Nitrogen Balance in Goats Fed Flemingia (*Flemingia Macrophylla*) and Jackfruit (*Artocarpus Heterophyllus*) Foliage Based Diets and Effect of a Daily Supplementation of Polyethylene Glycol (PEG) on Intake and Digestion

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ABSTRACT : Diets with foliage of Flemingia (*Flemingia macrophylla*) or Jackfruit (*Artocapus heterophyllus* were fed to goats with the objective to study nitrogen (N) balance and effect of a daily supplementation of polyethylene glycol (PEG) on intake and digestion. In experiment 1, three male Alpine Jamnapary goats with initial weights varying from 26.9 to 27.7 kg were used in a 3×3 Latin square design in the dry season. Three Alpine Bachthao crosses, 15.3-16.7 kg, were used in the same design in the wet season. The three diets were based on chopped whole sugar cane complemented with the two green foliages, Jackfruit and Flemingia, or soybean meal (SBM). The level of dry matter (DM) offered was 4% of body weight (BW), 2.7% as foliage and 1.3% as chopped whole sugar cane. The amount of SBM offered was calculated to give the same amount of crude protein (CP) as the foliages. Each experimental period lasted 32 days (14 days for adaptation, 7 days for collection and 10 days for rest). Feed intake, apparent digestibility of DM, organic matter (OM), CP, neutral detergent fiber (NDF) and acid detergent fiber (ADF) and retained nitrogen (N) were measured by total faecal and urine collection. In experiment 2, four male goats (Alpine Jamnapary) with initial weights from 17.1 to 23.1 kg were used in a 4×4 Latin square design. The four treatments were Jackfruit or Flemingia with or without addition of PEG, which was fed at a level of 5 g/goat and day by mixing with a small amount of rice bran. Each experimental period lasted 15 days (8 days for adaptation, 7 days for collection). Measurements were done as in experiment 1. The DM digestibility was highest (65.9-74.3%) for goats fed the SBM diet in both the dry and wet season. The DM digestibility of goats fed the Jackfruit and the Flemingia diets was similar in both the dry (58.6-59.2% respectively) and the wet season (53.9-56.1% respectively). The CP digestibility was highest (73.0-73.6%) for the SBM diet followed by the Jackfruit diet (47.0-38.5%) and was lowest (36.8-30.0%) for the Flemingia diet in both dry and wet seasons, respectively. The NDF digestibility was low for both the Jackfruit (36.4%) and Flemingia (38.0%) diets in the wet season. All diets resulted in a positive N balance. The N retention was highest (0.465-0.604 g/kg $W^{0.75}$) in the SBM diets and lowest (0.012-0.250 g/kg $W^{0.75}$) in the Flemingia diet. Addition of PEG had no effect on feed intake for any of the diets. PEG added in the Flemingia diet had a positive effect only on NDF digestibility, but the digestibility of the Jackfruit diet was significantly increased. Supplementation with PEG reduced digestibility and N retention of Flemingia, possibly because of the low tannin level, but increased digestibility and N retention for Jackfruit foliage. ***(Asian-Aust. J. Anim. Sci. 2002. Vol 15, No. 5 : 699-707)***

메모 [SL1]: Full word

Key Words : Goats, Sugar Cane, Foliages, Nitrogen Balance, Digestibility, PEG

INTRODUCTION

Leguminous forages and fodder trees have been identified as suitable for maintaining the quality and continuity of supply of feed for animals in tropical areas. However, a major limitation to feed quality is the presence of secondary plant compounds such as hydrolysable and condensed tannins, which can depress feed intake and utilisation by animals (Kumar and Vaithiyanathan, 1990; Kibon and Orskov, 1993; Norton, 2000). The influence of tannins on the dry matter (DM) digestibility of browse is attributed to their bacteriostatic and bactericidal effects on rumen microbes (McNeill et al., 1999) and inactivation of rumen microbial enzymes (Theodorou et al., 1999; Qiyu and Guanghai, 1999). Polyethylene glycol (PEG) is a compound that forms complexes with tannins. The PEG-tannin complex is irreversible over a wide range of pH, and its presence reduces the formation of a protein-tannin complex. Jones and Mangan (1977) showed that the digestibility of the feed in goats increased when PEG-4000 was added to tannin rich feeds. Silanikove et al. (1996) found that the intake of digestible crude protein (CP) and metabolizable energy (ME) increased in PEG supplemented goats. Application of PEG has also been reported to increase feed intake, digestibility and wool growth in sheep (Pritchard et al., 1988).

Foliage from Jackfruit (*Artocarpus heterophyllus*) is a potential source of nitrogen (N) for livestock. Jackfruit leaves have a relatively high content of CP (Mui et al., 2001) and are a good source of Ca and Na (Ibrahim et al., 1998). Several workers have reported positive effects of Jackfruit leaves in the diet on DM intake, pH, total volatile fatty acids and ammonia and on the DM and N degradability of Jackfruit in the rumen of goats (Huq and Saadullah, 1987; Baruah et al., 1988; Baruah et al., 1989). Jackfruit can be used as a protein source replacing

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concentrate in goat production (Mui et al., 2001).

Flemingia (*Flemingia macrophylla*) is a leguminous shrub cultivated mainly in acid soils in Vietnam. It is used either for soil fixation, as a fuel or as a source of forage, and is available throughout the year. Several studies (Dzowela et al., 1995; Fassler and Lascano, 1995; Binh et al., 1998) have shown that Flemingia has a high CP content in the leaves and a high biomass production. Growth and milk production of goats fed the foliage are often low (Mui et al., 2001) but the large amount of biomass produced by this plant species may alleviate forage shortage in the dry season (Thomas and Schultze-Kraft, 1990; Chen et al., 1993).

Foliages of Jackfruit and Flemingia both contain tannins. According to Mui et al. (2001) the tannin content ranges from 2.4 to 3.3% of DM for different parts of Flemingia foliage and 3.3 to 3.6% for Jackfruit. Goats selected stems and twigs of Flemingia or the leaves of Jackfruit, which have a higher tannin content (Mui et al., 2001). The presence of condensed tannins when feeding Jackfruit or Flemingia can result in an over or underestimation of their true nutritive value based on chemical analysis. However, it may be possible to increase the nutritive value of Jackfruit or Flemingia with PEG. It is important to find out if there are components in a feed that may reduce its nutritive value as assessed by chemical composition. Thus the nutritive value of Jackfruit and Flemingia would most accurately be determined by feeding trials.

The purposes of the present experiments were to study the nitrogen balance in mature goats fed Flemingia or Jackfruit foliage and to assess if addition of PEG to the diet would have an effect on voluntary intake and digestion of these foliages.

MATERIALS AND METHODS

Experimental feeds

Diets offered were based on chopped whole sugar cane (CWSC), Jackfruit foliage and Flemingia foliage (foliage=leaf+petioles+35-40 cm of twigs) and soybean meal (SBM). The green feeds were collected from the areas around the Goat and Rabbit Research Centre, Hatay province, 60 km north-west of Hanoi where the experiments were conducted. The foliage of Jackfruit was pruned from 7 to 10 year old trees, ensuring that some branches were left for continued growth. The foliage of Flemingia was collected from 2 year old shrubs. The foliages of Jackfruit and Flemingia were harvested daily in the morning and offered fresh. Whole sugar cane, with 2.5 m cutting height, was harvested weekly at 10 months after planting, stored in a house and chopped daily with a machete into 1 to 3 cm slices. The SBM used in the experiments was bought locally. The animals were given 5 g NaCl and 5 g minerals (70% rock phosphate and 30% bone meal) daily and had free access to fresh water in buckets.

Animals and treatments

Experiment 1 was conducted to determine the digestibility and N balance when feeding Jackfruit or Flemingia foliage compared to SBM. Three male Alpine×Jamnapary goats with initial weights varying from 26.9 to 27.7 kg were used in a 3×3 Latin square design in the dry season. Three male Alpine×Bachthao crosses, 15.3-16.7 kg, were used in the same design in the wet season. The three diets were based on CWSC as an energy source with a low N content complemented with Jackfruit foliage, Flemingia foliage or SBM (table 1).

The goats were drenched against internal and external parasites with Ivermectin (1 ml/10 kg body weight (BW) injected subcutaneously) and Albendazol (0.1 mg/kg BW given orally) before the experiment commenced. The goats were kept in metal metabolism cages, allowing the collection of faeces and urine separately, but were allowed 10 days of free feeding/grazing between the experimental periods. The animals were fed twice daily (07:30 h and 14:00 h).

The goats were given the experimental feeds for a 14 day preliminary adjustment period. The level of DM offered was 4% of BW, 2.7% of BW of foliage and 1.3% of BW of CWSC. The amount of SBM offered was calculated to give the same amount of CP as the foliages. From days 15 to 22, the daily amount of feed offered and refused was recorded and the total quantity of faeces was collected during days 16 to 23. Twenty percent of the faeces were put in a freezer

Table 1. Experimental design in experiment 1

Dry season	Animal 1	Animal 2	Animal 3
Period 1	FM+CWSC	SBM+CWSC	JF+CWSC
Period 2	SBM+CWSC	JF+CWSC	FM+CWSC
Period 3	JF+CWSC	FM+CWSC	SBM+CWSC
Wet season	Animal 4	Animal 5	Animal 6
Period 1	FM+CWSC	SBM+CWSC	JF+CWSC
Period 2	JF+CWSC	FM+CWSC	SBM+CWSC
Period 3	SBM+CWSC	JF+CWSC	FM+CWSC

JF=Jackfruit, FM=Flemingia, SBM=soybean meal, CWSC=chopped whole sugar cane.

until analysis. Urine was collected in glass bottles, to which 50 ml of 0.1 N sulphuric acid was added to avoid nitrogen loss. Approximately 10% of the daily urine output was frozen and pooled for each animal.

All animals were weighed for two consecutive days at the beginning and the end of each 7 day collection period, prior to being offered feed and water in the morning to minimise variation in gut fill.

In experiment 2 the digestibility of the foliages with and without addition PEG was studied using four male goats (Alpine×Jamnapary) with initial weights from 17.1 to 23.1 kg. The animals were stall-fed individually in wooden pens equipped with troughs and nets that facilitated quantitative measurement of feed intake and faecal excretion. Urine was collected using a special plastic bag hanging under the belly of each goat. In all treatments, the animals were fed the same Jackfruit and Flemingia foliage as in the first study. The animals were fed the foliage twice per day at 08:00 h and 14:00 h at 2.7% of BW. The PEG used had a molecular weight of 4000. It was fed at a level of 2.5 g/goat and feeding time by mixing with a small amount (5 g) of rice bran and was given to each animal separately in the morning and afternoon before feeding the foliages. The four treatments, Jackfruit or Flemingia with or without addition of PEG were used in a 4×4 Latin square design (table 2).

The goats were given the experimental feeds for a 7 day preliminary adjustment period, which was sufficient to reach a stable consumption level. From day 8 to 15 the daily amount fed and feed refusals were recorded. The two foliages were sampled prior to feeding (09:00 h) and dried at 60°C for 24 h. Because of limited oven facilities, all samples were initially frozen until they could be processed further. The amount of faeces was recorded and faecal samples were taken every 6 h (06:00 h to 24:00 h per day) over a period of 7 days and representative 20% aliquot samples of faeces were stored at -20°C for further analysis.

The animals were weighed after each experimental period and were then started on the following treatment.

Chemical analysis

Ash and DM were analysed using standard AOAC (1985) methods. Total nitrogen of the feeds was determined by the Kjeldahl technique and CP calculated as N×6.25. Neutral detergent fibre (NDF), NDF bound N (NDF-N) and acid detergent fibre (ADF) were determined by the methods of Van Soest et al. (1991).

Statistical analysis

The data from the experiments was analysed using one-way analysis of variance (Minitab, 1998). Treatment means which showed significant differences at the probability level of $p<0.05$ were compared using the Fisher pairwise comparisons procedure.

The model used in the analysis was

$$Y_{ijk}=\mu-P_i-A_j+T_{k(ij)}-e_{ijk}$$

where Y_{ijk}=the ijkth observation, μ=the general mean, P_i=the effect of the ith period, A_j=the effect of the jth animal, $T_{k(ij)}$=the effect of the ith treatment and e_{ijk}=the random error effect.

메모 [SL2]: Full word

RESULTS

Experiment 1

Composition of intake and refusals from Jackfruit, Flemingia, SBM and CWSC during the two seasons in experiment 1 are given in tables 3 and 4. There was no difference in the DM or CP content of feed offered between the two seasons but there was a difference in the CP content in refusals compared to feed offered. In the wet season the NDF and ADF contents of Flemingia were higher than in the dry season, while in Jackfruit the opposite was found. The Jackfruit diet resulted in a higher ash content and lower CP content in the urinary excretion.

메모 [SL3]: What does this mean?

Throughout the 7 days of collection, the DM intake of foliages by the goats ranged from 15 to 41 g/kgW$^{0.75}$. Goats receiving Flemingia consumed a smaller amount of foliage than goats receiving Jackfruit in the dry season. In the wet season consumption of Flemingia was also lower and in this case the difference was significant. Goats in both dry and wet season consumed about 75% of the SBM offered.

DM consumption of CWSC varied from 20 to 26 g/kgW$^{0.75}$ (table 5), with the exception of goats on the Flemingia diet in the wet season, which consumed only 16 g/kgW$^{0.75}$. The amount of CP from CWSC consumed by goats in both trials was very small (0.05 to 0.3 g/kgW$^{0.75}$).

In the dry season, total intakes of Jackfruit and Flemingia foliage diets were similar, but in the wet season,

Table 2. Experimental design in experiment 2

Period	Animal 1	Animal 2	Animal 3	Animal 4
Period 1	FM+PEG	FM	JF−PEG	JF
Period 2	FM	JF+PEG	JF	FM−PEG
Period 3	JF	FM−PEG	FM	JF+PEG
Period 4	JF−PEG	JF	FM+PEG	FM

JF=Jackfruit, FM=Flemingia, PEG=Polyethylene glycol.

Table 3. Exp. 1. Composition of experimental feeds, refusals and faeces in the dry season[1]

Item	DM %	% of DM			
		CP	Ash	NDF	ADF
All diets					
CWSC offered	25.0±0.7	1.3±0.1	1.4±0.1	48.8±1.4	22.5±0.6
Jackfruit diet					
Jackfruit offered	30.3±0.7	16.3±0.2	12.7±0.3	54.9±2.6	41.5±1.4
Jackfruit refusals	41.6±1.9	11.0±0.7	0.9±0.4	53.5±2.4	42.8±3.7
CWSC refusals	29.6±0.1	2.5±0.4	2.1±0.1	48.1±3.2	31.6±1.1
Flemingia diet					
Flemingia offered	30.0±0.5	16.3±0.3	4.3±0.1	57.3±0.9	41.2±1.2
Flemingia refusals	35.6±1.0	13.9±1.2	5.1±1.1	55.9±3.8	44.4±2.2
CWSC refusals	30.1±0.8	2.4±0.1	2.2±0.1	48.4±2.5	31.5±1.6
Soybean meal diet					
Soybean meal offered	92.5±0.9	44.2±0.3	6.7±0.1	19.1±0.4	8.3±0.9
CWSC refusals	33.1±0.3	2.6±0.2	2.2±0.1	48.9±2.4	29.9±1.7
Faecal excretion					
Jackfruit diet	47.9±6.9	16.7±1.3	10.3±1.9	63.5±2.3	49.9±3.7
Flemingia diet	46.2±2.5	16.5±0.8	5.7±0.3	67.9±8.1	49.5±4.9
Soybean diet	47.6±1.3	13.2±2.5	6.9±0.3	62.2±4.6	38.8±2.3

[1] Means and standard error of means, CWSC=chopped whole sugar cane.

Table 4. Exp. 1. Composition of experimental feeds, refusals and faces in the wet season[1]

Item	DM %	% of DM			
		CP	Ash	NDF	ADF
All diets					
CWSC offered	26.6±1.5	1.3±0.1	1.4±0.1	44.2±2.4	23.4±0.8
Jackfruit diet					
Jackfruit offered	30.2±0.3	16.3±0.5	9.8±0.5	51.0±4.6	35.0±1.3
Jackfruit refusals	52.5±9.1	10.2±2.1	4.1±1.2	57.9±2.7	40.8±4.9
CWSC refusals	36.1±2.1	2.7±0.2	2.2±0.1	49.0±1.3	30.0±1.7
Flemingia diet					
Flemingia offered	30.3±1.3	16.4±0.2	5.0±0.7	58.4±3.6	46.1±3.5
Flemingia refusals	52.5±5.2	14.9±0.9	5.0±1.1	53.5±3.5	28.7±2.8
CWSC refusals	35.1±3.1	2.2±0.3	2.3±0.5	49.2±4.7	30.0±1.1
Soybean meal diet					
Soybean meal offered	92.5±0.6	44.1±0.4	6.8±0.3	19.1±0.1	8.3±0.7
CWSC refusals	37.7±3.0	2.6±0.4	2.4±0.2	48.9±3.5	29.8±2.9
Faecal excretion					
Jackfruit diet	51.5±8.1	17.4±0.9	12.1±3.1	64.4±5.0	46.4±2.4
Flemingia diet	49.7±6.3	16.4±1.1	8.1±0.4	73.7±4.0	56.5±3.8
Soybean diet	48.1±2.8	15.8±3.8	8.8±1.4	59.1±1.9	40.3±5.5

[1] Means and standard error of means, CWSC=chopped whole sugar cane.

total DM intake of the Jackfruit diet was higher than for the Flemingia and SBM diets. Total CP intake of goats fed the Jackfruit and SBM diet was similar both in dry and wet seasons, and was higher than for the Flemingia diets in both seasons.

The DM digestibility was similar for the Jackfruit and the Flemingia diets (table 6) in both seasons, but was lower than the SBM diet. There was a lower NDF digestibility for both the Jackfruit and Flemingia diets in the wet season. The apparent ADF digestibility was low and ranged from 23.9 to 37.9% in both seasons.

All diets resulted in a positive N balance. The N retention was highest in the SBM diets and lowest in the Flemingia diet. There was no significant difference in amount of faecal N in the dry season between Jackfruit and Flemingia feeds but a significant difference in the wet season. The lowest faecal N and highest urinary N were obtained from SBM diets for both seasons.

Table 5. Exp.1. Body weight, daily intake and faecal and urinary excretion for the different diets[1]

Items	Dry season				Wet season			
	Jackfruit	Flemingia	SBM	SEM	Jackfruit	Flemingia	SBM	SEM
Body weight, kg $W^{0.75}$								
	11.82	11.85	11.95	-	8.25	7.95	7.72	-
Feed offered, g/kg $W^{0.75}$								
Foliages or SBM								
DM	62	62	22	-	55	55	20	-
CP	10	10	10	-	9	9	9	-
CWSC								
DM	33	33	33	-	31	31	31	-
CP	0.5	0.5	0.5	-	0.4	0.4	0.4	-
Feed intake, g/kg $W^{0.75}$								
Foliages or SBM								
DM	41^{a}	37^{b}	17^{b}	1.2	41^{a}	20^{b}	15^{c}	0.9
OM	35^{a}	35^{a}	15^{b}	1.1	37^{a}	19^{b}	14^{c}	0.9
CP	8.8^{a}	6.6^{b}	7.4^{a}	0.3	7.5^{a}	3.8^{b}	6.4^{c}	0.2
NDF	23^{a}	22^{a}	3^{b}	0.6	21^{a}	13^{b}	2.8^{c}	0.5
ADF	17^{a}	15^{a}	1.3^{b}	0.5	14^{a}	15^{a}	1.2^{b}	0.6
CWSC, g/kg $W^{0.75}$								
DM	20^{a}	26^{b}	24^{ab}	1.2	15^{a}	16^{a}	27^{b}	4.6
OM	20^{a}	26^{b}	24^{ab}	1.2	15^{a}	16^{a}	27^{b}	4.5
CP	0.1^{a}	0.2^{b}	0.2^{b}	0.03	0.1^{a}	0.1^{a}	0.3^{b}	0.01
NDF	10^{a}	12^{b}	12^{b}	0.6	6^{a}	6^{a}	12^{b}	2.1
ADF	3^{a}	5^{b}	5^{b}	0.4	2^{a}	2^{a}	6^{b}	1.3
Water intake, g/kg $W^{0.75}$								
	18^{a}	5^{b}	27^{c}	4.2	77^{a}	43^{b}	96^{c}	7.6

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

[1] Least square means. SEM=standard error of means. CWSC=chopped whole sugar cane. SBM=soybean meal.

Experiment 2

Feed offered, composition of feed offered and the effect of addition of PEG to the Flemingia and Jackfruit foliage based diets on feed intake and digestibility of Jackfruit and Flemingia are given in table 7. The composition of Jackfruit and Flemingia was similar, except for the ash content.

DM intakes were lower in the Flemingia diets than in the Jackfruit diets. There was no effect of PEG inclusion on feed intake for any of the diets. Water intake was higher for goats fed the Jackfruit diet with PEG addition.

Addition of PEG to the Flemingia diet had no significant effect on any of the parameters measured except for a positive effect on NDF digestibility. Addition of PEG to the Jackfruit diet significantly increased the digestibility, especially for CP, which increased from 50.5 to 59.0% with PEG in the diet.

The N balance data are given in table 8. There was a significant effect of PEG on CP urinary excretion of goats fed the Flemingia diet. N retention was low for goats receiving the Flemingia diets and a negative N retention was obtained for goats given PEG. When PEG was added to Jackfruit the effect on CP digestibility resulted in higher N retention which was associated with a decrease in faecal N. The urinary N excretion was similar for Jackfruit with or without PEG. The highest N retention was obtained in goats receiving Jackfruit with PEG addition.

DISCUSSION

Effect on feed intake

Experiment 1 was designed to give equal protein levels in the diets, but the diets were not equal in terms of digestible OM, digestible DM or ME. The amount of CP was chosen to cover requirements for maintenance of goats (Devendra and McLeroy, 1982) and the diets consumed contained 11-18% CP, which is considered adequate to meet the requirements for microbial growth (Van Soest, 1994). The consumption of Flemingia was not different from that of Jackfruit in the dry season, but significantly lower in the wet season, which corresponded to a higher content of ADF.

In experiment 2, there was no significant effect on intake of Jackfruit and Flemingia when PEG was added to the feed. The results are in agreement with the findings of Decandia et al. (2000) who fed dry goats with foliage of *Pistaci lentiscus* containing 21.7% extractable condensed tannins. Ben Salem et al. (2000) showed that the DM intake

Table 6. Exp. 1. Digestibility and nitrogen utilization of the different diets[1]

Items	Dry season				Wet season			
	Jackfruit	Flemingia	SBM	SEM	Jackfruit	Flemingia	SBM	SEM
Digestibility, %								
DM	58.6^{a}	59.2^{a}	65.9^{b}	0.18	53.9^{a}	56.1^{a}	74.3^{b}	0.02
OM	59.1^{a}	61.1^{a}	66.9^{b}	0.18	54.2^{a}	58.5^{b}	75.9^{c}	0.02
NDF	50.7^{a}	50.7^{a}	43.8^{b}	0.27	36.4^{a}	38.0^{a}	56.0^{b}	0.36
ADF	37.9^{a}	34.1^{b}	15.6^{c}	0.42	23.9^{a}	37.6^{a}	34.1^{c}	0.05
N intake, g/day								
Foliages	14.70^{a}	12.30^{b}	14.15^{a}	0.42	9.86^{a}	4.77^{b}	7.82^{c}	0.24
CWSC	0.24^{a}	0.43^{b}	0.48^{b}	0.03	0.20^{a}	0.40^{b}	0.36^{b}	0.03
N intake, g/kg $W^{0.75}$ and day								
Total	1.26^{a}	1.10^{b}	1.23^{a}	0.05	1.19^{a}	0.62^{b}	1.06^{c}	0.04
N excretion, g/kg $W^{0.75}$ and day								
In faeces	0.662^{a}	0.659^{a}	0.285^{b}	0.04	0.732^{a}	0.399^{b}	0.274^{c}	0.02
In urine	0.302^{a}	0.193^{b}	0.337^{c}	0.03	0.287^{a}	0.204^{b}	0.327^{c}	0.03
N retention, g/kg $W^{0.75}$ and day								
	0.298^{a}	0.250^{b}	0.604^{c}	0.06	0.175^{a}	0.012^{b}	0.465^{c}	0.04
% of N intake								
Faecal N	53.0^{a}	63.2^{b}	27.0^{c}	0.29	61.5^{a}	64.7^{b}	26.4^{c}	0.31
Urinary N	24.0^{a}	18.8^{a}	34.4^{c}	0.27	24.2^{a}	33.1^{b}	32.1^{c}	0.29
Retention N	22.9^{a}	18.0^{b}	38.6^{c}	0.49	14.6^{a}	2.23^{b}	41.4^{c}	0.47

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

[1] Least square means, SEM=standard error of means, CWSC=chopped whole sugar cane, SBM=soybean meal.

of acacia foliage by sheep was not affected by the addition of PEG. The results obtained in the present study are in contrast with the reports of some other authors (Pritchard et al., 1988; Silanikove et al., 1996; Ben Salem et al., 2000) who showed that intake of goats fed legume or shrub foliage (containing between 3.2 to 20.5% of condensed tannins in DM) was improved by the addition of PEG. According to Silanikove et al. (1996), the amount of PEG needed to produce a maximal increase in feed intake by goats varies with shrub species. The highest DM intake was obtained after PEG supplementation at a level of 10 g/day to goats fed carob and oak foliage. Ben Salem et al. (2000) reported that the optimum response of acacia intake was obtained in sheep given feed blocks with 18% PEG, corresponding to a PEG consumption of about 23 g/day, while goats in this study were dosed with 5 g/day, which may not have been enough to affect intake.

Effect on diet digestibility and nitrogen retention

According to a previous study (Mui et al., 2001) the contents of condensed soluble tannins were 0.207 for Flemingia and 0.501 for Jackfruit foliage analysed with HCL-butanol absorbance (expressed as A_{550}/cm and g DM) methods. The goats in this study had a lower digestibility of CP in Exp. 1 and Exp. 2 for Flemingia compared to Jackfruit. Jackson and Barry (1996) showed that 40% of the condensed tannins (CT) in Flemingia were bound to protein and fiber. The high level of bound CT may be one reason for the very low digestibility of Flemingia, due to bound CT reducing cell wall fermentation by rumen organisms and inactivating hemicellulase and cellulase enzymes secreted by rumen bacteria. Fassler and Lascano (1995) reported that increasing levels of up to 16% DM of Flemingia in the diet resulted in a reduction in DM and fiber digestion and an increase in faecal N and faecal NDF-N, which is consistent with this study.

The higher CP digestibility of the SBM diet may have been due to the increased CP content of total DM intake in both wet and dry seasons. High urinary N excretion in the SBM diets indicated high protein intake and rapid ruminal digestion, resulting in ammonia production in excess of microbial needs. Ammonia in excess of recycling needs is absorbed into the bloodstream, converted to urea in the liver and excreted in the urine.

The tendency a for higher percentage of faecal N-loss in the Flemingia and Jackfruit diets compared to the SBM diet in the present study can relate to the negative effect of total tannins. Condensed tannins (CT) have been shown to reduce rumen ammonia and urinary N excretion (Barry et al., 1985; Reed et al., 1990; Merkel et al., 1999). Tannin is considered to be as important as N content in the effects on microbial degradation of protein through the formation of indigestible complexes with protein (Hanely et al., 1992; Ben Salem et al., 1997; Norton, 2000). Consequently, the average daily N retention was significantly higher in the SBM diet in both seasons. Studies with forages of varying

Table 7. Exp. 2. Feed offered and daily intake and digestibility of Jackfruit and Flemingia foliages with and without addition of PEG[1]

Item	Treatments				SEM
	Flemingia −PEG	Flemingia	Jackfruit +PEG	Jackfruit	
Liveweight, kg $W^{0.75}$					
	10.0	10.0	10.2	10.2	-
Feed offered, g/kg $W^{0.75}$					
DM	55	55	55	55	-
CP	9	9	9	9	-
Composition of feed offered, %					
DM		29.8±1.7		30.3±1.9	
CP		16.3±0.3		16.2±0.4	
Ash		2.8±0.3		11.4±1.1	
NDF		58.3±3.7		55.6±5.4	
NDF-N		1.6±0.4		1.3±0.4	
ADF		42.9±1.2		42.1±0.8	
Intake, g/kg $W^{0.75}$					
DM	22^{a}	22^{a}	45^{b}	46^{b}	0.9
OM	21^{a}	21^{a}	39^{b}	39^{b}	0.9
CP	3.6^{a}	3.8^{a}	8.4^{b}	8.5^{b}	0.2
NDF	14^{a}	14^{a}	25^{b}	25^{b}	1.0
NDF-N	1.1^{a}	1.2^{a}	2.5^{b}	2.3^{b}	0.1
ADF	9.0^{a}	11^{a}	19^{b}	19^{b}	0.7
DM refusal, %	64.1^{a}	62.7^{a}	23.4^{b}	23.9^{b}	2.7
Cons. CP in DM, %	16.6	14.1^{a}	18.5^{b}	18.5^{b}	1.6
Water intake					
g/day	434^{a}	459^{a}	880^{b}	764^{b}	113
g/kg $W^{0.75}$	45^{a}	46^{a}	85^{b}	72^{c}	0.2
Digestibility, %					
DM	41.5^{a}	40.3^{a}	55.7^{b}	45.0^{c}	0.6
OM	43.3^{a}	42.5^{a}	53.5^{b}	48.1^{c}	0.5
CP	41.5^{a}	41.8^{a}	59.0^{b}	50.5^{c}	0.5
NDF	46.5^{a}	37.8^{b}	51.8^{c}	43.0^{d}	0.6
NDF-N	19.0^{a}	18.0^{a}	42.0^{b}	16.8^{a}	0.8
ADF	32.5^{a}	35.0^{a}	40.3^{b}	34.2^{a}	0.3

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

[1] Least square means, SEM=standard error of means, PEG=polyethylenglycol.

CT concentration (2.2%-5.5%) confirmed that protein bound tannin could escape ruminal digestion and be digested and utilised in the lower part of the digestive tract, thus acting as a by-pass protein source (Dzowela et al., 1995; Jackson and Barry, 1996; Norton, 2000). At high CT concentration, the efficiency of essential amino acid absorption in the intestine decreased significantly. Feeds with a high CT concentration should be given as supplements together with other feedstuffs to dilute the CT content and prevent CT from restricting feed intake (Waghorn, 1990). Kumar and D'Mello (1995) reported that high levels of tannin may depress the feed intake in two ways, either by inhibition of DM digestion or by reducing the palatability of the foliage.

The higher N retention of goats in the dry season may have been due to higher voluntary feed intake rather than to tannins. In this study the intake of total tannins, calculated from a previous study of Mui et al. (2001) was 2.3% of DM for the Jackfruit diet. It was higher than the value of 1.8% obtained for the Flemingia diet but higher intake and digestibility of CP were shown for the Jackfruit diets. The high intake of goats and the fact that the bark was eaten indicated high preference for the Jackfruit foliage and no negative effect of the tannin content. The result is in agreement with Norton (2000) who found no relationship between preference and CT.

Effect of PEG on digestibility

The biological effect of tannins on rumen fermentation may be affected by PEG. Makkar (2000) showed that PEG

Table 8. Exp. 2. Nitrogen retention of goats fed Jackfruit and Flemingia foliages with and without addition of PEG[1]

Item	Treatments				SEM
	Flemingia−PEG	Flemingia	Jackfruit+PEG	Jackfruit	
Intake, g/kg $W^{0.75}$	0.579^{a}	0.601^{a}	1.343^{b}	1.354^{b}	0.039
Faecal N, g/kg $W^{0.75}$	0.325^{a}	0.337^{a}	0.546^{b}	0.674^{c}	0.052
Urinary N, g/kg $W^{0.75}$	0.323^{a}	0.232^{b}	0.369^{a}	0.345^{a}	0.038
N retention, g/kg $W^{0.75}$	-0.069^{a}	0.032^{b}	0.428^{c}	0.335^{d}	0.063
Percentage of N intake					
Faecal N	56.05^{a}	56.10^{a}	40.65^{b}	50.03^{c}	0.58
Urinary N	55.78^{a}	38.60^{b}	27.47^{c}	25.47^{c}	0.41
N retention	-11.92^{a}	5.32^{b}	31.85c	24.75^{d}	0.82

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

[1] Least square means SEM=Standard error of means. PEG=Polyethylenglycol.

binds to tannins and makes them inert, and also has the capacity to release protein from already formed tannin-protein complexes. In the present study the effect of PEG on the digestibility was much more important than on intake, especially for protein. When adding PEG the amount of tannin-rich species can be increased in the diet and CP digestibility will also be increased (Ben Salem et al., 2000; Landau et al., 2000; Gilboa et al., 2000). In the present study, PEG added to the Flemingia diet increased the digestibility of NDF by 7.7% units, but the digestibilities of other components such as DM, CP, NDF-N and ADF were not improved by addition of PEG. According to Tolera et al. (1997), the response to PEG treatment increased with increased concentration of phenolic compounds in the browse plants and the response was zero in species with low contents of phenolic compounds. Makkar (2000) also stated that addition of PEG to tannin-rich diets was advantageous when tannin content of the feed was high but it was deleterious when the tannin content was low. The digestibility of feedstuffs high in phenolics is improved by adding PEG, which is a result of the binding of phenolic compounds to PEG, which is mainly dependent on the condensed tannin content of the browse species rather than the total phenolics or total tannins. This agrees with the results in the present study where PEG had less effect in Flemingia than in Jackfruit foliage.

CONCLUSION

Jackfruit foliage has high potential as a protein supplement, and can improve feed intake and give a positive nitrogen balance when fed to growing goats. Using Flemingia foliage as a protein supplement in the dry season was more efficient than in the wet season, but Flemingia has a lower potential as a protein source compared to Jackfruit.

Use of polyethylene glycol is an attractive method for enhancing the feeding value of tanniferous feeds. Supplementation twice daily with small amounts of polyethylene glycol increased digestibility and nitrogen retention for Jackfruit foliage but reduced digestibility and nitrogen retention of Flemingia. Nitrogen retention from Jackfruit and Flemingia, with and without addition of polyethylene glycol, in the present experiments suggests that the negative effect of condensed tannins in Flemingia is uncertain. For Jackfruit the presence of condensed tannins may be a major constraint to efficient utilisation by goats.

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