Tropical and Subtropical Agroecosystems, 14 (2011): 793 - 805

NUTRITIVE VALUE OF MORPHOLOGICAL FRACTIONS OF *Sesbania sesban* and *Desmodium intortum*

[VALOR NUTRITIVO DE LAS FRACCIONES MORFOLÓGICAS DE *Sesbania sesban* Y *Desmodium intortum*]

Etana Debela [a, b*] , Adugna Tolera[c], Lars O. Eik [a], Ragnar Salte [a],

[a] *Department of Animal and Aquacultural Sciences, Norwegian University of Life Sciences, P.O. Box 5003, N-1432, Ås, Norway*
[b] *School of Veterinary Medicine, Hawassa University, P.O. Box 5, Hawassa, Ethiopia*
[c] *Department of Animal and Range Sciences, College of Agriculture, Hawassa University, P.O. Box 5, Hawassa, Ethiopia*
E-mail: etana_debela@yahoo.com
**Corresponding Author*

SUMMARY

Nutritive value of morphological fractions of *Sesbania sesban* [accession 15019] and *Desmodium intortum cv.* Greenleaf was estimated based on chemical composition, in sacco dry matter (DM) degradability, *in vitro* gas production (IVGP) and *in vitro* organic matter digestibility (IVOMD). In *Sesbania*, neutral detergent fiber (NDFom) and acid detergent fiber (ADFom) contents were higher ($P<0.05$) in twigs and green pods, whereas the acid detergent lignin (ADLsa) content showed the following ranking order ($P<0.05$): green pods > twigs > whole forage > leaves. The soluble tannins (STs) content was higher ($P<0.05$) in green pods and whereas the content of condensed tannins (CTs) was higher ($P<0.05$) in leaves and whole forage. All fractions had sufficient levels of macro and micro minerals, except sodium. *Sesbania* leaves and whole forage had higher ($P<0.05$) potential in sacco degradability (A+B) and in vitro organic matter digestibility (IVOMD). In the case of *Desmodium*, the twigs had lower CP contents and leaves had lower NDFom, ADFom and ADLsa contents. The STs content was highest in leaves whereas the CTs content was higher in whole forage. The washing loss (A) was higher in twigs, while the slowly degradable fraction (B) was higher in greed pods. In the view of the nutrient contents, both *Sesbania* and *Desmodium* can be used as a supplement to improve the nutritional status of ruminants fed low quality roughages.

Key words: Chemical composition; in sacco DM degradability; in vitro gas production; minerals; tannins.

RESUMEN

Se estimó el valor nutritivo de diferentes fracciones morfológicas de *Sesbania sesban* [accesión 15019] y *Desmodium intortum* cv. Greenleaf empleando la composición química, degradabilidad *in situ*, producción de gas *in vitro* (IVGP), y digestibilidad *in vitro* de la materia organica (IVOMD). En la *Sesbania*, los contenidos de fibra detergente neutra (NDFom) y la fibra detergente ácida (ADFom) fueron mayores en los rebrotes y vainas verdes, mientras que el contenido lignina ácido detergente (ADLsa) fue vaina verdes > rebrotes > follaje > hojas. El contenido de taninos solubles (STs) fue mayor en las vainas verdes y el de taninos condensados (CTs) fue mayor en las hojas y el follaje. Todas las fracciones tuvieron niveles adecuados de macro y micro minerales con excepción de su contenido de sodio. Las hojas y el follaje tuvieron una mayor degradabilidad *in situ* e IVOMD. En el caso del *Desmodium*, los rebrotes tuvieron los menores contenidos de PC, NDFom, ADFom y ADLsa. El contenido de STs fue mayor en las hojas y los CTs en el follaje. La pérdida por lavado de la fracción soluble (A) fue mayor en los rebrotes y la fracción lentamente degradable (B) fue mayor en las vainas verdes. Por su contenido de nutrientes, tanto la *Sesbania* como el *Desmodium* pueden ser empleados como suplemento de rumiantes consumiendo forrajes de baja calidad.

Palabras clave: Composición química; degradabilidad *in sacco*; producción de gas *in vitro*; taninos.

INTRODUCTION

Nutritional inadequacy limits the performance of herbivore animals during the dry season when the quality and quantity of the natural pasture declines (Tolera, 2007). Under such conditions, shrubs and legume tree fodders are important sources of supplementary proteins, vitamins and minerals for livestock (Hove et al., 2001). The presence of antinutritional factors such as polyphenols in tropical forage species may reduce intake, digestibility and availability of nutrients thereby affecting productivity of ruminant animals (Makkar, 1993). However some of the polyphenols possess medicinal, e.g. anthelmitic properties (Robertson et al., 1995, Githiori et al., 2004). Among these, proanthocyanidins or condensed tannins (CTs), are widespread in nature and occur in a range of herbaceous and tree or shrubby legumes (Jones et al., 1976; Terrill et al., 1992). Condensed tannin concentrations vary both between plant species and within the same specie influenced by environmental factors (Barry and Forss, 1983; Roberts et al., 1993). They may also differ in structure and biological activity (Foo et al., 1996). CTs are commonly found in the leaves of plants, but in some forages such as white and red clover, they occur in the flower petals (Barry, 1985). This justifies the need to investigate concentrations of condensed tannins in forage species of a given environmental and geographical condition and in different parts of the forage plants.

The chemical composition and digestibility of forages are influenced by plant species, plant morphological fractions, environmental factors and stage of maturity (Papachristou and Papanastasis, 1994). Under cut-and-carry forage feeding systems practised in smallholder animal production systems, leaves and twigs are commonly used as feed for small ruminants, especially during the dry season (Karachi, 1998). Leaf loss is quite common during harvesting, transporting and storage of forages, which justifies study of morphological fractions. In Ethiopia, *Sesbania sesban* and *Desmodium intortum* are used as fodder for small ruminants (Solomon et al., 2004; Tolera, 2007). Both legumes are high-producing, short-lived perennials that are easy to establish even on low-quality soils.

Although studies have been undertaken on the chemical composition and nutritive value of *Sesbania sesban* hay (Solomon et al., 2003) and seeds (Hossain and Becker, 2001), and *Desmodium intortum* hay (Tolera and Sundstøl, 2000; Nurfeta et al. 2008), information is lacking on the feeding value of different morphological fractions of these forage crops, except the chemical and mineral analysis carried out by Kabaija and Little (1988). Data on the nutritive value and CT content of each fraction of *Sesbania* and *Desmodium* are important in order to utilize both the nutritional and the anthelmintic potentials of these legume forages. Such information could provide a basis on which adequate feed rations can be established for feeding on a year-round-basis. The objective of this study was, therefore, to determine the chemical composition, in sacco DM degradability, in vitro organic matter digestibility and in vitro gas production of morphological fractions of *Sesbania sesban* and *Desmodium intortum*.

MATERIALS AND METHODS

Description of study area, the forages and sample collection

Desmodium intortum cv. Greenleaf and *Sesbania sesban* (accession 15019), characterized by high level of CTs, were each established on one ha of land with sandy loam soils at Hawassa University (7°04′ N and 38°31′ E; 1650 m above sea level) in southern Ethiopia. The main rainy season extends from April to September interrupted by some dry spells in May or June with annual precipitation ranging between 1000 and 1200mm. The average minimum and maximum temperatures of the area are 12° and 27°C, respectively.

The edible parts of the forage samples from 20 individual *Sesbania* trees and from 12 plots (1m x 1m) of *Desmodium* stand randomly selected from different locations on the farm were collected. The samples were cut at the green stage using a sickle and taken to a laboratory, where they were weighed and divided into two equal parts; one half was taken as whole forage representing all fractions, while the remaining half was separated into leaves, green pods and twigs. Samples were dried in a draft oven at 50°C for 48 h. A portion of each sample was ground through 1.0 mm sieve using a Wiley mill (Thomas-Wiley, Laboratory Mill Model 4, Arthur H. Thomas Company, Philadelphia, PA, USA) for chemical analysis, in vitro organic matter digestibility (IVOMD) and in vitro gas production while the remaining portion was ground through 2.0 mm sieve for *in sacco* DM degradability.

Chemical analysis

Dry matter (DM), ash and acid detergent fibre (ADFom) content of the forage samples were determined using methods no. 934.01, 942.05, 973.18) (AOAC,1990), respectively. Nitrogen (N) content was determined by the micro-Kjeldahl method and crude protein (CP) was calculated as N × 6.25. Phosphorus (P) contents were determined by continuous flow analysis (ChemLab, 1981). Neutral detergent fibre (NDFom) was analyzed according to Van Soest et al. (1991). Sulfite and α-amylase were not used as reagents in the determination of NDF. Both NDFom and ADFom were reported exclusive of residual ash. Acid detergent lignin (ADLsa) was determined in ADF residues (Robertson and Van Soest, 1981). The contents of condensed tannin (CT) was determined by heating NDFom samples at 95°C for one hour in n-butanol containing 5% concentrated HCl, after which the absorbance was read at 550 nm (Reed et al., 1985). Soluble tannin (ST) was measured according to the method of Porter et al. (1986).

Mineral contents of the forage fractions were determined by a wet ashing procedure using H_2SO_4 and H_2O_2. The samples were analyzed for the macro minerals calcium (Ca), sodium (Na), potassium (K), and magnesium (Mg) and the micro minerals iron (Fe), manganese (Mn), copper (Cu), zinc (Zn) and cobalt (Co) by atomic absorption spectrophotometer (Perkin-Elmer, model 2380, USA).

In sacco DM degradability

Approximately 2.5 g sample was weighed into nylon bags (6.5 cm × 14 cm, 41µm mesh size, Polymon, Switzerland) and the bags were inserted into the rumen of three fistulated, mature sheep fitted with a permanent rumen cannula. The animals were housed in individual pens, and were each offered 800 g mixture of Rhodes grass and *Desmodium* or *Sesbania* hay supplemented with 200 g of concentrate a day in two equal feedings. After an incubation of 4, 8, 16, 24, 48, 72 and 96 h, the bags were removed from the rumen and immediately rinsed in cold water to stop fermentation and to remove the feed particles adhering to the bags. Then, the bags were transferred to a domestic washing machine and washed for 30 min in three cycles (15, 10 and 5 min, respectively) at 22-25°C, dried to a constant weight at 60°C for 48 h, and weighed.

The exponential model of Ørskov and McDonald (1979) was used to describe the degradability constants of the feed samples: $Y = a + b\ (1\text{-}e^{-ct})$ where, Y is DM degradation rate (%) at time *t*. Since washing loss (A) is higher than the estimated soluble fraction (a), the lag time was estimated according to McDonald (1981) by fitting the model $Y = A$ for $t \le t_0$, $Y = a + b\ (1\text{-}e^{-ct})$ for $t > t_0$ and the degradation characteristics of the samples was defined as: A = washing loss (representing the soluble fraction of the feed); B = (a+b)-A, i.e. the insoluble but slowly degradable fraction; *c* = the rate of degradation of fraction B per hour at time *t* and the lag phase (L)=(1/c) log [b/(a+b)-A)]. The effective DM degradability was calculated as ED = A+[Bc/ (k+c)], where A, B and c are as described above and *k* is rumen outflow rate, which was assumed to be $0.05h^{-1}$ (Dhanoa, 1988; Ørskov and Ryle, 1990).

In vitro organic matter digestibility and gas production

In vitro organic matter digestibility (IVOMD) was determined by the method of Tilley and Terry (1963) as modified by Van Soest and Robertson (1985), which replaces the second-stage pepsin digestion with a neutral detergent extraction. *In vitro* gas production of the forage fractions was determined following the procedure of Menke and Steingass (1988). About 200 mg of dry sample (milled through a 1.0 mm sieve) was incubated *in vitro* with rumen fluid in a calibrated glass syringe of 100 ml in triplicate. Vaseline was applied to the pistons to ease movement and prevent escape of gas. The syringes were pre-warmed at 39°C before addition of 30 ml of rumen liquor and buffer mixture into each syringe. The syringes were shaken gently 30 min after the start of incubation and every hour for the first 10 h of incubation. Blanks with buffered rumen fluid without feed sample were also included in triplicate. All the syringes were incubated in a water bath maintained at 39°C. Gas production was recorded after 3, 6, 12, 24, 48, 72, and 96 h of incubation. The gas production characteristics were estimated by fitting the mean gas volumes to the exponential equation of Ørskov and McDonald (1979): $G = a + b\ (1\text{-}e^{-ct})$, where *G* is the gas production (ml/200mg OM) at time *t*, *a* is the intercept of the gas production curve, *b* is the extent of gas production, *a* + *b* is the potential gas production (ml/200 mg OM), and *c* is the rate constant of gas production (Blümmel and Ørskov, 1993).

Statistical analysis

Chemical composition, in sacco DM degradability, IVOMD and gas production data were subjected to analysis of variance using the GLM procedure available in the Statistical Analysis System (SAS, 2001). Duncan's multiple range tests was used for means separation. Correlation between chemical compositions, *in vitro* gas production parameters, IVOMD and *in sacco* degradation characteristics were performed with the Pearson product moment correlation procedure (SAS, 2001). No statistical analyses were undertaken on mineral contents of the morphological fractions of the forages.

RESULTS

Chemical composition

The DM content of *Sesbania* (Table 1) was the highest ($P<0.05$) in twigs and the lowest in the whole forage whereas the ash content was significantly ($P<0.05$) higher in leaves and twigs than in green pods and whole forage. No differences were found in CP and ADF-ash content between fractions. The NDFom and ADFom contents were significantly ($P<0.05$) higher in twigs and green pods compared with leaves and whole forage. The ADFom content was the lowest ($P<0.05$) in leaves and the highest in twigs and green pods. The ADLsa values showed the following declining trend ($P<0.05$) among the different fractions: green pods > twigs > whole forage > leaves. The concentration of STs was significantly ($P<0.05$) lower in the twigs than in the leaves and green pods, whereas the content of CTs was significantly ($P<0.05$) higher in leaves and whole forage than in twigs and green pods.

Desmodium twigs had significantly (P<0.05) higher ash content than other fractions (Table 1). The CP was the highest in leaves and the lowest in twigs whereas the NDFom content was significantly (P<0.05) lower in leaves than in the other fractions. The ADFom content showed the following ranking order among the different fractions: twigs > green pods and whole forage > leaves. The ADLsa content was significantly (P<0.05) lower in leaves than in the other morphological fractions. The concentration of soluble tannins was the lowest (P<0.05) in green pods and the highest the in leaves whereas the CT content was significantly (P<0.05) higher in whole forage than in twigs.

The macro and micro mineral contents of the morphological fractions are shown in Table 2. All the minerals, except sodium, were found to be within or above the range required by ruminant animals.

Table 1. Dry matter (fresh basis) and chemical composition of morphological fractions of *Sesbania sesban* and *Desmodium intortum*

Forages and morphological fractions	DM (g/kg)	Ash (g/kg DM)	CP (g/kg DM)	NDF (g/kg DM)	ADF (g/kg DM)	ADL (g/kg DM)	ADF-Ash (g/kg DM)	ST (g kg $^{-}$DM)	CT abs/g NDF)
Sesbania									
Leaves	267^{ab}	108^{a}	297^{a}	174^{b}	131^{c}	40^{d}	3.5^{a}	130^{a}	121.1^{a}
Twigs	304^{a}	108^{a}	194^{a}	479^{a}	401^{a}	82^{b}	7.2^{a}	88^{b}	51.2^{b}
Whole forage	193^{c}	83^{b}	228^{a}	238^{b}	202^{b}	57^{c}	2.4^{a}	121^{ab}	109.4^{a}
Green pods	255^{b}	75^{b}	248^{a}	494^{a}	407^{a}	99^{a}	2.3^{a}	142^{a}	48.9^{b}
SEM	11.8	8.04	26.6	19.2	6.8	3.1	0.2	0.8	7.9
P-Value	<0.001	0.04	0.1217	<0.0001	<0.0001	<0.0001	0.4113	0.01	0.001
Desmodium									
Leaves	192^{a}	82^{b}	275^{a}	262^{b}	250^{c}	73^{b}	18.6^{a}	207^{a}	64.1^{ab}
Twigs	201^{a}	106^{a}	133^{c}	473^{a}	437^{a}	100^{a}	10.1^{a}	136^{bc}	54.1^{b}
Whole forage	199^{a}	91^{b}	250^{ab}	431^{a}	343^{b}	94^{a}	12.9^{a}	173^{ab}	78.6^{a}
Green pods	207^{a}	92^{b}	230^{b}	454^{a}	362^{b}	114^{a}	5.2^{a}	100^{c}	60.9^{ab}
SEM	18.1	2.5	9.9	15.1	7.1	4.6	0.41	1.5	4.2
P-Value	0.9444	0.001	0.001	0.0001	<0.0001	<0.001	0.1251	0.01	0.1

DM=dry matter, CP= crude protein, NDF= neutral detergent fiber, ADF=acid detergent fiber, ADL= acid detergent, ADF Ash= acid detergent fiber-ash, ST= soluble tannin, CT=condensed tannin; SEM = Standard error of the mean; [a] Means followed by different letters within a column are significantly different (P<0.05). All comparisons are within forage species.

Table 2. Contents of major (g/kg DM) and trace (mg/kg DM) minerals, Ca: P and K/Ca+Mg ratio of morphological fractions of *Sesbania sesban* and *Desmodium intortum.*

Category	Major elements					Ratio		Trace elements				
	Ca	P	Na	K	Mg	Ca: P	K/Ca+Mg	Mn	Co	Cu	Fe	Zn
Sesbania												
Leaves	25.4	1.8	0.25	13.5	1.7	14.1	0.5	196.9	103.4	15.5	424.9	29.3
Twigs	5.8	3.4	0.28	20.9	1.1	1.7	3.03	61.7	104	15.4	323.2	26.8
Whole browse	10.7	3.5	0.22	19.6	1.2	3.1	1.65	105.4	207.6	17.2	255.8	30.2
Green pods	7.4	3.7	0.31	20.6	1.0	2.0	2.45	55.3	92.6	13.0	185.3	25.2
Desmodium												
Leaves	9.4	4.1	0.09	13.9	1.8	2.3	1.24	124.3	62.5	19.6	291.1	27.8
Twigs	8.7	2.4	0.19	27.5	1.8	3.6	2.62	52.9	129.4	14.7	345.2	25.2
Whole browse	7.6	3.5	0.15	17.8	1.6	2.2	2.17	91.4	120.7	17.9	264.3	25.3
Green pods	9.0	5.0	0.11	14.2	1.9	1.8	1.49	101.5	83.8	20.1	161.9	28.9
[@]Requirements	1.9-8.2	1.2-4.8	0.6-1.8	5-10	1.0-2.5	1:1-2:1	2.2**	20-40	0.1-0.2[†]	7-11	30-50	20-40

[@] Recommended mineral requirements for all classes of ruminants (McDowell, 1997; [†]McDowell, 2003) for macro (g/kg DM) and trace (mg/kg DM) elements

** K/Ca+Mg ratio in milli-equivalent (mEq), (Kemp and t' Hart, 1957)

In sacco DM degradability

The DM disappearance and degradability parameters of the different morphological fractions of *Sesbania* and *Desmodium* are given in Figure 1a and in Table 3. Leaves and whole forage from *Sesbania* did not differ significantly in their DM disappearance (P>0.05), except at 4 hrs, and maintained significantly (P<0.05) higher DM disappearance than other fractions at all incubation times (Figure 1a). Green pods showed significantly (P<0.05) lower DM disappearance values at all incubation times than twigs, leaves and whole forages. In the case of *Desmodium*, however, there were no significant differences in DM disappearance between the different morphological fractions at any incubation time.

The soluble or rapidly degradable fraction (A) and the potential degradability (A+B) differed significantly (P<0.05) between morphological fractions of *Sesbania* in the following order: leaves > whole forage > twigs > green pods. The slowly degradable fraction (B) was significantly (P<0.05) higher in twigs and whole forage than in leaves, which in turn showed higher B values than the green pods. There were no significant differences between fractions with respect to degradation rate (c) or lag phase (L). The effective degradability (ED) was higher (P<0.05) in leaves and whole forage than in twigs and green pods.

There were no differences among *Desmodium* fractions (P>0.05) in potential degradability (A+B), effective degradability (ED) and degradation rate (c). The washing loss (A) was higher in twigs than in whole forage, which in turn had higher A values than leaves and green pods. The slowly degradable fraction (B) was significantly (P<0.05) higher in green pods than in twigs whereas the lag time was lower in the green pods than in the other fractions.

In vitro organic matter digestibility and gas production

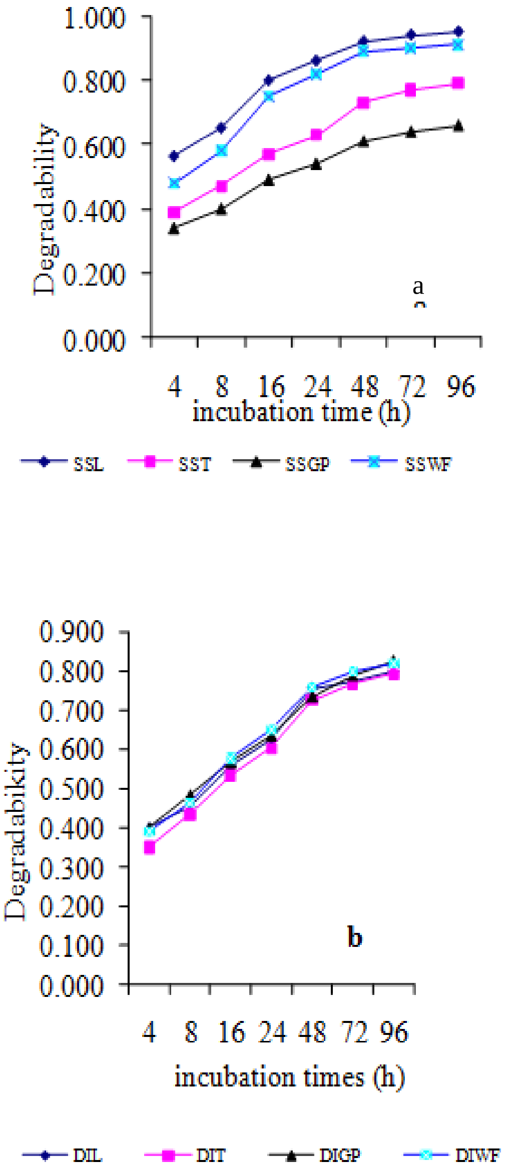
In vitro organic matter digestibility of the two forages is shown in Table 3. The IVOMD of *Sesbania* was significantly (P<0.05) higher in leaves and whole forage than in the twigs and the lowest (P<0.05) value was found in green pods. Fractions of *Desmodium* did not show significant differences (P>0.05) in their IVOMD digestibility values.

Gas produced from the soluble component (a) was higher in leaves and whole forage than in twigs and green pods of *Sesbania* (Table 4). The extent of gas production due to the insoluble but slowly fermentable component (b) was highest in twigs and lowest in green pods with intermediate values in leaves and whole forage, whereas the rate of gas production (c) and potential gas production (a+b) were significantly (P<0.05) lower in green pods than in the other fractions. Leaves, twigs and whole forage of *Sesbania* produced significantly (P<0.05) higher volumes of gas at all incubation times than did green pods (Figure 2a). All fractions showed rapid gas production between 12 and 24 h of incubation.

Gas production from the soluble component (a) of *Desmodium* was the highest in green pods and the lowest in whole forage (Table 4) .The extent of gas produced from the insoluble but slowly fermentable component (b) was significantly (P<0.05) higher from twigs and whole forage than in leaves and green pods. The rate of gas production (c) was higher in twigs and green pods than in leaves and whole forage, whereas the gas production potential (a+b) was higher in twigs than in the other fractions. The leaves and whole forage produced less volume of gas than the twigs and green pods from 3 to 12 h of incubation (Figure 2b). The volume of gas produced from 12 h onwards was highest in twigs and lowest in the leaves of *Desmodium*. All *Desmodium* fractions showed rapid gas production between 12 and 24 h of incubation (Fig 2b).

Correlations between chemical composition, *in vitro* OM digestibility, *in sacco* DM degradability and gas production characteristics.

Correlation between chemical composition, IVOMD, *in sacco* DM degradability and gas production characteristics are given in Table 4. NDF, ADF and ADL were negatively correlated (P<0.05) with IVOMD, the readily degradable fraction, effective degradability, potential degradability, rate of dry matter degradation and the readily fermentable components of the forage fractions. Soluble tannin was negatively correlated with the rate and extent of gas production and with the potential of gas production (P<0.01) from the forage fraction components. Condensed tannins were negatively correlated with NDF and ADF but positively correlated with all degradability parameters, CP and IVOMD. Positive correlation was observed between *in sacco* DM degradability and *in vitro* gas production characteristics and IVOMD.



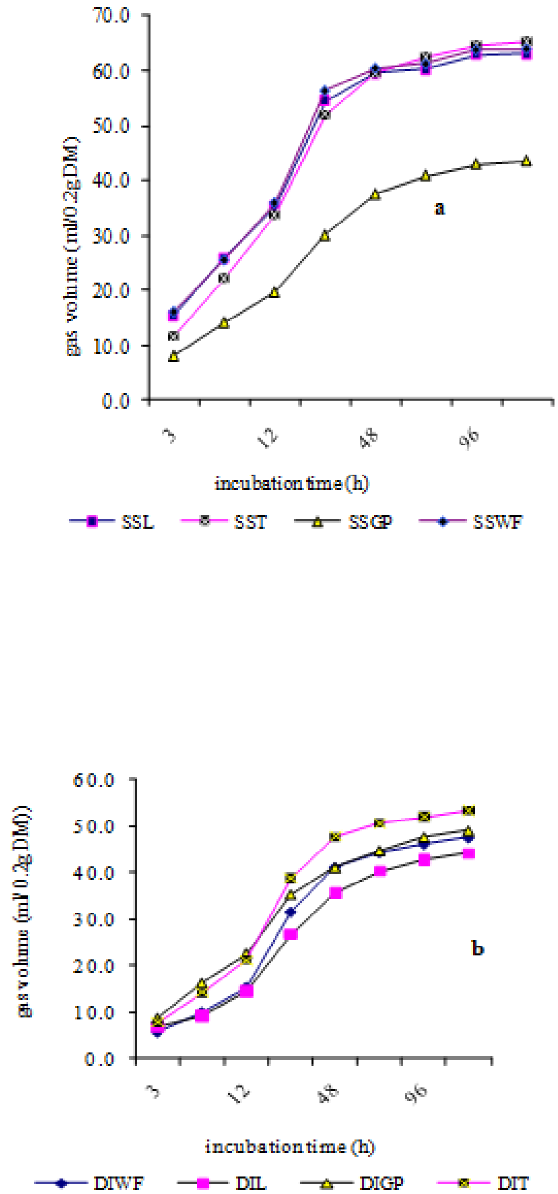


Figure 1. DM degradability of the different morphological fractions of *S. sesban* (a) and *D. intortum* (b) at different incubation times.
SSL= *Sesbania sesban* leaves; SST = *Sesbania sesban* twigs; SSGP = *Sesbania sesban* green pods;
SSWF = *Sesbania sesban* whole forage; DIL = *Desmodium intortum* leaves; DIT = *Desmodium intortum* twigs;
DIGP = *Desmodium intortum* green pods; DIWF = *Desmodium intortum* whole forage

Figure 2. In vitro gas production values of the different morphological fractions of *S. sesban* (a) and *D. intortum* (b)
SSL= *Sesbania sesban* leaves; SST = *Sesbania sesban* twigs; SSGP = *Sesbania sesban* green pods; SSWF = *Sesbania sesban* whole forage; DIL = *Desmodium intortum* leaves; DIT = *Desmodium intortum* twigs; DIGP = *Desmodium intortum* green pods; DIWF = *Desmodium intortum* whole forage

Table 3. In Sacco DM degradability, in vitro OM digestibility and gas production characteristics of morphological fractions of *Sesbania sesban* and *Desmodium intortum.*

Forages and morphological fractions	Degradability characteristics						IVOMD (g/kg DM)	In vitro gas production characteristics			
	A	B	c/ h	L(h)	(A+B)	ED (k=0.05(h^{-1})		*a*	*b*	*c*	*a+b*
Sesbania											
Leaves	0.538^{a}	0.408^{b}	0.081^{a}	3.3^{a}	0.945^{a}	0.747^{a}	0. 760^{a}	4.65^{a}	57.95^{b}	0.014^{a}	62.60^{a}
Twigs	0.353^{c}	0.445^{a}	0.048^{a}	2.6^{a}	0.798^{c}	0.547^{c}	0.633^{b}	1.21^{b}	63.21^{a}	0.013^{a}	64.42^{a}
Whole forage	0.446^{b}	0.464^{a}	0.081^{a}	3.3^{a}	0.910^{b}	0.689^{a}	0.726^{a}	5.61^{a}	57.51^{b}	0.014^{a}	63.12^{a}
Green pods	0.329^{d}	0.334^{c}	0.051^{a}	3.2^{a}	0.663^{d}	0.468^{c}	0.488^{c}	3.42^{b}	39.82^{c}	0.009^{b}	43.23^{b}
SEM	0.006	0.011	0.001	0.007	0.011	0.017	0.016	0.009	0.016	0.001	0.014
P-Value	<0.001	0.001	0.2331	0.2540	<0.0001	0.0001	<0.0001	0.05	<0.0001	0.002	<0.0001
Desmodium											
Leaves	0.353^{c}	0.455^{ab}	0.047^{a}	4.6^{a}	0.809^{a}	0.518^{a}	0.634^{a}	1.98^{ab}	42.39^{b}	0.007^{bc}	44.37^{b}
Twigs	0.397^{a}	0.415^{b}	0.042^{a}	4.1^{a}	0.812^{a}	0.550^{a}	0.557^{a}	-0.13^{bc}	52.40^{a}	0.010^{a}	52.27^{a}
Whole forage	0.374^{b}	0.469^{ab}	0.047^{a}	3.2^{a}	0.843^{a}	0.557^{a}	0.601^{a}	-0.63^{c}	48.3^{a}	0.008^{b}	47.7^{b}
Green pods	0.355^{c}	0.498^{a}	0.042^{a}	1.27^{b}	0.853^{a}	0.552^{a}	0.565^{a}	2.94^{a}	43.07^{b}	0.011^{a}	46.01^{b}
SEM	0.008	0.019	0.001	0.005	0.019	0.028	0.022	0.069	0.015	0.001	0.012
P-Value	<0.001	0.008	0.9879	0.001	0.3377	0.7593	0.1229	0.02	0.004	0.002	0.01

A=readily soluble fraction, B=insoluble but slowly degradable fraction, c=rate of degradation, L=lag time, PD=potential degradability, ED=effective degradability, K = particulate out-flow rate; IVOMD= in vitro organic matter digestibility, a=intercept of gas production, b=extent of gas production, c=rate of gas production, PD=potential of gas production; SEM=Standard error of the means; ^{a} Means followed by different letters within a column are significantly different (P<0.05). All comparisons are within forage species.

Table 4. Correlation coefficients of chemical composition, in vitro OM digestibility and degradability characteristics of different morphological fractions of *Sesbania sesban* and *Desmodium intortum*

	***a*DM**	**b**DM	*c*DM	PD	ED	IVOMD	*b*gas	*pd*gas	*c*gas	CP	NDF	ADF	ADL	ST	CT
*a*DM	1.00	0.07	0.32	0.76***	0.85***	0.75***	0.52*	0.60**	0.71***	0.13	-0.71***	-0.73***	-0.74***	-0.14	0.51*
*b*DM		1.00	-0.17	0.63**	0.15	0.33	0.16	0.09	0.06	0.16	-0.15	-0.16	0.02	0.03	0.20
*c*DM			1.00	0.27	0.75***	0.42	0.21	0.33	0.32	0.26	-0.49*	-0.51*	-0.53*	-0.13	0.40
PD				1.00	0.78***	0.83***	0.52*	0.55**	0.56**	0.11	-0.67***	-0.71***	-0.59**	-0.06	0.52*
ED					1.00	0.79***	0.53*	0.63**	0.68***	0.15	-0.73***	-0.75***	-0.76***	-0.21	0.50*
IVOMD						1.00	0.65**	0.72***	0.61***	0.26	-0.79***	-0.83***	-0.83***	-0.09	0.60**
*a*gas							0.02	0.28	0.43*	0.47*	-0.53*	-0.59**	-0.51*	-0.23	0.28
*b*gas							1.00	0.96***	0.75***	-0.24	-0.23	-0.25	-0.52*	-0.47*	0.15
*pd*gas								1.00	0.84***	-0.10	-0.36	-0.40*	-0.63**	-0.51*	0.22
*c*gas									1.00	0.01	-0.33	-0.40*	-0.53*	-0.63**	0.12
CP										1.00	-0.41*	-0.50*	-0.33	0.22	0.50*
NDF											1.00	0.97***	0.88***	-0.29	-0.69***
ADF												1.00	0.88***	-0.19	-0.71***
ADL													1.00	-0.07	-0.53*

*a*DM, rapidly degradable dry matter; *b*DM, extent of degradation; *c*DM, rate of degradation; PD, potential degradability of dry matter; ED, effective degradability of dry matter; IVOMD, in vitro organic matter digestibility; *a*gas, intercept of gas production; *b*gas, extent of gas production; *c*gas, rate of gas production; CP, crude protein; NDF, neutral detergent fibre; ADF, acid detergent fibre; ADL, acid detergent fibre; ST, soluble tannin; CT, condensed tannin;
* $p<0.01$; ** $p<0.001$; *** $p<0.0001$

DISCUSSION

Chemical composition

Leguminous forages have been used as feed for livestock in many regions of the world, mainly because of their high protein contents throughout the year (Tolera et al., 1997; Tolera, 2007). In this study, crude protein contents were in agreements with earlier findings (Kabija and Little, 1988; Tolera and Sundstøl, 2000; Solomon et al., 2004). The CP contents of *Sesbania* fractions varied from 194 g/kg DM in twigs to 297 g/kg DM in leaves, whereas that of *Desmodium* fractions varied from 133 g/kg DM in twigs to 275 g/kg DM in leaves. Thus, the different fractions of the two forages had moderate to high levels of CP, which indicates that all the morphological fractions of the two forages could provide supplemental protein to ruminants offered diets low or deficient in CP, especially at times when the quality and quantity of available feed is low.

Utilization of CP in leguminous forages may be negatively affected by the contents of CTs, alkaloids and saponins (D'Mello, 1992; Kumar and D'Mello, 1995). Contents of alkaloid and saponin were not determined in this study, but the concentrations of CTs in all fractions of *Sesbania* were higher than previously reported (Solomon et al., 2003). On the other hand, the CTs content of *Desmodium* fractions was lower than earlier reports for *Desmodium intortum* hay (Tolera and Sundstøl, 2000). Differences could be due to changes in the extractability of tannins with season, changes in leaf morphology, moisture content or chemical composition (Hagerman, 1988).

The content and type of cell wall fractions in plants will influence DM intake and digestibility of the forage (Buxton, 1996; Bakshi and Wadhwa, 2007). The higher NDFom, ADFom and ADLsa contents in twigs and green pods of both *Sesbania* and *Desmodium* than in other fractions reflects the fibrous nature of these fractions. The ADF/NDF proportion was within the high range of 0.76 to 0.85 for *Sesbania* fractions and 0.80 to 0.95 for *Desmodium* fractions, which is indicative of high contents of cellulose and lignin and lower levels of hemi-cellulose (Abdulrazak *et al.*, 2000). However, the mean NDF contents of whole forage from both species is close to the optimum concentration in diets of high producing dairy cows at peak lactation, and it is higher than the value recommended for fast growing ruminants (Mertens, 1994).

Information on the mineral composition of different morphological fractions of *Sesbania* and *Desmodium* is limited. The present results show that all fractions had sufficient levels of Ca, P, K, Mn, Co, Cu, Zn and Fe, which in most cases compared with the recommended requirements for all classes of animals (McDowell, 1997). Kabaija and Little (1988) reported marginal to deficient Na, Cu, and P contents in most crop residues and some forage fractions fed to ruminants in Ethiopia. And copper deficiencies has also been reported in ruminants in the rift valley of east Africa (Faye et al., 1991) as have sway back in lambs and goats in the rift valley system around Zway in Ethiopia (E. Debela, personal observation, 2007). All fractions from the two forages were, however, deficient in Na content. Provided Na is supplied *Sesbania* and *Desmodium* fractions could alleviate deficiencies of Ca, Mg, K, P, Zn, Cu, Mn, and Fe. A Ca: P ratio of 1:1 to 2:1 in the feed is considered to be adequate for farm animals other than poultry (McDonald et al., 1988). The values of all fractions in the present study were relatively closer to the 2:1 ratio (except for *Sesbania* leaves, which had a higher ratio).

In sacco dry matter degradability

The solubility of roughage, the insoluble but potentially degradable fraction and degradation rate are important factors that affect the intake of poor quality forages (Ørskov, 1994), and A, B and c values are considered to be precise predictors of feed intake, digestibility and growth rate (Tolera and Sundstøl, 2001). The washing loss (A), potential degradability (A+B), effective degradability (ED) and lag time (L) values of *Desmodium* fractions in this study were all higher than the values reported for *Desmodium* hay (Tolera and Sundstøl, 2001).

DM disappearance of *Sesbania* fractions decreased in the order of leaves ≥whole forage > twigs > pod. The washing loss (A), which represents the degradability of the readily soluble fraction, also followed a similar ranking order implying the varying degree of availability of the soluble components from the different fractions of the species. The higher potential degradability (PD) and effective degradability (ED) of leaves and whole forage from *Sesbania* could be associated with the low lignin content compared to other fractions (Table 1). The washing loss (A) obtained for all fractions from the two forages was higher than the values reported high quality forages like alfalfa and common vetch (Turgut and Yanar, 2004). The findings indicate that both roughage species may be used to improve feeding of small ruminants.

In vitro organic matter digestibility and gas production

The low IVOMD in twigs and green pods from the two forages is likely an effect of high fibre contents in these fractions (Table 1), as is supported by the negative correlation between fibre fractions of the feeds and IVOMD (Table 4). Conversely, the higher

IVOMD in leaves from *Sesbania* and *Desmodium* and whole forage from *Sesbania* would be associated with higher CP and lower fibre concentrations, thus underlining the potential of these fractions to enhance the digestibility of low quality feeds fed to animals when other feed resources are scarce.

The *in vitro* gas production in this study could not rank the morphological fractions in the same order as the *in sacco* DM degradability. This is in agreement with the findings of Tolera and Sundstøl (1999) who demonstrated a similar phenomenon in ranking morphological fractions from maize stover. This variation in values would be an indication of the amount of soluble fractions being fermented. Negative gas production values due to the readily degradable fraction (a) were recorded for twigs and whole forage from *Desmodium*. Similar negative values have been reported earlier for some grass species (Berhane et al., 2006) and were ascribed to the low soluble content that could ferment instantly. Blừmmel and Becker (1997) suggested, on the other hand, that negative values could be due to a lag phase in the fermentation of insoluble feed components that lead to a deviation from the exponential curve of fermentation. The relatively lower rate and extent of gas production from green pods of the two forages and leaves from *Desmodium* could be associated with the cumulative impact of fiber and tannin contents as both components showed a strong inverse relationship with gas production characteristics. In support of this suggestion are the findings of Abdulrazak et al. (2000) who reported an inverse relationship between gas production and NDF and ADF contents, and those of Kamalak et al. (2005) who found a negative correlation between gas production and polyphenolics present in browse forages.

CONCLUSION

The different fractions of *Desmodium* and *Sesbania* have nutritive values that compare favourably to other leguminous forages available in climatic zones similar to Hawassa area of southern Ethiopia. The plants combine qualities of high nutrient content and good digestibility that makes the whole forage or the different fractions both species useful supplements to low quality roughages, particularly on smallholder farms.

ACKNOWLEDGEMENTS

The authors would like to thank Norwegian Agency for Development Co-operation (NORAD) for financial support.

REFERENCES

Abdulrazak, S.A., Fujihara, T., Ondiek, J.K., Ørskov, E.R. 2000. Nutritive evaluation of some Acacia tree leaves from Kenya. Animal Feed Science and Technology. 85: 89-98.

AOAC. 1990. Official Methods of Analysis. Vol. I, 15th ed. Association of Official Analytical Chemists, Washington, DC, PP 69-88.

Bakshi, M.P.S., Wadhwa, M. 2007. Tree leaves as complete feed for goat bucks. Small Ruminant Research. 69: 74 -78.

Barry T.N. 1985. The role of condensed tannins in the nutritive value of *Lotus pedunculatus* for sheep. 3. Rates of body and wool growth. British Journal of Nutrition. 54: 211-217.

Barry, T.N, Forss, D. A. 1983. The condensed tannin content of vegetative *Lotus pedunculatus*, its regulation by fertilizer application and effects on protein solubility. Journal of the Science Food and Agriculture. 34: 1047-1056.

Berhane, G., Eik, L.O., Tolera, A. 2006. Chemical composition and in-vitro gas production of Vetch (*Vicia sativa*) and some forage and grass species in northern Ethiopia. African Journal of Range and Forage Science. 23: 69-75.

Blümmel, M., Ørskov, E.R. 1993. Comparison of in vitro gas production and nylon bag degradability of roughages in predicting feed intake in cattle. Animal Feed Science and Technology. 40: 109-119.

Blümmel, M., Becker, E, R. 1997. The degradability characteristics of fifty four roughages and roughage neutral detergent fibres as described by in vitro gas production and their relationship to voluntary feed intake. British Journal of Nutrition. 77: 757-768.

Buxton, D.R. 1996. Quality related characteristics of forages as influenced by plant environment and agronomic factors. Animal Feed Science and Technology. 59: 37-49.

Chemlab, 1981. Continuous Flow Analysis. Method sheet no. CW2-008-11 (Ammonia (0-1 and 0-50 ppm N). Chemlab Instruments Ltd. Hornchurch, Essex.

Dhanoa M.S. 1988. On the analysis of Dacron bag data for low degradability feeds. Grass and Forage Science. 43: 441-444.

D'Mello J.P.F. 1992. Chemical constraints to the use of tropical legumes in animal nutrition. Animal Feed Science and Technology. 38: 237-261.

Faye, B., Grillet, A., Tessema, A., Kamil, M. 1991. Copper deficiency in ruminants in the rift valley of East Africa. Tropical Animal Health and Production. 23: 172-179.

Foo, L.Y., Newman, R., Waghorn, G., McNabb, W.C., Ulyatt, M.J. 1996. Proanthocyandins from *Lotus corniculatus*. Phytochemistry. 41: 617-624.

Githiori, J.B., Hoglund, J., Waller, P.J. Baker, R.L. 2004. Evaluation of anthelmintic properties of some plants used as livestock dewormers against *Haemonchus contortus* infection in sheep. Parasitology. 129: 245-253.

Hagerman, A.E. 1988. Extraction of tannins from fresh and preserved leaves. Journal of Chemical Ecology. 40: 453-461.

Hossain, M. A., Becker, K. 2001. Nutritional value and antinutritional factors in different varieties of *Sesbania sesban* seeds and their morphological fractions. Food Chemistry. 73: 421-431.

Hove, L., Topps, J.H., Sibanda, S., Ndlovu, L.R. 2001. Nutrient intake and utilisation by goats fed dried leaves of the shrub legumes *Acacia angustissima, Calliandra calothyrsus,* and *Leucaemia leucocephala* as supplements to native pasture hay. Animal Feed Science and Technology. 91: 95-106.

Jones, W.T., Broudhurst, R.B., Lyttleton, J.W. 1976. The condensed tannins of pasture legume species. Phytochemistry. 15:1407-1407.

Kabaija, E., Little, D.A. 1988. Nutrient quality of forages in Ethiopia with particular reference to mineral elements. In: B.H. Dzowela (Ed.), *African Forage Plant Genetic Resource, Evaluation of Forage Germplasms and Extensive Livestock Production Systems*, Proceedings of the third Pasture Network of Eastern and Southern Africa (PANESA) workshop, International Conference Centre, Arusha, Tanzania, 27-30 April 1987, (International Livestock Research Centre for Africa (ILCA), Addis Ababa) pp.440-448.

Kamalak, A., Canbolat, O., Gurbuz, Y., Erol, A., Ozay, O. 2005. Effect of maturity stage on chemical composition, in vitro and in situ dry matter degradability of tumbleweed hay *(Gundelia tournefortii L.).* Small Ruminant Research. 58: 149-156.

Karachi M. 1998. Variations in the nutritive value of leaves and stem fractions of nineteen leucaenia lines. Animal Feed Science and Technology 70: 305-314.

Kemp, A., t'Hart, M.L., 1957. Grass tetany in grazing milking cows. Netherlands Journal of Agricultural Science. 5: 4-17.

Kumar, P., D'Mello, J.P.F. 1995. Anti-nutritional factors in forage legumes. In: D'Mello, J.P.F., Devendra, C. (Eds.), Tropical Legumes in Animal Nutrition. CAB International, pp. 95-133.

Makkar H.P.S. 1993. Antinutritional factors in foods of livestock. In: Gill M, Owen, E, Pollot, G.E., Lawrence, T.L.J (Eds.), Animal Production in Developing Countries, Occasional Publication No. 16, British Society of Animal Production. pp 69-85

McDonald, I., 1981. A revised model for the estimation of protein degradability in the rumen. Journal of Agricultural Science 96: 251-257.

McDonald, P., Edwards, R.A., Greenhalgh, J.F.D. 1988. Animal Nutrition, 4th ed., Longman Scientific and Technical, UK.

McDowell L.R. 1997. Minerals for Grazing Ruminants in Tropical Regions. Third edition, University of Florida, Gainesville, Florida, USA 81 PP.

McDowell L.R. 2003. Minerals in Animal and Human Nutrition. Second edition, Elsevier Science B.V. Amsterdam, The Netherlands.

Menke, K.H., Steingas, H. 1988. Estimation of the energetic feed value from chemical analysis and in vitro gas production using rumen fluid, Animal Research and Development. 28: 7-55.

Mertens D.J. 1994. Regulation of forage intake. In: Fahey, G.C., Jr. et al., (Eds.), Forage Quality Evaluation and Utilization. American Society of Agronomy, Madison, W1, USA. PP. 450-493.

Nurfeta, A., Tolera, A., Eik, L. O., Sunsdtøl, F. 2008. Yield and mineral content of ten enset (*Ensete* *ventricosum*) varieties. Tropical Animal Health and Production. 40: 299-309.

Ørskov, E.R., McDonald, I. 1979. The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. Journal of Agricultural Science. 92: 499-503

Ørskov, E.R. 1994. Plant factors limiting roughage intake in ruminants. In: Thacker, P.A. (Ed.), Livestock production in the 21st century: Priorities and Research Needs. University of Saskatchewan, Saskatoon, Saskatchewan.

Ørskov, E.R., Ryle, M., 1990. Energy Nutrition in Ruminants. Elsevier, Oxford, p. 149.

Papachristou, T.G., Papanastasis, V. P. 1994. Forage value of Mediterranean deciduous woodyfodder species and its implication to management of silvo-pastoral systems for goats. Agroforestry Systems. 27: 269-282.

Porter, L.J., Hrstich, L.N., Chan, B.G. 1986. The conversion of procyanidins and prodelphidin to cyaniding and delphidin. Phytochemistry. 25: 223-230.

Reed, J.D., Horvath P.J., Allen, M.S., Van Soest, P.J., 1985. Gravimetric determination of soluble phenolics including tannins from leaves by precipitation with trivalent ytterbium. Journal of the Science of Food and Agriculture. 36: 255-261

Roberts, C.A., Beuselinck, P.R., Ellersieck, M.R., Davis, D.K., McGraw. R.L. 1993. Quantification of tannins in birdsfoot trefoil germplasm. Crop Science. 33: 675-679.

Robertson, J.B., Van Soest, P.J. 1981. The detergent system of analysis. In: James, W.P.T, Theander, O., (Eds.), The Analysis of Dietary Fibre in Food. Marcel Dekker, NY, pp. 123-158.

Robertson, H.A., Niezen, J.H., Waghorn, G.C., Charleston, W.A.G., Jinlong, M. 1995. The effect of six herbages on live weight gain, wool growth and faecal egg count of parasitized ewe lambs. Proceedings of New Zealand Society of Animal Production. 55: 199-201.

SAS, 2001. SAS User's Giude, SAS Institute Inc., Cary, NC, USA.

Solomon, M., Peters, K.J., Tegene, A. 2003. In vitro and in situ evaluation of selected multipurpose trees, wheat bran and *Lablab purpureus* as potential feed supplements to tef (*Eragrostis tef)* starw. Animal Feed Science and Technology. 108: 159-179.

Solomon, M., Peters, K.J., Tegene, A., 2004. Microbial nitrogen supply, nitrogen retention and rumen function in Menz sheep supplemented with dried leaves of multipurpose trees, their mixtures or wheat bran. Small Ruminant Research. 52: 25-36.

Terrill, T. H., Rowan, A. M. Douglas, G. B Barry, T. N. 1992. Determination of extractable and bound tannin concentrations in forage plants, proteins concentrate meals and cereal grains. Journal of the Science of Food and Agriculture. 58: 321-329.

Tilley, J.M.A., Terry, R.A. 1963. A two stage technique for in vitro digestion of forage crops. Journal of British Grassland Society 18: 104.

Tolera, A., Khazaal, K., Ørskov, E. R. 1997. Nutritive evaluations of some forage species. Animal Feed Science and Technology. 67: 181-195.

Tolera, A., Sundstøl, F. 1999. Morphological fractions of maize Stover harvested at different stages of grain maturity and their nutritive value of different fractions of the stover. Animal Feed Science and Technology. 81: 1-16.

Tolera, A., Sundstøl, F. 2000. Supplementation of graded levels of *Desmodium intortum* hay to sheep feeding on maize Stover harvested at three stages of maturity. 2. Rumen fermentation and nitrogen metabolism. Animal Feed Science and Technology. 87: 215-229.

Tolera, A., Sundstøl, F. 2001. Prediction of feed intake, digestibility and growth rate of sheep fed basal diet of maize Stover supplemented with *Desmodium intortum* hay from dry matter degradability of the diets. Livestock Production Science. 68: 13-23.

Tolera A. 2007. The role of forage supplements in smallholder mixed farming systems. In: Hare, M.D., Wongpichet, K., (Eds.). Forages: A Pathway to Prosperity for Smallholder Farmers. Proceedings of an International Forage Symposium. Ubon Ratchathani University, Thailand, March 5-7, 2007. pp. 165-186.

Turgut, L., Yanar, M. 2004. In situ dry matter and crude protein degradation kinetics of some forage in Eastern Turkey. Small Ruminant Research. 53: 217-222.

Van Soest, P.J., Robertson, J.B. 1985. Analysis of forages and fibrous foods. A laboratory manual for Animal Science 613, Cornell University. USA

Van Soest, P.J., Robertson, J.B., Lewi, B.A. 1991.Methods for dietary fibre, neutral detergent fibre and non starch polysaccharides in relation to animal nutrition. Journal of Dairy Science. 123: 109-119.

Submitted December 14, 2009 – Accepted October 10, 2010
Revised received June 08, 2011