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Chemical Composition of Some Tropical Foliage Species and Their Intake and Digestibility by Goats

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ABSTRACT : The chemical composition and water extractable dry matter (DM) of foliages from Erythrina (*Erythrina variegata*), Fig (*Ficus racemosa*), Jackfruit (*Artocarpus heterophyllus*), Jujube (*Ziziphus jujuba Mill*), Kapok (*Ceiba pentandra*) and Mango (*Mangifera indica*) and the feed intake, digestibility and N retention when feeding these foliages were studied in two experiments. In Experiment 1, 12 male goats, 3.5 months old and weighing 14.6 kg, were randomly allocated to a diet consisting of one of the foliages in a change-over design with three periods. The foliages were offered *ad libitum* at the level of 130% of the average daily feed intake. The Erythrina foliage had a low content of DM and condensed tannins (CT) and a high concentration of crude protein (CP) in leaves plus petioles (193 g/kg DM) and stem, while the Mango foliage had a low CP (69 g/kg DM) and high DM content. The other foliages were intermediate. High content of CT was found in the leaves plus petioles of Jackfruit foliage and in the stem of Fig and Mango foliage. There was a difference in feed intake, nutrient intake, apparent digestibility and N retention between the foliages, with Erythrina, Jackfruit and Kapok foliage being significantly higher in these parameters than Fig, Jujube and Mango foliage. The water extractable DM could be used to estimate N retention, but not DM digestibility in this study. In Experiment 2, 4 male goats weighing 13.4 kg and 6 months old were allocated to a 4×4 Latin square design. The treatments were: water spinach *ad libitum* and Fig, Jujube or Mango foliage *ad libitum* +0.5% of BW as water spinach DM. Feed intake, apparent digestibility and N retention were not significantly different among the foliage diets, but higher than for water spinach alone ($p<0.05$). Supplementation with water spinach to a diet consisting of low quality foliages such as Fig, Jujube and Mango, increased DM and CP intake, apparent digestibility and N retention, compared to feeding these foliages as sole feeds. (**Key Words :** Intake, Digestibility, N retention, Tropical Foliages)

INTRODUCTION

Foliages from trees and shrubs have traditionally been used as feed for goats in tropical countries due to the content of crude protein (CP) and the availability during the dry season. Some reports show that, for example, foliage from Jackfruit (*Artocarpus heterophyllus*) and Erythrina (*Erythrina variegata*) are good protein sources and has a high intake potential for goats (Mui et al., 2001; Aregheore and Perera, 2004; Van et al., 2005). Kapok (*Ceiba pentandra*) and Mango (*Mangifera indica*) have been less researched but the leaves can be used as a feed and have been found to contain from 186 to 204 g CP/kg dry matter (DM) (Ajayi et al., 2005; Kouch et al., 2005). Jujube (*Ziziphus jujuba* Mill) is known to be preferred by goats but there is little research available. According to Reich (1991), fresh Jujube leaves contain a saponin and Nath et al. (1996) reported that Jujube leaves are a rich source of protein and minerals with 140 g CP, 28 g Ca and 1.4 g P/kg DM. Fig (*Ficus racemosa*) is not well known as a feed but is a commonly available tree in tropical areas.

Water spinach (*Ipomoea aquatica*) is an aquatic plant, which produces high yields of protein-rich biomass and is often used as a protein supplement for pigs, but also for ruminants, in South East Asia. Water spinach has a high nutritive value and is available in large amounts in the dry season (Phuc et al., 2001).

The main limitation when using tree foliages as feed resources for ruminants is the content of anti-nutritional substances, of which the most important are the tannins. In low amounts tannins may increase the productivity of the animals by binding with the dietary proteins during mastication and protecting the protein from microbial attack in the rumen thus increasing the supply of by-pass proteins (Norton, 2000). Tannins also seem to play a role in the

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ability of animals to withstand the effects of parasitism (Waller, 1999; Hur et al., 2005). Feeds with high tannin content and/or high activity of the tannins may have detrimental effects on the performance of animals. However, goats can consume large amounts of tannin-rich plant material without exhibiting toxic effects, due to their ability to avoid consuming browse in amounts exceeding their capacity to detoxify tannins (Silanikove et al., 1996).

The digestibility of a feed is closely related to its chemical composition. The fibre fraction has the greatest influence on the digestibility and both the amount and chemical composition of the fibre are important. A method that has been used to determine digestibility *in vitro* is the water extractable DM. It is essentially equivalent to the washing loss in the equation for estimating DM digestibility for ruminants using the *in sacco* method, as described by Ørskov et al. (1980). Chermiti et al. (1996) showed that there was a close relationship between water extractable DM and neutral detergent fibre (NDF).

The aim of this experiment was to analyse the chemical composition and water extractable DM of some foliages available for goats and compare intake, *in vivo* digestibility and nitrogen balance when feeding these foliages either as a sole feed or for foliages with low intake and digestibility, together with water spinach.

MATERIALS AND METHODS

Location and climate

The experiments were conducted on the farm of the Livestock and Fisheries Department, National University of Laos, 35 km south of Vientiane, Lao PDR (14° 20’ N, 100° 108’ W). The climate in this area is tropical monsoon with a rainy season between May and October and a dry season from November to April. Average annual rainfall is 2,000 mm/year. The two trials were conducted during June to December 2006.

Experiment 1

The animals used in the experiment were 12 male growing goats with an average weight of 14.6 kg (SD = 1.4). The goats were of the Ma T’ou breed, which originally came from China. The breed is 45 to 65 cm high at the withers and with a mature body weight (BW) of 35 to 40 kg for males. The goats were bought from farmers in the area around the farm. Before starting the experiments, the goats were treated with Ivermectin solution (1 ml/4 kg BW) against parasites and were vaccinated against Foot and Mouth disease.

The feeds used in the experiment were foliages from Erythrina (*Erythrina variegata*), Fig (*Ficus racemosa*), Jackfruit (*Artocarpus heterophyllus*), Jujube (*Ziziphus jujuba* Mill), Kapok (*Ceiba pentandra*) and Mango (*Mangifera indica*). The foliages were used in their fresh form, including leaves, petioles and 30 cm of the stem and were offered hanging, tied to a bamboo stick over the cage and above the feed trough to collect leaves that may be falling down. Harvesting of the foliages was done by cutting trees and shrubs around the experimental unit in the morning for feeding in the afternoon and in the afternoon for feeding the next day in the morning. The feed was offered *ad libitum* at the level of 130% of the average daily individual feed intake the previous week, three times per day at 08:00 h, 12:00 h and 16:00 h. A mineral lick block containing 140 g Na, 140 g Ca, 51 g P, 10.5 g S, 22 g K, 10 g Mg, 2.5 g Fe, 900 mg Zn, 350 mg Mn, 400 mg Cu, 90 mg Co, 380 mg I and 12 mg Se, per kg block was available. The goats were housed in individual metabolism crates made from wood, 80 cm long and wide and 75 cm high.

The experimental design was a change over model with six treatments, consisting of the different foliages fed as a sole feed. The experiment was run for three periods and the goats were randomly allocated to 12 individual metabolism cages and a particular foliage at the beginning of each period. In every period each foliage was offered to two animals. The periods consisted of 14 d of adaptation to the diets and 7 d of data collection. Between each period there were 7 d for rehabilitation with a diet of grass, cassava chip and a mixture of foliages from Jackfruit, Erythrina, Jujube and Kapok. The experiment lasted 11 weeks in total.

The feeds offered and refused and water consumed were recorded daily for each animal during the experimental periods. Six samples of each foliage were separated and weighed to estimate the average proportion of leaves plus petiole and stem. Samples of refusals (also divided into leaves plus petiole and stem) by each animal were taken daily during the data collection periods in order to measure the selection of the different parts. The faeces and urine excreted were recorded twice daily at 7:00 h and 17:00 h. At each data collecting time, 10% of the faeces was sampled and stored frozen at -20°C. Urine was collected in a jar containing 50 ml of 10% sulphuric acid (urine pH<3) to preserve the nitrogen (Chen and Gomes, 1992) and 10% of the urine was also sampled and stored at 4°C for further analysis.

The foliages were analysed for DM, ash and nitrogen (N) according to AOAC (1990). NDF was assayed without a heat stable amylase and expressed inclusive of residual ash using the procedure of Van Soest et al. (1991). Condensed tannins (CT) were analysed according to the procedures of Makkar (1995). Triplicate samples (0.01 g) were weighed into (individual) tubes and 6 ml butanol-HCL (95:5) reagent added. The tubes were then placed into boiling water and heated for 1 h after which they were removed, cooled and centrifuged at 3,000 g for 10 min. The supernatant was decanted into vials and absorbance read at 550 nm using a CE 2030 single beam spectrophotometer. The concentrates of CT were calculated using the formula: CT (g/kg DM) = A×B/C, where A (mg/ml) is -0.00005+ 0.114X (reading value), B (ml) is the volume of solution (butanol-HCl = 6 ml) and C (g) = 0.01 is the sample weight.

The water extractable DM was analysed according to the procedure described by Ly and Preston (1997). The samples were dried in a micro-wave oven (Undersander et al., 1993) to constant weight and then ground in a coffee mill. A sample of about 3 g (known weight) of the dry, ground material was put in pre-weighed nylon bags (50× 150 mm) with a pore size of 45 to 55 μm. The bags containing the samples were tied and put into a washing machine with 3 L of water per bag. Washing was done for six cycles, with 15 minutes in each cycle. After washing, the bags were dried and weighed.

The data were analysed statistically using the GLM procedure of Minitab Software, version 13.31 (Minitab, 2000). Treatment means, which showed significant differences at the probability level of p<0.05, were compared using Tukey's pairwise comparison procedures. The statistical model used was: $Y_{ij} = \mu+F_i+P_j+F_i\times P_j+e_{ij}$ where Y_{ij} is the dependent variable, F_i is the effect of treatment (different foliages), P_j is the effect of period, $F_i\times P_j$ is the effect of interaction between foliage and period and e_{ij} is the random error effect.

Experiment 2

Four male growing goats weighing 13.4 kg (SD = 2.2) and around 6 months old of the same breed as used in Experiment (Exp.) 1 were used in the experiment. The treatment and management of the goats were the same as in Exp. 1.

The feeds used in Exp. 2 were foliages from Water spinach (*Ipomoea aquatica*), Fig, Jujube and Mango. The foliages were collected and presented in the same way as in Exp. 1. The water spinach was bought from farmers in the morning and weighed for feeding during the whole day.

The experimental design was a 4×4 Latin Square. The treatments were four diets: Water spinach *ad libitum* and Fig, Jujube or Mango *ad libitum* +0.5% of the BW as DM Water spinach. Each period of the experiment consisted of 10 d of adaptation to the diets and 5 d of data collection and between each period there was a 3 d period for rehabilitation with the same feeds as in Exp. 1. The length of the periods was decreased since the results from Exp. 1 showed that the adaptation to the foliages was faster than expected.

Daily feed offered and refused and water consumption were recorded for each animal during the experimental periods. The faeces and urine were collected and preserved and the foliages analysed as in Exp.2. The statistical model used was: $Y_{ijk} = \mu+F_i+A_j+P_k+e_{ijk}$ where Y_{ijk} is the dependent variable, F_i is the effect of treatment, A_j is the effect of

Table 1. Proportion of stem and leaves and chemical composition of the foliages in Exp. 1[1,2]

	Erythrina	Fig	Jackfruit	Jujube	Kapok	Mango
As DM						
Leaves+petioles	0.79 (0.11)	0.73 (0.05)	0.69 (0.05)	0.74 (0.06)	0.76 (0.07)	0.77 (0.04)
Stem	0.21 (0.11)	0.27 (0.05)	0.31 (0.05)	0.26 (0.06)	0.24 (0.07)	0.23 (0.04)
In leaves+petioles						
DM (g/kg)	197 (18)	289 (61)	327 (52)	347 (53)	300 (37)	459 (57)
In g/kg DM						
OM	898 (12)	847 (38)	901 (46)	930 (13)	894 (27)	940 (18)
CP	193 (35)	119 (25)	114 (16)	94 (22)	120 (29)	69 (11)
NDF	463 (48)	489 (38)	461 (33)	451 (44)	502 (46)	501 (18)
CT	51 (14)	102 (21)	130 (50)	117 (2)	117 (4)	90 (19)
In the stem						
DM (g/kg)	198 (37)	236 (63)	309 (65)	375 (42)	231 (28)	352 (91)
In g/kg DM						
OM	906 (10)	912 (27)	876 (21)	958 (7)	885 (50)	942 (18)
CP	89 (22)	63 (14)	62 (14)	56 (14)	57 (17)	47 (11)
NDF	525 (40)	461 (35)	548 (37)	571 (33)	554 (27)	569 (35)
CT	51 (21)	116 (2)	110 (9)	100 (19)	74 (29)	112 (6)
Total						
DM (g/kg)	197 (20)	274 (60)	322 (56)	354 (49)	283 (35)	435 (62)
In g/kg DM						
OM	900 (11)	866 (29)	892 (31)	937 (10)	891 (31)	940 (17)
CP	172 (32)	104 (23)	98 (10)	84 (18)	105 (25)	64 (10)
NDF	476 (46)	481 (38)	488 (31)	482 (42)	514 (38)	517 (21)
CT	51 (14)	101 (17)	123 (33)	112 (5)	108 (8)	94 (16)

[1] Mean and standard deviation (SD). [2] N = 6; CT = Condensed tannins.

animal, P_j is the effect of period and e_{ijk} is the random error effect.

RESULTS

Experiment 1

The chemical composition of leaves plus petioles and stem of the foliages and the proportion of these two parts are presented in Table 1. The Erythrina foliage had a DM content of 197 g/kg and a high CP content of 193 g/kg DM in the leaves plus petioles. The Mango foliage had a low CP content of 69 g/kg DM but a high DM content of 459 g/kg in leaves plus petioles. The CP contents of the other foliages were intermediate between Erythrina and Mango. The stems were generally low in CP and had lower or similar DM as the leaves plus petioles with the exception of the stem of Jujube, which had higher DM content than the leaves. The content of CT of leaves plus petioles ranged from 51 g/kg DM in the Erythrina foliage to 130 g/kg DM in the Jackfruit foliage. In Fig and Mango the content of CT was higher in the stem than in the leaves and petioles while it was lower in Erythrina, Jackfruit, Jujube and Kapok.

Foliages offered and amounts consumed for the six foliages are shown in Table 2. The total DM intake of Jujube and Mango foliage was lowest (380 and 393 g/d, respectively), and significantly different ($p<0.05$) from Jackfruit (with the highest DM intake of 650 g/d), Erythrina and Kapok foliage, but similar to the intake of Fig foliage. Feed intake expressed as a percentage of BW varied from 2.5% to 4.4%; the highest being for Jackfruit and lowest for

Table 2. Foliages offered and consumed in Exp. 1[1]

	Erythrina	Fig	Jackfruit	Jujube	Kapok	Mango	SE
Foliage offered (g DM)							
Leaves+petioles	617^{ab}	534^{bc}	662^{a}	501^{c}	639^{ab}	560^{abc}	24.5
Stem	164^{c}	201^{b}	303^{a}	180^{bc}	200^{bc}	171^{bc}	8.0
Total	781^{bc}	734^{bc}	965^{a}	681^{c}	838^{ab}	731^{bc}	32.3
Foliage intake (g DM)							
Leaves+petioles	516^{a}	428^{ab}	558^{a}	316^{b}	536^{a}	331^{b}	28.6
Stem	97	58	92	64	73	62	9.1
Total	613^{ab}	485^{bc}	650^{a}	380^{c}	609^{ab}	393^{c}	28.3
Foliage intake in % of BW	4.0^{a}	3.4^{b}	4.4^{a}	2.5^{c}	3.8^{ab}	2.7^{c}	0.1
Water intake (g/d)	94	195	201	194	142	192	44.0

$^{a, b, c}$ Means within rows with different superscripts differ significantly ($p<0.05$).

[1] Least squares means and standard error of the means.

Table 3. Nutrient intake, digestibility and N balance of goats offered six different foliages (Exp. 1[1])

Nutrient intake (g/d)	Erythrina	Fig	Jackfruit	Jujube	Kapok	Mango	SE
From leaves+petioles							
OM	463^{ab}	365^{bc}	503^{a}	294^{c}	479^{ab}	312^{c}	26.3
CP	100^{a}	51^{b}	64^{b}	30^{c}	65^{b}	22^{c}	3.4
NDF	240^{ab} c	207^{ab}	257^{a}	141^{d}	269^{a}	165^{cd}	14.1
From stem							
OM	88	53	80	62	65	58	8.4
CP	9^{a}	4^{bc}	5^{b}	4^{bc}	4^{bc}	3^{c}	0.5
NDF	51	30	50	37	40	35	5.0
Total							
OM	551^{a}	418^{b}	583^{a}	356^{b}	543^{a}	370^{b}	26.1
CP	109^{a}	55^{b}	69^{b}	34^{c}	69^{b}	25^{c}	3.5
NDF	291^{ab}	238^{b}	307^{a}	179^{b}	309^{a}	200^{b}	13.9
Apparent digestibility							
DM	0.62^{ab}	0.47^{c}	0.51^{bc}	0.53^{bc}	0.57^{b}	0.49^{c}	0.02
OM	0.64^{a}	0.50^{c}	0.57^{abc}	0.56^{bc}	0.60^{ab}	0.52^{c}	0.02
CP	0.73^{a}	0.24^{d}	0.54^{b}	0.39^{c}	0.66^{ab}	0.25^{d}	0.03
NDF	0.54^{ab}	0.32^{dc}	0.39^{bcd}	0.34^{d}	0.51^{b}	0.34^{d}	0.03
N-balance							
N intake (g/d)	17.4^{a}	8.8^{b}	11.1^{b}	5.4^{c}	11.0^{b}	4.0^{c}	0.6
N in faeces[2]	0.27^{d}	0.76^{a}	0.46^{c}	0.60^{b}	0.34^{cd}	0.71^{ab}	0.03
N in urine[2]	0.49^{a}	0.11^{d}	0.28^{bc}	0.20^{c}	0.34^{b}	0.16^{cd}	0.02
N-retention[2]	0.24^{abc}	0.14^{c}	0.26^{b}	0.20^{bc}	0.32^{a}	0.13^{c}	0.03

$^{a, b, c}$ Means within rows with different superscripts differ significantly ($p<0.05$).

[1] Least squares means and standard error of the means. [2] Expressed as a fraction of N-intake.

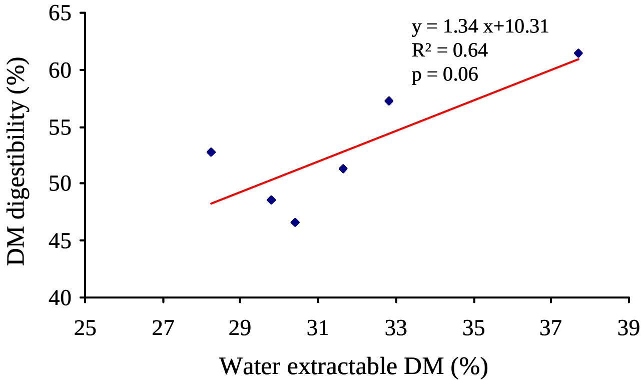

Figure 1. Relation between water extractable DM and DM digestibility (The different points are the means of each of the 6 foliages in the experiment).

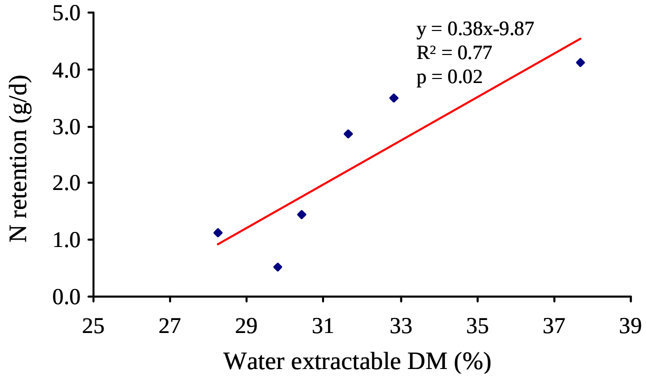

Figure 2. Relation between water extractable DM and N retention (The different points are the means of each of the 6 foliages in the experiment).

Jujube. Water intake varied from 94 to 201 ml/d, but was not significantly different among foliages.

The nutrient intake, apparent digestibility and N balance are presented in Table 3. Feeding Erythrina foliage resulted in significantly ($p<0.05$) higher CP intake (109 g/d) compared to the other foliages. The lowest CP intake was obtained with Mango foliage (25 g/d). The DM digestibility, the nutrient digestibility (organic matter (OM), NDF and CP) and the N retention were generally significantly ($p<0.05$) higher for Erythrina, Jackfruit and Kapok foliage than for Fig, Jujube and Mango foliage.

The relationship between DM digestibility and N retention, and water extractable DM is shown in Figure 1 and 2, respectively. The water extractable DM was not significantly related to DM digestibility ($p = 0.06$, $R^2 = 0.64$) but the relationship between N retention and water extractable DM ($p = 0.02$, $R^2 = 0.77$) was significant. There was no close relationship between the concentration of NDF and DM digestibility or N retention, $R^2 = 0.17$ and $R^2 = 0.12$, respectively.

Experiment 2

The DM, OM and NDF content of the foliages in Exp. 2 was similar to in Exp. 1 but CP content was higher in Exp. 2 (Table 4). The CP content in water spinach was high (193 g/kg DM).

The total feed intake was lowest for the Water spinach diet (246 g/d) (Table 4), significantly lower ($p<0.05$) than for the Fig, Jujube and Mango diets. Feed intake expressed as a percentage of BW varied from 2% for water spinach as a sole feed to 3.7% for the Fig diet, but there were no significant differences among the three mixed diets. There was no significant difference in water intake among treatments.

Table 5 shows the nutrient intake, digestibility and N balance for the different diets in Exp. 2. The CP intake in

Table 4. Chemical composition of the foliage[1] and foliages offered and consumed[2] in Exp. 2

	Wathe spinach	Fig	Jujube	Mango	SE
Chemical composition of the foliage					
DM (g/kg)	69 (4)	258 (64)	332 (46)	423 (40)	
In g/kg DM					
OM	814 (28)	868 (18)	943 (15)	939 (26)	
CP	193 (19)	113 (16)	115 (20)	83 (11)	
NDF	424 (16)	486 (51)	521 (35)	445 (32)	
Feed offered (g DM)[3]					
Foliage	-	633	696	659	58.2
Water spinach	336[a]	59[b]	61[b]	57[b]	4.7
Total	336[b]	692[a]	757[a]	716[a]	58.0
Feed intake (g DM)					
Foliage	-	444	461	399	39.4
Water spinach	246[a]	57[b]	44[b]	52[b]	6.0
Total	246[b]	501[a]	505[a]	451[a]	40.5
Feed intake in % of BW	2.0[b]	3.7[a]	3.6[a]	3.4[a]	0.2
Water intake (g/d)	31	114	29	36	21.2

[1] Mean and standard deviation (SD). [2] Least squares means and standard error of the means; N = 8.

[3] Each foliage was offered together with 0.5% of BW (in DM) as water spinach.

[a, b, c] Means within rows with different letters differ significantly ($p<0.05$).

Table 5. Nutrient intake, digestibility and N balance of goats offered different foliages together with water spinach in Exp. 2[1]

	Water spinach	0.5% of BW as water spinach +			SE
		Fig	Jujube	Mango	
Nutrient intake (g/d)					
From foliage					
OM	0	360	410	343	35.0
CP	0	54[a]	58[a]	33[b]	3.6
NDF	0	211	235	173	18.1
From water spinach					
OM	201[a]	46[b]	36[b]	43[b]	5.9
CP	48[a]	11[b]	8[b]	10[b]	1.7
NDF	105[a]	24[b]	19[b]	22[b]	3.0
Total					
OM	201[b]	406[a]	445[a]	385[a]	38.1
CP	48[ab]	65[a]	66[a]	43[b]	4.1
NDF	105[b]	235[a]	254[a]	195[ab]	18.9
Digestibility (g/kg)					
DM	0.76[a]	0.61[b]	0.64[ab]	0.62[ab]	0.03
OM	0.77	0.61	0.64	0.63	0.04
CP	0.79[a]	0.44[b]	0.58[b]	0.55[b]	0.04
NDF	0.72[a]	0.46[b]	0.51[ab]	0.44[b]	0.05
N-balance					
N intake (g/d)	7.7[ab]	10.5[a]	10.6[a]	6.9[b]	0.6
N in faeces[2]	0.21[b]	0.55[a]	0.41[a]	0.44[a]	0.04
N in urine[2]	0.53[a]	0.17[c]	0.28[b]	0.26[bc]	0.02
N-retention[2]	0.26	0.28	0.31	0.30	0.04

[a, b, c] Means within rows with different letters differ significantly (p<0.05).
[1] Least squares means and standard error of the means. [2] Expressed as a fraction of N-intake.

the Jujube diet was highest (66 g/d), significantly (p<0.05) higher than the Mango diet but similar to the Fig diet and the Water spinach diet. Both OM and NDF intake from Water spinach as a sole feed were significantly (p<0.05) lower than for the other diets. The digestibility of CP and NDF of the Water spinach diet was significantly (p<0.05) higher compared to the Fig and the Mango diets. There were no significant differences in the digestibility of OM, and all diets resulted in a positive N retention, ranging from 2.0 g to 3.1 g/d.

DISCUSSION

Experiment 1

Chemical composition of the foliages : The foliage from Erythrina had a high CP content. This is probably due to the fact that Erythrina is the only one of the studied plants that belongs to the Leguminosae family and consequently has the ability to fix N. Many authors have found that Erythrina has a high CP content compared to other foliages such as Acacia (Simbaya, 2002), Fig (Schurrie, 1990), Jackfruit (Mui et al., 2001), Gliricidia (Aregheore and Perera, 2004), Leucaena (Aregheore and Perera, 2004), Mango (Kibria et al., 1994; Ajayi et al., 2005), Sesbania (Simbaya, 2002) and Tamarind (Kouch, 2003) However, the results previously reported on CP content in Erythrina leaves (205 to 258 g/kg DM) are higher than the value from this study (193 g/kg DM). This could possibly be due to different ages of the trees or the shoots, the season for collecting samples or different varieties. Erythrina also had a low and Mango a very high content of DM, 197 and 459 g/kg DM, respectively. Kibria et al. (1994) also reported a low DM content (196 g/kg DM) in Erythrina leaves and a high DM content (470 g/kg DM) in Mango leaves.

The content of CT in Jackfruit leaves plus petioles was 130 g/kg DM, higher than the 36 g/kg DM of total tannins recorded by Mui et al. (2001) and 51 g/kg DM of total tannins obtained by Van et al. (2005). The methods of analysis are different, but total tannins should be the same or higher than CT, which are only one fraction of the total tannins. The way the samples are treated before analysis is very important e.g. drying at a temperature higher than 45°C will result in lower tannin values, since the tannins will be strongly bound to protein and fiber (Palmer et al., 2000). However, Mui et al. (2001) and Van et al. (2005) also showed that the Jackfruit foliage had a higher content of tannins than other foliages and that the tannin content of the leaves was higher than in the stems, which is in agreement with the present study.

Intake characteristics and digestibility : The foliages showing the best intake characteristics were Erythrina, Jackfruit and Kapok. The DM intake of Mango was lowest of all foliages, at 2.7% of BW, which was mainly an effect of a CP content below the level required to support optimum microbial activity in the rumen (60 to 80 g CP/kg DM) (Minson, 1990). Kibria et al. (1994) also found a low intake of Mango leaves (2.9% of BW) in Black Bengal goats. The tannin content was highest in Jackfruit and Jujube and not very high in Mango and did not seem be a determining factor for feed intake. The differences in feed intake can also be due to other factors e.g. structure of the leaves, soft versus hard, and smooth versus waxy or hairy, content of substances causing the foliages to smell or taste distinctly, or morphology of the plants resulting in different bite sizes (Van, 2006). The highest DM and CP digestibility and N retention were obtained when feeding Erythrina, Jackfruit and Kapok foliage. These results are supported by Kibria et al. (1994), Baidya et al. (1995), Mui et al. (2002), Aregheore and Perera (2004), and Van et al. (2005). The digestibility of DM did not seem to be closely related to tannin content, and McSweeney et al. (1999) also found that tannin content was poorly correlated with digestibility of DM and N in foliages from some Leucaena varieties and Calliandra. According to Mandal et al. (2005), the requirement for a goat weighing 15 kg and growing at 75 g/d is 79 g CP or 50 g digestible CP. This means that the consumption of Erythrina, Jackfruit and Kapok covered the CP requirements of the goats while the other foliages did not. When considering the high digestibility of CP in Erythrina the goats consumed 160% of the requirement of digestible CP.

Water extractable DM as a method for estimating digestibility : The water extractable DM was related to DM digestibility (R^2 = 0.64, p = 0.06) but the correlation with N retention was higher (R^2 = 0.77, p = 0.02). In contrast Buntha and Ty (2006) found a strong relationship (R^2 = 0.98) between water extractable DM and (*in vivo*) DM digestibility in goats. The relationship between NDF content and DM digestibility (R^2 = 0.17) was not significant, and lower than the R^2 = 0.74 obtained by Buntha and Ty (2006). This may be due to different cellulose, hemicelluloses and lignin content in the forages. In this study, the water extractable DM was a better predictor than NDF for digestibility and the correlation was close to significant. A R^2 of 0.64 gives quite a good reliability in the estimation of digestibility of the foliages in this study.

Experiment 2

Chemical composition of feeds and diets : The CP levels in Water spinach were high compared to Fig, Jujube and Mango foliage and similar to the results of Pathoummalangsy and Preston (2006) but lower than the values 262 to 278 g/kg DM of leaves plus petioles reported by Buntha and Ty (2006) and Samkol et al. (2006). The higher CP levels reported by these authors can be due to harvesting age of the Water spinach or nutrients available in the soil e.g. through supply of fertilizer. The Water spinach also had a low DM content, which has also been noted by other authors (Buntha and Ty, 2006; Samkol et al., 2006).

Feed intake and digestibility : Total feed intake of Water spinach as a sole feed was lowest (246 g DM or 2.0% of BW) of all the feeds offered. Buntha and Ty (2006) also found that the DM intake was lower for Water spinach (2.2% of BW) compared to Guinea grass and Stylo. This is probably due to the high water content. However, the intake of CP from Water spinach as a sole feed was not significantly different from any of the other diets. Water spinach also had significantly higher DM, CP and NDF digestibility than the other diets.

The low intake of Fig, Jujube and Mango fed as sole feeds in Exp. 1 was followed up in Exp. 2 in which the CP content of these diets was improved by adding Water spinach. Although Exp. 1 and 2 were not run at the same time and thus could not be compared statistically it can be noted that feed intake, apparent digestibility and N retention of animals fed Fig, Jujube and Mango foliage were improved when the foliages were supplemented with Water spinach. Pathoummalangsy and Preston (2006) also found that feed intake and digestibility increased to double the overall values, when supplementing Cassava foliage with Water spinach (2% of BW), compared to feeding Cassava foliage alone. Apart from the effect of increased dietary supply of CP, there can also be an increased level of protein delivered to the small intestine if the proteins in the Water spinach form complexes with the CT in the foliages (Reed et al., 1982).

CONCLUSIONS

Erythrina, Jackfruit and Kapok foliages had better intake characteristics, CP digestibility and N retention than Fig, Jujube and Mango foliages. Water spinach can be used as a supplement to the foliages of lower quality to increase DM and CP intake, apparent digestibility and N retention. The water extractable DM as a method of analysis can be used to predict N retention and DM digestibility.

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