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Nutritive values of the drought tolerant food and fodder crop enset

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Enset (*Ensete ventricosum*) is a drought tolerant crop, traditionally grown in Ethiopia. It has many usages: food, fodder, fibres and traditional medicine. Being perennial, enset improves local climate and soil conditions. It could contribute to improved food security in several drought-prone parts of the world. The aims of this study were to reveal the amino acids of enset corm, which can be cooked as a root crop, and to increase the general knowledge regarding chemical composition and energy values of different enset fractions. Water content was high, 85 to 90%, which is beneficial when used as fodder during dry periods. Enset corm contained 17 of 20 amino acids and had similar or higher concentration than potato of 12 of these. Leaves had 13% protein, among the highest available in Ethiopia, 20% crude fibre and 10% sugar; a good fodder and suitable for ensilage. The pseudostem, the main food source, was rich in soluble carbohydrates (80%) and starch (65%), but had low protein content (4%). An enset based diet should be supplemented with protein and complementary amino acids; for example from beans, which are suitable to intercrop with enset.

Key words: Amino acids, corm, *Ensete ventricosum*, Ethiopia, Kocho, pseudo stem, root crop.

INTRODUCTION

Enset [false banana, *Ensete ventricosum* (Welw.) Cheesman, Musaceae] is a monocarpic short-lived perennial plant which is cultivated in Ethiopia since ancient times. It is drought tolerant; withstanding droughts that seriously damage cereals (Shigeta, 1990). About 20% of the human population in Ethiopia depends on enset as a food source (Brandt et al., 1997). Enset contributes to the local environment by improving the nutrient balance in soil (Elias et al., 1998), providing shadow, thus moderating temperature, and being part of farming systems with high biodiversity (Tesfaye, 2008). Enset is usually harvested at onset of flowering, ca. 5 to 8 years after planting, and is grown with generations of plants mixed, thus being a reliable food source over time (Brandt et al., 1997; Dalbato, 2000). The vegetative growth habit of enset is similar to banana plants, but enset is not grown for the fruits; enset fruits contain mostly large and very hard seeds (Karlsson et al., 2011). For humans, edible parts of enset are the pseudostem (squeezing and fermentation gives the main food source from enset, a product called "kocho") and the corm (the underground stem) that can be cooked like an enormous potato, weighing up to 70 kg (Brandt et al., 1997).

Droughts affect humans not only by seriously reducing crop harvest but also by affecting grazing and browsing livestock, reducing the possibility for humans to get milk and meat. Enset is used to supplement the feed, especially for lactating cows, during dry seasons. Plant leaves and agricultural by-products constitute an important fodder source in Ethiopia. For example in

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Hawassa Woreda (southern Ethiopia, ca. 300,000 habitants) crop residues, including enset parts, is the major fodder source; about 500,000 kg dry matter (DM) per year is used (Alemayehu et al., 2001), and in Wolaita Awraja (southern Ethiopia, ca. 1.7 million habitants) 8,000 kg DM ha^{-1} enset residues was produced during one year (FAO, 1987).

Kocho, which can be baked to a thin bread, provides a good source for Ca and Fe (Abebe et al., 2007; Atlabachew and Chandravanchi, 2008) but is low in protein; this can be substantially improved by adding for example kidney beans to the diet (Abebe et al., 2006); beans are frequently intercropped with enset in homegarden agriculture (Abebe et al., 2010). The chemical composition and mineral content of enset make it is a relatively suitable fodder for ruminants (Fekadu and Ledin, 1997; Nurfeta et al., 2008a, b), which in turn provide proteins to humans.

It is expected that climate changes will make droughts even more unpredictable, and measure should be taken in rural communities to handle such future difficulties (Meadovs, 2011). Ethiopia, being a food insecure country and in protracted crisis (FAO, 2010), would benefit from increased and improved use of enset. Enset cultivation is a straight-forward method to facilitate for people to achieve independent livelihood security (Negash and Niehof, 2004). Enset can improve food security in drought-prone areas where the climate is warm but not too hot, thus in much larger areas than where currently used. This paper aims at contributing to food security in a changing climate by generally increasing the knowledge about enset as a food and fodder resource by analysing the nutritive values in fractions and combinations of fractions used, gaining more information about the variation within the species, and especially to analyse the amino acid content and concentration of the enset corm.

MATERIALS AND METHODS

Enset plant parts were collected from three enset plants at inflorescence (matured, that is, normal harvest for maximum kocho yield) of about 6 to 7 years age, and a fourth plant short before inflorescence (nearly matured). The plants were ca. 7 m high and had a pseudostem circumference of ca. 1.5 m. The plants were harvested during the short rainy season in March 2004 from a peasant enset farm in Tulla Kifle (N 07°03'15', E 38°30'52''), close to Hawassa in southern Ethiopia. The plants had been propagated vegetatively for many generations and belonged to clones traditionally cultivated locally. Climate at the site is hot steppe (BSh), on the border to savannah (Aw), according to the Köppen-Geiger classification (Peel et al., 2007). One of the three matured plants was used for collecting the leaves, pseudostem and corm (that is, the underground stem) separately, one was used to collect leaves and pseudostem together (above ground parts) and one to collect pseudostem, leaf and corm together (whole plant, except roots, which are fibrous and are always left in soil at harvest); for the two latter plants, original fraction sizes between different parts were kept throughout handling and analyses. Only leaves of the younger plant were collected. At the nutrition laboratory at Hawassa College of Agriculture, plant material was chopped and thoroughly mixed. Dry matter (DM) was determined as the weight differences between fresh samples and samples dried at 105°C. The dried material was grounded and sieved through 2 mm mesh size.

At Institute of Animal Science and Technology, Rostock University, Germany, samples were again dried at 105°C, grounded and sieved through 1 mm mesh size before further analyses. The Weende system (Burns, 2011) was used to separate samples into general fractions. Ash was defined as the residue after combustion of known amounts of DM at 600°C and organic matter (OM) as DM−ash. Crude fibre (CF) fraction was determined in Foss Analyser with subsequent ashing. Crude fat (ether extract, EE) was determined after samples were boiled (35°C) and extracted with petroleum ether in Gerhardts-Soxtherm-Apparatus. Nitrogen free extractives (NFE) that is, soluble carbohydrates were calculated as OM−(CF+CP+EE).

Total nitrogen (N) content was determined with Macro-N-Apparatus (ELEMENTAR Analysensysteme GmbH, Germany) following the Dumas method (Schuster et al., 1991), and crude protein (CP) amount was calculated as N×6.25. Cellulose, hemicellulose and lignin fractions of cell walls were determined by fibre analyses according to Goering and van Soest (1970). Cell content was washed away and cell wall fractions were separated in (i) Neutral Detergent Fibre (NDF) that is, the total fibre content after boiling in alkali solution, (ii) Acid Detergent Fibre (ADF) that is, the total fibre content after boiling in acid solution and (iii) Acid Detergent Lignin (ADL) that is, the lignin content after boiling in acid solution. Cellulose and hemicellulose contents were calculated as ADF−ADL and NDF−ADF, respectively. Starch and sugar contents were determined with the enzyme method developed at Rostock University (Personal communication: Friedel, K., Institute for Farm Animal Science and Technology, Rostock University). Major and trace minerals were analysed by atomic absorption spectrophotometry (AAS) at Landwirtschaftliche Untersuchungs- und Forshungsanstalt (LUFA), Rostock.

Fractions of dry matter, organic matter, chemical and mineral contents were used for overall comparison of enset fractions by principal component analysis (PCA) StatSoft, 2011. *In vitro* digestible organic matter ($DOM_{in\ vitro}$) and *in vitro* indigestible organic matter ($iOM_{in\ vitro}$) were determined according to the modified cellulase method and thereafter the *in vivo* digestible organic matte ($DOM_{in\ vivo}$) was estimated by $gDOM_{in\ vivo} = 0.93{*}gOM - 0.89{*}iOM_{in\ vitro}$, (Friedel and Poppe, 1990). Metabolizable energy (ME) was calculated following the conversion method of Friedel and Poppe (1990), that is, MJ ME kg^{-1} DM=0,0146×gDOM-0,0004×giOM+0,0026×gCP, while MJ NE_L (Net $Energy_{Lactation}$) was calculated from ME following GfE (2001) and Moe et al. (1972); recalculating MJ from Mcal. For the corm, the amounts of twenty amino acids were measured using high-performance liquid chromatography (HPLC) (Schmadzu, Japan) and Kationentrennsäule (LCA-K06, GROM Analytic + HPLC GmbH, Germany).

RESULTS

Composition

Dry matter (DM) content of enset was 11 to 15% of fresh weight and the organic matter fraction of DM was around 90% (Table 1). As fractions of DM, crude protein content was 3 to 13%, crude fat 0.4 to 5%, crude fibre 6 to 24% and soluble carbohydrates ca. 50 to 80% for different parts of enset (Table 1). Leaves had the highest concentration of protein, fat, sugar, fibre, cellulose, hemicellulose and lignin, and least of soluble carbohydrates and starch (Table 1). The corm had the

Table 1. Relative composition of *Ensete ventricosum*. Dry matter as percentage of fresh weight; other components as percentage of dry weight. Leaves, pseudostem and corm were analysed separately, and in addition leaves + pseudostem (above ground) and leaves + pseudostem + corm (whole plant) were analysed as units keeping original relation (DM) of plant parts. Plants were 6-7 years and harvested during the short rainy season in Ethiopia. Except one set of leaves, all plants were at inflorescence.

Variable	Leaves[1]	Leaves[2]	Corm	Pseudostem	Above ground	Whole plant
Dry matter	12.90	10.88	14.08	14.59	14.54	14.34
Organic matter	83.23	88.34	91.83	92.54	92.00	90.87
Ash	16.80	11.70	8.17	7.47	8.01	9.13
Crude protein	13.15	12.41	3.33	3.65	4.24	5.98
Crude fat	5.23	2.49	0.41	0.36	0.73	0.84
Crude fibre	20.38	24.13	5.65	7.51	9.64	9.48
Soluble carbohydrates	44.47	49.31	82.44	81.02	77.39	74.57
Cellulose	25.94	32.96	8.75	10.81	14.16	14.95
Hemicellulose	23.54	20.69	5.93	8.61	5.55	9.39
Lignin	3.26	4.24	2.11	0.79	0.88	1.97
Starch	1.21	2.45	71.19	64.93	59.76	60.62
Sugar	8.44	11.14	-	2.28	4.11	0.85

[1]At flower bud development, [2]At inflorescence.

Table 2. Mineral composition (as weight fraction of dry matter) of *Ensete ventricosum*. Leaves, pseudostem and corm were analysed separately, and in addition leaves + pseudostem (above ground) and leaves + pseudostem + corm (whole plant) were analyzed as units keeping original relation of plant parts. Except one set of leaves, all plants were at inflorescence.

Unit	Mineral	Leaves[1]	Leaves[2]	Corm	Pseudostem	Above ground	Whole plant
%	Na	0.02	0.11	0.03	0.02	0.03	0.01
	P	0.18	0.21	0.11	0.12	0.07	0.15
	K	3.08	3.90	3.06	3.07	3.19	3.40
	Ca	2.18	0.83	0.37	0.41	0.22	0.33
	Mg	0.29	0.22	0.15	0.15	0.09	0.13
mg/kg	Se	0.08	0.08	0.07	0.06	0.06	0.05
	Cu	2.5	3.2	2.9	2.7	1.9	1.3
	Mn	188.0	124.0	43.3	61.0	50.2	64.6
	Co	-	0.01	-	0.01	0.01	0.01
	Zn	19.7	66.8	90.0	116.0	88.5	48.0

[1]At flower bud development, [2]At inflorescence.

highest concentration of most soluble carbohydrates and starch, and least of protein, fibre, cellulose and sugar, while the pseudostem had least of lignin (Table 1). The mineral content was 3 to 4% of potassium (K) and below 2%, in most cases below or much below 1%, of all other (Table 2). Leaves had the highest concentration of P, Ca, Mg, Se and Mn, the pseudostem had the highest concentration of Zn and corm had the least of K and Mn (Table 2).

Digestibility and energy for ruminants

Leaves differed markedly against the other fractions regarding digestibility and energy (Table 3), having the lowest concentration of organic matter and the lowest fraction of metabolizable energy and net energy lactation, despite the highest fraction of gross energy (Table 3). Net energy for lactation was ca. 7.5 MJ kg^{-1} DM for corm and pseudostem and ca. 5.5 MJ kg^{-1} DM for leaves (Table 3).

Amino acids in corm

The corm contained 17 of 20 amino acids, in concentrations from 1.2 to 8.7 g per 100 g protein and from 25.6 to 186.6 mg per 100 g fresh corm (Table 4). The amino acids not present in enset corm were

Table 3. Digestible organic matter (DOM) and energy content of different *Ensete ventricosum* fractions. $\text{DOM}_{in\ vitro}$ was measured; $\text{DOM}_{in\ vivo}$ and indigestible organic matter ($\text{iOM}_{in\ vivo}$) were calculated.

Variable	Leaves[1]	Leaves[2]	Corm[2]	Pseudostem[2]	Above ground[2]	Whole plant[2]
$\text{DOM}_{in\ vitro}$ % OM	75.14	75.05	94.50	93.18	95.63	92.64
$\text{DOM}_{in\ vivo}$ % OM	70.88	70.79	88.09	86.93	89.11	86.45
$\text{DOM}_{in\ vivo}$ g kg^{-1} DM	590.00	625.00	815.00	800.00	818.00	786.00
$\text{iOM}_{in\ vivo}$ g kg^{-1} DM	242.00	258.00	110.00	120.00	100.00	123.00
MJ GE kg^{-1} DM	17.30	17.70	16.80	16.90	16.60	16.80
MJ ME kg^{-1} DM	8.90	9.30	11.90	11.70	12.00	11.60
MJ NE_L kg^{-1} DM*	5.20	5.50	7.60	7.40	7.60	7.30
MJ NE_L kg^{-1} DM**	5.40	5.80	7.60	7.50	7.60	7.30

[1]At flower bud development, [2]At inflorescence, GE: gross energy, ME: metabolic energy, NE_L: Net energy for lactation, * Calculated as MJ NE_L kg^{-1} DM = 0,6(1+0,004(ME/GE-57))MJ ME (GfE, 2001), ** Calculated as MJ NE_L kg^{-1} DM = 0,703ME-0,795 (Moe et al., 1972).

Table 4. Amino acid content of raw corm of enset (*Ensete ventricosum*), harvested at plant inflorescence and comparison with kocho (food type from enset pseudostem), sweet potato and potato.

Variable	Amount (g per 100 g protein)		Amount (mg per 100 g fresh)		
Amino acid	Enset corm	Kocho[1]	Enset corm	Potato[2]	Sweet potato[3]
Alanine (ala)	5.1		108.8	-	80.1
Arginine (arg)	3.3		70.4	82.08	31.4
Aspargine (asn)	-		-		
Aspartic acid (asp)	6.9		147.2	495.00	123.1
Cysteine (cys)	1.3	1.72[1]	27.7		
Glutamine (gln)	-		-		
Glutamic acid (glu)	8.7		185.6	280.00	262.5
Glycine (gly)	4.8		102.4	82.63	35.4
Histidine (his)	1.4	2.06	29.9	32.25	42.9
Isoleucine (ile)	3.1	4.12	66.1	79.00	34.0
Leucine (leu)	5.8	7.56	123.7	124.23	76.1
Lysine (lys)	3.0	5.50	64.0	56.39	62.1
Methionine (met)	1.2	1.72[1]	25.6	22.68	1.3
Phenylalanine (phe)	3.4	3.44[1]	72.5	114.00	41.4
Proline (pro)	3.2		68.3		
Serine (ser)	3.5		74.6	23.30	71.1
Threonine (thr)	3.1	2.75	66.1	62.90	29.4
Tryptophan (trp)	-	2.75	-	-	
Tyrosine (tyr)	1.9	3.44[1]	40.5	46.18	0.5
Valine (val)	3.9	5.50	83.2	180.00	52.8

[1]Abebe et al. (2006): met + cys and phe+tyr, respectively, were merged; here reported as half the measured amount for each. [2]Elfaki and Abbsher (2010). [3] Shin et al. (2011). - Not detected; blank: not reported.

aspargine, glutamine and tryptophan (Table 4).

Differences between fractions

Principal component analysis showed that the leaves differed substantially from the other fractions regarding the first PCA factor, being positive correlated to the presence of protein, fat sugar and fibre and negatively correlated to starch. The X-axis (Factor 1) explains 63.48% of the overall differences between plant fractions and combinations of plant fractions. The fractions that

Table 5. Overall, reciprocal comparison (Tukey test) between fractions of enset. Analysed data was relative amounts of chemical (Table 1) and mineral (Table 2) contents, digestible organic matter (DOM g kg^{-1} DM) and energy (MJ ME kg^{-1} DM).

Fraction	Compared fraction	Significance	p
Leaves[1]	Leaves[2]	ns	0.996
	Corm	**	0.007
	Pseudostem	*	0.037
	Above ground	*	0.020
	Whole plant	*	0.021
Leaves[2]	Corm	**	0.002
	Pseudostem	**	0.008
	Above ground	**	0.004
	Whole plant	**	0.004
Corm	Pseudostem	ns	0.995
	Above ground	ns	0.999
	Whole plant	ns	0.999
Pseudostem	Above ground	ns	0.999
	Whole plant	ns	0.999
Above ground	Whole plant	ns	0.999

[1] At flower bud development, [2] At inflorescence.

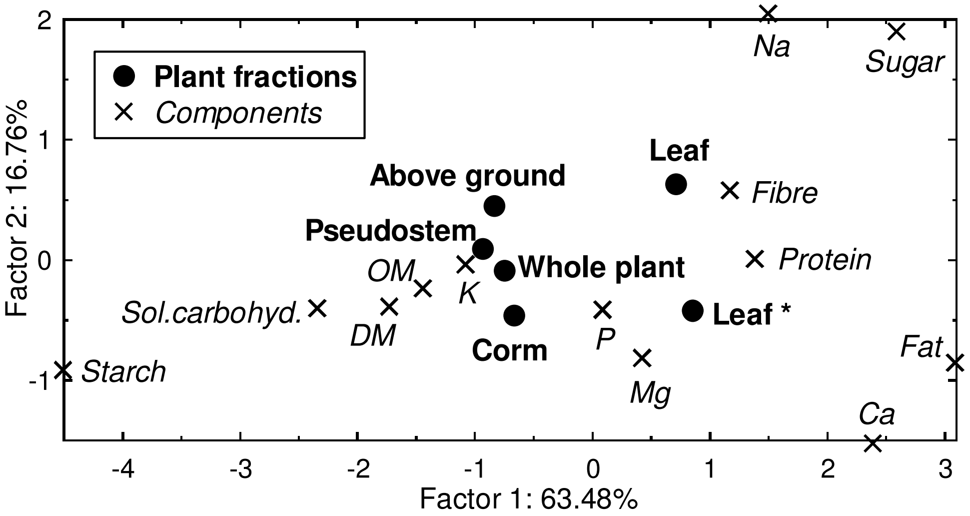

Figure 1. Principal component analysis based on chemical and mineral content of *Ensete ventricosum* fractions, including projections of important components. Leaves, pseudostem and corm were included as separate fractions and leaves + pseudostem (above ground) and leaves + pseudostem + corm (whole plant) were merged, keeping original ratios. Plants were harvested at inflorescence, except one set of leaves (*) that was harvested at flower bud development. DM=dry matter, OM = organic matter.

included corm were negatively correlated with sugar content (Y-axis, Figure 1). When analysing the general composition as relative to average for each component, there were significant differences between the leaf fractions and all other fractions (Table 5). The leaf fractions did not differ from each other, neither were there general differences between corm, pseudostem and combined fractions (Table 5).

DISCUSSION

All fractions of enset had high water content (85 to 90%, Table 1), which is advantageous when drinking water for animal is scarce during dry periods. The high water holding capacity is one factor that contributes to enset drought tolerance, other factors are well protected apical meristem and deep root system (Tensaye et al., 1998), making it a food and fodder source during droughts for many self subsidence farmers. In Ethiopia, enset is cultivated in many home-gardens (Abebe et al., 2010), and it is amazing to observe the green and large plants among failing annual crops during droughts.

Leaves

Enset leaves (botanically the leaf blades; the enset leaf stalks form the pseudostem) are not used as food for humans, but are used as wrapping material for food when storing or baking, and are important as fodder. During droughts, green enset leaves can be cut off and given to animals. Thus, enset leaves are especially important as fodder resource when grasslands and annual crops fail due to extended, unpredictable, droughts. The protein content of the leaves, ca. 13% (Table 1), was markedly higher than that of the pseudostem and corm (Table 1; Tolera and Said, 1994; Nurfeta et al., 2008a), which is in line with the general fact that more proteins are found in the leaves than in the stems or roots of plants. Protein content of enset leaves was from 10 to 23% when analyzed from 118 different landraces grown at different locations in Ethiopia (Fekadu, 2009). Enset leaves have one of the highest protein concentrations of available fodder sources during the dry season in Wolaita, Ethiopia, (Tolera and Said, 1994), much higher than for example timothy hay (Woodward et al., 2011). The minimum level required for proper rumen function is 7.5% crude protein (van Soest, 1982) and for small breed cows (live weight 454 kg, milk production: 10 kg with 4% fat) during lactation it is 14% (NRC, 2001). Because Ethiopian breeds are generally small, 200 to 400 kg, the protein content of enset leaves (Table 1) fulfil the requirements. Enset leaves contained 20 to 24% crude fibre (Table 1), thus well exceeded the 16 to18% that are needed to avoid digestive problems for dairy cattle and other lactating ruminants (Todorov, 1988). The amount of cellulose and hemicellulose in enset leaves resembled those of timothy hay (Woodward et al., 2011).

Compared to the other enset fractions, the starch content of leaves was low and the sugar content was high (Table 1), which is the expected distribution within plants. The sugar amount identified enset leaves as suitable for silage. For ruminants, enset leaves contained more than sufficient amounts of K, Mg, Zn and Mn, still all were below the toxicity level, but was fully deficient regarding P, Na, Cu, Co and Se (Table 2; NRC, 2001). Regarding Ca, enset leaves (Table 2) had higher concentration than hay from natural pastures in Ethiopia (Gizachew et al., 2002), and was within the acceptable range for cattle (NRC, 2001).

Calculated digestibility *in vivo* (Table 3) was similar to digestibility *in sacco* (Nurfeta et al., 2008a), and show less digestibility for leaves than for the other parts of enset (Table 3), while still higher levels than the grass *Panicum maximum* (Sato et al., 1992). Metabolizable energy was ca. 9 MJ kg^{-1} DM for the leaves (Table 3), which is higher than reported by Nurfeta et al. (2008a), showing there is variation between enset plants, which may be due to landrace and/or local environment. The effect of growth situation on enset production should be investigated further. Net energy for lactation in leaves was less than in the other enset fractions (Table 3); leaves had 5-6 MJ NE_L kg^{-1} DM; the corresponding value for barley is ca. 7-9 (Van der Honing and Steg, 1984). Enset leaves are thus a generally suitable feed for ruminants, but require complement fodder containing some minerals and energy to be optimal. The leaves constitute a relatively small fraction of the enset plant when mature. Therefore, even though they differed from the other fractions, the qualities of leaves had hardly any influence on the overall qualities of the combinations of fractions making up 'aboveground part' (that is, leaves + pseudostem) or 'entire plant' (that is, leaves + pseudostem + corm) regarding nutritive values (Figure 1, Table 5).

Pseudostem

The pseudostem is the main source of human food from the enset crop. Usually residuals are given to animals, but occasionally also the entire pseudostem is used as fodder, e.g. when the plant is uprooted to cook the corm as a root crop for humans. The pseudostem was rich in soluble carbohydrates and starch, while it contained relatively small amount of protein (Table 1), less than in corn (Abebe et al., 2006) and potato (Elfaki and Abbsher, 2010). The fraction of starch in enset pseudostem was similar to sorghum (Todorov, 1988; Table 1) which has the highest concentration found among cereals.

When enset pseudostem is used to prepare food for humans, the most common way is to make “kocho” that in turn can be baked to different kinds of bread. Kocho is a starch-rich product (relatively solid) achieved from decorticating (scrapping/fine-cutting) and fermentation. A small fraction of liquid may be separated during kocho preparation; that fraction is called bulla. Kocho and bulla are energy rich: 6.46 and 8.46 MJ kg^{-1} fresh weight, respectively (Pijls et al., 1995). The nutritive values of kocho and bulla satisfy human’s need in similar extent as cereal flours (Atlabachew and Chandravanchi, 2008). Thus, the qualities of enset at harvest (Tables 1 and 2) are retained in the food products. The relatively low protein content (Table 1) and the amino acid composition (Abebe et al., 2006) make it recommendable to add legumes to a kocho-based diet, especially if no or only little animal products are consumed.

The fibre content in the pseudostem (Table 1) was too low to make it a suitable fodder for ruminants; there should be at least 16 to 18% fibre to not cause digestive problems (Todorov, 1988). The pseudostem is a large fraction of the entire plant at maturity (time for flowering), and therefore the merged fractions (aboveground parts and the entire plant) contained less fibre than the required for ruminants (Table 1, Figure 1, Todorov, 1988). The problem with low fibre content can be avoided if the residues of pseudostem, after kocho preparation, are given to animals together with leaves or grass hay is mixed with the pseudostem. In the pseudostem, as in the leaves, the minerals K, Mg, Zn and Mn (Table 2) occurred in suitable amounts for ruminants, while Ca (Table 2) was just enough to maintain the animal itself, not enough for lactation (NRC, 2001). Regarding energy content, the pseudostem was similar to oat grain in metabolizable energy and similar to barley in net energy for lactation (Table 3, NRC, 2001). Combining leaves and part of a pseudostem from a mature plant can give suitable amounts of fibre and energy for ruminants. Young enset plants have less pseudostem volume in relation to leaf blades; to what extent entire young plants are suitable fodder remains to be investigated.

Corm

The corm, botanically the underground stem, is used when propagating enset vegetatively. From a pre-treated and buried corm new sprouts can emerge; the number of sprouts depends on landrace and corm pre-treatment (Karlsson et al., 2013). In this way, enset has been propagated since ancient times, and each landrace is theoretically one clone; in reality, plants named as the same landrace may belong to different clones and plants with different names may belong to the same clone – further studies are needed to properly identify clones. Alternatively to be used for propagation, the corm can be cooked and eaten. It is a trustable food source because it can be uprooted and used whenever during the life span of the plant, for example during extended droughts when cultivation of annual cereals has failed. Within enset plants, the corm had the smallest fibre and the largest starch concentration (Table 1), which makes it resemble a very large potato. Taro corm, which can be intercropped with enset, has circa 35% starch (Mare and Modi, 2012). The amino acid composition of enset corm (Table 4) was similar to kocho, sweet potato and potato regarding concentration of several amino acids (Table 4; Abebe et al., 2006; Elfaki and Abbsher, 2010; Shin et al., 2011). These food sources should be complemented with other kinds of food to provide protein in general and specifically the amino acids being deficient in enset kocho and the rootcrops. A recommended protein source is kidney beans (Abebe et al., 2006). There is cultivation of various beans in Ethiopia, and common bean (*Phaseolus vulgaris*) is frequently grown in homegardens (Abebe et al., 2010); this habit should be encouraged.

When enset corm is fed to animals, it is given in addition to other fodder sources. Thus, the animals can benefit from the large fraction of starch (Table 1) and the high energy (Table 3). Complementary fodder should have relatively high concentration of protein and fibre to provide a balanced diet for ruminants; enset leaves can be a part of such a complement, since they differed from the other parts of an enset plant in this regard (Figure 1, Table 5).

Conclusion

Even though the general result of enset nutritive values are similar between studies, there are differences between plants and also regarding distribution within plants. For example for crude protein (which occurs in low amount in enset), Fekadu and Ledin (1997) reported similar amount in corm but circa 1.4 times more in pseudostem compared to our results (Table 1). Further, mineral content of enset differ between reports (Table 2; Nurfeta et al., 2008b; Fekadu, 2009). It is not surprising that there are differences: hundreds of different enset clones are utilised by farmers and the plants used for analyses grew at different places at different time periods and thus in different environments and soil qualities. Differences between recorded values should be taken into account when providing advice to users.

The tradition to grow enset in drought-prone areas in Ethiopia gives food and fodder in the current climate, and will be even more important if rainy and dry periods will occur more random in the future, as predicted (Meadovs, 2011). Enset is high-yielding (Tsegaye and Struik, 2001), can be harvested during different times of the year and the product kocho is possible to store long times without refrigerators. Enset could be an important part of the diet for humans as well as ruminants in much larger areas than currently used. Legumes can be, and are often, intercropped with enset. Together these products constitute a very good main part of a balanced diet. We conclude that the cultivation of enset should be encouraged in areas with suitable environment and with drought problems, since it can substantially improve the food security for people.

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