Daniellia oliveri as a fodder tree for small ruminant and the interaction of its tannin with ruminal ammonia

I. I. Osakwe^{1*}, H. Steingass² and W. Drochner²

¹Department of Animal Science and Fisheries, Ebonyi State University, PMB 053, Abakaliki.

²Institute of Animal Nutrition (450), University of Hohenheim, 70599 Stuttgart, Germany

Abstract

Daniellia oliveri was examined as a potential fodder for small ruminant, using nine castrated and ruminally fistulated West African Dwarf sheep (29 kg BW) to determine rumen ammonia and nutrient digestibility. Dried leaves of *Daniellia oliveri* were offered at two levels (25% and 50% of DMI) as supplement to a basal hay diet. A digestibility trial of 8 days was conducted after 10 days of adaptation period. Rumen liquor was sampled one hour before, and one, three and five hours after the morning feeding for three consecutive days. Diet D50% showed a higher ($P < 0.05$) pH than both the control and D25% diets, respectively. Diet D25% had an inferior ($P < 0.05$) pH than the controls. The ruminal ammonia concentration of D25% was superior ($P < 0.05$) to D50% and the controls, respectively. Similarly, diet D50% had a superior ($P < 0.05$) ruminal ammonia concentration than the controls. There were significant increases ($P < 0.05$) in the OM, CP, NDF, ADF, ADL and cellulose intake of D50% diet compared with the controls. Similarly, inclusion level of 50% *Daniellia oliveri* resulted in a reduction ($P < 0.05$) in digestibility of DMI, OM, NDF, ADF and ADL, in comparison to sheep fed the control diet. Cellulose and hemi-cellulose digestibility of diet D50% was superior ($P < 0.05$) to that of the controls. It would appear that condensed tannins had inhibitory effect on organic matter and detergent fibre digestibility. It was concluded that *Daniellia oliveri* with a high CP and GE (165 g/kg and 20.3 kJ/g DM) respectively, could serve as a fodder tree for small ruminant in spite of its relatively high content of condensed tannin (48 g/kg DM). An inclusion range of 25 to 50% was recommended during period of scarcity.

Key words: *Daniellia oliveri*, nutrient digestibilities, ruminal ammonia, WAD sheep.

Introduction

Sub Sahara African and Middle Eastern countries have large tracts of arid and semi-arid lands that cannot be cultivated but are used to raise livestock, mainly sheep and goats. The raising of livestock is however, uncertain in these areas because of low, unpredictable rainfall and low primary education. Even in favourable rainfall years animal performance is poor due to a lack of adequate dietary protein and energy intake in the dry season. Crude protein declines to less than 2% of forage intake

and digestible protein is often less than 1 gkg⁻¹ of dry matter (DM) consumption. Furthermore, the herbaceous forage is fibrous and of low quality, and in the event of drought, livestock mortality can be high (Benjamin 1992).

In contrast to herbaceous vegetation many trees and shrubs remain green all year, even during droughts. As a result, it has been suggested that they could be useful as fodder for livestock in arid and semi-arid areas (Bohra 1980; Felker 1981). This has led to the examination of a large

*Corresponding author <phone/Fax 043-221093; email: osakwe_i@yahoo.com>

variety of trees and shrubs as potential sources of fodder (Seligman *et al.*, 1989; Topps 1992; Osakwe *et al.*, 1999).

Leguminous trees, in particular, have been examined as they maintain a relatively high crude protein content throughout the year. In addition, these trees have a small canopy which allow intercropping to provide additional feed for livestock. Some legume fodders also have a positive effect on other diets in that they increase intake and improve digestibility (Topps 1999). In general, however, limited success has been achieved with the use of trees and shrubs as livestock fodder because of low forage consumption. This is due mainly to the presence of anti-nutritional factors, notably tannins, which plants are stated to possess as protection against herbivores (Zucker 1983; Kumar and Singh 1984; Robbins *et al.*, 1987a). They form precipitates with proteins, resulting in the formation of indigestible tannin-protein complexes (Robbins *et al.*, 1987b; Hagermann 1989; Makkar 1993). They also form complexes with carbohydrates, cellulose, hemi cellulose and amino acids reducing their digestibility (Barry 1989). Nonetheless, promising results were reported on the feeding of multipurpose trees, such as *Leucaena l.*, *Gliricidia sepium*, *Phyllanthus discoideus* etc, to small ruminants (Dumancic and Le Houerou 1980; Armstrong 1992; Osakwe *et al.*, 2000). In the light of the foregoing, this study was conducted to determine the nutritional value of *Daniellia oliveri* as a fodder tree for small ruminant and the interaction of its tannin with ruminal ammonia and nutrient digestibility.

Materials and methods

Site

Branches from mature *Daniellia oliveri* browse plant were collected from Cotonou (Benin), sun dried and transported to University of Hohenheim, Germany for analysis and feeding trial.

Composition of *Daniellia oliveri*

Dried leaf samples were ground in a cutting mill to pass a 1 mm mesh sieve for chemical

analysis. N content was determined by the kjeldahl method and ash by burning at 550°C (AOAC, 1990). CP was calculated as 6.25xN. NDF, ADF and ADL were determined as described by Goering and Van Soest (1970). Hemi cellulose content was calculated as difference between NDF and ADF, and cellulose as difference between ADF and ADL.

Analyses of Tannins

Analyses of extractable condensed tannins were as described by Makkar *et al.* (1993). Total extractable phenol and tannin phenol were as described by Osakwe *et al.* (2000).

Animal Trial and experimental diets

Nine WAD sheep (average live weight 29kg) all castrates and about two years old were used in a completely randomised design. Six of the sheep were fistulated at the rumen and used for ruminal pH and ammonia in a repeated measurement analysis. Dried leaves of *Daniellia oliveri* were offered at two levels (25% and 50% of DM intake) replacing hay as supplement to a basal diet. The experimental diet were:

100% hay (control diet)

25% *Daniellia oliveri* leaves + 75% hay (Diet D25%)

50% *Daniellia oliveri* leaves + 50% hay (Diet D50%)

In the digestibility trial, three animals were each randomly assigned to each of the experimental diet in individual pens. The animals were adapted for 10 days on this diet before an 8 days collection period of feeds and faeces. Thereafter, rumen liquor was collected for three consecutive days from the fistulated animals. Animals received mineral premix (10 g/d) in addition to the experimental diet. Feed was offered twice daily at 0800 and 1600 hours and water provided *ad libitum*.

Daniellia oliveri (Benn.)

This multipurpose tree of the Caesalpiniaceae family, reaches a height of 60-80 feet and 12 feet in girth, sometimes larger. The tree was named after Dr. Daniell, who visited Sierra Leone and Senegal in the middle of 19th century. This savanna tree is particularly abundant in the Southern Guinea and Derived Savanna Zones in

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Nigeria. It may be easily identified by its twisted trunk and ascending branches which often form a flat-topped triangular crown with conspicuous masses of whitish flowers among the leaves at the summit. Its Hausa name is -maje and kadaura; Yoruba- iya; and Ibo name is ozabwa.

Rumen pH

Rumen liquor was taken one hour prior to feeding and one, three and five hours after feeding directly by means of a vacuum pump with plastic tube thrust into the rumen compartment. Immediately after collection, pH was measured with Schott CG 840-pH Meter. The samples were then immediately freed of coarse particles by filtration through cheese-cloth and centrifuged at 2500g for 20 min under refrigeration.

Rumen ammonia

Ruminal ammonia was determined using 5 ml filtrate that was diluted with 45 ml of de-ionised water and then 0.5 ml of 10 mol/l NaOH added. The gas released was measured immediately using a gas sensitive electrode. A standard

solution was used for the calibration curve for an ammonia electrode as described by Cammann (1979).

Statistical Analysis

Multivariate analysis of variance (MANOVA) was used to analyse the data using the General Linear Model Procedure (SAS, 1985). The sources of error that were analysed included effects of time and treatments and their interaction. Treatments were separated using Duncan Multiple Range Test (Duncan, 1955).

Results and discussion

The chemical composition and gross energy content of *Daniellia oliveri* and the experimental diets are presented in tables 1 and 2. Although *Daniellia oliveri* has a high CP content (165 g/kg) and gross energy (GE) content (20.3 kJ/g DM), it also contains a relatively high level of condensed tannin (CT) (48 g/kg DM) and tannin phenol (43 g/kg DM).

Table 1: Chemical composition of *Daniellia oliveri* (% DM)

Item	<i>Daniellia oliveri</i>
CP	16.5
Ash	7.1
Ether extract	1.5
Crude fibre	28.1
NFE	38.4
NDF	60.9
ADF	39.2
ADL	3.9
Cellulose	35.3
Hemi cellulose	21.7
Total phenol ¹	5.9
Tannin phenol ¹	4.3
Condensed tannins ²	4.8
GE [kJ g ⁻¹ DM]	20.3

¹ As tannic acid equivalent

² As leucocyanidin equivalent

Table 2: *Composition of experimental diets (% of DM)*

Item	Control (Hay)	Diet D25%	Diet D50%
CP	8.4	10.4	12.5
Ash	7.3	7.3	7.2
Ether extract	1.6	1.6	1.5
Crude fibre	31.4	30.6	29.8
NFE	44.6	43.1	41.5
NDF	61.2	61.1	61.0
ADF	36.5	37.2	37.9
ADL	4.2	4.1	4.0
Cellulose	32.3	33.1	33.8
Hemi-cellulose	24.7	23.9	23.2
Total phenol ¹	-	1.5	3.0
Tannin phenol ¹	-	1.1	2.2
Condensed tannins ²	n.a.	1.2	2.4
GE [kJ g ⁻¹ DM]	18.0	18.6	19.2
Mineral premix ³ (g/d)	10.0	10.0	10.0

¹Tannic acid equivalent²Leucocyanidin equivalent³Composition per kg: vit. A 600,000 IU: vit. D3 75,000 IU: vit. E 300 mg: Zn 3,000 mg; Mn 480 mg; Co 12 mg; Se 10 mg.**Ruminal pH, Ammonia and Nutrient digestibilities**

The results obtained for ruminal pH, ammonia concentration and nutrient digestibility are shown in Figures 1, 2 and Table 3 respectively.

Diet D50% showed a higher ($P<0.05$) pH than both the control and D25% diets respectively.

This could be due to less fermentation activity probably due to the effect of condensed tannins.

The pH dropped significantly ($P<0.05$) after feeding, reaching its lowest value after one hour, and then began to increase to pre feeding value five hours later. McLeod, (1974) reported the

effect of pH on complex formation of tannin and protein. Condensed tannins (CT) can react and form complexes by H-bonding with carbohydrates and proteins, but at neutral pH form stronger bonds with proteins. According to Jones and Mangan (1977), the CT: protein complex is stable and insoluble in the pH range 3.5-7.0, but is unstable and releases protein at pH of <3.0 and at pH 8.0. The higher ($P<0.05$) pH of diet D50% compared with the control and D25% diets respectively could indicate an inhibition effect arising from condensed tannin-protein and carbohydrate complex formation.

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Figure 1: Ruminal pH of sheep supplemented with *Daniellia oliveri*

Figure 2: Ruminal ammonia concentration in sheep supplemented with *Daniellia oliveri*

Table 3: Total nutrient intake (g d⁻¹) and digestibilities (g 100 g⁻¹) of sheep supplemented with *Daniellia oliveri*

Items	Control	D25%	D50%	SEM	P-Values
Nutrient intake (g d⁻¹)					
DMI	562.6 ^b	492.5 ^c	594.1 ^a	5.66	.001
Organic matter	521.5 ^b	457.8 ^c	553.9 ^a	5.26	.001
Ash	41.1 ^a	34.7 ^b	40.3 ^a	0.4	.001
Crude protein	47.4 ^c	50.8 ^b	73.1 ^a	0.57	.01
NDF	344.1 ^b	301.2 ^c	363.4 ^a	3.46	.001
ADF	205.1 ^b	184.0 ^c	227.7 ^a	2.11	.001
ADL	23.7 ^b	30.1 ^c	48.4 ^a	0.33	.001
Cellulose	181.7 ^b	162.7 ^c	200.9 ^a	1.86	.001
Hemi-cellulose	138.9 ^a	118.0 ^b	137.8 ^a	1.36	.01
Digestibilities (g 100 g⁻¹)					
DMI	61.5 ^a	56.9 ^b	55.9 ^b	0.60	.03
Organic matter	61.0 ^a	57.5 ^b	53.0 ^c	0.52	.01
Ash	33.0 ^a	19.6 ^b	33.1 ^a	2.47	.01
Crude protein	78.4 ^a	67.5 ^b	81.1 ^a	0.95	.001
NDF	54.6 ^a	48.6 ^b	39.7 ^c	0.68	.001
ADF	49.5 ^a	32.0 ^b	17.0 ^c	0.85	.001
ADL	-5.0 ^a	-110.2 ^b	-144.2 ^c	43.2	.001
Cellulose	56.7 ^b	62.0 ^a	64.7 ^a	0.76	.01
Hemi-cellulose	62.0 ^b	74.7 ^a	78.1 ^a	0.83	.001

a,b,c Means in a row with different superscripts differ significantly (P<0.05)

The ruminal ammonia concentration of diet D25% was superior (P<0.05) to that of both D50% and the control diets respectively. Similarly, diet D50% was superior (P<0.05) to the control diet. The ruminal ammonia concentration increased (P<0.05) one hour after feeding to its peak and thereafter declined (P<0.05) five hours later. There was no difference (P>0.05) in the concentration of ruminal ammonia sampled at minus one hour and three hours after feeding. Condensed tannins present in legumes and browse trees may result in tannin-protein complex formation that inhibit microbial attack. This may not pose a negative impact on the animal if the proteins can be made available post-ruminally and hence be available to enzyme digestion (Mueller-Harvey *et al.*, 1988; Osakwe *et al.*, 2000). The superior (P<0.05) ruminal ammonia concentration of diets D25% and D50% compared to the control

could indicate an improvement in fermentation intensity and with that a higher uptake of nitrogen for microbial protein synthesis. The lowest (P<0.05) pH of diet D25% (6.5) compared to diet D50% (7.0) and the control (6.8) would suggest different fermentation intensities. This corresponded to the ruminal ammonia concentration observed with diet D25% (23.6 mg/dl), D50% (14.2 mg/dl) and the control (11.0 mg/dl). It would appear increasing the supplementation to 50% led to an inhibition effect of tannin on protein degradability by rumen microbes. This observation is in consonance with the reports of (Reid *et al.*, 1974; Driedger and Hatfield, 1972; Rodriguez *et al.*, 1975; Kumar and Singh 1984a).

Total nutrient intake and digestibility of sheep supplemented with *Daniellia oliveri* (Table 3), showed significant increases (P<0.05) in the OM, CP, NDF, ADF, ADL and cellulose intake

of diet D50% compared with the controls. Similarly, diet D50% resulted in a reduction ($P<0.05$) in digestibility of DMI, OM, NDF, ADF and ADL, in comparison to sheep fed the control diet. It would appear that condensed tannins had inhibitory effect on organic matter and detergent fibre digestibility, an observation that is in agreement with the reports of (Barry and Manley, 1984; Barry *et al.*, 1986; Reed, 1986). Cellulose and hemi-cellulose digestibility of diet D50% was superior ($P<0.05$) to that of the controls. This could be as a result of the high ($P<0.05$) pH observed in diet D50% compared with the controls since Kumar, (1992) reported that rumen cellulolytic bacteria are very sensitive to low rumen pH which decrease digestibility. He further noted that the digestibility-reducing effects of tannins are not uniform and concluded that the diversity of effects may arise in part due to the differences in the chemical nature of tannins and in part due to differences in the physiological capabilities of animals to handle tannins. The superior ($P<0.05$) cellulose and hemi cellulose digestibilities of diet D50% compared with the controls might as well be due to the non uniform digestibility-reducing effects of tannins.

In conclusion, the results presented here showed the inhibitory effect of condensed tannins on the ruminal pH and ammonia concentrations well as on nutrient digestibilities of *Daniellia oliveri* as a feed supplement. *Daniellia oliveri* with a high CP and GE (165 gkg^{-1} and $20.3 \text{ kJg}^{-1}\text{DM}$) respectively, could serve as a fodder tree for small ruminant in spite of its relatively high content of condensed tannin ($48 \text{ gkg}^{-1}\text{DM}$). Overall, results suggest that 25% level of inclusion proved to be the best even though a range of 25 to 50% could be fed during period of scarcity.

Acknowledgments

The author is grateful to the Ecumenical Scholarship Programme, Germany for sponsorship. The assistance of Dr. J. Greiling is highly appreciated.

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(Received 12 November 2002; Accepted 29 November 2003)