Effects of Type and Level of Forage Supplementation on Voluntary Intake, Digestion, Rumen Microbial Protein Synthesis and Growth in Sheep Fed a Basal Diet of Rice Straw and Cassava

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ABSTRACT : An experiment was conducted with eight growing sheep (average initial weight 20.6 kg and average final weight 23.7 kg) in a 4 × 4 Latin square design to study the effect of type of forage supplementation to a basal diet of rice straw (*ad libitum*) and cassava (*Manihot esculanta*, approximately 9 g of dry matter (DM).$kg^{-0.75} \cdot day^{-1}$) on voluntary intake, digestion, rumen microbial protein synthesis and daily weight gain. Forages used were Leucaena (L, *Leucaena leucocephala*), Gliricidia (G, *Gliricidia maculata*) and Tithonia (T, *Tithonia diversifolia*, wild sunflower) at a DM supplementation level of approximately 13 $g.kg^{-0.75}.day^{-1}$. Organic matter intake was 40.4, 55.5, 55.0 and 54.9 $g \cdot kg.^{-0.75} \cdot day^{-1}$ for control (C, *ad libitum* straw and cassava), L, G and T. respectively, significantly lower for C than for the supplemented diets. Intake of supplementary forage had also a significantly positive effect on voluntary rice straw intake. All forage supplemented diets showed a significantly higher whole diet organic matter digestion than C (488 $g \cdot kg^{-1}$), while T (557 $g \cdot kg^{-1}$) differed significantly from L (516 $g \cdot kg^{-1}$) but not from G (526 $g \cdot kg^{-1}$). Daily weight gain was −1.7, 5.2, 5.4 and 4.7 $g \cdot kg^{-0.75}$, for C, L, G and T. respectively, significantly lower for C than for the forage-supplemented diets. Efficiency of microbial protein synthesis estimated from urinary excretion of purine derivatives was lower for C (3.8 g microbial N. (kg digestible organic matter intake (DOMI))$^{-1}$ than for the forage supplemented diets (11.3, 9.0 and 9.4 g microbial N.(kg DOMI)$^{-1}$ for L, G and T. respectively).

(**Key Words**: Forage Supplementation, Intake, Digestibility, Rice Straw, Livestock Performance, Purine Derivatives)

INTRODUCTION

Performance of ruminant livestock in the tropics is largely limited by voluntary intake and digestibility of the basal feed, which mainly consists of crop residues. Additional constraints are imposed by mineral inadequacies and an unbalanced nutrient mixture made available for intermediary metabolism, particularly amino acids. Amino acids are derived from protein that is digested in the small intestine. The quantity of small intestinally degraded protein is largely determined by the extent and efficiency of microbial protein synthesized in the rumen (Oosting et al., 1995). The latter is related to voluntary intake of rumen degradable organic matter and rumen conditions, e.g. NH_3-concentration and pH (Agricultural Research Council (ARC), 1980; Hoover, 1986).

The nutrient mixture derived from, on the one hand, rumen fermentation and on the other hand, digestion of microbial protein in the small intestine, may be insufficiently balanced. For example for higher levels of production, e.g. early growth, the quantity and profile of the available amino acids may constitute a limiting factor (Preston and Leng, 1987). This shortage of protein can be overcome by providing proteins that escape rumen degradation. As a consequence of such supplementation, rumen conditions are improved and intake of the basal fibrous feed may increase (Oosting et al., 1995).

The objective of the present experiment was to study effects of various forages that provide proteins escaping rumen degradation as well as rumen degradable protein on intake and digestion of a rice straw-based diet, efficiency of rumen microbial protein synthesis and animal performance.

MATERIALS AND METHODS

Animals and feeds

Eight immature male sheep (Dorset × South Down)

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with and average live weight of 20.6 (s.e. 0.76) kg at the beginning of the experiment and 23.7 (s.e. 1.42) kg at the end were maintained individually in metabolism cages. Cassava (*Manihot esculanta, crantz*), Leucaena (*Leucaena leucocephala*), Gliricidia (*Gliricidia maculata*) and Wild sunflower (*Tithonia diversifolia*) were used as supplements in the experimental diets. The control diet consisted of rice straw (*ad libitum* approximately 55 g dry matter (DM).kg$^{-0.75}$ · day^{-1} was offered for each treatment) and on DM-basis 9 g · kg$^{-0.75}$.day^{-1} cassava. For treatments L (Leucaena), G (Gliricidia) and T (Tithonia) 13 g DM · kg$^{-0.75}$ · day^{-1} was supplemented to the control diet. These forage supplements were newly collected, sun dried for 24 h and subsequently fed. The composition of the various dietary components is presented in table 1.

Table 1. Chemical composition of feedstuffs (g. (kg DM)$^{-1}$)

	Cassava	Rice straw	*Leucaena leucocephala*	*Gliricidia maculata*	*Tithonia diversifolia*
OM	985	848	877	854	869
Crude protein	26	69	295	265	283
Crude fiber	18	324	159	167	131
Crude fat	0	10	55	52	45
In vitro DM digestibility	nd	399	542	689	542

nd : not determined.

Experimental design

Sheep were allocated to four diets according to a 4 × 4 Latin square design with two sheep per experimental cell. The experimental design was such that each treatment was followed by another treatment only once to avoid any systematic carry-over effect. In addition, adaptation periods of three weeks were applied. Sheep were fed twice daily at 06 : 00 and 18 : 00 hrs. Water was freely available. Frequent inspection of animals was done to assure complete consumption of the supplements.

Experimental periods lasted 30 days, during which two 15-d collection periods were executed.

Samples and measurements

Sampling of feed, and weighing and sampling of feed refusals, faeces and urine was done at each feeding. Subsamples of feed, feed refusals and faeces were subsequently dried at 55℃ to a constant dry matter (DM) weight. After grinding to pass a 1 mm sieve, samples were pooled for each animal and collection period and stored pending analysis.

Ash was determined by ashing at 550℃ and N according to the Kjeldahl procedure. Organic matter was similar to DM minus ash. Animals were weighed before and after each experimental period.

As a measure for microbial protein synthesis in the rumen, urinary excretion of the purine derivatives allantoin, xanthine, hypoxanthine and uric acid was determined at the Rowett Researc Institute, UK (Chen et al., 1990). Microbial protein available at the small intestine was calculated from urinary purine derivative excretion values according to Chen et al. (1992a).

Results were statistically analyzed using the program DBSTAT (Brouwer, 1991) with the model $Y_{ijkl} = \mu + \text{diet}_i + \text{animal}_j + \text{period}_k + \text{error}_{ijkl}$. Results of the two collection periods within each experimental period were averaged before statistical analysis.

RESULTS AND DISCUSSION

Ad libitum intake of rice straw was achieved by offering at least 1.5 times daily intake. Actual values (multiples of intake) were 1.9, 1.5, 1.5 and 1.5 (s.e.m. 0.05) for C, L, G and T, respectively, significantly more for C than for the other treatments.

In the present experiment the supplementation level of the protein-rich forages was 13 g of DM · kg$^{-0.75}$ · day^{-1}. This supplementation level was chosen based on limited availability of these forages to farmers. The plants and trees from which the supplements were derived are usually planted in the form of fences (Premaratne, 1991, 1992 and 1993; Premaratne et al., 1997), with therefore only a limited growing area per farm. In addition, collection of forage from the species used in the present experiment has a high labour requirement (Ifar, 1996). However, as discussed by Van Bruchem and Zemmelink (1995), at production system level it could be worthwhile feeding high supplementation levels, higher than the level used in the present experiment, to a relatively small number of animals. Individual animals will then have a higher intake and less of the locally available supplements is used for maintenance. A higher total production system output in terms of meat or milk could be achieved with such a feeding strategy, however, with a limited number of animals.

As shown in table 2, voluntary organic matter intake (OMI) of rice straw responded positively to forage supplementation ($p < 0.05$), without significant differences between the three protein-rich forages. These results are in agreement with those of other workers (Tissera, 1994; Baumer, 1992; Premaratne, 1992 and 1993; Devendra, 1988).

Table 2. Whole diet organic matter intake (OMI), organic matter digestibility (OMD) and intake of digestible OM (DOMI), urinary excretion of purine derivatives (PD), efficiency of microbial protein synthesis, daily weight gain, N-balance and average animal weight

	C	L	G	T	S.E.M.
OMI ($g \cdot kg^{-0.75} \cdot day^{-1}$)					
• straw	31.5^{a}	36.6^{b}	35.4^{b}	36.1^{b}	1.34
• cassava	8.9^{b}	8.8^{a}	8.7^{a}	8.7^{a}	0.04
• forage	–	10.1^{a}	10.9^{b}	10.1^{a}	0.07
• whole diet	40.4^{a}	55.5^{b}	55.0^{b}	54.9^{b}	1.31
DOMI ($g \cdot kg^{-0.75} \cdot day^{-1}$)	19.9^{a}	28.6^{b}	28.8^{b}	30.5^{b}	1.04
OMD ($g \cdot kg^{-1}$)	488^{a}	516^{ab}	526^{bc}	557^{c}	11.4
Urinary excretion PD ($\mu mol \cdot kg^{-0.75} \cdot day^{-1}$)	198^{a}	422^{b}	366^{b}	388^{b}	19.1
Efficiency of microbial protein synthesis ($mg\ N \cdot kg\ DOMI^{-1}$)	3.8^{a}	11.3^{c}	9.0^{b}	9.4^{b}	0.66
DWG ($g \cdot kg^{-0.75} \cdot day^{-1}$)	-1.7^{a}	5.2^{b}	5.4^{b}	4.7^{b}	0.93
N balance ($mg \cdot kg^{-0.75} \cdot day^{-1}$)	-74^{a}	241^{bc}	210^{b}	272^{c}	18.7
Average animal weight (kg)	22.0	22.6	21.0	21.9	0.41

Forage supplementation increased organic matter digestion (OMD) of the whole diet compared to that of C for L ($p > 0.05$) and G and T ($p < 0.05$). These results are in agreement with the work of Tissera (1994) and Premaratne (1992). Increased voluntary OMI and OMD resulted in a significantly higher intake of digestible organic matter (DOMI) for the forage supplemented diets.

Regression of daily weight gain (DWG) on DOMI revealed as regression equation:

$$DWG\ (g \cdot kg^{-0.75} \cdot day^{-0.1}) = -13.8\ (\text{s.e.m. } 2.41) + 0.64\ (\text{s.e.m. } 0.088) \times DOMI\ (g \cdot kg^{-0.75} \cdot day^{-1})\ (R^2 = 0.667,\ n = 32)$$

which implies maintenance requirements as low as 21.6 g DOMI $\cdot\ kg^{-0.75} \cdot day^{-1}$. This value is lower than estimates given by ARC (1980) and Oosting et al. (1995) for sheep. The relation between DWG and DOMI is basically a relationship between net energy (NE) accretion and metabolizable energy (ME) intake on the assumption of a constant energy content of DWG for the sheep in the present experiment and a fixed relationship between DOMI and ME intake (ARC, 1980). ARC (1980) gives different relationships between NE and ME for different classes of feeds. If C should be classified as a belonging to a different feed class than L, G and T (which seems realistic when looking at the whole diet's digestibility and the lower protein availability from the diet), then a regression of DWG on DOMI is an improper means for estimation of maintenance requirements.

Regression of N-balance on DOMI yielded as regression equation:

$$N\text{-balance}\ (mg \cdot kg^{-0.75} \cdot day^{-1}) = -531\ (\text{s.e.m. } 77.7) + 25.8\ (\text{s.e.m. } 2.84) \times DOMI\ (g \cdot kg^{-0.75} \cdot day^{-1})\ (R^2 = 0.780,\ n = 32),$$

which results in an estimated of DOMI-requirements for a zero N-balance of 20.6 $g \cdot kg^{-0.75} \cdot day^{-1}$. The regression coefficient of this equation is higher than values ranging from 14.4 to 15.4 as reported by Oosting et al. (1995). Grenet and Demarquilly (1977) observed also a higher regression coefficient (20.9 mg N-balance. g $DOMI^{-1}$) for Texel sheep. The estimate of the regression coefficient and of maintenance requirements could also in this case be biased when C would have a different relationship between N-balance and DOMI than L, G and T.

Urinary excretion of the purine derivatives allantoin, xanthine, hypoxanthine and uric acid and the conversion of these values to estimates of daily rumen microbial protein synthesis is also given in table 2. Purine derivative excretion in urine and consequently estimates of rumen microbial protein synthesis were significantly higher for the protein-rich forage supplemented diets than for the control. Estimates of efficiency of microbial protein synthesis (EMPS equal to g microbial N. (kg DOMI)$^{-1}$) were low when compared to the average of approximately 20 as given by ARC (1980) and values of approximately 18 to 24 for straw-based rations with or without protein supplements (Oosting et al., 1995), though closer to values varying from 12.8 to 15.7 for ammonia treated barley straw with or without sugar beet pulp or rolled barley (Chen et al., 1992a). As discussed by Chen et al. (1992b), a low EMPS may be caused by a low DMI and the associated low rate of rumen passage of microbial material. However, DMI of the forage-supplemented diets was not extremely low, and based on the model given by Chen et al. (1992b) a higher EMPS was expected. It was, however, reported (Broderick and Balthrop, 1979) that hydrogencyanide (HCN) has a inhibitory effect on deamination of amino acids by rumen microbes. Hence, a negative effect on microbial growth rate and consequently lower EMPS may be expected due to the HCN-containing cassava.

In another experiment with the same forage supplements, but offered at levels of approximately 15 and 30 g DM · kg$^{-0.75}$ · day^{-1} to rice straw, straw intake was reduced due to forage supplementation, though not significantly (Premaratne et al., 1997). No significant reduction of straw intake was found between the two supplementation levels. The conditions in the present experiment were, however, such, that forage supplementation resulted in an increased forage intake. Differences between the present expeiment and the one conducted by Premaratne et al. (1997) was that in the present cassava was fed, while also the sheep in the present experiment were younger.

In line with the findings of Broderick and Balthrop (1979) it could be suggested, that HCN in cassava resulted in a lower rumen availability of NH_3 due to the reduced deamination of amino acids and consequently in a reduced microbial growth and ruminal digestion. Provision of additional protein through the forages could have a positive effect on DOMI either through an increase of protein availability for NH_3-release in the rumen and hence, a better rumen digestion, or through the supply of more rumen escape protein to increase small intestinal protein availability. The latter may result in an increased intake (Tolkamp and Ketelaars, 1992; Oosting et al., 1995).

The present and other experiments (e.g. Premaratne et al., 1997, Oosting et al., 1995)) showed that protein-rich supplements may result in similar or increased intakes of the basal feeds, while energy-rich supplements often result in a partial or complete substitution of roughage intake (Doyle et al., 1986; Oosting et al., 1995). The forages in the present experiment were more or less similar in response. Farmers appreciate and know the value of these supplements. In eastern Indonesia, a considerable amount of the time spent on forage supplement collection is attributed to gliricidia, because it is recognized as a forage that can elevate a sub-maintenance feed to a feed for production (Ifar, 1996).

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