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ORIGINAL ARTICLE

Feeding value of enset (*Ensete ventricosum*), *Desmodium intortum* hay and untreated or urea and calcium oxide treated wheat straw for sheep

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Summary

Feed intake, *in vivo* nutrient digestibility and nitrogen utilization were evaluated in male sheep fed different fractions (leaf, pseudostem, corm, whole plant) of enset, untreated or 2% urea- and 3% calcium oxide-(CaO or lime) treated wheat straw and *Desmodium intortum* hay as sole diets. All feeds, except *D. intortum* hay and enset leaf had low crude protein (CP) content. Non-fiber carbohydrate contents were higher in enset fractions, especially in pseudostem and corm relative to other feeds. Enset leaf and pseudostem had high calcium, phosphorus and manganese contents. Corm, whole enset and *D. intortum* hay were rich sources of zinc. Daily dry matter and CP intakes were higher ($p < 0.05$) in sheep fed *D. intortum* hay (830 and 133 g, respectively) than those fed pseudostem (92 and 7.8 g, respectively). Organic matter digestibilities were highest for corm (0.780) and whole enset (0.776) and lowest for *D. intortum* hay (0.534) and untreated wheat straw (0.522). The CP digestibility ranged from 0.636 in *D. intortum* hay to 0.408 in corm. Nitrogen (N) balance was highest ($p < 0.05$) in *D. intortum* hay (10.4 g/day) and lowest in corm (−1.3 g/day). Enset leaf could be a useful protein supplement whereas the pseudostem and corm could be good sources of energy.

Introduction

Enset (*Ensete ventricosum*) is a herbaceous perennial monocarpic crop which morphologically resembles a banana plant although banana is in a different but related genus *Musa*. Enset has paddle-shaped leaves, pseudostem and an underground corm. Our unpublished data showed that the pseudostem, corm, leaf lamina and leaf midrib make up 53%, 24%, 11% and 12%, respectively, of the enset plant on a dry matter (DM) basis. The pseudostem may attain a diameter of 1 m and a height of 12 m (Birmeta et al., 2002). Cultivated enset grows in a wider area comprising the central, south and south-western parts of Ethiopia and it is used as a staple food by 7–10 million people and its use is expanding in other parts of the country (Tsegaye and Struik, 2000).

In addition to its use as a source of carbohydrate-rich human food, enset is utilized as animal forage. Cut fresh enset leaves contribute to livestock diets in all areas where enset is grown (Tolera, 1990; Fekadu, 1996) and they may be used for as long as 7–8 months (Yilma, 2001) and even throughout the year (Karin and Alemu, 1995) in some agro-ecological areas such as the highlands of Sidama and Gedeo. Sometimes the whole enset plant is chopped and fed to livestock during the dry seasons (Tolera, 1990; Fekadu, 1996). Desta and Oba (2004) showed that about 85% of the farmers in the Bale highlands of southern Ethiopia provide enset leaves, corm, pseudostem, fluid and processed by-products of enset to livestock during the dry season.

In enset-livestock-cereal production systems of Ethiopia, the smallholder farmers feed different enset fractions with cereal straws during the long dry season. However, information on feeding value of such combination of feeds is very limited. Nutritionally, cereal straws are poor in energy, nitrogen (N) and minerals and have low digestibility and intake. Feeding pseudostem and corm that are poor in crude protein (CP) (Fekadu and Ledin, 1997) can aggravate the problem of protein deficiency. Improvement in nutritive value of crop residues through chemical treatment is well documented (Sundstøl and Owen, 1984). Despite the demonstrated potential of these technologies, their application is not widespread as one would expect in developing countries (Owen, 1994). One of the obstacles hindering adoption of straw treatment by subsistence farmers could be the cost of chemicals. Trach et al. (2001) indicated that rice straw treatment using 3% lime with a low level of urea (2%) is of particular interest wherein lime, which is cheaper than urea may act as the main alkalinity enhancer and urea, in addition to its treatment and mould-inhibiting effects can supplement enough nitrogen for rumen micro-organisms. However, alkali treatments of cereal straws may have variable and disappointing effects on animal production (Williams et al., 1997) because of various factors such as straw genotype (Habib et al., 1998) and level of calcium hydroxide and urea, moisture, treatment time and temperature (Zaman et al., 1994). We have planned to carry out series of experiments in which different enset fractions and *Desmodium intortum* hay were supplemented to a basal diet of urea- and lime-treated or untreated wheat straw in sheep feeding. However, as a preliminary work, the main objective of this study was to investigate the digestibility and nitrogen balance in sheep fed different enset fractions, urea- and lime- treated or untreated wheat straw and *D. intortum* hay as a sole diet.

Materials and methods

Description of experimental site, experimental animals and their management

The experiment was conducted at the Hawassa University, College of Agriculture which is situated 275 km south of Addis Ababa at 7°4′N latitude and 38°31′E longitude at an altitude of 1 650 m above sea level. The average annual rainfall is 1 110 mm.

Twenty-one, 1-year-old male sheep with a mean live weight of 26.3 ± 0.5 kg were purchased from local market. Before the start of the experiment, the sheep were de-wormed against internal parasites with the injection of Kepromec (Ivermectin) as prescribed by the manufacturer. The animals were kept in individual pens and adapted to their respective experimental feeds for 2 weeks before the commencement of the experiment.

Feed preparation

Desmodium intortum hay was made at the University farm (Awassa, Ethiopia) in December 2004 and harvested at approximately 10% bloom stage. It was hand-chopped to about 5-cm lengths before feeding. Bales of wheat straw were bought from Kuyera Adventist College (Kuyera, Ethiopia). Untreated straw was also chopped before feeding. For treatment of wheat straw, three pits with a volume of 1 m^3 each were dug in hay shed for ensiling. The wheat straw was hand-chopped with a knife before treatment to facilitate packing and feeding. The straw was treated with 3% calcium oxide or lime (CaO) and 2% fertilizer grade urea solution. Urea and CaO were dissolved in water to assure 50% moisture in the treated material (Zaman et al., 1994). Known weight of wheat straw was added into the pit. The suspension was sprayed on the straw layer-by-layer and thoroughly mixed. It was pressed by trampling before the next layer was placed and finally sealed using polyethylene sheet. The pit was opened after 3 weeks as per the recommendations of Zaman et al. (1994) and Sirohi and Rai (1998).

Mature enset of the same variety was bought from the same farmer and transported to the experimental site every second day. It was fractionated into leaf (leaf lamina and leaf midrib), pseudostem and corm. Each fraction was chopped before feeding it on a fresh basis. Preparation of enset fractions to be fed the next morning took place in the afternoon of the day before. Whole enset was made up of approximately equal proportions of leaf, pseudostem and corm on a DM basis.

Experimental design and dietary treatments

Three male sheep were assigned to each of the seven experimental diets in a completely randomized design. The experimental diets included enset leaf, enset pseudostem, enset corm, whole enset plant, untreated wheat straw, urea- and lime- treated wheat straw and *D. intortum* hay which were fed as sole diets.

Feed was provided at 3% of the body weight of sheep on a DM basis. The daily allowance was provided in three equal feedings at 9:00, 13:00 and 22:00 hours. Refusals were collected every morning and bulked for 7 days for each lamb. Representative samples of *D. intortum* and untreated straw were kept at room temperature until processing for chemical analysis. Samples of wet feeds (enset fractions and treated straw) were taken from each feed at each weighing time and kept in a freezer. As there were no freeze-drying facilities in the study area, urea- and lime- treated wheat straw were dried at 50 °C for 48 h (Trach, 2000). Enset fractions were dried at 65 °C for 72 h as described by Fekadu and Ledin (1997). *Desmodium intortum* hay and untreated straw were dried at 65 °C for 48 h. The nutrient intake was calculated as dietary nutrient offered minus dietary nutrient refused.

Faeces and urine collection

Sheep were put in individual metabolic cages and allowed an adaptation period of 7 days followed by a collection period of 7 days. Faeces were collected in faecal bags attached to the sheep. Faeces from each lamb were weighed and 10% of the daily output for the 7-day collection period was taken and bulked in a freezer. Separate samples of faeces were dried daily at 105 °C overnight to determine the DM content. The total urine output was collected in bottles containing 100 ml of 10% HCl for each lamb. Ten per cent was taken, bulked and stored in a freezer. At the end of the experiment, samples of faeces and urine were kept at room temperature and allowed to thaw for 24 h before sub-sampling for each lamb. Samples of faeces to be used for chemical analysis other than N were dried at 65 °C for 48 h. After that they were milled and kept in tightly covered plastic bottles until analysis. Fresh faeces for nitrogen determination were left in a freezer until analysis.

Chemical analysis

Dry matter content of feed offered and refusal samples was determined by drying the sample at 105 °C overnight. Ash was determined by combusting the sample at 550 °C for 5 h. Total nitrogen was determined using micro-Kjeldahl method. Crude protein was calculated as $N \times 6.25$. Neutral detergent fiber (NDF) and acid detergent fiber (ADF)-ash were analyzed according to Van Soest et al. (1991). Sulphite and α-amylase were not used as reagents in the determination of NDF. Acid detergent fiber contents were determined according to AOAC (1990). Both NDF and ADF were reported exclusive of residual ash. Acid detergent lignin (ADL) was determined on ADF residue (Robertson and Van Soest, 1981). Cellulose and hemicellulose were calculated as ADF minus ADL and NDF minus ADF respectively. Ether extract was determined gravimetrically after extraction using petroleum ether, in a Soxhlet extractor (AOAC, 1990). Non-fiber carbohydrate (NFC) content of feeds was calculated as 100 − (NDF + CP + ether extract + ash) according to Ferreira and Mertens (2005). Samples were prepared for mineral analysis by the wet digestion method using concentrated sulphuric acid in the presence of hydrogen peroxide. The concentrations of calcium (Ca), potassium (K), magnesium (Mg), copper (Cu), manganese (Mn) and zinc (Zn) were analyzed using atomic absorption spectrophotometer. Phosphorus (P) was determined by continuous flow auto-analyzer (Chemlab, 1978). Sample digestion for P determination was carried out using the same procedure as for Kjeldahl digestion using a block digestor. Metabolizable energy (ME) of feed was estimated from the digestibility of organic matter in DM (DOMD) by the formula, ME (MJ/kg DM) = $0.15 \times$ DOMD% (MAFF, 1984). All samples were analyzed in duplicates.

Data analysis

One way analysis of variance was carried out using the general linear model procedure of Statistical Analysis Systems (SAS, 2001) to determine the effects of treatment on intake, apparent digestibility and N balance. Where significant difference occurred, Tukey test was used for mean separation.

Results

Chemical composition

The chemical composition of the feeds used in this experiment is shown in Table 1. The DM content ranged from 63 g/kg in pseudostem to 927 g/kg in untreated wheat straw. Among the enset fractions, corm had the highest DM content. The ash content varied from 84 to 141 g/kg DM. There was significant increase in ash content in the treated straw because lime was used in the treatment. The NDF content ranged from 231 g/kg DM in corm to 743 g/kg DM in untreated wheat straw. The highest ADF was in urea- and lime- treated wheat straw and the lowest in corm. The ADL content was highest in *D. intortum* hay and lowest in corm. All enset

Table 1 Chemical composition* of leaf, pseudostem, corm, whole enset, untreated straw, treated straw and *Desmodium intortum* hay

	Enset fractions				Wheat straw		
Parameter	Leaf	Pseudostem	Corm	Whole enset	Untreated	Treated	*Desmodium intortum* hay
Dry matter (DM) (g/kg)	101	63	144	100	927	561	926
In g/kg DM:							
Ash	138	135	84	119	96	132	141
Neutral detergent fiber	562	415	231	501	743	713	518
Acid detergent fiber	366	267	113	260	495	502	414
Acid detergent lignin	70	29	20	51	52	64	122
Ether extract	48	17	8.0	25	15	11	32
Crude protein	123	62	27	67	30	45	160
Cellulose	296	238	93	209	443	438	291
Hemicellulose	196	148	118	241	247	212	105
Non-fiber carbohydrates[a]	129	371	650	288	116	99	152
Acid detergent fiber-ash	10.4	3.7	ND	5.2	29	29	22

ND = Not Detected.

*Mean of two observations.

[a]Non-fiber carbohydrate was calculated as 1000 − (NDF + CP + ether extract + ash).

fractions except the leaf had lower lignin content than straw and *D. intortum* hay. The CP content of the experimental feeds ranged from 27 g/kg DM in corm to 160 g/kg DM in *D. intortum* hay. Treatment of wheat straw with lime and urea increased the CP content from 30 g/kg DM in the untreated wheat straw to 45 g/kg DM in the treated straw. Differences were observed in the CP content of offered and refusal samples: leaf (123 vs. 77.7 g/kg DM), pseudostem (61.5 vs. 54.1 g/kg DM) and whole enset (66.9 vs. 55.2 g/kg DM) respectively. The protein content was 4.53% units higher in offer than the refusal in leaf.

There was large variation in the NFC content among the experimental feeds with higher values in enset fractions. The highest NFC was observed in corm followed by pseudostem and whole enset and the lowest in treated straw.

Mineral concentration

The Ca content of the feeds varied from 1.6 g/kg DM in corm to 17.4 g/kg DM in urea- and lime-treated straw (Table 2). Corm and untreated wheat straw were poor sources of Ca. Enset leaf had the highest Ca content as compared to other enset components. Mixing leaf, pseudostem and corm as in whole enset raised the level of Ca to 5.5 g/kg DM compared with 4.2 and 1.6 g/kg DM in pseudostem and corm respectively. The P content ranged from 1.0 to 4.1 g/kg DM, the lowest in straw and the highest in pseudostem with the highest ratio of Ca to P as 17.4:1 in treated straw. Magnesium varied from 0.4 g/kg DM in untreated straw to 2.7 g/kg DM in enset leaf. Pseudostem, corm and straws were poor in Mg. All enset fractions had K

Table 2 Mineral concentration of enset leaf, enset pseudostem, enset corm, whole enset, untreated straw, treated straw and *Desmodium intortum* hay

	Enset fractions				Wheat straw			
Minerals	Leaf	Pseudostem	Corm	Whole enset	Untreated	Treated	*Desmodium intortum* hay	Daily requirement[a]
Macrominerals (g/kg DM):								
Ca	11.2	4.2	1.6	5.5	1.7	17.4	13.8	2.0–8.2
P	3.9	4.1	2.4	2.9	1.0	1.0	2.3	1.6–3.8
K	41.0	49.0	29.8	41.5	15.5	16.2	21.8	5.0–8.0
Mg	2.7	1.1	0.6	1.5	0.4	0.7	2.1	1.2–1.8
Microminerals (mg/kg DM):								
Cu	2.2	0.9	1.7	2.2	0.6	2.5	1.2	7–11
Mn	194	47	33	89	28	79	143	20–40
Zn	10.8	8.2	61.7	41.8	2.1	3.8	26.7	20–33

[a]Daily requirement for all classes of sheep (NRC, 1985).

between 30 and 50 g/kg DM which is higher than that of straws and *D. intortum* hay. The Cu content was low in all feeds, with the highest for treated wheat straw. All the feeds were rich in Mn which ranged from 28 mg/kg DM in untreated straw to 194 mg/kg DM in enset leaf. Enset leaf, pseudostem and wheat straws were poor in Zn while corm, whole enset and *D. intortum* hay were good sources of Zn.

Intake, digestibility and ME concentration

Intake and apparent digestibility of the different feeds used in the experiment are shown in Table 3. The intake of DM and OM were highest ($p < 0.05$) in sheep fed *D. intortum* hay and lowest ($p < 0.05$) in those sheep that received pseudostem. The CP intake was also highest ($p < 0.05$) in sheep fed *D. intortum* while the lowest values were seen in pseudostem, corm and untreated straw. Urea and lime treatment of wheat straw increased ($p < 0.05$) the intake of DM, OM, CP and NDF as compared to the untreated straw. Among the enset fractions, the highest ($p < 0.05$) CP intake was observed in the leaf followed by whole enset.

The digestibilities of DM and OM in sheep fed enset leaf were comparable with treated straw but lower ($p < 0.05$) than the other enset fractions. The DM digestibility of urea- plus lime- treated straw was about 8% unit higher ($p < 0.05$) than the untreated and *D. intortum* hay. Those sheep fed corm and treated straw had greater ($p < 0.05$) NDF digestibility than those fed enset leaf, pseudostem and *D. intortum* hay.

The CP digestibility was highest ($p < 0.05$) in sheep fed enset leaf, *D. intortum* hay and whole enset fed sheep whereas sheep fed untreated straw and corm had the lowest and negative CP digestibility values. The DOMD and ME concentrations were higher in sheep fed whole enset and corm than in other feeds, which had comparable DOMD and ME values.

Nitrogen balance

There were significant differences ($p < 0.05$) between treatments in N balance as indicated in Table 4. Sheep fed pseudostem, untreated straw and corm were in a negative N balance. The N intake, and faecal and urinary N losses were higher ($p < 0.05$) in *D. intortum* hay and enset leaf fed sheep. For all treatments, the N lost in faeces was higher than the amount lost in urine. When expressed as a percentage of intakes, the loss was much higher in the feeds where the intake of N was very low (corm, pseudostem and untreated straw).

Table 3 Mean daily intake and apparent digestibility of sheep fed different enset fractions, treated straw, untreated straw and *Desmodium intortum* hay

	Enset fractions				Wheat straw			
Parameter	Leaf	Pseudostem	Corm	Whole enset	Untreated	Treated	*Desmodium intortum* hay	SEM
Intake:								
DM intake (g/kgW $^{0.75}$/day)	42.6^{b}	8.2^{e}	24.2^{d}	48.3^{b}	34.6^{c}	47.3^{b}	70.4^{a}	1.6
DM (g/day)	492^{bc}	92^{e}	282^{d}	554^{b}	411^{c}	549^{b}	830^{a}	20.5
OM (g/day)	423^{bc}	74^{e}	248^{d}	484^{b}	366^{c}	471^{b}	716^{a}	18.4
CP (g/day)	72^{b}	7.8^{e}	8.7^{e}	42^{c}	12^{e}	27^{d}	133^{a}	1.3
NDF (g/day)	248^{cd}	38^{e}	65^{e}	213^{d}	291^{c}	378^{b}	433^{a}	11.9
ADF (g/day)	147^{d}	35^{e}	40^{e}	132^{d}	212^{c}	271^{b}	346^{a}	7.1
Digestibility coefficients:								
DM	0.589^{b}	0.717^{a}	0.783^{a}	0.765^{a}	0.488^{c}	0.571^{b}	0.489^{c}	1.7
OM	0.594^{bc}	0.672^{b}	0.780^{a}	0.776^{a}	0.522^{c}	0.609^{bc}	0.534^{c}	2.1
CP	0.636^{a}	0.280^{b}	-0.408^{d}	0.570^{a}	-0.118^{c}	0.276^{b}	0.572^{a}	4.9
NDF	0.412^{b}	0.431^{b}	0.665^{a}	0.543^{ab}	0.547^{ab}	0.664^{a}	0.455^{b}	3.2
ADF	0.502^{e}	0.810^{a}	0.751^{ab}	0.666^{cd}	0.603^{d}	0.691^{bc}	0.362^{f}	1.9
DOMD(g/kg DM)	512^{b}	519^{b}	665^{a}	677^{a}	467^{b}	520^{b}	461^{b}	2.1
Metabolizable energy (MJ/kg DM)	7.7^{b}	7.8^{b}	10.0^{a}	10.2^{a}	7.0^{b}	7.8^{b}	6.9^{b}	0.31

DM = dry matter, OM = organic matter, CP = crude protein, NDF = neutral detergent fiber, ADF = acid detergent fiber, DOMD = digestible organic matter in the dry matter, SEM = standard error of the means.

Metabolizable energy of the feed (MJ/kg DM) = 0.15 × DOMD% (MAFF, 1984).

Means without a common superscript within a row are not significantly different ($p < 0.05$).

Table 4 Mean nitrogen (N) intake, N losses and N balance of sheep fed different enset fractions, treated straw, untreated straw and *Desmodium intortum* hay

	Enset fractions				Wheat straw			
Parameter	Leaf	Pseudostem	Corm	Whole enset	Untreated	Treated	*Desmodium intortum* hay	SEM
N intake, g/day	11.6^{b}	1.3^{e}	1.4^{e}	6.7^{c}	1.9^{e}	4.2^{d}	21.3^{a}	1.3
N losses:								
Faecal N, g/day	4.2^{b}	0.9^{e}	1.9^{d}	2.9^{c}	2.2^{d}	3.1^{c}	9.1^{a}	0.04
Urinary N, g/day	1.3^{b}	0.6^{c}	0.8^{c}	0.8^{c}	0.5^{c}	0.6^{c}	1.8^{a}	0.5
Losses of N as percentage of intake:								
Faecal N	36.4^{d}	72^{c}	141^{a}	43^{d}	112^{b}	72.4^{c}	42.9^{d}	4.9
Urinary N	10.8^{c}	50.8^{a}	61.2^{a}	12.2^{bc}	27.1^{b}	15.1^{bc}	8.7^{c}	3.6
N balance, g/day	6.1^{b}	-0.3^{de}	-1.3^{f}	3.0^{c}	-0.8^{ef}	0.6^{d}	10.4^{a}	1.3
N retained as a % of intake	52.8^{a}	-22.8^{c}	-102^{d}	44.8^{a}	-38.9^{c}	12.5^{b}	48.5^{a}	5.4

SEM = standard error of the means.
Means without a common superscript within a row are not significantly different ($p < 0.05$).

Nitrogen lost through urine as a percentage of N intake in *D. intortum* hay, enset leaf and whole enset fed sheep were lower ($p < 0.05$) than other experimental feeds, resulting in higher ($p < 0.05$) N balance.

Discussion

Chemical composition

The DM content of the enset leaf reported in this study was higher than the values reported by Tolera (1990) and Fekadu and Ledin (1997). This could be because of differences in variety of enset and age of the leaf (Fekadu, 1996). The high DM content of corm compared with other fractions is consistent with the result of Fekadu (1996). In previous studies, DM value similar to that of the enset pseudostem was reported for banana pseudostem (Ffoulkes and Preston, 1977; Pezo and Fanola, 1980). The low DM content of enset pseudostem can cause a concern on its utilization as ruminant feed. Indeed, the low DM content of enset fractions can affect feed intake negatively but can be an advantage if drinking water is in short supply (Fekadu and Ledin, 1997).

The CP content of the corm in this study was lower than the value reported by Fekadu and Ledin (1997) but it is within the range of 18–100 g/kg DM (our unpublished data) in ten different enset varieties. Therefore enset variety, age and location might have contributed to this variation. The CP contents of enset pseudostem (62 g/kg DM) and leaf (123 g/kg DM) found in this experiment were lower than the mean values reported by Fekadu and Ledin (1997) for enset pseudostem (70 g/kg DM) and leaf (130 g/kg DM). Tolera (1990) reported higher level of CP (175 g/kg DM) for enset leaf. The CP contents of enset leaf and *D. intortum* hay were above the minimum requirement (7–8% of DM) for rumen microbes to optimize cell wall degradation (Durand, 1989). Use of whole enset also raised the CP content almost to the level suggested by Durand (1989). The higher CP content in offer than refusal in enset fractions, especially in enset leaf indicated that sheep probably selected the more nutritious part. Sheep and goats are selective feeders capable of selecting the more nutritious fractions of a feed (Owen, 1994). Therefore, provision of excess amounts of enset leaf may play a beneficial role in allowing selection for leaf lamina which is rich in protein over leaf midrib with low CP content.

Urea and lime treatment increased the CP content by 1.5% units relative to the untreated wheat straw. Jayasuriya and Pearce (1983) indicated that loss of N could occur during treatment, when opening the silo and during oven drying of the samples. However, Zaman and Owen (1995) observed a small percentage of N loss in the presence of lime. They suggested that the low N loss could be because of the lower hydrolysis of urea in the presence of lime, which inhibited loss of N in the form of ammonia.

The high NFC content in enset fractions could be useful as a supplement to low energy feeds such as cereal straw but the concentration in the diet should be limited to avoid the negative impact on utilization of low quality forages. The NFC contents in corm and pseudostem were high. Non-fiber carbohydrates which includes starch, sugars, pectins and beta-glucans (Van Soest et al., 1991) are considered to be highly digestible (98%) and rapidly fermentable as compared to the carbohydrates in NDF (NRC, 2001). There is no information available about all NFC fractions in different enset morphological fractions. However, Gebre-Mariam and Schmidt (1996) reported that Bulla, a type of food from pseudostem and corm contains equivalent amount of starch as maize and potatoes. Urea and lime treatment of wheat straw decreased the contents of NDF, cellulose and hemicelluloses because of solubilization of the cell wall and its constituents (Sirohi and Rai, 1998). However, there was an increase in ADF and lignin content in the current report. Similarly, Habib et al. (1998) and Van Soest et al. (1983) reported an increase in ADF and decrease in NDF content because of ammonia treatment. However, fiber results should be interpreted cautiously because of the effect of high temperature on fiber content. Papachristou and Nastis (1994) indicated that oven-dried samples even at 40 °C have increased the fiber content compared with freeze drying.

Mineral concentration

The Ca content of enset leaf reported in this study is comparable to the value reported by Tolera (1990). Enset leaf is richer in Ca content than pasture and hay and much richer than cereal crop residues reported by Khalili et al. (1993). Urea and lime treatment of wheat straw resulted in 10-fold increase in Ca content. However, the high Ca to P ratio of 17.4:1 reported in this study for treated straw was far from the recommended ratio of 1:1 to 2:1 (McDonald et al., 2002). *D. intortum* hay, treated straw and enset fractions except corm were found to be rich sources of Ca that can satisfy the Ca requirement for all classes of sheep according to NRC (1985) recommendations (Table 2).

Except straws, the content of P in all the feeds could satisfy the recommended P requirement of 1.6–3.8 g/kg DM (NRC, 1985). It has also been indicated that P concentration in tropical grasses is extremely low (Kebreab et al., 2005). Therefore in areas where ruminants are dependent on cereal straws and grazing, provision of enset and forage legumes such as *D. intortum* hay could play a crucial role in alleviating P deficiency. The Mg content of enset leaf, whole enset and *D. intortum* were within the recommended level (1.2–1.8 g/kg DM) for sheep (NRC, 1985). Pseudostem, corm and straws are deficient in Mg. The K content in all feeds was above the recommended level for sheep (Table 2) and cattle (McDowell, 1996).

All feeds had Cu concentrations below the level of requirement indicated for sheep (NRC, 1985). In general, Cu deficiency is a common problem in the Rift valley that stretches from Ethiopia to Tanzania (Schillhorn van Veen and Loeffler, 1990). In all feeds, the Mn content was above the recommended level for sheep (Table 2) but below the maximum tolerable level of 1 000 mg/kg DM (NRC, 1978). All enset fractions, *D. intortum* hay and treated straw could be considered as good sources of Mn for sheep.

The relatively high level of Zn in whole enset among enset fractions might have originated from the corm which is rich in Zn. The level of zinc in *D. intortum* hay was within the requirement while corm and whole enset had higher than the recommended value for sheep (NRC, 1985) which could be very important, where sheep are dependent on straw and grasses. Kebreab et al. (2005) reported that Zn is deficient in 35–50% of tropical grasses. The feeding of whole enset, corm and *D. intortum* hay in Zn deficient areas and diets could thus alleviate the problem of Zn deficiency.

In general, the higher Ca, Mg, Cu, Mn and Zn content in treated straw than the untreated straw indicates the presence of some impurities in the lime used for treatment. All the feeds were low in Cu, which is much below the level of requirement indicated for sheep (NRC, 1985). Gowda et al. (2004) reported that for the poor livestock owners, feeding mineral supplement is not commonly practiced and suggested strategic supplementation with green fodder or unconventional feeds available in tropical regions, as an alternative approach. In general, enset fractions contain higher level of minerals than untreated straw. This strategy practiced by the farmers using cereal straw as a basal diet, and enset fractions as a supplement could improve the performance of livestock in enset-producing regions of the country. However, further work is necessary with regard to the supply of minerals from different enset fractions in meeting the requirement of animals because not only the concentration but also the availability of mineral to the animal is equally important.

Intake, digestibility and ME concentration

Except in pseudostem and corm fed sheep, the DM intake was within the recommended range of 310–870 g/day as adequate for sheep with body weight of 20 to 35 kg (ARC, 1980). The lower DM intake of pseudostem is presumably because of its high moisture content. The DM intake decreased in the following order: *D. intortum* hay > whole enset = treated straw = enset leaf > untreated straw > enset corm > pseudostem. The increased intake of DM, OM, CP and NDF in treated wheat straw compared with the untreated straw could be because of improved digestibility and increased N supply in the urea- and lime- treated wheat straw. In previous studies, increased OM intake, OM and NDF digestibility (Djajanegara et al., 1985) and increased DM intake (Sahoo et al., 2002) were observed in calcium hydroxide-treated wheat straw. Moreover, an increase in digestible OM intake was observed in urea plus calcium hydroxide-treated wheat straw (Zaman and Owen, 1990). Trach et al. (2001) showed that treatment of rice straw with 2% urea and 3% lime was more effective than only 4% urea in terms of OM digestibility, DM intake, digestible OM intake, average daily gain and feed conversion ratio in cross-bred dairy cattle.

Among the enset fractions, the highest CP intake was observed in those sheep fed enset leaf. Ruiz and Rowe (1980) compared tops (leaves and petioles), stem and a mixture of tops and stems of banana, and observed an increase in DM intake when the tops and the mixture of tops and stems were used. They also suggested that the whole banana plant could be used as efficiently as tops, if supplementary protein is provided to improve the efficiency of rumen function. The CP intake of sheep fed corm and pseudostem was poorer than even that of sheep fed untreated wheat straw. Pezo and Fanola (1980) observed that the pseudostem of banana had high digestibility but low intake because of high water content. The low CP intake in enset corm and pseudostem could be because of high water and low CP content in these fractions. Fekadu (1996) observed a 16% improvement in DM intake of pseudostem as a result of urea treatment.

The DM digestibility of enset leaf was lower than that of whole enset or the other enset fractions, which could be because of the high lignin content of enset leaf. Similarly, Ffoulkes and Preston (1977) found that the digestibility of banana leaf was lower than that of the stem perhaps, because of a shorter retention time in the rumen, as the DM intake of the banana leaf was higher than that of the pseudostem. Of all the feeds, pseudostem, corm and whole enset were highly digestible and may have a potential for development of improved animal feeding system provided that they are supplemented with CP to overcome their protein deficiency. However, the higher digestibilities of these fractions may be a reflection of their lower DM intake. Doreau et al. (2003) reviewed the relationship between intake and digestibility and confirmed the negative relationship between the amount of feed consumed and OM digestibility. Such negative relationship between intake and digestibility could be because of the extent of modification in ruminal digestion of the diets, which in turn depends on microbial activity and on the time of contact between microbes and feed particles.

Even though the intakes of *D. intortum* hay were the highest, the digestibilities were the lowest and similar to untreated wheat straw. The low digestibility value observed in *D. intortum* hay could be because of its higher content of lignin and possibly other phenolic compounds such as tannin than in the other feeds. Tolera and Sundstøl (2000) reported very high proanthocynadin content in *D. intortum* hay. Perez-Maldonado and Norton (1996) observed lower proportion of ruminal OM and N digestibility in *Desmodium* and *Calliandra* compared with pangola and centrosema, which they attributed to the higher tannin content in *Desmodium* and *Calliandra*. Moreover, digestibility results in the current experiment should be interpreted cautiously because of the possible impact of high drying temperature used. Papachristou and Nastis (1994) dried forage samples at 40 °C and observed decreased *in vitro* OM digestibility compared with freeze drying. The effect was pronounced on forages with high moisture content.

The negative CP digestibility in corm and untreated straw agrees with the findings of Tolera and Sundstøl (2000), who observed negative apparent CP digestibility in protein deficient feed, maize stover because of inadequate N intake coupled with high metabolic faecal N loss. Urea and lime treatment of wheat straw improved the digestibility of straw compared with untreated straw. According to Sahoo et al. (2002), wheat straw treated with 3% urea and 3% calcium hydroxide had increased the digestibility of NDF, ADF, hemicellulose and cellulose probably because of cleavage of linkages between lignin and hemicellulose that makes hemicellulose more accessible for hydrolyzing enzymes.

Nitrogen balance

The negative N balance in sheep fed pseudostem, untreated straw and corm might be because of low DM intake thus N intake and high losses of N in faeces and urine in addition to low N content of these feeds. The N balance was in the following order: *D. intortum* hay > enset leaf > whole enset > treated straw > pseudostem > untreated straw > corm. The sheep fed treated straw were in a positive N balance, and hence retained more N compared with untreated straw. Negative N balance was observed in feeds with low N content (Kaitho et al., 1998; Tolera and Sundstøl, 2000). Robinson et al. (2005) indicated that negative N balance is indicative of catabolism of body protein reserves to meet energy requirements while high N intake coupled with high urine N excretion demonstrates feed protein catabolism and excretion of the excess N.

Conclusion

It is concluded that enset fractions, especially enset leaf could be very important as source of feed, particularly during the dry season. However, corm and pseudostem were found to be poor with respect to the intake of DM, OM, CP as well as N retention when fed as sole diets. There is a need to supplement corm and pseudostem with protein-rich feeds such as *D. intortum* hay or enset leaf. Similarly, in areas where crop residues are used as basal diet, treatment of the straw with urea and lime or supplementation with enset leaf and/or leguminous forages such as *D. intortum* hay could play a significant role in improving the utilization of the straws.

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