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Evaluation of major feed resources in crop-livestock mixed farming systems, southern Ethiopia: Indigenous knowledge versus laboratory analysis results

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Abstract

Evaluation of major feed resources was conducted in four crop-livestock mixed farming systems of central southern Ethiopia, with 90 farmers, selected using multi-stage purposive and random sampling methods. Discussions were held with focused groups and key informants for vernacular name identification of feed, followed by feed sampling to analyse chemical composition (CP, ADF and NDF), *in-vitro* dry matter digestibility (IVDMD), and correlate with indigenous technical knowledge (ITK). Native pastures, crop residues (CR) and multi-purpose trees (MPT) are the major feed resources, demonstrated great variations in seasonality, chemical composition and IVDMD. The average CP, NDF and IVDMD values for grasses were 83.8 (ranged: 62.9–190), 619 (ranged: 357–877) and 572 (ranged: 317–743) $g\,kg^{-1}$ DM, respectively. Likewise, the average CP, NDF and IVDMD for CR were 58 (ranged: 20–90), 760 (ranged: 340–931) and 461 (ranged: 285–637) $g\,kg^{-1}$ DM, respectively. Generally, the MPT and non-conventional feeds (NCF, *Ensete ventricosum* and *Ipomoea batatas*) possessed higher CP (ranged: 155–164 $g\,kg^{-1}$ DM) and IVDMD values (611–657 $g\,kg^{-1}$ DM) while lower NDF (331–387 $g\,kg^{-1}$ DM) and ADF (321–344 $g\,kg^{-1}$ DM) values. The MPT and NCF were ranked as the best nutritious feeds by ITK while crop residues were the least. This study indicates that there are remarkable variations within and among forage resources in terms of chemical composition. There were also complementarities between ITK and feed laboratory results, and thus the ITK need to be taken into consideration in evaluation of local feed resources.

Keywords: crop residue, fodder tree, natural pasture, nutritive value, indigenous knowledge

1 Introduction

Smallholder agriculture in the central highlands of Ethiopia is dominated by crop-livestock mixed farming systems. In these systems, livestock provide with traction power, manure for fuel and fertiliser, milk, meat, and cash income for subsistent farmers (Solomon *et al.*, 2004). Despite the large livestock population (54 million cattle, 25.5 million sheep and 24.1 million goats), productivity remained too low to satisfy food requirement of the ever-growing human population in the country (CSA, 2013).

Feed scarcity is one of the major technical constraints in livestock production and thus it challenges the economic contribution of the livestock sub-sector. The critical feed nutrient, crude protein (CP), of the herbaceous plants declines during the dry season, leading to prolonged periods of under-nutrition of livestock reared under such environmental conditions (Yayneshet

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et al., 2009). Moreover, the adoption and use of improved feed technologies remained limited (CSA, 2013; Deribe *et al.*, 2013), calling for exploring indigenous feed resources (Mekonnen *et al.*, 2009; Deribe *et al.*, 2013), giving due emphasis on indigenous knowledge on adapted feed resources in the crop-livestock farming systems. However, the significance of major indigenous feed resources, their nutritional value and related farmer's preferences and evaluation has not been adequately studied and documented.

The recurrent drought and climatic variability has exerted great pressure on the availability and use of feed resources (Assefa *et al.*, 2013). The Ethiopian government and non-governmental organisations have been undertaking significant measures to alleviate the situations, by improving local feeds and introducing exotic forage species and varieties. In this regard, participatory identification and evaluation of local and/or exotic feed resources is essential. According to CSA (2013) and Deribe *et al.* (2013), the feed shortage has resulted in a decline of animal products such as milk, meat, and traction and at the worst the death of animals during the periods of serious feed scarcity. However, except few reports (Adugna, 1990; Deribe *et al.*, 2013), the various aspects of nutritional feed constraints in these farming systems have not been well documented, with active participation of the end users or community of the area. Hence, this study was aimed at assessing and evaluating major feed resources in crop-livestock mixed farming systems of central southern Ethiopia.

2 Materials and methods

2.1 Description of the study areas

The study was undertaken in four zones: Wolayita, Dawuro, Hadiya and Gurage that are located in the central parts of Southern Nations, Nationalities Peoples Region (SNNPR), in sub-humid agro-ecological areas. The zones and respective representative districts were selected purposefully following a survey work of farming system characterisation (Endrias *et al.*, 2009). Accordingly, Soddo Zuria, Mareka, Sorro and Gumer districts, which are located at latitudes and longitudes of 6º 51'N, 37º 47'E (Soddo Zuria), 7º 2'N, 37º 56'E (Mareka), 7º 43'N, 37º 5'E (Sorro) and 7º 58'N, 37º 56'E (Gumer), were selected. The altitude of the districts ranged between 1500 m in Soddo Zuria to 2950 m above sea level in Gumer while annual total rainfall ranged from 1000 to 1855 mm. The districts have three distinct seasons: light rainy season (April to May), heavy rainy season (June to October) and dry season (November to March). The districts are characterised by crop-livestock mixed farming systems: Sorro and Gumer predominantly produce wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*), respectively. Soddo Zuria district is enset (*Ensete ventricosum*) based coffee (*Coffea arabica*) production system while Mareka site is predominantly agroforestry system, i.e indigenous tree-based fodder and maize (*Zea mays*) production.

2.2 Household sampling

Multi-stage random and purposive sampling techniques were used to select zones, districts and peasant associations (PA), in which target villages and households were selected. Representative peasant associations (PA's, sites) were purposefully selected based on: their proximity to roads and availability of livestock holdings. Two target villages were randomly selected in each site. Households with at least 5 years experiences of livestock rearing and feeding were identified in each village. Based on the heterogeneity level of the districts, it was decided to sample 25 households each from Soddo Zuria and Gumer and 20 households each from Sorro and Mareka, making a total of 90 households. Structured and semi-structured questionnaires were used to collect information. Group discussions were held at eight villages (two from each district) using 12 key informants (knowledgeable people) from PA to gather information on indigenous feed resources and their utilisations.

2.3 Feed sampling and preparation

Selection of feed types or plant species was done based on information obtained during group discussions regarding their relative abundance in the district and their consumption by grazing and/ or browsing ruminants. Grasses and herbaceous legumes were sampled as described by Tarawali *et al.* (1995) during plant flowering period. Crop residues were sampled during the dry season (November to May) while grasses, roots (tubers) and aerial parts of horticultural crops (non-conventional feeds) were sampled during the heavy rainy season (August–October). Crop residues were collected according to the crop production calendar and period of availability as identified during the previous survey (Endrias *et al.*, 2009). Edible leaves and twigs of browse plants were sampled during the dry season, a critical time when these plants serve as the alternative feed source. Leaves, tender branches and some fruiting parts (when available) were clipped with scissors from the fodder trees, and were labelled. After sampling, the same feed samples were bulked together, thoroughly mixed and sub-samples taken for analysis. Feed samples were air-dried before being transported to the laboratory, then dried at 65 °C for 72 hours, milled to pass a 1 mm sieve and finally stored in air tight plastic containers until analysis. Identification of different grass and browse species was undertaken following the guide provided in the Flora of Ethiopia (Hedberg & Edwards, 1989). For samples whose scientific names were not properly identified, specimen were prepared in duplicate, pressed between newspaper and one of the specimens was sent to the herbarium of Addis Ababa University for identification, while the other one was left in Areka Agricultural Research Centre.

2.4 *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 at Holeta Agricultural Research Centre (HARC). The dry matter (DM), ash and nitrogen contents of the samples were analysed following the methods of AOAC (2000). Crude protein (CP) was determined using the micro-Kjeldahl method (AOAC, 2000). The neutral detergent fibre (NDF) and acid detergent fibre (ADF) were analysed according to Van Soest *et al.* (1991).

Rumen fluid was collected from three cannulated Boran bulls at HARC fed medium quality mixed-hay diet, and prepared anaerobically using standard procedures while the culture media was prepared as described in Goering & Van Soest (1970). 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 & Terry (1963).

2.5 *Data analysis*

Descriptive statistics were used to analyse famer's perceptions and rankings. Indexes were developed to provide the aggregated ranking of major feed resources in the study districts. The index was calculated as the sum of single item ranks [(7 for rank 1) + (6 for rank 2) + (5 for rank 3) + (4 for rank 4) + (3 for rank 5) + (2 for rank 6) + (1 for rank 7)] divided by sum of all weighed feed resources mentioned by the respondent. The chemical composition data were analysed using the SAS statistical package (SAS, 2008), using ANOVA procedures, 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.

3 Results

3.1 *Feed availability and seasonality in crop-livestock mixed farming system*

Crop-livestock mixed system is the dominant farming system in the central southern Ethiopia, where animals are reared together with crop production. In this system, crops and animals have complementary relationships, as animals provide manure and draught power for crop production while crop residues are used for animal feeding. Natural pasture and crop residues are important feed resources in this system, while cultivated forages have been introduced very recently, although their adoption is limited due to land shortage. There is great seasonal feed availability variations in all the districts considered in this study. Animals were found grazing on already overgrazed lands, because of land scarcity due to high human population pressure (Table 1). The contribution of the four major feed resources of these districts to the total feed available to livestock is: natural pasture 21.6–29.2 %, crop residues 41.9 to 69.4 %, indigenous browses 2.81–6.10 % and non-conventional crops 3.4–20.8 %. Crop residues and roughages are the major feeds in the dry season, but are poor in quantity and quality. Although natural pastures (communal lands) are the major feed sources mainly during wet seasons, they are generally low in quantity and quality. In extreme cases, feed shortage leads to the mortality of calves and mature animals. In these districts, enset plant parts (root, pseudostem and leaves) have been contributing a lot as basal feed as well as supplement especially for draught animals and milking cows.

3.2 *Ranking of forage species by smallholder farmers*

Farmers ranked indigenous fodder trees and non-conventional feeds as the best nutritious while feeds from natural pastures and crop residues as least nutritious (Table 2). From the crop residues, wheat straw ranked last. Farmers from their long-term experiences reasoned out that wheat straw is non-digestible. In Gumer district, farmers stopped feeding wheat straw except under serious feed shortage conditions. Naper (*Pennisetum purpureum* Schumach.) and 'desho' grass (*Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf), and labab (*Lablab purpureus* (L.) Sweet) were reported to be some of the improved forages widely cultivated in the districts.

Table 1: *Seasonal feed availability as described and rated by ITK in the central southern Ethiopia.*

Types of feeds	*Major feed sources*					
	Natural pasture	*Crop residues*	*Indigenous and cultivated forage and fodder* †	*Enset* ‡	*Musa spp*	*Indigenous Browses*
Dry season						
Gumer	*	***	na	***	na	**
Sorro	**	***	*	**	***	***
Soddo Zuria	*	***	*	***	***	***
Mareka	***	***	na	*	***	***
Wet season						
Gumer	***	na	na	*	na	*
Sorro	***	na	*	R	R	**
Soddo Zuria	***	na	*	R	R	**
Mareka	***	na	na	R	R	**

† Cultivated pastures are pasture sites with improved forage species planted by smallholders, introduced through agricultural extension programme; ‡ leaves, pseudo stems and roots, *: available, **: plenty, ***: abundantly available, R: rare, na: not available.

Table 2: *Feed resources as ranked by the livestock keepers (group discussants and key informants) in the central southern Ethiopia.*

Feed sources	*Indices (study sites)*			
	Gumer	*Sorro*	*Soddo*	*Mareka*
Indigenous and cultivated forage and fodder	0.38	0.28	0.36	0.33
Non-conventional feeds	0.21	0.21	0.22	0.21
Crop residues (pulse and oil crops)	0.17	0.17	0.19	0.18
Crop residues (barley & maize)	0.11	0.22	0.12	0.16
Exclosures (protected pasture)	0.08	0.09	0.08	0.05
Communal natural pasture	0.04	0.02	0.01	0.04
Crop residues (wheat)	0.01	0.01	0.02	0.01
Total	1	1	1	1

3.3 *Indigenous livestock feeding system and strategy*

Incorporating indigenous technical knowledge (ITK) into a scientific approach has been advocated in previous studies to understand local, site-specific problems and potentials. We were able to identify ITK of the districts with knowledgeable participants (Table 3). There are some similarities and differences in the ITK of the districts, regarding animal feeding and supplementation strategies. Mixing crop residues (teff, barley, and wheat straw, maize and sorghum stover,) with enset, sweet potato and banana leaves, have commonly been practiced to increase intake and palatability of crop residues. In Sorro and Soddo Zuria sites, fattening sheep were supplemented with half-boiled haricot bean seeds. Some farmers have a practice of protecting pasture lands by fencing for production of better quality hay and feeding for productive (lactating cows, calves and draught oxen) animals. Mineral lick supplementation has been used across the studied sites.

3.4 *Chemical composition*

Major grass species demonstrated great variations in their chemical composition (Table 4). The CP contents ranged between 62.9 g kg^{-1} DM in *Eleusine floccifolia* (Forssk.) Spreng. to 189.5 g kg^{-1} DM in *Andropogon gayanus* Kunth, both values for the Soddo Zuria district.

Table 3: *Indigenous Technical Knowledge (ITK) in feeding system and local feed utilisation in the central southern Ethiopia.*

Gumer	*Sorro*	*Soddo*	*Mareka*
Chopped 'hamicho' (enset roots) feeding for fattening animals	Enset leaves and crop residue mixing	Mixing tef straw with enset to boost palatability of tef residue	Mixing teff straw with enset
Mixing pea straw with barley straw to improve palatability of barely residue	Selecting and feeding indigenous sweet grasses	Sugarcane supplementation with crop residues	Salt and 'mineral lick' (bole) mixtures for fattening animals
Mixing pea straw with wheat straw	Feeding half-boiled haricot beans for fattening animals	Supplementing half-boiled haricot bean seed and enset root for fattening and sick animals	Feeding with residues of local beverages
Spraying mineral ('bole') on crop residues to increase palatability of residues	Mineral supplementation	Feeding green sweet grasses for calves and sick animals Mineral lick	Grain feeding when available Mineral lick

Similarly, the NDF values of key grasses ranged between 356.9 g kg^{-1} DM to 876.6 g kg^{-1} DM. The highest digestibility value (742.6 g kg^{-1} DM) was observed for *Andropogon gayanus*, while the lowest was found for *Eleusine floccifolia* (317 g kg^{-1} DM).

Similar to natural pastures, crop residues showed high variations in chemical composition within and across sites. For instance, the CP values of crop residues ranged between 20.1 to 89.7 g kg^{-1} DM, the lowest in *Triticum aestivum* L. while the highest in *Eragrostis tef* (Zucc.) Trotter. Similarly, the NDF values ranged between 339.7 g kg^{-1} DM in *Pisum sativum* L. to 930.5 g kg^{-1} DM in *Triticum aestivum* (Table 5). The highest NDF value was recorded for *Triticum aestivum* and the lowest for *Pisum sativum*. The IVDMD values ranged between 284.7 to 636.8 g kg^{-1} DM. The highest IVDMD was recorded for *Pisum sativum* and the lowest for *Hordeum vulgare* L. The mean digestibility value was 460.5 g kg^{-1} DM (below 50 %), suggesting the poor digestibility of crop residues across all studied sites.

There were great variations in chemical composition within and among the browse species studied (Table 6). The mean CP content was 164 g kg^{-1} DM, ranging from 81.3 g kg^{-1} DM in *Hyphaene thebaica* (L.) Mart. to 243 g kg^{-1} DM in *Ricinus communis* L. tree leaf. The highest NDF content (459 g kg^{-1} DM) was found in *Vernonia amygdalina* Delile while the lowest was found for *Eucalyptus* spp. (129 g kg^{-1} DM), both in Soddo Zuria district. The IVDMD values of indigenous browses varied significantly, ranging from 253 g kg^{-1} DM in *Eucalyptus* spp. to 713 g kg^{-1} DM in *V. amygdalina*, both in Soddo Zuria district. However, generally the IVDMD values of indigenous browse species are high and their pattern is comparable across the sites.

In most cases, non-conventional feeds, such as *Ensete ventricosum* (Welw.) Cheesman (enset) and *Ipomoea batatas* (L.) Lam., (sweet potato) demonstrated high CP contents, usually above 15 % in DM basis (Table 7). The vines of sweet potato contained significantly ($p < 0.05$) higher CP than most of the feeds mentioned under this category except the clones of enset in Soddo Zuria district. The pseudo-stem of enset contains significantly ($p < 0.05$) higher proportion of NDF content and IVDMD compared to other feeds. The ADF content ranged from 68 in taro (*Colocasia esculenta* (L.) Schott) to 321 g kg^{-1} DM in sweet potato across districts. Taro had significantly ($p < 0.05$) lower ADF value than other feeds. The IVDMD value ranged from 561 g kg^{-1} DM in enset pseudo-stem in Sorro district to 692 g kg^{-1} DM in enset leaves and stem in Soddo Zuria district. The majority of these root and horticultural crops feeds have the IVDMD value of above 600 g kg^{-1} DM (>60 %).

Table 4: *Chemical composition (g kg^{-1} DM) of dominant grass species from natural pasture (heavy rainy season) in the central southern Ethiopia.*

Site	*Scientific name (*)*	*CP*	*NDF*	*ADF*	*IVDMD*
Soddo Zuria	*Cynodon dactylon*	136.0 ^{bB}	643.3 ^{gB}	378.4 ^{dB}	681.4 ^{cB}
	Eleusine floccifolia	62.9 ^{cC}	876.6 ^{aA}	533.9 ^{abA}	317.0 ^{kC}
	Andropogon gayanus	189.5 ^{aA}	613.2 ^{hC}	291.2 ^{fC}	742.6 ^{aA}
	P-value	***	**	**	***
Mareka	*Eleusine floccifolia*	23.5 ^{fC}	779.9 ^{bA}	546.3 ^{ab}	435.3 ^{iD}
Sorro	*Eleusine floccifolia*	15.8 ^{fC}	356.9 ^{jD}	219.7 ^{gC}	635.8 ^{eB}
	Sporobolus fimbriatus	178.7 ^{aA}	576.1 ^{viC}	326.9 ^{eB}	705.8 ^{bA}
	Cynodon dactylon	126.5 ^{bB}	638.4 ^{gB}	321.7 ^{ef}	660.8 ^{cdC}
	P-value	***	***	**	**
Gumer	*Eleusine floccifolia*	25.2 ^{f}	756.2 ^{cd}	550.4 ^{a}	358.3 ^{j}
	P-value	–	–	–	–
Overall	Mean	83.8	618.6	407.1	572.0
	SE	11.4	11.1	19.1	13.2
	P-value	<.0001	<.0001	<.0001	<.0001

Means in column with different lowercase letters across sites and different upper case letters within site are significantly different at $p<0.05$; ** $p<0.01$; *** $p<0.001$

Table 5: *Chemical composition (g kg^{-1} DM) of crop residues sampled during dry season from the central southern Ethiopia.*

Site	*Scientific name (*)*	*Parts sampled*	*CP*	*NDF*	*ADF*	*IVDMD*
Soddo Zuria	*Zea mays*	stover	74.4 ^{bcAB}	734.4 ^{gB}	448.5 ^{gB}	552.2 ^{bA}
	Sorghum bicolor	stover	82.9 ^{abB}	736.3 ^{gB}	411.3 ^{iC}	564.9 ^{bA}
	Eragrostis tef	straw	64.1 ^{cdA}	776.5 ^{efA}	468.6 ^{fA}	509.9 ^{cB}
	P-value		***	***	***	***
Mareka	*Triticum aestivum*	straw	20.1 ^{hB}	930.5 ^{aA}	629.1 ^{aA}	436.2 ^{fA}
	Hordeum vulgare	straw	27.1 ^{hgB}	908.2 ^{bB}	597.3 ^{bB}	427.9 ^{fA}
	Eragrostis tef	straw	89.7 ^{aA}	730.9 ^{gC}	423.6 ^{hC}	379.2 ^{gB}
	P-value		***	***	***	**
Sorro	*Zea mays* (local var.)	stover	47.8 ^{efC}	721.1 ^{gC}	494.9 ^{eC}	511.9 ^{eB}
	Triticum aestivum	straw	53.9d ^{eBC}	844.4 ^{cA}	540.5 ^{cA}	232.8 ^{jD}
	Eragrostis tef	straw	64.8 ^{cdAB}	789.8 ^{eB}	521.6 ^{dB}	507.2 ^{eC}
	Sorghum bicolor	stover	73.2 ^{bcA}	778.7 ^{efB}	535.0 ^{cA}	547.9 ^{cdA}
	P-value		*	***	***	***
Gumer	*Hordeum vulgare*	straw	35.0 ^{fghB}	853.2 ^{cA}	541.3 ^{cA}	284.7 ^{iB}
	Pisum sativum	straw	72.3 ^{bcA}	339.7 ^{iB}	235.9 ^{kB}	636.8 ^{bA}
	P-value		**	***	***	***
Overall	Mean		57.7	759.7	451.6	460.5
	SE		8.40	10.40	6.60	11.3
	P-value		<.001	<.001	<.001	<.001

Means in column with different lower case letters across sites and different upper case letters within site are significantly different at $p<0.05$; * $p<0.05$; ** $p<0.01$; *** $p<0.001$

Table 6: *Chemical composition (g kg^{-1} DM) of indigenous browses (sampled during dry season) in the central southern Ethiopia.*

Site	*Scientific name (*)*	*Parts sampled*	*CP*	*NDF*	*ADF*	*IVDMD*
Soddo Zuria	*Eucalyptus* spp.	leaves	87.5^{kC}	129^{kD}	324d^{eC}	253^{gC}
	Hyphaene thebaica	leaves	81.3^{kC}	317^{hC}	219^{mD}	631^{cdefB}
	Cordia africana	leaves & twigs	237^{aA}	387^{cdB}	365^{bB}	689^{abA}
	Vernonia amygdalina	leaves	166.1^{fB}	459^{aA}	410^{aA}	713^{aA}
	P-value		***	***	***	***
Mareka	*Eucalyptus* spp.	leaves	111.6^{ijC}	285^{jC}	207^{mC}	616^{fB}
	Hyphaene thebaica	leaves	104^{jC}	347^{fB}	259^{jkB}	651^{cdeA}
	Erythrina abyssinica	leaves & twigs	204^{dA}	371^{deA}	341^{cA}	638^{cdefAB}
	P-value		***	***	***	ns
Sorro	*Eucalyptus* spp.		119.7^{hiD}	322^{ghB}	249^{klE}	638^{cdefA}
	Coffea arabica	leaves	221^{bcB}	344^{fA}	321^{eA}	633^{cdefA}
	Cordia africana	leaves	208.8^{cdBC}	312^{hiBC}	281^{ghiBC}	649^{cdeA}
	Erythrina abyssinica	leaves & twigs	204.4^{dC}	307^{hiBC}	277^{hiBC}	649^{cde}
	Ricinus communis	leaves	243.4^{aA}	279^{jD}	268^{ijC}	693^{hB}
	P-value		***	***	***	***
Gumer	*Erythrina abyssinica*	leaves & twigs	223^{bA}	319^{hA}	301^{fA}	659^{bcdA}
	Hagenia abyssinica	leaves	181.2^{eC}	283^{jB}	238^{lB}	628^{defA}
	Betula papyrifera	leave & twigs	202.9^{dB}	282^{jB}	248^{klB}	633^{cdefA}
	P-value		**	**	***	ns
	Overall mean		164.0	330.1	289.7	611.6
	SE		7.9	11.0	8.0	16.2
	P-value		<.001	<.001	<.001	<.001

Means in column with different lower case letters across sites and different upper case letters within site are significantly different ($p<0.05$), ns, non-significant; ** $p<0.01$; *** $p<0.001$

Table 7: *Chemical composition (g kg^{-1} DM) of root and horticultural crops (sampled during heavy rainy season) in the central southern Ethiopia.*

Site	*Scientific name (*)*	*Parts sampled*	*CP*	*NDF*	*ADF*	*IVDMD*
Soddo Zuria	*Ensete ventricosum*	leave & stem	219^{aA}	387.4^{cdB}	364.3^{aA}	692.3^{aA}
	Colocasia esculenta	leave, tuber	126^{eB}	488.0^{bA}	68.0^{dC}	668.7^{bB}
	Saccharum officinarum	leaves & top	86.8^{fC}	399.4^{cB}	288.1^{bcB}	665.4^{bcB}
	P-value		***	***	***	*
Mareka	*C. esculenta*	leaves	160.1^{cd}	333.1^{f}	273.9^{c}	651.5^{c}
	P-value		–	–	–	–
Sorro	*Ipomoea batatas*	leaves & vine	221^{aA}	343.5^{efC}	320.7^{bA}	669.7^{aA}
	E. ventricosum	pseudo-stem	95.4^{fD}	540.9^{aA}	275.4^{cB}	560.6^{dB}
	E. ventricosum	leaves	175.1^{bcB}	339.5^{fBC}	292.6^{bcAB}	661.8^{bcA}
	Musa spp.	leave and stem	140^{deC}	356.1^{eB}	293.5^{bcAB}	664.3^{abA}
	P-value		***	***	ns	***
Gumer	*E. ventricosum*	leaves	142.2^{deB}	379.7^{dA}	314.7^{bA}	674.3^{bcA}
	E. ventricosum	leave & stem	187.5^{bA}	330.5^{fB}	291.6^{bcB}	660.3^{bcB}
	P-value		*	**	ns	ns
Overall	Mean		155.3	389.8	278.3	656.9
	SE		12.5	7.7	19.2	8.6
	P-value		<.001	<.001	<.001	<.001

Means in column with different lower case letters across sites and different upper case letters within site are significantly different ($p<0.05$), ns, non-significant; * $p<0.05$; ** $p<0.01$; *** $p<0.001$

4 Discussion

Feed chemical composition and digestibility of the major feed resources were studied in four agro-ecologically similar sites of central southern Ethiopia. The results indicated that there are remarkable variations in feed chemical composition and digestibility within and across sites. Except for *Eleusine floccifolia*, other grass species constitute high CP content as they were sampled during mid-rainy season. *Eleusine floccifolia* was found in all study sites, however, the CP content was below the required level of 7 % CP for animals in the tropics (Kearl, 1982; Van Soest, 1994; Mlay *et al.*, 2006). Feeds with the CP level less than 7.5 % inhibits voluntary feed intakes and the activity of microbial action declines, resulting in lower digestibility of roughages (Van Soest, 1994).

Crop residues, mainly cereal crops (aftermaths being collected and stored), are used as major feeds for ruminant livestock, particularly during the dry season. However, the fact that straws and stover are high in structural components and their associated fibre contents, their utilisation for animals is limited due to their poor quality. Adugna (1990) reported that the CP content of crop residues ranges between 3.3 to 13.3 % on DM basis, which agrees with this study. However, the majority of the crop residues analysed in our study had CP values that were in the minimum ranges. These variation in feed quality reflects the variation in maturity level, soil fertility, climate, etc (McDowell, 1988; Shenkute *et al.*, 2011; Deribe *et al.*, 2013). Fibre (ADF and NDF) is often used as a negative index of nutritive value in total digestible nutrients (TDN) and net energy (Van Soest, 1994). Generally, the *in-vitro* digestibility of these straws was low across all districts. In spite of their poor nutritional value, high percentage of crop residues are used for livestock feed in areas where land holdings are small (Adugna, 1990). Furthermore, wastage during collection and utilisation of the crop residues reaches as high as 10 % (Adugna, 1990) implying the need of appropriate intervention strategies to minimize the wastage.

Feeding leaves and twigs of indigenous trees for livestock, particularly during the dry season is common practise in all the studied districts. The CP content of these indigenous fodder trees ranged between 18.2 % for Korch (*Erythrina abyssinica*) to 24.34 % for Gulo leaves (*Ricinus communis*) in Sorro district. This finding is in agreement with other reports who found high CP contents for browse of *Vernonia amygdalina*, *Maesa lanceolata*, *Cordia africana* and *Erythrina abyssinica* (Aynalem Haile & Taye Tolemariam, 2008; Mekonnen *et al.*, 2009; Deribe *et al.*, 2013). The ITK have also ranked these feeds as the best nutritious. These browse trees and other protein-rich feeds are potential sources of crude protein which can facilitate the growth of rumen microbes that play a significant role in digestion of feeds in ruminant animals (Ammar *et al.*, 2000; Njidda & Ikhimioya, 2010). Browse tree leaves are commonly harvested and supplemented to lactating ewes and/or does, kids and lambs.

Enset is a widely cultivated crop in mid (sub-humid) and highland districts of the region, which is used for both human and livestock food. Enset parts (leaf and pseudo stem) is usually fed to livestock during the dry season. Enset root is fed for fattening oxen and sheep, and to heal sick animals. The importance of enset for livestock feed has been reported previously (Adugna, 1990; Amsalu *et al.*, 2008; Deribe *et al.*, 2013). In our results too, enset leaf and stem have CP content of 21.9 %, suggesting its high potential for strategic supplementation during the dry season. The enset CP content of our study is comparable with *Sesbania sesban*, a local browse tree, which contains a CP of 13.8 % (Deribe *et al.*, 2013). However, the CP content of enset parts varied considerably, ranging from 3.62 % in Sorro to 22 % in Soddo Zuria. Differences in enset clones, soil type, and farmer's management practices may have contributed for the variation in CP contents of enset. Farmers mentioned that production potential of enset has been affected by a bacterial wilt, across all studied districts, and thus currently there is a declining trend in enset production. The low IVDMD in enset pseudo stem could be attributed to its relatively higher contents of cell wall components.

The CP content and *in-vitro* digestibility of sweet potato leaf was 22.1 % and 67.0 %, respectively, which agrees with previous reports (Deribe *et al.*, 2013). Sweet potato tuber and wilted cassava leaves feeding of fattening animals is a common practice everywhere (Amsalu *et al.*, 2008; Tadesse Megersa *et al.*, 2012). Antia *et al.* (2006) reported CP contents of 24.85 % for sweet potato leaves, which is comparable to the values recorded in the present study. Banana (*Musa* spp.) leaf and stem as an energy feed are becoming common practice as banana is commonly cultivated as a drought resilient crop. In the critical drought period, pseudo stem and roots of banana are usually used for animal feeding. We found great complementary between chemical composition of the studied feeds and the local indigenous knowledge of these non-conventional feeds.

We found strong evidences that the chemical composition of most of the feeds considered in this study had high correlation with the local ITK of the districts. For instance, farmers suggested that wheat straw has less nutritional value (unless supplemented with chopped enset and/or browse tree leaves), which has been confirmed by the laboratory results. This finding is in agreement with reports of Keba *et al.* (2013) who compared the ITK of pastoralists against feed chemical composition on major local feeds. The ITK should be used as an important approach to better understand the potential and/or nutritive importance of local feed resources under prevailing environmental conditions.

5 Conclusions & management implications

This study showed that dry season natural pastures and crop residues are of poor quality due to high cell wall fibre components (ADF and NDF) hence their digestibility is low. Moreover, these feed resources showed CP contents below the critical level (7 %) required for optimum rumen function and feed intake. On the other hand, indigenous browses and non-conventional feeds contain low NDF and high CP values with better digestibility, and that suggests their potential suitability for strategic supplementation, particularly during the dry season. Strong evidences were found for complementarities between the ITK and feed chemical composition. Further studies that aim to integrate feeds that have better nutritive values into the feeding system are required to further evaluate feed intake, digestibility, level of inclusion (supplementary feeds), animal's responses, and anti-nutritional factors, for more efficient utilisation of these indigenous and well adapted feed resources for sustainable animal production.

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