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# Rumen Degradation and Intestinal Digestibility of Some Sri Lankan Tree/shrub Forage Proteins.

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*ABSTRACT. Ruminal degradation of nine shrub/tree fodders was estimated by the in-sacco procedure. Fresh foliage samples were included in nylon bags (7*13 cm, mesh size 41 μm) and incubated in the rumen of sheep. Dietary protein was subdivided into water soluble (S), truly rumen undegradable (U) and water insoluble but potentially degradable (D) fractions. S was assumed fully degraded, and D gradually degraded with fractional rate $k_d$ (%/h). The rumen degraded (RDP) and undegraded (UDP) protein fractions were estimated, assuming a rate of particle passage from the rumen of 4 %/h.*

*The intestinal digestion of the UDP fraction was estimated with the mobile nylon bag technique. After pre-incubation in the rumen, the residues were included in small nylon bags (3*6 cm), predigested with pepsin/HCl and introduced through a cannula into the duodenum of dairy cows. Intestinal protein digestion was derived from the residues voided with the faeces (IDP). For straw based diets and a supplement level of 15 g/kg$^{0.75}$ (DM), RDP values for Sesbania and Tithonia ranged 200-300 g/kg, about sufficient for microbial requirements. In Gliricidia, Erythrina and Samanea, RDP values ranged 100-200 g/kg. Leucaena, jackfruit, Calliandra and Albizia gave less favourable results with RDP values of less than 100 g/kg. For a feeding level of 10 g DOMI/kg$^{0.75}$ above maintenance, i.e. a daily gain of approximately 5 g/kg$^{0.75}$, small intestinal amino acid N from supplementary protein, needed in addition to microbial protein, was met by 15 g/kg$^{0.75}$ supplement DM of Samanea and Tithonia. Erythrina, Sesbania and*

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*Gliricidia provided 75-90% of these requirements, but Leucaena and Calliandra less than 50%.*

## INTRODUCTION

One of the major problems of ruminant livestock production in the tropics is associated with an inadequate supply of good quality feed. Especially, in densely populated regions the basal diet consists mainly of fibrous low protein crop residues, particularly during the dry season. The nutrients available in the rumen, the proportion of protein escaping from rumen degradation and its digestion in the small intestine are major determinants of ruminant performance (Foster *et al.*, 1983). For optimal rumen functioning, readily available energy as well as protein are needed. The level and efficiency of rumen microbial protein synthesis may increase by supplementary rumen degradable protein, while protein escaping from rumen degradation enhances the availability of amino acids from the small intestine to a level that can support moderate levels of production. Besides, voluntary intake of the basal fibrous feed may respond positively to a protein supplement (Oosting, 1993).

For reasons of efficiency of nutrient conversion and economics, by-products of oil and milling industries are preferably used for non-ruminant livestock. Hence, for ruminants alternative supplementary protein sources need to be identified. In this context, the foliage of multipurpose shrubs and trees is widely considered to be a good protein supplement. Their nutritive value depends on the extent and partitioning of protein digestion along the gastrointestinal tract. The objectives of this study were to evaluate some commonly available shrub/tree fodders in terms of (1) characteristics of protein degradation in the rumen, and (2) intestinal digestion of protein escaping rumen degradation.

## MATERIALS AND METHODS

Shrub/tree leaves were collected from the mid-country region of Sri Lanka, at an altitude of approximately 750 m above see level. Details are presented in Table 1 (Jansen *et al.*, 1991; 't Mannetje and Jones, 1992).

The leaves were cut to particles of about 0.5 cm. Samples of 20 g were included in 7*13 cm heat sealed nylon bags with mesh size 41 $\mu$m. The

bags were incubated in duplicate for 6, 12, 18 and 336 hr in the rumen of 4 cannulated sheep (Dorseth*South Down, LW 30-40 kg), ad libitum fed on Guinea A grass (Panicum maximum - ecotype A) and supplemented with a commercial mineral mixture. After removal, these bags and two non-incubated (0 hr) bags were washed for 1 hr with cold water in a domestic rotating drum type washing machine without spinning, and dried for 48 hr in a vacuum oven at 70 C. The residues were ground to pass a 3 mm sieve and stored pending intestinal incubation.

**Table 1. Details on tree/shrub forages.**

| Local name | Botanical name | Family |
|---|---|---|
| Albizia | *Albizia falcata*[1] | Leguminosae |
| Calliandra | *Calliandra calothyrsus* | Leguminosae |
| Erythrina | *Erythrina variegata* | Leguminosae |
| Gliricidia | *Gliricidia sepium* | Leguminosae |
| Ipil-ipil | *Leucaena leucocephala* | Leguminosae |
| Jackfruit | *Artocarpus heterophyllus* | Moraceae |
| Rain tree | *Samanea saman* | Leguminosae |
| Sesbania | *Sesbania grandiflora* | Leguminosae |
| Wild sunflower | *Tithonia diversifolia* | Compositae |

[1]) also: Paraserianthes falcataria

Mobile nylon bags (MNB) of 3*6 cm and mesh size 41 $\mu$m, were heat sealed and filled with 0.5 g of the dried and ground ruminal residue. The bags were pre-incubated in an HCl solution (0.1 mol/l) with pepsin (1 g/l, Merck, 2000 FIP-U/g) for 1 hr at 37 C. Subsequently, the bags were inserted via a T-piece cannula in the proximal duodenum of 4 lactating cows (HF*FH), fed a mixture of (DM basis) 50/50 concentrates/wilted grass silage. Two bags used per forage sample, rumen incubation time and cow. The bags were introduced into the duodenum at a frequency of 3-4 bags per 20 minutes for a period of 3.5 hrs on two days (1 and 3). Replicate bags were distributed over both days. Faeces were collected every 2 hr until 48 hr after introduction of the last bag. The bags were recovered from the

faeces by washing over a 5-mm screen, cleaned with water, and stored at -18 C. After collection from the faeces had been stopped, the bags were thawed and washed in a domestic washing machine using 120 l of 40 C water, without spinning (Van Straalen *et al.*, 1993). Then the bags were dried at 70 C and the residues pooled per forage and rumen incubation period. Finally the samples, including those without intestinal incubation, were ground to pass a 1 mm sieve, and stored pending analysis. Dry matter was assessed by drying in an oven at 101 C until constant weight. N was determined according to Kjeldahl, using $K_2SO_4$ and $CuSO_4$ as catalysts.

Nitrogen disappearance from the nylon bags in the rumen was analyzed by non-linear regression (SAS, 1985) according to the model of Robinson *et al.*, (1986):

$$R_t = U + (100 - S - U) * \text{Exp}(-k_d * t * 0.01)$$

where,

- $R_t$ = residue at time t (%)
- U = rumen undegradable fraction (336 hr incubation, %)
- S = water soluble fraction (0 hr incubation, %)
- D = 100 - S - U; water insoluble but potentially degradable fraction (%) and
- $k_d$ = fractional rate of degradation of D (%/h)

The rumen undegradable U fraction escapes from rumen degradation, while the S fraction is assumed to be entirely degraded in the rumen. The proportion of the D fraction effectively degraded in the rumen depends on the rate of degradation ($k_d$) relative to the rate of passage ($k_p$). Assuming 4%/hr for the latter rate constant, total crude protein was subdivided into fractions degraded in the rumen (RDP) and escaping rumen degradation (UDP), according to the following equations:

$$RDP = S + D * k_d/(k_d + k_p)$$

$$UDP = UDP_U + UDP_D,$$

where,

$$UDP_U = U \text{ and}$$

$$UDP_D = D * k_p/(k_d + k_p)$$

Intestinal protein digestibility was estimated by comparing the residues voided with the faeces with the amounts introduced into the duodenum. For the U fraction this value ($d_U$) was derived from the residue after 336 hr of rumen incubation. According to the model of Robinson *et al.*, (1986), the protein residues after 6-18 hr rumen pre-incubation were subdivided into D and U fractions. From their mean digestibility (d) and the proportions of D and U, the digestibility of D ($d_D$) was estimated from the relationship:

$$d = (d_D * D + d_U * U)/(D + U)$$

Subsequently, intestinal digested protein (IDP) was approximated as:

$$IDP = d_D * UDP_D + d_U * UDP_U$$

Finally, the remaining crude protein was designated faecal protein:

$$FCP = CP - RDP - IDP = UDP - IDP$$

## RESULTS AND DISCUSSION

The productivity of ruminant livestock fed diets based on fibrous crop residues is usually low. Primary limiting factors are: (1) low voluntary intake and digestibility, (2) low rate of turnover, *i.e.* comminution, degradation and passage, of the feed in/from the rumen, (3) low extent/efficiency of microbial protein production in the rumen, and (4) high endogenous protein loss in the intestines related to a high flow of fibre. Fibrous crop residues as the sole diet do usually not meet maintenance requirements. To enhance production, supplementary feeds are needed. Supplements should contain protein (N*6.25), which is at least partly degraded in the rumen (RDP) to ensure that rumen ammonia concentration can support maximal microbial growth (Hoover, 1986). Further, cellulolytic microbes require some amino acids and/or branched chain volatile fatty acids (Maeng *et al.*, 1989). Besides, for the evaluation of the protein value of forages, the intestinal digestibility of the protein escaping from rumen degradation needs to be considered.

For moderate to higher levels of production, small intestinal available amino acid N (SI-AAN) is needed in addition to the amount provided by the rumen microbial biomass. On average, OM degradation in the rumen is about 70% of whole tract digestion, while about 200 g microbial crude

protein is synthesized per kg apparently rumen degraded OM (RDOM). Microbial crude protein consists for about 75% of true protein with a true digestibility in the small intestine of approximately 85%. Hence, small intestinal available amino acid N from microbial origin is equivalent to about 15 g SI-AAN/kg DOMI. This is considered sufficient to cover maintenance requirements. For sheep fed straw based diets, maintenance requirements for energy and protein were approximated at 29 g DOMI/$kg^{0.75}$ and 500 mg SI-AAN/$kg^{0.75}$, respectively (Oosting, 1993).

According to McDonald *et al.*, (1988) sheep at half of their mature weight deposit about 325 g fat and 163 g protein per kg gain. Hence, with an efficiency of ME conversion into NE (net energy) of 0.70-0.75 and 0.50-0.55 for fat and protein, respectively, and for SI-AAN into lean meat AAN of 0.50-0.55. about 30 g SI-AAN is required per kg DOMI (ARC, 1984; Oosting, 1993).

A summary of the crude protein content and rumen degradation characteristics of the supplements is presented in Table 2. On dry matter basis, all forages except jackfruit, contained more than 20% crude protein, varying from 20.5% (Leucaena) to 29.9% (Sesbania/Tithonia). Albizia and Calliandra showed the lowest S and the highest U fractions. This can presumably be attributed to higher levels of condensed tannins, which form complexes with the proteins rendering them more resistant to rumen microbes and lower gut proteolytic enzymes (Barry and Manley, 1984). All other forages showed U values lower than 15%. The rate of degradation ($k_d$) varied from 0.96 %/hr (Leucaena) to 7.36 %/hr (Gliricidia) and 9.50%/hr (Sesbania). As a result, Calliandra, Albizia, jackfruit and Leucaena showed rumen degradable protein (RDP) values in dry matter of less than 7%. Premaratne and co-workers of Peradeniya University fed growing (Dorset*South Down) sheep on rice straw with 10 g/$kg^{0.75}$ cassava and 15 g/$kg^{0.75}$ shrub/tree fodder supplement DM (De Jong and Van Bruchem, 1993). Daily gain was 4.5 to 5.5 g/$kg^{0.75}$. Whole diet DOMI approximated 30 g/$kg^{0.75}$. This is about equivalent to 20 g RDOM/$kg^{0.75}$ and would require 4 g RDP/$kg^{0.75}$ or 300 g/kg supplement dry matter. None of the forages met this criterion. For Sesbania and Tithonia values slightly higher than 200 g/kg were found, whereas Gliricidia, Erythrina and Samanea showed RDP values in the range 100-200 g/kg.

**Table 2. Characteristics of in-sacco crude protein (CP) degradation, rumen degradable (RDP) and undegradable (UDP) protein.**

| | CP[1] | S[2] | U[2] | $k_d$[3] | RDP[1] | $UDP_D$[14] | $UDP_U$[14] |
|---|---|---|---|---|---|---|---|
| Albizia | 216 | 10.8 | 59.3 | 1.02 | 36 | 52 | 128 |
| Calliandra | 258 | 2.5 | 48.4 | 0.52 | 21 | 112 | 125 |
| Erythrina | 213 | 23.0 | 11.9 | 5.65 | 130 | 58 | 25 |
| Gliricidia | 218 | 23.8 | 9.2 | 7.36 | 147 | 51 | 20 |
| Jackfruit | 133 | 8.0 | 13.3 | 1.65 | 41 | 74 | 18 |
| Leucaena | 205 | 16.1 | 9.5 | 0.96 | 63 | 123 | 19 |
| Samanea | 255 | 16.3 | 8.8 | 3.09 | 125 | 108 | 22 |
| Sesbania | 299 | 25.5 | 3.7 | 9.50 | 225 | 63 | 11 |
| Tithonia | 299 | 23.9 | 1.1 | 5.43 | 201 | 95 | 3 |

[1] g/kg DM; [2] % of crude protein; [3] %/hr; [4] D: potentially degradable; U: rumen undegradable

Fortunately, the N deficit can partly be made up by urea entering the rumen with saliva or via the rumen wall, rendering rumen ammonia concentrations sufficiently high for supporting microbial growth (Broderick *et al.*, 1991). In sheep fed on rice straw and 15 $g/kg^{0.75}$ supplement (DM) of Leucaena, Gliricidia of Tithonia, Premaratne *et al.*, (1992) found rumen ammonia concentrations to range between 6.7 and 8.3 mM/l. According to Hoover (1986), this would meet requirements for microbial growth.

Table 3 gives a summary of the intestinal digestion of the residues of rumen pre-incubation. For Albizia and Calliandra, digestibility tended to increase with the period of pre-incubation, particularly for the 336-hr residue. This can presumably be attributed to progressive degradation of cell walls and/or a gradual disappearance of tannins, resulting in a gradually improving accessibility. For these forages, the average digestibility of the 6-18 hr incubation residues was taken for further calculations. For forages with a higher rumen degradability, digestibility tended to be inversely related with duration of rumen incubation. This was also observed by Hvelplund *et al.* (1992), and can be related to a gradually decreasing D/U ratio. Based on the Robinson's model the D and U proportions could be approximated for the 6-18 hr rumen pre-incubation residues. For the U fraction, the digestion of the 336-hr residue was taken (dU).

**Table 3. Intestinal digestibility (d, %) of crude protein not degraded in the rumen.**

| | 0 | 6[1] | 12[1] | 18[1] | 336[1] | $d_D$ | $d_U$ |
|---|---|---|---|---|---|---|---|
| Albizia | 11.5 | 9.4 | 11.8 | 13.9 | 33.7 | 11.7[2] | 11.7[2] |
| Calliandra | 7.3 | 14.9 | 24.6 | 13.4 | 26.3 | 17.6[2] | 17.6[2] |
| Erythrina | 76.5 | 76.0 | 76.0 | 74.6 | 29.2 | 91.6[4] | 29.2[3] |
| Gliricidia | 67.5 | 75.9 | 69.6 | 68.5 | 44.0 | 79.8[4] | 44.0[3] |
| Jackfruit | 33.9 | 30.1 | 32.9 | 39.7 | 6.9 | 39.8[4] | 6.9[3] |
| Leucaena | 28.2 | 30.1 | 40.4 | 32.1 | 24.8 | 35.5[4] | 24.8[3] |
| Samanea | 84.8 | 81.5 | 85.0 | 79.7 | 34.4 | 90.1[4] | 34.4[3] |
| Sesbania | 83.5 | 82.0 | 65.3 | 58.9 | ** | 68.7[5] | |
| Tithonia | 81.4 | 83.6 | ** | ** | ** | 83.6[5] | |

** insufficient residue for lower gut incubation

[1]) rumen pre-incubation (h); [2]) mean of 6, 12 and 18-hr residues;
[3]) of 336-hr residue [4]) details in text;
[5]) assumed equal for D and U.

Subsequently, the digestion of the D fraction (dD) in the 6-18 hr residues was estimated as described in the methodology section. The high rate and extent of degradation found for Sesbania and Tithonia did not allow the determination of intestinal digestibility of the residues after a prolonged period of rumen incubation. For the D and U fractions of these forages a digestibility equal to the average value for the residues of rumen pre-incubation was assumed.

Based on the $UDP_D$ and $UDP_U$ values in Table 2 and the $d_D$ and $d_U$ values in Table 3, intestinally digested protein (IDP) values were derived as $UDP_D*d_D + UDP_U*d_U$. The values ranged from 105 g/kg for Samanea and 82 g/kg for Tithonia to 46 g/kg for Calliandra and 31 g/kg for jackfruit. A summary of the RDP and IDP values is presented in Figure 1. The remaining part is designated to be faecal protein (FCP).

At a level of 10 g DOMI/$kg^{0.75}$ above maintenance energy requirements, 300 mg SI-AAN/$kg^{0.75}$ is needed for growth (De Jong and Van Bruchem, 1993). This is 150 mg SI-AAN/$kg^{0.75}$ or about 1 g IDP/$kg^{0.75}$ more than SI-

AAN available from rumen microbial protein. With a forage supplement of 15 g/kg$^{0.75}$, on dry matter basis this would be about 65 g IDP/kg. This criterion was met by Samanea and Tithonia. The IDP values ranged 50-60 g/kg for Erythrina, Albizia, Sesbania and Gliricidia, and 40-50 g/kg for Leucaena and Calliandra. For some forages, it may therefore be argued that a slightly higher level of forage supplement would be needed to fully benefit from the low-quality basal fibrous feed.

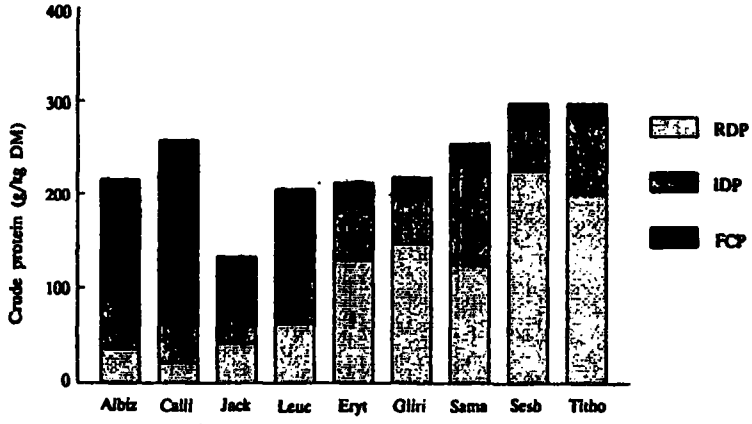


**Figure 1. Rumen degradable protein (RDP), intestinally digestible protein (IDP) and faecal crude protein (FCP = UDP - IDP) of shrub/tree forages.**

## CONCLUSION

Some shrub/tree fodders can provide an effective source of protein for ruminant diets. Rumen degradable (RDP) and intestinally digestible (IDP) protein could be qualified as sufficient (+), almost sufficient (±), about 50% sufficient (-/+) or insufficient (-). RDP plus IDP values were 285 g/kg DM for Tithonia (RDP±, IDP+), 275 for Sesbania (RDP±, IDP±), 230 for Samanea (RDP-/+, IDP+), 195 for Gliricidia (RDP-/+, IDP±), 190 for Erythrina (RDP-/+, IDP±) and 110 g/kg for Leucaena (RDP-/+, IDP-/+). For jackfruit, Calliandra and Albizia the total of RDP and IDP was lower than 100 g/kg. The required quantity of IDP increases for higher

rates of gain. Samanea showed the highest value, followed by Tithonia and Erythrina. Part of the IDP deficit in Gliricidia and Sesbania could be corrected by slightly increasing the level of supplementation. For Leucaena RDP and IDP values were below expectation.

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