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Improvement of Feeding Value of Low Quality Roughages to Enhance Ruminants Production in Tropical Regions

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Abstract Four selected studies carried out to evaluate the utilization of rice straw based diet and poor quality forages with energy and protein supplements which are applicable to farmers in developing countries at farm level are presented. 1) Wethers fed on rice straw *ad libitum* supplemented with soybean meal (SBM) at the rate of 75 and 150g/d to supply 50 to 100% of maintenance level of the metabolizable protein. Supplementation of SBM resulted in higher feed intake and digestibility through the effect on rumen fermentation status, although there was no further effect on nitrogen (N) retention at increased level of SBM supplement. It was considered that high fermentable energy is required to support optimum activity of the rumen microbes at the high protein supplementation. 2) The effects of protein and energy supplementation with straw diet on N retention and rumen microbial yield (MBY) were studied using wethers. The three rations, 100% ammoniated rice straw (ARS), 65% untreated rice straw (URS) ＋ 30% rice bran (RB) ＋ 5% SBM, and 85% ARS ＋ 15% RB, were formulated to contain almost the same amount of protein and energy. RB ＋ ARS improved N retention and MBY, but RB ＋ SBM supplementation with URS showed similar response on N utilization and efficiency of MBY compared to ARS based diet. 3) Voluntary intake, digestibility and live weight gain were evaluated in yearling goats fed on Rhodes grass hay *ad libitum*, and supplemented dried *Gliricidia* leaf meal (GLM), GLM and maize bran (1 : 1), and maize bran at the rate of 120g/d. Feed intakes and the digestibility of organic matter (OM) and N were greater for supplemented groups than for control. The live weight gains were the highest in goats supplemented with mixture of GLM ＋ maize bran. The result indicated that GLM could be used as a source of supplement for growing ruminants fed on low quality hay. 4) To evaluate the effect of supplementing legume tree leaf on intake, digestibility, live weight gain and MBY, two experiments were conducted using 20 crossbred steers offered fresh napier grass *ad libitum*. *Gliricidia* supplementation slightly decreased napier grass intake, although *Leucaena* increased the total feed intake without depressing napier grass intake. There were no clear effects of supplementing *Gliricidia* and *Leucaena* on OM digestibility, MBY and its efficiency. Live weight gain was obviously greater in *Leucaena* supplemented group than in *Gliricidia* group.

Key words: roughage, ruminants, protein supplements, energy supplements

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Introduction

In tropical regions, grass forages grown with minimal application of fertilizer are generally low nitrogen (N) and digestible organic matter (OM). Animals offered such forages are therefore unlikely to consume adequate N for efficient rumen digestion and resultant intake and animal performance will be low (Leng, 1990). Protein supplementation of forage based diets containing less than 70 g crude protein (CP) per kg dry matter (DM) has increased DM intake (DMI) and animal performance (Minson and Milford, 1967).

In most tropical Asian countries, rice is considered as one of the most important crops, because it is a major staple food for millions of people in these areas. Likewise, rice straw serves as feeds for different species of animals, particularly ruminants. Therefore, ruminant production systems are mainly based on rice straw, agricultural by-products and natural low quality forages. Under these conditions, the animal performance is mostly below their potential productivity (Ranjhan, 1980). Matching available feed resources and the potential of the ruminant animal is vital in tropical developing countries.

In general, roughage diets such as rice straw are low quality because of low protein and high cell wall constituents concentrations resulting in low intake and digestibility. Therefore, it has been a long-term aim of many researchers to improve the nutritive value of roughage diets for feeding animals. Physical treatments (grinding, pelleting and steam pressuring) and chemical treatment (urea, ammonia and sodium hydroxide) have been used to upgrade the feeding value of rice straw (Sundstol and Coxworth, 1984). However, this approach is expensive and involves hazardous chemicals, which may not be economical and applicable to small holder farmers in developing countries. While such treatments are suitable for improving the nutritive value of rice straw, the real need is for simple and cheap methods that can be used by small holder farmers.

Although feeding rice straw to ruminants together with energy supplement and protein supplement is commonly used in tropical countries, little is known about the effect of supplementation on animal performance. In this paper, we reported four selected studies (study 1. Lili Warly *et al*., 1992; study 2. Orden *et al*., 2000; study 3. Ondiek *et al*., 1999 and study 4. Abdulrazak *et al*., 1996) to evaluate the utilization of rice straw based ration and poor quality forages with energy and protein supplements. The implications of the results could be applicable to farmers in tropical developing countries at farm level. The study 1 and 2 presented herein had been carried out as PhD studies at United Graduated School of Agricultural Science, Tottori University; and study 3 and 4 had been conducted as collaborative studies together with animal science laboratory of Shimane University and Egerton University. The all had been briefly summarized by Fujihara *et al*. (2002).

Study 1. The effect of soybean meal supplementation on utilization of rice straw

Table 1. Effect of soybean meal supplementation on the voluntary intake of rice straw, weight gain, digestibility and nitrogen balance in sheep fed rice straw as a basal diet

Item	Level of soybean meal (g/day)			SEM
	0	75	150	
Rice straw intake (g DM/day)	540.4[a]	791.7[b]	794.4[b]	53.4
TDN intake (g/day)	239.5[c]	439.7[d]	494.8[d]	27.4
Weight gain (g/day)	−190.0[c]	−12.0[d]	35.0[d]	23.5
Digestibility (%)				
OM	52.7	60.1	61.6	2.5
CP	23.7[c]	59.2[d]	74.0[d]	3.8
NDF	47.8	53.0	51.0	3.5
ADF	42.8	46.0	45.9	3.3
Nitrogen (g/day)				
Intake	2.20[a]	8.23[b]	13.45[c]	0.8
Feces	1.92	3.22	3.45	0.6
Urine	2.36[a]	4.77[b]	8.26[c]	0.1
Retention	−2.08[a]	0.24[b]	1.74[c]	0.4

[a,b,c,d] Means in the same row with different superscripts differ significantly (a,b: $P<0.05$; c,d: $P<0.01$).

The effect of supplementation levels of soybean meal （SBM） on the utilization of rice straw was investigated using three rumen cannulated wethers, weighing 42±3.5 kg. Dietary treatments were as follows: untreated rice straw （URS）, URS with 75g of SBM and URS with 150g of SBM. URS was offered to the animals *ad libitum* for each treatment. SBM was supplemented to provide 50 and 100% of maintenance level of metabolizable protein （AFRC 1993）. The experiment was carried out in a 3×3 Latin square design.

The rice straw used in this study contained 3.6 % DM of CP, which was far below the critical level of CP required （7.0 %DM） for normal forage consumption by sheep （Minson, 1967）. The supplement with 75 and 100g SBM increased the dietary CP content to 7.1 and 10.1% DM, respectively. As shown in Table 1, the voluntary intake of rice straw was significantly increased （$P<0.05$） by SBM supplementation, and the increment was approximately 47 % in both 75 and 150 g of SBM. It was probably due to enhancing cellulolysis and increasing the rate of breakdown of cell walls in the rumen, and partly due to an effect on metabolic rate in the body tissues （Weston, 1967）. The increasing of SBM from 75 to 150 g did not further increase the rice straw intake, and was in agreement with the results obtained by other workers （Church and Santos, 1981; Liu *et al*., 1988）. Sheep lost their body weights in the treatments of control and 75 g of SBM supplementation, however the inclusion of 150g SBM significantly increased （$P<0.01$） the daily gain. This result was consistent with the report of Devendra （1978）, who showed the rice straw was insufficient to maintain the live weight of sheep due to a low voluntary intake and a low digestible energy content, when it was given a sole diet. This finding suggests that the improvement on daily gain of sheep fed SBM supplemented diets was due to the additional digestible energy and protein, and other essential nutrients supplied by the supplement, and through the increased intake of the straw.

The N retention was negative for sheep fed control diet and it was significantly increased （$P<0.01$） by supplementation of 75 and 150g of SBM. The increasing N retention due to protein supplement with low quality forage in sheep has also been reported by Caton *et al*. （1988）. The low content and low digestibility of N of rice straw mirrored directly the negative N balance in sheep fed control diet. When expressed as percent of N intake, urinary N excretion was 107, 58 and 60% for sheep fed 0, 75 and 150g of SBM supplemented diets, respectively. Increased SBM level to 150 g/d, however, had no further effect on the N retention. Church and Fontenot （1984） also pointed out that N excreted into urine was greatly dependent on the level of N intake, and was higher on low and high level of N intake but minimum at medium intake. As indicated in Table 1, TDN intakes, which reflects metabolizable energy intakes, did not differ between the SBM treatments. If more energy source is supplied at higher SBM treatment, then greater N retention can be obtained.

The results have clearly shown that the utilization of rice straw as a ruminant feed will be improved by SBM supplementation, and at the higher supplementing level, it was considered that more fermentable energy is required to support optimum activity of the rumen microbes.

Study 2. The effects of protein and energy supplementation on utilization of rice straw

The effects of protein and energy supplementation with rice straw diet on N retention and rumen microbial protein yield

Table 2. Chemical composition of feedstuffs and experimental diets （%DM）

	RB	SBM	URS	D_1	D_2	D_3
OM	89.7	91.8	77.9	81.7	82.5	82.8
N	2.0	7.3	0.6	1.4	1.5	1.5
NDF	21.7	11.2	64.0	60.7	49.9	54.3
ADF	9.4	9.0	40.7	39.3	31.0	37.4
Lignin	2.7	0.3	5.5	4.6	5.1	4.2
Silica	0.1	0.2	15.9	11.0	9.9	10.5
ME* （MJ/kg DM）	10.2	11.9	4.2	6.6	7.0	7.1

*Calculated based on Standard Tables of Feed Composition in Japan （1995）.
D_1=100% ARS; D_2=65% URS+30% RB+5% SBM; D_3=85% ARS+15% RB.

(MBY) were studied using three rumen cannulated wethers with mean body weight of 32 kg. The following rations were fed to the animals in a 3×3 Latin square design: 100% ammoniated rice straw (ARS, D_1), 65% URS + 30% rice bran (RB) + 5% SBM (D_2), and 85% ARS + 15%RB (D_3). The rations were formulated to contain almost the same amount of N and metabolizable energy.

The treatment of rice straw with ammonia increased the total N content by almost 2.5 times from 0.6 to 1.4% DM (Table 2). However, only a small portion of N was attached to the cell walls (0.3% of neutral detergent fiber) as a result of the treatment, then most of the N incorporated is probably present as soluble NH_3-N. There was a slight decrease in the NDF fraction due to partial solubilization of hemicellulose, while the acid detergent fiber (ADF) remained almost same concentration. The increase in N content and the reduction in cell wall fractions, are consistent with the earlier findings (Pradhen *et al*., 1996). As indicated in Table 3, animals fed with D_3 had higher ($P<0.05$) DMI than those fed with D_1 and D_2. No significant difference was observed in DMI between D_1 and D_2. Results indicated that the increased consumption in D_3 is a result of RB inclusion and the use of ARS. The addition of RB to ARS improved DM digestibility of the diet and feed intake. Higher digestion coefficients of DM and OM in D_3 resulted in higher daily intake of digestible DM and OM compared with D_1. The marked improvement in the overall digestibility of D_3 could be attributed to the extremely high detergent fiber digestibility of ARS in combination with RB. DM digestibility of D_3 was significantly ($P<0.05$) greater than D_1 and D_2, but the OM digestibility (65%) is almost the same as the corresponding mean values for ammoniated barley straw (ABS) + 300g rolled barley grains (Castillo *et al*., 1995). However, DM digestibility in the present study was lower than those earlier reported; ARS supplemented with SBM (Pradhen *et al*., 1996), and ARS supplemented by either SBM or alfalfa hay (Han *et al*., 1989; Maeng and Chung, 1989). Result tends to emphasize the differential effects of protein supplementation on nutrient digestibility of ammoniated straw diet. Conversely, the CP digestibility in D_3 was significantly lower ($P<0.05$) than D_2, but not significantly different from D_1. The CP digestibility of D_1 and D_3 supported the conclusion of Males (1987) that only about 50% of N from ammoniated or urea treated straw is available for digestion. There was no significant effect of the RB inclusion on N digestibility of ARS based diets. The low CP digestibility of D_1 and D_3 emphasizes the importance of true protein supplementation in straw-based diets to correct nutrient deficiencies in order to increase nutrient availability (Silva *et al*., 1989; Leng, 1990; Oosting

Table 3. Dry matter intake, digestibility, nitrogen balance, rumen NH_3-N, purine derivatives (PD) excretions and microbial N yield in sheep fed with URS and ARS diet supplemented with rice bran

Item	D_1	D_2	D_3	SEM	Level of significance
DM intake (g DM/kg $BW^{0.75}$)	42.5^a	47.2^a	54.8^b	2.9	*
Nutrient digestibility (%)					
DM	50.7^a	55.2^b	61.3^c	1.6	**
OM	53.1^a	54.8^a	65.2^b	2.2	**
CP	54.5^a	70.7^b	57.7^a	3.5	*
NDF	71.1^a	50.9^b	73.3^a	3.7	**
ADF	64.2^a	58.6^b	71.4^a	2.9	*
Nitrogen Balance (g/d)					
Intake	8.8^a	13.4^b	13.1^b	0.9	*
Feces	4.0^a	3.9^a	5.5^a	0.4	*
Urine	4.4	4.0	4.5	0.4	*
Retention	0.4^a	5.4^b	3.2^b	0.8	*
Total PD (mmol/d)	3.8^a	4.8^b	6.2^b	0.4	*
Microbial N yield (g/d)	2.5^a	4.9^b	5.0^b	0.3	*

[a,b,c] Means with common letter superscript within rows are not significant.
D_1=100% ARS; D_2=65% URS+30% RB+5% SBM; D_3=85% ARS+15% RB.
* $P<0.05$; ** $P<0.01$.

et al., 1993). Results also indicate that the inclusion of small amount of SBM in RB supplemented URS diet (D_2) provided a better N source, which eventually yielded higher CP digestibility.

As shown in Table 3, all animals showed positive N-balance in response to the dietary N intake from the experimental diets. The D_2 and D_3 had significantly higher N-balance than D_1 due to the improvement in protein and energy source used in the treatments. The D_2 had the highest retained N among treatments indicating that the addition of SBM and RB to a URS diet has a positive effect on N retention. The D_1 had the lowest retained N because of high fecal and urinary excretion relative to the N intake. The lesser amount of N added by ammoniation was made available to the animal as a protein source, but supplementation of RB provided a better N source. The significantly higher ($P<0.05$) N retention and OM digestibility of RB supplemented groups resulted in higher urinary excretions of purine derivatives (PD) in animals fed with D_2 and D_3, and greater microbial N yields when compared with the control group. Although both supplemented diets (D_2 and D_3) had better MBY than the control diet, microbial efficiency (g N/kg RDOM) was not differ between D_1 and D_3. There was a higher digestibility of OM in D_3, this did not result in better MBY compared with D_2. This result is contrary to the findings of Moller and Hvelplund (1982) who showed that cows receiving ABS supplementing urea or SBM had no positive effect on the MBY. In spite of the significantly higher OM digestibility of rice straw brought about by ammoniation, Herrera-Saldana *et al*. (1982) recommended that supplemental energy in the form of RB is needed for maximum utilization of added N.

Results of this experiment indicated that minimal supplementation with RB can improve N utilization of either URS or ARS based diets when fed to sheep. Furthermore, it proved that energy supplementation could be more beneficial than protein supplementation in improving MBY feeding ammoniated rice straw.

Study 3. The effects of protein and energy supplementation on utilization of Rhodes grass hay diet

A wide varieties of legume tree grow in the tropics and their protein-rich leaf parts can improve the production of ruminants consuming low quality grasses (Devendra, 1993). One of the most widely used legumes is *Leucaena leucocephala*, and recently, *Gliricidia sepium* has also been recognized as another legume tree producing high quality fodder (Bennison and Paterson, 1993). The objective of this study was to evaluate the effect of supplementing Rhodes grass hay with *Gliricidia sepium* leaf meal and maize bran alone or in combination on voluntary feed intake, digestibility and live weight gain in growing goats.

Sixteen crossbred (Toggenburg×Saanen, 8 males and 8 females) dairy goat (8-months-old; 18±4.8 kg BW) were used and Rhodes grass hay was offered *ad libitum* alone or supplemented with 120g/d of dried *Gliricidia* leaf meal, *Gliricidia* meal plus maize bran (1：1 as a DM basis) or maze bran (Table 4) in a completely randomized design (4 heads per treatment). All goats were kept in individual well-ventilated pens, and were weighed weekly for 9 weeks.

Low acceptability of *Gliricidia* meal was observed during the first week of the experiment, however, during the subsequent weeks all the *Gliricidia* offered was consumed. As indicated in Table 5, supplementation did not have a significant effect on hay intake. However, animals supplemented with *Gliricidia* meal alone tended to have a high intake of hay. The total DMI was significantly lower ($P<0.05$) in the control group than in the supplemented groups, whereas there was no differences among the supplemented groups. These results are in agreement with those of Ash (1990) where *Gliricidia* was offered as a supplement to Guinea grass diets and the DMI of the basal diet was not depressed, therefore, leading to a significant increase in total intake. In contrast, Van Eys *et al*. (1986) supplemented napier grass with *Gliricidia* and found no effect on total DMI, although weight gains were improved in growing goats. However, napier grass in their study contained more CP (119 *v.s*. 48 g/kg DM) than in Rhodes grass hay used in the present study. Egan (1986) reported that legume supplements are usually most effective

Table 4. Chemical composition of the ingredient used in the experimental diets

	Hay	*Gliricidia*	Maize bran
DM (g/kg)	934	905	902
CP (g/kg DM)	48	208	95
OM (g/kg DM)	837	789	870
NDF (g/kg DM)	705	240	299
ADF (g/kg DM)	219	164	93

Table 5. Dry matter intake (DMI), average daily gain (ADG) and digestibility in goats offered either Rhodes grass hay *ad libitum* alone (H), Rhodes grass hay with *Gliricidia* meal (HG) or *Gliricidia* meal and maize bran (HGB), or maize bran (HB)

Treatment	H	HG	HGB	HB	SEM
DMI (g/day)					
Hay	474	504	455	437	21.7
Supplement	—	100	110	108	
Total	474[a]	604[b]	565[b]	545[b]	21.5
ADG (g/day)	26[a]	43[b]	69[c]	27[a]	3.2
Digestibility (%)					
DM	49.8[a]	58.1[ab]	58.4[ab]	60.8[b]	3.4
OM	77.1[a]	81.3[ab]	81.9[ab]	83.5[b]	1.6
NDF	76.8[a]	71.1[a]	75.3[a]	63.5[b]	2.1
ADF	43.6	41.2	40.6	38.5	3.0
CP	32.2[a]	86.2[b]	88.5[b]	86.3[b]	2.4

[a,b,c] Means within a row with different superscripts are significantly different ($P<0.05$).

when offered with roughage containing more than 20 g/kg digestible OM, because they increase the rumen degradable N.

The control group had the lowest digestion coefficients for DM, OM and CP, but the highest value for ADF. The *Gliricidia* and maize bran supplemented group had the highest CP digestibility (Table 5). These results are consistent with those of McMeniman *et al*. (1988) who supplemented rice straw with legumes comprising 30% of the diet. By contrast, some reports showed no significant increase in digestibility of forage diets, when napier grass was supplemented with legume forages (Van Eys *et al*., 1986; Abdulrazak *et al*., 1996). The improvement in digestibility could have resulted from reduced levels of indigestible ADF and lignin (Van Soest, 1982). Liveweight gains were higher ($P<0.05$) for goats offered the *Gliricidia* plus bran mixture (69 g/d) and lowest (26 g/d) for the control group. Supplementation with legume forage increased total N supply and together with an increase in digestibility would have contributed to better performance in supplemented groups. In this study, microbial N supply was not measured but is likely that it contributed to the increase in live—weight gains. It is possible that the *Gliricidia*-bran mixed diet created a more suitable rumen environment by supplying a ready source of energy for the microbes, which, in turn, may led to a higher microbial activity and NH_3-N turnover. Better performance in *Gliricidia*-bran supplemented group may be explained by the phenomenon of synchronization of energy and N supply to rumen microbes. Richards *et al*. (1994) reported a high N solubility of *Gliricidia*, which when fed together with napier grass, which had a slower energy release, lead to asynchronous supply of N and energy in the rumen of goats.

In conclusion, these results indicate that *Gliricidia* meal is a potential source of protein supplement for growing goats fed with low quality hay, which is better utilized when offered with an energy source, like maize bran.

Study 4. The effects of supplementation of legume tree leaves on utilization of napier grass

Estimates are required for animal performance and rumen characteristics when these legumes are given as supplement to low-N basal diets. Then recommendations can be developed for feeding systems that utilize optimal levels of the forages for growing ruminants. To contribute to those objectives, two experiments were carried out to determine voluntary food intake, digestibility and live-weight changes in steers given napier grass as a basal diet supplemented with incremental levels of *Leucaena* and *Gliricidia* forages.

The same 20 crossbred (*Bos taurus*×*Bos indicus*) steers were used in both experiments. At the start of experiment 1 and 2, mean age and live weight of steers were 12 months and 173±17.9 kg, and 15 months and 208±18.1 kg, respectively. All the steers were confined in individual, well-ventilated stalls, and each week were weighed and sprayed with an acaricide. Napier grass was harvested daily, and chopped to pieces of *ca*. 50 mm. *Gliricidia* and *Leucaena* were also harvested daily in the morning for feeding the same afternoon, with some allowed to wilt overnight for the feed offered the next morning. Stems thicker than 50 mm were removed from the legume forages to ensure the fodder composition was uniform. *Gliricidia* or *Leucaena* were offered to the animals at five levels: 0, 7.5, 15.0, 22.5 and 30.0 g DM per kg metabolic body size ($BW^{0.75}$), respectively.

As shown in Table 6, the legume forages had higher DM and CP but lower NDF contents than Napier grass. *Gliricidia* contained relatively more NDF than *Leucaena* forage (493 *v.s.* 469 g/kgDM). Low acceptability of *Gliricidia* was observed during 1st week of the experiment, and during the subsequent weeks all *Gliricidia* offered was consumed. While napier grass DMI decreased linearly with increased level of *Gliricidia* ($P<0.01$, Table 7), the total DMI was increased but not significantly. The incremental supplementation with *Leucaena* increased total DMI of the 20 steers linearly ($P<0.001$) without affecting the intake of the napier grass (Table 7). Supplementation with either of the legumes had no significant effect on the OM digestibility of the diet. In both experiments, incremental levels of legumes increased the mean live-weight linearly ($P<0.05$). Live-weight gains were relatively higher with *Leucaena* than *Gliricidia* supplementation. *Gliricidia* supplementation increased the daily excretion of PD ($P<0.05$, Table 8). The estimated purine absorption and calculated microbial N supply was the lowest in the control group, but not significantly increased with *Gliricidia* supplementation. The average intakes of napier grass in control groups of both experiments were above the intake of standard tropical forages (containing *ca*. 70% of digestible DM) as suggested by Crampton *et al*. (1960), *i.e*. 80 g DM/kg $BW^{0.75}$/day. The supplementation with *Leucaena* did not depress the intake of napier grass diet; it led to a significant linear increase ($P<0.001$) in total DMI. The increase in total DMI is consistent with the results of Bonsi *et al*. (1994) and Muinga *et al*. (1995) with *Leucaena* supplementation. On the other hand,

Table 6. Chemical composition of food used in experiments

	DM (g/kg)		Ash (g/kgDM)		CP (g/kgDM)		NDF (g/kgDM)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Experiment 1								
Napier grass	176	24.0	141	1.8	76	5.3	753	13.0
Gliricidia	260	11.8	106	9.9	214	8.1	493	21.3
Experiment 2								
Napier grass	164	27.9	130	1.1	79	9.6	678	12.7
Leucaena	300	27.0	90	5.9	218	3.4	469	4.9

Table 7. Dry matter intakes (DMI), digestibility of organic matter (OMD) and live-weight gains (ADG) in steers given napier grass ad libitum alone or with 7.5, 15.0, 22.5 and 30.0 gDM per kg $BW^{0.75}$ of *Gliricidia* and *Leucaena*

	Level of supplement (g DM per kg $BW^{0.75}$)					SED	Significance of linear response
	0	7.5	15.0	22.5	30.0		
Experiment 1							
DMI (kg/day)							
Napier	5.2	4.7	4.5	4.3	4.2	0.2	**
Gliricidia	0	0.4	0.7	1.1	1.5		
Total	5.2	5.1	5.2	5.4	5.7	0.2	
OMD (%)	63.8	65.3	63.1	62.5	66.1	1.2	
ADG (g/day)	306	358	429	371	478	53.5	*
Experiment 2							
DMI (kg/day)							
Napier	5.2	5.3	5.3	5.3	5.0	0.2	
Leucaena	0	0.5	0.9	1.3	1.7		
Total	5.2	5.8	6.2	6.6	6.7	0.3	***
OMD (%)	65.7	69.5	65.0	65.7	71.2	5.2	
ADG (g/day)	538	711	719	789	850	76.5	*

Table 8. Urinary purine derivatives (PD) excretion and microbial N supply in steers given napier grass *ad libitum* alone and with 7.5, 15.0, 22.5 or 30.0 g DM per kg $BW^{0.75}$ of *Gliricidia* forage

	Level of *Gliricidia* (g DM per kg $BW^{0.75}$)					SED	Significance	
	0	7.5	15.0	22.5	30.0		Linear	Quadratic
PDexcreted (mM/day)	68.6	80.4	79.3	81.9	70.6	6.3		*
DOMI† (g/day)	2824	2789	2988	2951	3165	98.1	*	
Microbial N supply								
gN/day	41.4	50.7	49.6	52.6	49.0	5.1		
gN/kg DOMI	14.7	18.4	16.6	18.0	15.5	1.2		

†DOMI = digestible organic matter intake.

supplementation of *Gliricidia* depresses the napier grass intake linearly ($P<0.01$), but tended to increase total DMI. This finding is similar to that reported using napier grass as basal diet by Van Eys *et al*. (1986), who reported no depression of guinea grass intake when it was supplemented with *Gliricidia*.

In this study, the lack of response in the increase of intake and digestibility in basal diet would suggest that the CP content of basal diet did not limit the intake, and that when the rumen microbial requirements for N had been met, additional *Leucaena* or *Gliricidia* did not have any upgrading effect on the basal diet, the response of additional high quality forages could be mostly dependent on the CP content of basal diet (Egan, 1986). The difference in the response of basal diet intake between *Gliricidia* and *Leucaena* supplements on DMI of napier grass is very difficult to explain. Possibility the relative higher total DMI with *Leucaena* was associated with faster outflow rate of particulate matter. Retention time of particulate matter has been reduced following supplementation with *Leucaena* (Bamualin *et al*., 1984). Live weight gains increased linearly ($P<0.05$) with incremental supplementation in both experiments. Improved live weight performance when legumes supplemented with low-N roughage had been reported (Van Eys *et al*., 1986; Ash, 1990). The relatively faster gains in this experiment supplemented with *Gliricidia* could be attributed to higher ruminal turnover rate (Thornton and Minson, 1983), more N supply (as undegradable N) to the lower tract and an increase in total DMI.

Conclusion

Aforementioned results indicate that, ruminants performance can be improved by adequate quality and quantity of protein and energy supplements even though animals are offered poor quality basal diet such as rice straw and low N natural pasture forage. A wide variety of legume trees grow in tropics and such protein-rich foliage can be used as a protein supplement to low quality forages. Recommendation needs to be developed for various feeding systems that utilize optimum levels of legume tree leaves and bran as supplements with straw and tropical grasses for ruminant feed.

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熱帯域における反芻家畜生産成績向上のための低品質粗飼料の飼料価値改善

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要約　熱帯地域における小規模畜産農家が，実際に利用可能な反芻家畜飼養技術の確立を目指し，稲ワラおよび低品質粗飼料を基礎飼料とし，タンパクおよびエネルギーを補給した場合の飼料価値改善効果について調査した４試験について，それぞれを小括した．試験１：去勢メンヨウに稲ワラを自由摂取させ（対照），維持に要する代謝性タンパク質要求量の 50, 100% を充足する様にダイズ粕（SBM）を補給する区を設けた．SBM の補給は反芻胃内発酵性状に影響を及ぼし，飼料摂取量および消化率が向上したが，SBM の補給量が窒素出納成績に及ぼす効果は認められなかった．高いタンパク補給レベルにおいては，エネルギーの補給も同時に行う必要が示された．試験２：メンヨウを供試し，稲ワラ飼料へのエネルギーおよびタンパク質補給が窒素出納成績および微生物生産量に及ぼす効果を検討した．100% アンモニア処理稲ワラ飼料（ARS）および粗タンパク質と総エネルギー含量が同一となる様，65% 未処理稲ワラ（URS）＋30% 米ヌカ（RB）＋５%SBM 飼料および 85% ARS＋15%RB 飼料を調製した．ARS+RB 区は窒素（N）蓄積量が最も高かったが，微生物生産量（MBY）は URS+RB+SBM 飼料との差はなかった．試験３：ローズグラス乾草を自由採食させる区（対照），乾草に乾燥 *Gliricidia* 葉部（GLM），GLM とトウモロコシヌカ（MB）および MB をそれぞれ 120g/d 補給する４区を設け，当歳ヤギの飼料摂取量，消化率および日増体量を測定した．対照区に比べ，各処理区では飼料摂取量，消化率が向上した．日増体量は，GLM と MB を補給した区が最も高かった．マメ科の飼料樹葉部について，低品質粗飼料へのタンパク補給源としての有用性が認められた．試験４：20 頭の交雑種去勢雄牛を用い，青刈りネピアグラスを自由採食させ，*Gliricidia* および *Leucaena* を異なるレベルでの補給が，飼料摂取量，消化率，日増体量および MBY に及ぼす効果について検討した．*Gliricidia* の補給によりネピアグラスの採食量は減少したが，*Leucaena* の補給により総摂取量は増加した．消化率および MBY には補給するマメ科樹種の差はなかったが，日増体量については *Gliricidia* に比べて *Leucaena* の補給による飼料価値改善効果が認められた．