VII. Nutritional values of three indigenous woody fodder plant species in the Galessa-Jeldu areas of Ethiopia

7.1. Introduction

In the extreme highlands of central Ethiopia (> 2900 m.a..s.l), grasses and barley straw are major sources of animal feed. Grasses and barley straw are characterized by low digestibility, low protein content and poor mineral composition (SEYOUM and ZINASH 1989; KABAIJA and LITTLE 1987). In addition to grasses and crop residues, the foliage and flower bud of woody plants are important components of sheep and cattle diets where few or no alternative feed resources are available. Farmers cut branches of trees and feed them to animals. Some farmers allow their animals to feed on fallen leaves under the fodder plants. There are also a few farmers who feed leaves with salts (KINDU et al. 2006). Hence, the utilization of woody fodder species as a supplemental feed is becoming increasingly important in the highlands.

The introduction and promotion of exotic trees and shrubs have been exercised in the highlands to increase biomass for supplemental animal feed. In some cases the genetic base and adaptation of the introduced species was found to be poor. In other cases pests and diseases have threatened introduced species. For instance, the insect damage of *Leucaena* by psyllid (*Heteropsylla cubana* Crawford) has been a critical barrier to further dissemination and utilization of the tree species in the highlands. The failure from expansion of some exotic fodder species suggests the importance of considering indigenous species for further use in the farming system. Paying attention to indigenous fodder tree species can have advantages over the exotic species in terms of adaptability to the local environment, resistance to pests and diseases, availability of local planting material and familiarity to the farmers.

Very little research has been so far done on the nutritional value of indigenous tree and shrub species in Ethiopia in general and in the study area in particular. Similarly, local knowledge on fodder tree and shrub species is not strongly supported by scientific investigations. The objective of this study was to assess the nutritional value of three indigenous and an exotic woody fodder species based on their chemical composition, tannin contents and *in vitro* dry matter digestibility.

7.2. Materials and methods

7.2.1. Study site

The study site is situated in the upper plateaus of Dendi and Jeldu *Weredas* (districts), West Shewa Zone, Central Ethiopia (Appendix 1). The altitude ranges from 2900 to 3200 m.a.s.l. The Chilmo state forest borders the study site in the south. The rainfall pattern is bimodal. The main rainy season is from July to September with an annual rainfall of 1399 mm. Barley is the most dominant crop followed by potato and enset (*Ensete ventricosum*). Cattle, sheep and horses are dominant in the study sites. Farmers mainly fulfil their cash demand from the sale of live animals and their products. The soil is characterized as Haplic Luvisols. The physical and chemical properties of the soil are presented in Appendix 2.

7.2.2. Description of the three indigenous woody fodder species

More than 29 indigenous fodder tree and shrub species were identified in the study area (KINDU et al. 2006). Farmers preferred *Hagenia abyssinica* (Bruce) J.F. Gmel.*, Dombeya torrida* (J.F. Gmel.) P. Bamps and *Buddleja polystachya* Fres. for livestock fodder over the other tree and shrub species. The preference criteria of farmers for the three indigenous fodder species were palatability, harmlessness to animals, availability during the dry season, coppicing ability, high biomass and fast to intermediate growth.

Chamaecytisus palmensis (Christ) Bisby & K. Nicholls was recently introduced as an exotic N-fixing fodder species and included in the study for the purpose of comparison with the indigenous species. The location of the tree and shrub species was in hedges of homesteads. The tree and shrub species occur in the hedges as clusters as well as pure stands. None of the tree and shrub species have thorns. A more detailed description of the species is given in appendix 3.

7.2.3. Samples collection, preparation and chemical analysis

The study was conducted from 2004 to 2006. Initially, intensive site selection was carried out in homesteads of 14 different villages. Three villages where all required species present were identified. Each village was considered as a replication. The four fodder species were demarcated in each village. Foliage (leaves and twigs) and flower bud samples were collected from each fodder species in each village. The foliage samples were collected from all sides of the fodder plants. Flower buds were included in the sampling scheme since most species produce an abundance of flower buds that are palatable by livestock.

The total number of foliage and flower bud samples were 24 [fodder species (4) * sampled parts (2) * replications (3)]. All foliage and flower bud samples were oven-dried at

80 °C for 24 h. The foliage and bud flower samples were ground with a Cyclotec mill, then sieved using a 1 mm diameter mesh.

Total N content of the foliage and flower bud was determined by Kjeldahl digestion using Na_2SO_4 and $CuSO_4$ as catalysts. Digests were made alkaline and ammonia was determined by steam distillation, trapping in boric acid and titrating with 0.1N HCl. Oven dried foliage and flower bud samples were extracted with a mixture of HNO_3 and $HClO_4$. The total P, K, Ca, Mg and S content of the extracts was determined by the use of a simultaneous ICP-OES with an axial plasma and SCD (Perkin Elmer, OPTIMA 3000 XL).

Crude protein (CP) was calculated by multiplying N * 6.25. Acid Detergent Fibre (ADF), Acid Detergent Lignin (ADL), and Neutral Detergent Fibre (NDF) were determined by the methods of VAN SOEST and ROBERTSON (1985). NDF was determined with amylase and sodium sulphite and is expressed as ash free NDF. The *in vitro* digestiblity was determined by the method of TILLEY and TERRY (1963) as modified BY VAN SOEST and ROBERTSON (1985) by substituting the second stage (pepsin digestion) with neutral detergent extraction. Values are expressed as *in vitro* dry matter digestiblity percentage (IVDMD%). The insoluble NDF-bound proanthocyanidins (codensed tannins) were determined as described by REED et al. (1982).

7.2.4. Data management and analysis

A one-way analysis of variance (ANOVA) was carried out on CP, mineral composition, ADF, NDF, ADL, condensed tannins and IVDMD using SAS (SAS institute 1999). Significance between means was tested using the Least Significant Difference (LSD). A level of $P < 0.05$ was chosen as the minimum for significance. Standard errors of the means were calculated from the residual mean square in the analysis of variance. The following model was considered while running the ANOVA:

$$Y_{ij} = \mu + \alpha_i + \beta_j + e_{ij},$$

where μ is the overall mean, α_i the i^{th} treatment (species) effect, β_j the j^{th} block (site) effect and e_{ij} is the random error associated with Y_{ij}.

Correlation analysis was performed to understand the relation between IVDMD, CP, ADF, NDF, ADL and CT. Similarly, regression analysis was conducted to establish the relationship between dependent variable (IVDMD) and several independent or predictor variables such as ADF, NDF, ADL and CT.

7.3. Results and discussion

7.3.1. Mineral composition of fodder species

Differences among species for P were more pronounced in the foliage than in the flower bud (Table 7.1). The Mg content in the foliage and flower bud of the three indigenous fodder species was high as compared to C*. palmensis*. *Dombeya torrida* had the highest K content in the foliage and flower bud. The K level of the foliage and flower bud in the indigenous as well as exotic species was above the requirements and below the maximum tolerable concentration for beef and dairy cattle. The high K level in relation to Ca and Mg has been associated with reduced magnesium absorption. Potassium reduces Mg absorption when the K/(Ca + Mg) ratio exceeds 2.2 (KEMP and T'HART 1957). The K/(Ca + Mg) ratios of the foliage of the four species were below the critical level.

Table 7.1. Macronutrient and micronutrient composition of four tree species.

Foliage	*Hagenia abyssinica*	*Dombeya torrida*	*Buddleja polystachya*	*Chamaecytisus palmensis*	SEM$^{@}$	Normal requirment**
P	3.71^{b}	3.76^{b}	4.71^{a}	2.50^{c}	0.25	1.2-4.8
K	21.22^{b}	27.00^{a}	21.55^{b}	14.93^{c}	1.34	5.0-10.0
Ca	9.69^{b}	22.97^{a}	10.93^{b}	9.30^{b}	1.79	1.9-8.2
Mg	2.38^{ba}	2.81^{a}	2.07^{b}	1.97^{b}	0.13	1.0-2.5
S	2.03^{c}	3.62^{a}	3.46^{a}	2.55^{b}	0.21	1.5-4.0
Na	305^{a}	224^{a}	214^{a}	268^{a}	18.11	600-1800
Fe	197^{b}	364^{ba}	284^{ba}	450^{a}	36.21	30-50
Mn	61^{b}	144^{b}	104^{b}	374^{a}	41.53	20-40
Flower bud						
P	4.54^{a}	4.33^{a}	5.37^{a}	2.24^{b}	0.37	1.2-4.8
K	22.04^{ba}	24.59^{a}	16.52^{b}	10.35^{c}	1.81	5.0-10.0
Ca	5.54^{b}	10.59^{a}	5.64^{b}	2.08^{c}	0.95	1.9-8.2
Mg	2.53^{a}	2.34^{a}	1.67^{b}	0.80^{c}	0.22	1.0-2.5
S	2.70^{b}	3.74^{a}	2.98^{b}	1.73^{c}	0.23	1.5-4.0
Na	169^{a}	200^{a}	212^{a}	179^{a}	24.25	600-1800
Fe	442^{a}	263^{a}	248^{a}	223^{a}	54.32	30-50
Mn	39^{a}	67^{a}	44^{a}	95^{a}	11.46	20-40

P, K, Ca, Mg and S are in mg g^{-1} whereas Na, Fe and Mn are in mg g^{-1} .
$^{@}$Standard error of the means (n = 12).
Means with different letters within a row are significantly different ($p < 0.05$).
**Recommended mineral elements for all classes of ruminants according to NRC (1984, 1985, 1989, 1996).

The S content of the foliage in *D. torrida* and *B. polystachya* was higher than the S content of the foliage in *H. abyssinica* and *C. palmensis*. The S content of the flower bud in *D. torrida* was higher by 2.01 mg g^{-1} than the S content of the flower bud in *C. palmensis*. The Na content of the foliage and flower bud in the four species was comparable. The content of Na in the foliage and flower bud was below the requirement. Common salt or local mineral sources such as mineral soil can improve the deficiency of Na in the foliage and flower bud feed resources. Sodium is important to regulate osmotic pressure, acid-base and water balance in the animal body. Low levels of Na in feeds affect absorption of Mg (MARTENS et al. 1987). The Fe and Mn contents of the foliage in *C. palmensis* were higher than the Fe and Mn content in the three indigenous species. However, the four species did not show significant differences in the content of Fe and Mn in the flower bud. Manganese is a major component of enzymes and serves as an activator of enzymes. All the foliage and flower bud samples from the four species fulfill the Mn demand of beef and dairy cattle.

7.3.2. Crude protein, NDF, ADF, ADL, CT and IVDMD

The crude protein content in the foliage and flower bud of the four species varied from 188 to 234 mg g^{-1} and 124 to 170 mg g^{-1}, respectively (Table 7.2). The CP content of the foliage in *H. abyssinica* and the flower bud in *C. palmensis* were low as compared to the other species. The CP content of the foliage and flower bud in the four species was much higher than the minimum required CP level (70 mg g^{-1}) of beef cattle (MINSON and MILFORD 1967). The CP content of *D. torrida* (234 mg g^{-1}), *B. polystachya* (229 mg g^{-1}) and *C. palmensis* (228 mg g^{-1}) in the present study was high as compared to the CP range (134-213 mg g^{-1}) reported for six Acacia species in Kenya (ABDULRAZAK et al. 2000). The high CP content in the foliage of *C. palmensis* can be accounted for by the N fixing ability of the species. The non-N-fixing species in our study only cycle the N present in the soil. On the other hand, *C. palmensis* cycles the N present in the soil and also adds N into the system through biological nitrogen fixation.

The NDF content of the foliage and flower bud in *H. abyssinica* was less by 215 and 383 mg g^{-1} than the NDF content of the foliage and flower bud in *C. palmensis*, respectively (Table 7.2). The ADF content of the foliage in *H. abyssinica* and *D. torrida* was comparable. The ADF content of the flower bud was high in *B. polystachya* and low in *H. abyssinica*. The contents of NDF and ADF in *H. abyssinica*, *D. torrida, B. polystachya* and *C. palmensis* was within the range reported for browse tree species by EI HASSAN et al. (2000), LARBI et al. (1998), ABDULRAZAK et al. (2000) and KHANAL and SUBBA (2001).

The ADL content of the foliage in *H. abyssinica* was less by 46, 71 and 119 mg g^{-1} than the ADL content of the foliage in *D. torrida*, *C. palmensis* and *B. polystachya*, respectively. The ADL content of the flower bud in *H. abyssinica* was low as compared to other investigated species. The variability for CT content among species was more in the flower bud than in the foliage. The CT content of the flower bud in *D. torrida* was exceptionally high. High ADL and CT content can limit the voluntary feed intake, digestibility and nutrient utilization of ruminant animals (KHANAL and SUBBA 2001). The level of ADL and CT in foliage and flower bud of most of the species may not be considered to have effects on the feed intake and performance of ruminants because of two reasons. Firstly, farmers in the study area provide the foliage and flower bud of the fodder species not as a basal diet, but only as supplemental feed. Secondly, farmers do not find a sufficient quantity of foliage and flower bud to provide their animals for long duration.

Table 7.2. Foliage and flower bud nutritional value of four tree species.

Foliage	*Hagenia abyssinica*	*Dombeya torrida*	*Buddleja polystachya*	*Chamaecytisus palmensis*	SEM$^@$
CP	188^b	234^a	229^a	228^a	7.24
NDF	356^c	451^b	526^{ba}	571^a	26.47
ADF	303^b	354^b	449^a	361^{ba}	19.89
ADL	54^c	100^{bc}	173^a	125^{ba}	14.79
CT	4.59^c	19.25^b	29.76^a	11.68^c	2.98
IVDMD	70^a	59^b	47^c	71^a	3.10
Flower bud					
CP	170^a	165^a	170^a	124^b	7.63
NDF	340^c	610^b	608^b	723^a	42.70
ADF	295^c	473^a	435^b	463^{ba}	21.96
ADL	73^c	199^a	162^b	98^c	15.78
CT	9.34^b	119.51^a	24.40^b	8.76^b	14.18
IVDMD	60^a	52^b	58^a	60^a	1.14

CP, NDF, ADF and ADL are in mg g^{-1} dry matter; IVDMD is in %
CT is is expressed as A_{550} absorbance units per gram of NDF (AU g^{-1})
as described by REED et al. (1982)
$^@$ Standard error of the means (n = 12)
Means with different letters within a row are significantly different ($p < 0.05$).

The IVDMD of the foliage and the flower bud for *H. abyssinica* and *C. palmensis* was comparable. The high IVDMD of the foliage from *H. abyssinica* could be associated with the low level of NDF, ADF, ADL and CT. The IVDMD of *H. abyssinica* in our study was high as compared to the IVDMD reported for *C. palmensis, Leucanea leucocephala*, *Sesbania sesban* (15036), *Acacia angustissima* and *Vernonia amygdalina* (El HASSAN et al. 2000).

7.3.3. Correlations between CP, CT, ADL, ADF, NDF and IVDMD

ADL and CT in the foliage and flower bud were negatively and significantly correlated with IVDMD for the four species (Table 7.3). ADL in the foliage and flower bud was also positively and significantly correlated with CT. ADF in the foliage was highly and positively correlated with ADL and CT. Unlike in the foliage, CT alone or in various combinations with ADL and ADF explained 86 % of the variation of IVDMD in the four species (Table 7.4). Hence, CT, ADL and ADF can be good predictors of IVDMD for the foliage and flower bud of the four species.

Table 7.3. Correlation coefficient (r) of the relationship between CP, CT, ADL, ADF, NDF and IVDMD in the foliage and flower bud for the four tree species.

Foliage	CP	CT	ADL	ADF	NDF
CT	0.504				
ADL	0.455	0.863^{***}			
ADF	0.354	0.867^{***}	0.905^{***}		
NDF	0.503	0.545	0.817^{**}	0.699^{*}	
IVDMD	-0.359	-0.932^{***}	-0.735^{**}	-0.804^{**}	-0.309
Flower bud					
CT	0.308				
ADL	0.225	0.818^{**}			
ADF	-0.263	0.464	0.615^{*}		
NDF	-0.532	0.177	0.407	0.929^{***}	
IVDMD	-0.136	-0.829^{***}	-0.715^{**}	-0.496	-0.239

*Level of significance is $p<0.05$.

**Level of significance is $p<0.01$.

***Level of significance is $p<0.001$.

Table 7.4. Prediction of *in vitro* dry matter digestibility of tree foliage and flower bud from CP, NDF, ADF, ADL and CT.

Regression models for predicting IVDMD in foliage	Adjusted R^2	P-value
IVDMD= 95.62 - 0.153CP	0.04	0.252
IVDMD= 79.09 - 0.036NDF	0.01	0.329
IVDMD= 107.79 - 0.125ADF	0.61	0.002
IVDMD= 79.29-0.154ADL	0.50	0.006
IVDMD= 77.71 - 0.968CT	0.86	0.000
IVDMD= 106.56 - 0.119ADF - 0.009ADL	0.57	0.009
IVDMD= 79.96 + 0.003ADF - 0.983CT	0.84	0.000
IVDMD= 75.28 + 0.056ADL -1.209CT	0.86	0.000
IVDMD= 84.50 + 0.089ADL - 0.039ADF - 1.121CT	0.86	0.000
Regression models for predicting IVDMD in flower bud		
IVDMD= 60.63 - 0.020CP	-0.08	0.673
IVDMD= 61.07 - 0.006NDF	-0.04	0.455
IVDMD= 68.20 - 0.026ADF	0.17	0.101
IVDMD= 64.30 - 0.052ADL	0.46	0.009
IVDMD= 60.13 - 0.067CT	0.66	0.001
IVDMD= 65.74 - 0.005ADF - 0.048ADL	0.41	0.038
IVDMD= 63.00 - 0.007ADF - 0.062CT	0.64	0.004
IVDMD= 60.898 - 0.008ADL - 0.060CT	0.62	0.005
IVDMD= 63.02 - 0.007ADF - 0.001ADL - 0.061CT	0.59	0.017

7.4. Conclusions

The four woody fodder species had adequate mineral nutrients in their foliage and flower buds except for Na. The indigenous species had higher contents of P, K, Ca and Mg than the exotic species. The contents of Na, Fe and Mn in the foliage and flower bud both from the indigenous and exotic species were comparable. The three indigenous species had CP contents comparable to that of the exotic species. The foliage NDF, ADF and ADL content in *H. abyssinica* and *D. torrida* was relatively low. The *in vitro* dry matter digestibility of the foliage and flower bud from *H. abyssinica* and *C. palmensis* was reasonably high. In general, the foliage and flower bud of all investigated woody species can be used as sources of fodder with a proper feeding management scheme.