Effect of Type and Level of Foliage Supplementation on Voluntary Intake and Digestibility of Rice Straw in Sheep

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ABSTRACT: *In-vivo* balance and nylon bag studies were conducted with rumen fistulated sheep to investigate the effect of type, i.e. Leucaena (L), Gliricidia (G) and Tithonia (T), and level (1, ~15; 2, ~30g DM/kg$^{0.75}$) of foliage supplementation on voluntary intake and digestibility of rice straw. Inclusion of these leafy supplements in the diet significantly increased total feed intake. On a metabolic weight basis (kg$^{0.75}$), voluntary intake of digestible DM increased from 23.8 (control straw diet) till 27.7 (L1), 28.4 (G1) and 33.1 (T1) for the lower level, and till 34.8 (L2), 35.9 (G2) and 39.6 (T2) g/kg$^{0.75}$ for the higher level of supplementation, respectively. Rumen pH was stable, on average 6.75 (control values) and ranging from 6.67 till 6.91 with the supplements. Rumen ammonia increased from 4.9 till 6.7 to 11.8 mmol/l with the supplements. The highest increase was obtained with G and the lower with L and T. The nylon bag studies showed that contrary to the rate of degradation of the supplements themselves, supplementation did not affect the in-sacco rate of straw dry matter degradation (k_d; range 1.87-2.08 %/h). At the higher supplement level, for L, G and T, k_d values were 3.36, 8.16 and 8.58 %/h, respectively.

(**Key Words**: Forage Supplementation, Intake, Digestibility, Rice Straw)

INTRODUCTION

The major constraint to ruminant livestock production in Sri Lanka is the availability of good quality feedstuffs throughout the year. Therefore, particularly in the dry season, ruminants have to depend mainly on poor quality crop residues, such as rice straw, as their major source of nutrients. Both the energetic and protein feeding value of rice straw are very low, though it can slightly be improved by increasing the nitrogen content through addition of urea or increasing digestibility by urea-ammonia treatment (Ibrahim et al., 1992; Kiran Singh and Schiere, 1993). Probably a more appropriate method of utilizing fibrous residues more practically and efficiently, is supplementation with leaves (De Jong et al., 1992).

In Sri Lanka, amongst others the following species are grown widely, either on farm land or along borders and fences: *Leucaena leucocephala* (ipil−ipil), *Gliricidia maculata* (Gliricidia) and *Tithonia diversifolia* (wild sunflower).

The objectives of the present study were to investigate (1) the effect of type and level of foliage supplementation on voluntary intake and digestibility of rice straw in sheep, and (2) to evaluate the protein value of the fodder supplements in terms of rumen degradable and rumen undegradable though intestinally digestible protein.

MATERIALS AND METHODS

Sheep and their management

Eight rumen fistulated almost mature crossbred male sheep (Dorset × South Down) with an average live weight of approximately 30 kg were maintained individually in metabolism cages indoors.

The experimental diets (voluntary intakes as presented in table 2) tested were composed as follows:

1. G_1 : Rice straw (RS) + minerals
2. C_2 : Rice straw + NPS solution spray (~20, 4 and 1.2 g/kg DOM RS) + minerals
3. L_1 : Rice straw + ~15 g/kg$^{0.75}$ Leucaena + minerals
4. L_2 : Rice straw + ~30 g/kg$^{0.75}$ Leucaena + minerals
5. G_1 : Rice straw + ~15 g/kg$^{0.75}$ Gliricidia + minerals
6. G_2 : Rice straw + ~30 g/kg$^{0.75}$ Gliricidia + minerals
7. T_1 : Rice straw + ~15 g/kg$^{0.75}$ Tithonia + minerals
8. T_2 : Rice straw + ~30 g/kg$^{0.75}$ Tithonia + minerals

The approximate composition of the feedstuffs is presented in table 1.

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Table 1. Chemical composition and digestibility of feedstuffs

	rice straw		leucaena	gliricidia	tithonia
	C1	C2	L12	G12	T12$^{1)}$
OM$^{2)}$	84.8	81.4	87.7	85.4	86.9
CP$^{2)}$	6.9	9.2	29.5	26.5	28.3
CF$^{2)}$	32.4	32.9	15.9	16.7	13.1
EE$^{2)}$	1.0	1.0	5.5	5.2	4.5
dDM$^{3)}$	39.9	37.6	54.2	68.9	54.2

$^{1)}$ Details in materials and methods; $^{2)}$% in DM; $^{3)}$*in vitro* digestibility.

Digestibility studies

Four trials were conducted using the same sheep. Sheep were allotted to the diets with the following restrictions:

1. experimental diet combinations 1 and 2, 3 and 4, 5 and 6, 7 and 8 were only once allotted to the same sheep.
2. to avoid systematic carry over effects, each treatment was only once following a particular other treatment.
3. the lower (1, 3, 5, 7) and higher (2, 4, 6, 8) levels of supplementation were equally spread over the sheep.

The experimental routine was as follows. The sheep were fed twice daily at 6:00 and 18:00 hrs. Water was available in excess. Care was taken that the supplement, newly collected and sun dried, was consumed quantitatively. The rice straw residue was collected once daily at 6:00 hrs. Following the change over period, the sheep were fed the experimental diets for a 3-wk preliminary period followed by a 4-wk collection period during which feed intake and faeces were measured.

Table 2. Intake of rice straw and supplementary feeds, overall digestibility, and performance of the sheep

	control		leucaena		gliricidia		tithonia		SEM
	C1	C2	L1	L2	G1	G2	T1	T2$^{1)}$	
Intake DM									
– straw (g/d)	628^{a}	625^{a}	512^{ab}	518^{ab}	503^{b}	532^{ab}	624^{a}	544$^{ab2)}$	39.6
– supplement	–	–	185^{a}	396^{b}	181^{a}	350^{b}	181^{a}	345^{b}	16.3
– total	628^{a}	625^{a}	697^{ab}	914^{c}	684^{ab}	882^{c}	805^{bc}	890^{c}	40.8
– straw (g/d* kg$^{0.75}$)	47.0^{bc}	50.9^{bc}	38.5^{ab}	37.2^{a}	38.9^{ab}	38.6^{ab}	46.8^{bc}	42.6^{abc}	2.80
– supplement	–	–	14.2^{a}	27.4^{b}	13.8^{a}	25.8^{b}	13.4^{a}	27.2^{b}	0.81
– total	47.0^{a}	50.9^{a}	52.7^{ab}	64.6^{bc}	52.7^{ab}	64.4^{bc}	60.2^{b}	69.7^{c}	2.63
Intake OM (g/* kg$^{0.75}$)	39.8^{a}	43.3^{a}	45.1^{ab}	55.6^{bc}	44.7^{ab}	54.8^{bc}	51.4^{b}	59.8^{c}	2.23
N (g/d* kg$^{0.75}$)	0.52^{a}	1.01^{b}	1.08^{b}	1.71^{d}	1.01^{b}	1.52^{c}	1.13^{b}	1.69^{d}	0.044
N/OM (g/kg)	10.6^{a}	19.8^{b}	20.8^{b}	27.1^{d}	19.6^{b}	23.6^{c}	18.7^{b}	24.3^{c}	0.89
Level of excess straw	1.32^{ab}	1.54^{c}	1.44^{ac}	1.30^{ab}	1.30^{ab}	1.44^{ac}	1.26^{ab}	1.36^{ab}	0.052
DM digestibility (%)									
– whole diet	42.8^{a}	47.9^{b}	44.2^{ab}	45.4^{ab}	45.3^{ab}	47.0^{ab}	46.4^{ab}	48.0^{b}	1.42
– supplement	–	–	45.0^{a}	47.4^{a}	49.7^{a}	50.7^{ab}	55.8^{b}	54.3^{b}	3.20
Intake DDM (g/d)	271^{a}	301^{a}	309^{ab}	414^{c}	311^{ab}	413^{c}	372^{bc}	427^{c}	23.3
(g/d* kg$^{0.75}$)	23.8^{a}	29.3^{b}	27.7^{ab}	34.8^{cd}	28.4^{ab}	35.9^{cd}	33.1^{c}	39.6^{d}	1.72
Weight gain (g/d)	−25.0^{a}	−16.7^{a}	8.4^{ab}	41.7^{b}	16.7^{ab}	29.2^{b}	20.9^{ab}	45.7^{b}	16.6

$^{1)}$ Details in materials and methods; $^{2)}$ different superscripts within rows indicate significant differences ($p < 0.05$).

From 2 days before the start until 2 days prior to the end of the 4-wk collection period, the feeds were sampled at each feeding. Feed, refusals and faeces were dried at 55℃ to a constant weight for dry matter (DM) determination. After grinding to pass a 1 mm sieve, the samples were stored pending analyses. Animals were weighted before and after the trial. The average of the initial and final weights was used as an estimate of metabolic size ($W^{0.75}$, kg), based on which intake of dry matter (IDM) was calculated.

Rumen liquor samples were taken from each animal at about 0, 2, 4, 6, 8, 10 and 12 hrs post feeding for 3 days for measurements of pH and ammonia content (Markham, 1942).

***In-sacco* studies**

In conjunction with the digestibility studies, the *in-sacco* rate of degradation of the feedstuffs was also evaluated. The *in-sacco* experiments were conducted in duplicate per sheep and treatment. Three gramme of ground dry material were included in 7×13 cm^2 nylon bags with pore size of approximately 61 μm. Incubation periods used for rice straw (DM and OM) were 0, 3, 6, 12, 24, 48, 72 and 336 hrs, whereas 0, 2, 4, 8, 16, 24, 48 and 336 hrs were applied for the supplements (DM and N). The latter measurements (336 hrs) were carried out in duplicate during the preliminary period and were meant for determining the truly indigestible residue (U). For the 0-hr measurements, the samples were thoroughly hydrated before being washed. The quantity (ground to pass a 2 mm sieve) weighed in per nylon bag was 3 gm and 5 gm for straw and supplement, respectively. The bags were introduced into the rumen according to a time schedule so that all bags were collected at the same time, subsequently washed altogether and dried (55℃). The results were analyzed by non-linear regression (SAS, 1985), based on the following model (Robinson et al., 1986);

$$R_t = U + (1 - S - U) * EXP \ \{-k_d * (t-L)\}$$

with: R_t = residue at time t

U = truly indigestible residue (336 hr incubation)

S = water soluble part (0 hr measuring point)

K_d = rate of degradation (ship %/hr)

L = lag phase

The results (n = 32) were analyzed statistically according to Brouwer (1990) by a 3 sampled analysis of variance taking into account the factors treatment, sheep and time (df = 14). Significant differences ($p < 0.05$) were tested by two-tailed Student t values.

RESULTS AND DISCUSSION

Table 2 presents the effect of fodder supplementation on dry matter intake (IDM) and digestibility (dDM). At the lower level of supplementation, the best results were obtained with Tithonia (T1). Contrary to Leuceana (L1) and Gliricidia (G1), straw intake was not adversely affected, whereas with T1 the level of excess straw (LEF) was even the lowest. Accordingly with T1, on a MW basis the intake of digestible DM was significantly higher than with both leguminous supplements, which aspect, though less accurately, also was visualized in the daily weight gain. In terms of digestible DM intake, the effect of N supplementation was about comparable to that of L1 and G1. However, despite the higher intake, daily weight gain did insufficiently react, perhaps due to a still insufficient amino acid supply from the small intestine (Oosting et al., 1995).

At the higher level of supplementation, rice straw intakes were almost comparable. Relative to L1 and G1, no further decrease in rice straw intake was observed with L2 and G2. With T2, however, the rice straw intake fell to a level almost comparable to that of L2 and G2. Due to the higher digestibility of T, relative to L and G the ranking in digestible DM intake was similar to that of the lower supplementation level. The daily weight gain changed accordingly.

It should furthermore be noticed that L2 hardly had any significant effect on the DM digestibility of the diet compared to the control straw diet (C1) or L1. This finding is in agreement with the results reported by Devendra (1983) and Moran et al. (1983).

Devendra (1984) suggested that the increase in total feed intake could be due to an improved palatability, increased availability of minerals and vitamins. It should be noticed that rumen pH was hardly affected. Even with T, the supplement with the highest rate of fermentation (k_d) and the lowest truly undegradable residue (U, table 4), rumen pH did not fall to the level which would adversely affect the activity of cellulolytic bacteria. With the control straw diet rumen ammonia was higher than could be expected from the straw's CP content, presumably due to a significant influx of urea with saliva or across the rumen wall. With forage supplementation not only rumen ammonia is increased to a level sufficiently high for rumen microbial activity (Hoover, 1986), but in addition to that protein degradation products are made available, such as amino acids and branched chain fatty acids. Therefore one would expect that the effect of the supplement would be mediated by an increased rumen capacity, whether by improved rumen kinetics and/or an increased rumen particle pool size.

In view of this, in the present experiment, the *in-sacco* degradation of the feed components was determined as related to the level and type of supplementation. The results are presented in table 3. Surprisingly, however, hardly any significant effect of the supplements was observed on the *in sacco* degradation characteristics of the straw. With straw of a reasonably high digestibility, one would have expected that due to the more favourable conditions for the rumen microbes, their rates of attachment and subsequent colonization, as a result the rate of fermentative degradation of the straw would have increased. It cannot be excluded that this aspect might be related in part to the fact that under control dietary conditions rumen ammonia did not become really low. On the other hand, however, it should be noticed that contrary to the straw, the rate of degradation of the supplements was generally increased by N and foliage supplementation.

Despite the rate of degradation of the straw was not affected, the additional amounts of protein supplied by foliage supplementation may have increased microbial growth. These results are in agreement with the previous work of Premaratne (1990). An increased rate and efficiency of microbial biomass production may particularly have happened with Tithonia. As shown by Perera et al. (1992), Tithonia N is easily degraded in the rumen. Nevertheless, relative to Gliricidia rumen ammonia was significantly lower, perhaps due to increased incorporation of ammonia in synthesized rumen microbial biomass. In addition, the effect of the forage supplements should be considered in view of the quantities of undegraded protein arriving in the duodenum, which through an increased supply of amino acids from the small intestine also could affect feed intake positively (Oosting et al., 1995; Van Bruchem et al., 1993). In conclusion, supplementation with tree fodder legumes increased the dry matter intake in sheep. Of the supplementary foliages tested, the best results were obtained with Tithonia. The increased dry matter intake was not mediated by an increased rate of degradation of the rice straw in the rumen.

Table 3. Rumen conditions and in sacco dry matter degradation characteristics of rice straw and supplements

	control		leucaena		gliricidia		tithonia		SEM
	C1	C2	L1	L2	G1	G2	T1	T2[1)]	
Rumen – pH	$6.75^{a9)}$	6.78^{ab}	6.80^{a}	6.80^{a}	6.82^{ab}	6.67^{a}	6.78^{ab}	6.91^{b}	0.052
– ammonia[2)]	4.88^{a}	13.53^{c}	7.34^{ab}	7.44^{ab}	8.26^{b}	11.84^{c}	6.72^{ab}	7.68^{ab}	1.085
Rice straw									
water soluble – S	0.174^{a}	0.174^{a}	0.174^{a}	0.174^{a}	0.174^{a}	0.174^{a}	0.174^{a}	0.174^{a}	0.001
truly undegradable – U	0.372^{a}	0.357^{a}	0.368^{a}	0.370^{a}	0.356^{a}	0.346^{a}	0.370^{a}	0.375^{a}	0.010
lag phase[3)]	3.49^{a}	4.39^{a}	4.42^{a}	3.74^{a}	3.64^{a}	4.48^{a}	4.48^{a}	4.23^{a}	0.452
rate of degradation $-k_{d1}$[4)]	2.48^{ab}	2.59^{ab}	2.42^{ab}	2.26^{a}	2.45^{ab}	2.65^{ab}	2.47^{ab}	2.72^{b}	0.144
$-k_{d2}$	2.05^{a}	2.04^{a}	1.92^{a}	1.87^{a}	2.00^{a}	2.06^{a}	1.91^{a}	2.08^{a}	0.086
$-k_{d3}$	2.19^{b}	2.20^{b}	2.08^{ab}	1.89^{a}	2.06^{ab}	2.11^{ab}	2.00^{ab}	2.26^{b}	0.092
Supplements									
water soluble – S	–	–	0.243^{a}	0.243^{a}	0.367^{c}	0.367^{c}	0.326^{b}	0.326^{b}	0.011
truly undegradable – U	–	–	0.274^{c}	0.274^{c}	0.242^{b}	0.242^{b}	0.030^{a}	0.030^{a}	0.007
lag phase[3)]	–[5)]	–	1.79^{a}	1.78^{a}	1.95^{a}	1.42^{a}	2.12^{a}	1.88^{a}	0.291
rate of degradation $-k_{d1}$[4)]	–[6)]	–	3.81^{a}	3.97^{a}	9.31^{b}	10.75^{bc}	11.95^{c}	11.71^{c}	0.734
$-k_{d2}$	–[7)]	–	3.46^{a}	3.36^{a}	6.93^{b}	8.16^{b}	8.32^{b}	8.58^{b}	0.549
$-k_{d3}$	–[8)]	–	4.03^{a}	3.89^{a}	7.30^{b}	8.23^{b}	12.87^{c}	13.41^{c}	0.732

[1)] Details in materials and methods.
[2)] mmol/l; [3)] h; [4)] %/h, k_{d1} from NLR including lag phase, k_{d2} NLR excluding lag phase, k_{d3} ln transformation – LR.
[5)] LC1, LC2, 2.55, 2.65 (SEM 0.317); GC1, GC2 3.24, 3.51 (0.081); TC1, TC2 2.72, 2.58 (0.165).
[6)] LC1, LC2 3.00, 3.20 (0.101); GC1, GC2 8.62, 9.46 (0.720); TC1, TC2 7.69, 9.93 (0.196).
[7)] LC1, LC2 2.58, 2.68 (0.081); GC1, GC2 5.45, 5.59 (0.293); TC1, TC2 5.64, 6.85 (0.148).
[8)] LC1, LC2 3.32, 3.29 (0.138); GC1, GC2 6.57, 6.62 (0.327); TC1, TC2 11.68, 12.29 (0.545).
[9)] different superscripts within rows indicate significant differences ($p < 0.05$).

Further research is needed with small intestinally cannulated sheep for studying (1) the extent and efficiency of microbial protein synthesis in the rumen, (2) the quantity of protein escaping from rumen degradation, (3) protein digestion in the small intestine, and (4) the ileal endogenous protein losses.

Besides that, additional information seems needed on the level of supplementation, which would support a fibrous crop residues based ruminant livestock production system most optimally. If it is assumed that in the rumen the water soluble fraction (S) is degraded totally, the truly undegradable fraction (U) entirely escapes from rumen degradation, and extent of degradation the remainder water-insoluble though potentially degradable part is related to the ratio of k_d to the rate of passage (k_p), an estimate can be made of the relative proportions of rice straw and supplement dry matter degraded in the reticulo-rumen. Based on a k_p of 3 and 4 %/h for rice straw and supplements, respectively, estimates were obtained as shown in figure 1. From this figure, it seems evident that a level of supplementation of 30 g/kg$^{0.75}$ is perhaps not always needed under practical conditions. At this level of supplementation, the major part of rumen degradable dry matter was derived from the supplement. In addition, since supplements are usually grown on marginal lands, along boundaries and in fences only, such a level of supplementation could well be beyond a region's potential.

In tropical integrated farming systems, livestock generally serve a multiple of goals. Livestock are not only kept for production, but also for purposes such as capital investment/formation, draught power, manure and security. Taking these aspects into account, farmers generally aim at increasing their number of livestock. However, with basal diets below maintenance requirements, e.g. rice straw, and limited quantities of supplement available, the output of a production system is inversely related to the number of animals. Van Bruchem and Zemmelink (1995) recently argued that, at the level of the production system, scarce supplements are utilized more efficiently at higher levels of supplementation with a more limited number of livestock.

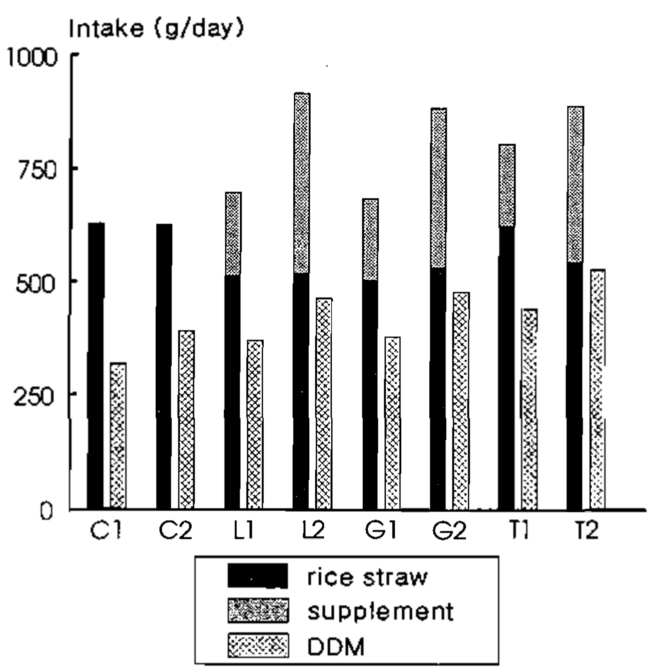

Figure 1. Rumen degradable dry matter (RDDM) of rice straw and supplementary forages (details C1-T2 in materials and methods).

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