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Source: Mountain Research and Development, 29(2) : 135-142

Published By: International Mountain Society

URL: https://doi.org/10.1659/mrd.1098

Mountain Research and Development (MRD)
An international, peer-reviewed open access journal
published by the International Mountain Society (IMS)
www.mrd-journal.org

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Assessments of Fodder Values of 3 Indigenous and 1 Exotic Woody Plant Species in the Highlands of Central Ethiopia

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Leaves and twigs of indigenous woody plant species are used as a source of supplemental animal feed in the mountainous landscapes of central Ethiopia. A study was carried out from 2004 to 2006 to assess the nutritional value of 3 indigenous and 1 exotic species, based on the chemical composition, tannin contents, in vitro dry matter digestibility, and digestible energy. The species studied were Hagenia abyssinica *(Bruce) J.F. Gmel.,* Dombeya torrida *(J.F. Gmel.) P. Bamps,* Buddleja polystachya *Fres., and* Chamaecytisus palmensis *(Christ) Bisby & K. Nicholls. The first three are indigenous, and the last one is an exotic species. The Na content of the foliage and flower bud in the 4 species was much lower than the minimum requirement for ruminants, while other micro- and macronutrients were within the recommended range of nutrient concentrations in animal feeds. On the other hand, the crude protein content of the foliage and flower bud in the 4 fodder species was higher than the minimum required level. The foliage and flower bud in vitro dry matter digestibility of* H. abyssinica *and* C. palmensis *was 70% and 71%, respectively. The digestible energy of the foliage of* H. abyssinica *and* C. palmensis *was significantly higher than the digestible energy of* D. torrida *and* B. polystachya*. Therefore, the foliage and flower bud of most of those species can be used as sources of supplemental fodder with a proper feeding management scheme.*

Keywords: *Fodder tree; condensed tannin; crude protein; dry matter digestibility; lignin; mineral nutrients; Ethiopia.*

Peer-reviewed: *February 2009* ***Accepted:*** *April 2009*

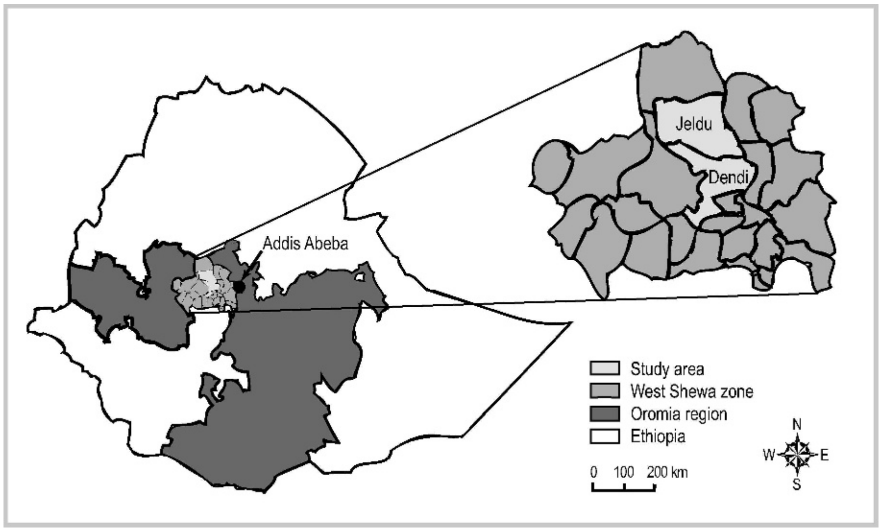
Introduction

The shortage of animal feed is a priority problem in the mountainous landscapes of central Ethiopia (ICRAF 1990; Seyoum et al 2001). In the highlands of central Ethiopia (2500–3000 meters above sea level [masl]), grasses and barley straw are major sources of animal feed. However, grasses and barley straw are characterized by low digestibility, low protein content, and poor mineral composition (Kabaija and Little 1987; Seyoum and Zinash 1989). In addition to grasses and crop residues, where few or no alternative feed resources are available, the foliage and flower bud of woody plants are important components of sheep and cattle diets. 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.

In the highlands, exotic trees and shrubs such as *Leucaena leucocephala* (Lam.) deWit., *Sesbania sesban* (L.) Merr., *Gliricidia sepium* (Jacq.) Steud., and *Calliandra calothyrsus* Meissn have been introduced and promoted to increase biomass for supplemental animal feed and soil fertility management. In some cases, the genetic base and adaptation of those introduced tree species were found to be poor. In other cases, pests and diseases have threatened them. For instance, insect damage of *Leucaena* by psyllids (*Heterosylla cubana* Crawford) has been a critical barrier to further dissemination and utilization of this tree species in the highlands. Failure of some exotic fodder species to expand suggests the need to focus on indigenous tree species in order to exploit the advantages of indigenous fodder tree and shrub species 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.

Apart from the work of Abebe et al (2008), very little research has been done so far on the nutritional value of indigenous tree and shrub species in Ethiopia in general and in the study area in particular. This also means that indigenous knowledge of fodder tree and shrub species is not strongly supported by scientific bases. Therefore, the objective of this study was to assess the nutritional value of 3 indigenous and 1 exotic woody fodder species based on their chemical composition, tannin contents, in vitro dry matter digestibility, and digestible energy.

FIGURE 1 Location map of the study areas. (Map by the authors)



Material and methods

Study site

The study site is situated in the upper plateaus of Dendi and Jeldu *Weredas* (districts), West Shewa Zone, central Ethiopia (Figure 1). The altitude ranges from 2900 to 3200 masl. The rainfall pattern is bimodal. The main rainy season is from July to September, and annual rainfall is 1399 mm. The soils are classified as Haplic Luvisols. The original vegetation in the area was mainly

FIGURE 2 Farmers demonstrating the palatability of *H. abyssinica* and *D. torrida* at Galessa, central Ethiopia. (Photo by Kindu Mekonnen)

TABLE 1 Description of tree and shrub species included in foliage and flower bud sampling.

Species	Family name	Altitude of sampling site (masl)	Estimated age of trees (year)	Propagation	Height of trees (m)
H. abyssinica	Rosaceae	2960–3015	5–8	Seed	4.0–4.6
D. torrida	Sterculiaceae	2895–3010	6–8	Seed	4.3–5.0
B. polystachya	Loganiaceae	2895–3020	5–9	Seed, cutting	3.1–4.6
C. palmensis	Fabaceae	2900–3000	4–5	Seed	4.5–4.9

Hagenia abyssinica and *Juniperus procera*. The most common land-use systems in the study areas are mixed crop–livestock systems and forest use. Trees and shrubs are concentrated around the homesteads and in the nearby Chilmo state forest. Barley (*Hordeum vulgar*) is the dominant crop, followed by potato (*Solanum tuberosum*) and enset (*Ensete ventricosum*). Cattle, sheep, and horses are the dominant livestock species.

Description of the three indigenous woody fodder species

More than 29 indigenous fodder tree and shrub species were identified in the study area through informal and formal survey approaches (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. Farmers' preference criteria for the 3 indigenous fodder

TABLE 2 Macronutrient and micronutrient composition of the 4 fodder tree species in the highlands of central Ethiopia. CP, NDF, ADF, and ADL are in mg g^{-1}, and DE is in Mcal kg^{-1} dry matter; IVDMD is in %. CT is expressed as A_{550} absorbance units per gram of NDF (AU g^{-1}) as described by Reed et al (1982). Means with different letters ($^{a,\ b}$) within a row are significantly different ($P < 0.05$). See Methods section for abbreviations.

Foliage	*H. abyssinica*	*D. torrida*	*B. polystachya*	*C. palmensis*	SEM$^{a)}$
CP	188.00^{b}	234.00^{a}	229.00^{a}	228.00^{a}	7.24
NDF	356.00^{c}	451.00^{b}	526.00^{ba}	571.00^{a}	26.47
ADF	303.00^{b}	354.00^{b}	449.00^{a}	361.00^{ba}	19.89
ADL	54.00^{c}	100.00^{bc}	173.00^{a}	125.00^{ba}	14.79
CT	4.59^{c}	19.25^{b}	29.76^{a}	11.68^{c}	2.98
IVDMD	70.00^{a}	59.00^{b}	47.00^{c}	71.00^{a}	3.10
DE	334.00^{a}	269.67^{b}	241.67^{b}	349.67^{a}	13.98
DE:CP	1.78^{a}	1.15^{b}	1.06^{b}	1.53^{a}	0.10
Flower bud					
CP	170.00^{a}	165.00^{a}	170.00^{a}	124.00^{b}	7.63
NDF	340.00^{c}	610.00^{b}	608.00^{b}	723.00^{a}	42.70
ADF	295.00^{c}	473.00^{a}	435.00^{b}	463.00^{ba}	21.96
ADL	73.00^{c}	199.00^{a}	162.00^{b}	98.00^{c}	15.78
CT	9.34^{b}	119.51^{a}	24.40^{b}	8.76^{b}	14.18
IVDMD	60.00^{a}	52.00^{b}	58.00^{a}	60.00^{a}	1.14
DE	292.70^{a}	262.70^{b}	292.30^{a}	308.30^{a}	5.40
DE:CP	1.72^{b}	1.59^{b}	1.72^{b}	2.49^{a}	0.12

[a)] Standard error of the means ($n = 12$).

TABLE 3 Foliage and flower bud chemical composition for the 4 tree species in the highlands of central Ethiopia. P, K, Ca, Mg, and S are in mg g^{-1} dry matter, whereas Na, Fe, and Mn are in $\mu g\ g^{-1}$ dry matter. Means with different letters within a row are significantly different ($P < 0.05$). See Methods section for abbreviations.

Foliage	*H. abyssinica*	*D. torrida*	*B. polystachya*	*C. palmensis*	SEM[a)]	Normal requirement[b)]
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	305.00^{a}	224.00^{a}	214.00^{a}	268.00^{a}	18.11	600–1800
Fe	197.00^{b}	364.00^{ba}	284.00^{ba}	450.00^{a}	36.21	30–50
Mn	61.00^{b}	144.00^{b}	104.00^{b}	374.00^{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	169.00^{a}	200.00^{a}	212.00^{a}	179.00^{a}	24.25	600–1800
Fe	442.00^{a}	263.00^{a}	248.00^{a}	223.00^{a}	54.32	30–50
Mn	39.00^{a}	67.00^{a}	44.00^{a}	95.00^{a}	11.46	20–40

[a)] Standard error of the means ($n = 12$).

[b)] Recommended mineral elements expressed as mg g^{-1} dry matter of animal feeds for all classes of ruminants according to NRC (1984, 1985, 1989, 1996).

species were palatability (Figure 2), harmlessness to animals, availability during the dry season, coppicing ability, high biomass, and fast to intermediate growth. *Chamaecytisus palmensis* (Christ) Bisby & K. Nicholls—an exotic fodder species—was recently introduced and included in the study for the purpose of comparison with the indigenous species. *Chamaecytisus* fixes nitrogen, unlike the indigenous species that are included in the present study. It also performs very well in the study areas.

In addition to the fodder value, the species included in the present study are useful to improve soil fertility. Moreover, *H. abyssinica*, *D. torrida*, and *B. polystachya* produce high biomass after pollarding, and *C. palmensis* does so after cutting. The location of the trees and shrubs is in hedges around the homesteads. The trees and shrubs occur in these hedges as clusters as well as pure stands. None of the tree or shrub species has thorns. Additional description of the species is given in Table 1.

Sample 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 the required species were present were identified from the 14 villages for the present study. Each of the 3 villages was considered as a replication. The 4 fodder species were demarcated in each village. Foliage (leaves and twigs) and flower bud samples were collected from representative branches on all sides of each of the 4 species in each village. In total, 20 trees per village and species were used for foliage and flower bud sampling. The composite samples from each village and tree species contained all palatable foliages as well as flower buds. Flower buds were included in the sampling scheme since most species produce an abundance of flower buds that are palatable for livestock.

All foliage and flower bud samples were oven-dried at 80°C for 24 hours. The foliage and bud flower samples were ground with a Cyclotec mill, then sieved using a

http://dx.doi.org/doi:10.1659/mrd.1098

TABLE 4 Correlation coefficient (*r*) of the relationships among CT, ADL, ADF, NDF, and IVDMD in the foliage and flower bud for the 4 tree species in the highlands of central Ethiopia. See Methods section for abbreviations.

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 $P < 0.001$.

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. The total P, K, Ca, Mg, S, Na, Fe, and Mn contents of the extracts were determined using a simultaneous ICP-OES (inductively coupled plasma–optical emission spectroscopy) with an axial plasma and SCD (Perkin Elmer, OPTIMA 3000 XL).

Crude protein (CP) was calculated by multiplying N by 6.25. Acid detergent fiber (ADF), acid detergent lignin (ADL), and neutral detergent fiber (NDF) were determined by the methods of Van Soest and Robertson (1985). In vitro digestiblity was determined using the method presented by Tilley and Terry (1963), as modified by Van Soest and Robertson (1985). Values are expressed as in vitro dry matter digestiblity percentage (IVDMD%). The insoluble NDF-bound proanthocyanidins (condensed tannins [CT]) were determined as described by Reed et al (1982). Digestible energy (DE) was calculated following a modification of the equation used by the National Research Council (NRC) (2001):

$$DE = 0.01\ OM(IVOMD + 12.9)4.4 - 0.3,$$

where OM is % of organic matter. For feeds for which data on IVDMD were available but OM was unknown, the latter was assumed to be 90% of the dry matter (DM); IVOMD (in vitro organic matter digestiblity) was assumed to be the same as IVDMD; 12.9 represents the endogenous losses of energy in feces; 4.4 is the average concentration of energy (Mcal kg^{-1}) in the digested OM; and −0.3 is the intercept.

Data management and analysis

A one-way analysis of variance (ANOVA) was carried out on CP, mineral composition, ADF, NDF, ADL, condensed tannins, IVDMD, and digestible energy (DE) using SAS (SAS 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. Correlation analysis was performed to understand the relationships among 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.

Results and discussion

Crude protein, NDF, ADF, ADL, CT, IVDMD, and DE

The ranges in crude protein content in the foliage and flower bud of the 4 species were 188–234 mg g^{-1} and 124–170 mg g^{-1}, respectively (Table 2). However, the CP content of the foliage and flower bud in the 4 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

TABLE 5 Prediction of in vitro dry matter digestibility of tree foliage and flower bud from CT, ADL, ADF and NDF. See Methods section for abbreviations.

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

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* could be due to the N-fixing ability of the species.

The NDF, ADF, ADL, and CT contents of the foliage and flower bud in *H. abyssinica* were relatively low as compared to the other species. The contents of NDF and ADF in *H. abyssinica*, *D. torrida*, *B. polystachya*, and *C. palmensis* were within the ranges reported for browsed tree species by Larbi et al (1998), Abdulrazak et al (2000), El Hassan et al (2000), and Khanal and Subba (2001). The variability in CT content among species was higher 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 contents can limit the voluntary feed intake, digestibility, and nutrient utilization of ruminant animals (Khanal and Subba 2001). In general, the levels of ADL and CT in foliage and flower bud of most of the species cannot be considered to have effects on the feed intake and performance of ruminants for 2 reasons. First, 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. Second, farmers do not find a sufficient quantity of foliage and flower buds for their animals over a long duration.

The IVDMD values of the foliage and the flower bud for *H. abyssinica* and *C. palmensis* were comparable. The high foliage IVDMD values of the 2 species could be associated with the low level mainly of CT. The IVDMD value of *H. abyssinica* in our study was high as compared to the IVDMD value reported for *Chamaecytisus palmensis*, *Leucaena leucocephala*, *Sesbania sesban* (15036), *Acacia angustissima*, and *Vernonia amygdalina* (El Hassan et al 2000). The digestible energy of the foliage of *H. abyssinica* and *C. palmensis* was significantly higher than the digestible energy of *D. torrida* and *B. Polystachya* (Table 3). *Dombeya torrida* had the lowest digestible energy as compared to the other 3 species. *H. abyssinica* and *C. palmensis* had a higher foliage DE:CP ratio than the other 2 tree species.

Mineral composition of fodder species

The contents of P, Mg, and S were within the recommended normal requirement range (Table 3). Differences among the species for P were more pronounced in the foliage than in the flower bud. The contents of K, Ca, Fe, and Mn were above the recommended range. 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 4 species were below the critical level. The content of Na in the foliage and flower bud was below the requirement, and Na is important to regulate osmotic pressure, acid–base, and water balance in animals' bodies. Low levels of Na in feeds affect absorption of Mg (Martens et al 1987). Common salt or local mineral sources such as mineral soil can improve the deficiency of Na in the foliage and flower bud feed resources.

Correlations among CP, CT, ADL, ADF, NDF, and IVDMD

ADL and CT value in the foliage and flower bud were negatively and significantly correlated with IVDMD for the 4 species (Table 4). 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 4 species (Table 5). Hence, CT, ADL, and ADF can be good predictors of IVDMD for the foliage and flower bud of the 4 species.

Conclusions

The 4 woody fodder species had adequate mineral nutrients in their foliage and flower buds except for Na. The CP contents in the 3 indigenous species were comparable to that of the exotic species. The digestible energy of the foliage for *H. abyssinica*, *D. torrida*, and *C. palmensis* was found to be high as compared to the digestible energy in their flower buds. In addition to favoring the indigenous species described here, it would be necessary to integrate the N-fixing woody fodder species into the farming system to sustain the production of N-rich fodder resources. In general, the foliage and flower bud of all investigated woody species can be used as sources of supplemental fodder within a proper feeding management scheme.

ACKNOWLEDGMENTS

The authors would like to thank the Austrian Development Cooperation, the Commission for Development Studies at the Austrian Academy of Sciences (KEF), the African Forestry Research Network (AFORNET), and the Ethiopian Institute of Agricultural Research (EIAR) for the financial assistance that supported this work. We would also like to express our gratitude to the Institute of Forest Ecology in Austria and the International Livestock Research Institute (ILRI) in Addis Ababa for the laboratory analysis of plant samples. The support from staffs of forestry, soil, and water management research divisions at Holetta, and farmers and development agents in the Galessa-Jeldu areas are highly appreciated. We thank the 2 reviewers for their constructive comments.

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