient in the ruminants diet) below the critical level for optimum rumen function and feed intake. On the other hand, indigenous browses and root and horticultural crops contain higher CP values with higher digestibility, indicating their suitability and potential for strategic supplementation, particularly during the dry season. Further studies that aim to integrate these feeds into the feeding system are required in order to quantify the feed intake, digestibility, level of inclusion (supplementary feeds), animal's responses and anti-nutritional factors that might be associated with the use of such feeds in future and efficient utilization of these indigenous and adaptable feed resources for optimal animal production.

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