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Effect of supplementing urea treated rice straw and molasses with different forage species on the performance of lambs

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Abstract

Weaned lambs of the Phan Rang breed with an initial weight of 14.9 kg and 3.5 months of age were used to study the effect of supplementing urea treated rice straw (UTRS) and molasses with different forage species as protein sources compared to a commercial concentrate with respect to digestibility, growth performance and number of gastro-intestinal parasite eggs. Eight males were used in a digestibility trial in a double 4 × 4 Latin square design and 32 lambs (12 males and 20 females) in a growth trial lasting 84 days. The treatments were four diets containing urea treated rice straw *ad lib* and molasses supplemented with concentrate (control), Stylosanthes (*Stylosanthes guianensis*) forage (UTR-S), Cassava (*Manihot esculenta* Crantz) foliage (UTR-C) or Jackfruit (*Artocarpus heterophyllus*) foliage (UTR-J). The live weight gain (LWG) was 73.3, 70.0, 77.7 and 70.2 g/day and the feed conversion ratio 9.3, 9.0, 7.5, 10.4 kg DM/kg LWG for control, UTR-S, UTR-C and UTR-J, respectively. The DM intake ranged from 33 to 44 g DM/kg body weight. The DM digestibility was 0.66, 0.55, 0.60 and 0.54 and the CP digestibility 0.64, 0.65, 0.67 and 0.52 for the control, UTR-S, UTR-C and UTR-J, respectively. The nitrogen retained was 10.4, 9.8, 10.9 and 9.8 g/day for the diets control, UTR-S, UTR-C and UTR-J, respectively, and was not significantly different among treatments. The UTR-C and UTR-J diets had a weak effect on the number of Nematode eggs, which was reduced or slightly increased during the experimental period. In conclusion Stylosanthes forage and Cassava and Jackfruit foliage could be used as protein sources in diets based on urea treated rice straw and replace a commercial concentrate without any effect on the live weight gain of the lambs.

Keywords: Urea treated rice straw; Molasses; *Stylosanthes guianensis*; *Manihot esculenta* Crantz; *Artocarpus heterophyllus*; Lambs; Growth; Digestibility; Parasites

1. Introduction

The major constraint for the development of sheep production in South East Asia (SEA) is shortage of feed in the dry season. Rice straw is available all the year around in large quantities in the region and can be used in the form of urea treated rice straw (UTR) as the main bulky feed for sheep. Urea treatment is a conventional technique for improving the quality of rice straw in terms of increasing the nitrogen content (Shen and Sundstöhl, 1998; Khang and Dan, 2001) and the digestibility (Chowdhury and Huque, 1996; Man and Wiktorsson, 2001; Trach et al., 2001a,b). The degradation of cellulose and hemi-cellulose, the dry matter (DM)

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and organic matter (OM) *in sacco* losses after 48 h of incubation and the extraction of silica were increased, when rice straw was treated with 5% of urea (Shen et al., 1998). Selim et al. (2004) found that the physical strength and the DM proportion of the large particles of straw in sheep rumen was significantly lower for ammonia treated straw compared to that in untreated rice straw, while the bacteria mass tightly associated with straw particles was increased. However, the low voluntary feed intake when using UTR as a sole feed, resulted in the low nutrient intake (energy and crude protein (CP)) compared to the requirement of sheep leading to low growth rates and poor reproductive performance (Hue et al., 2003).

One possibility to improve a diet based on UTR–molasses and keep the cost of the products low is to supplement with non-conventional sources of nitrogen (Prasad and Reddy, 1998), for instance protein rich foliages or legumes such as Stylosanthes (*Stylosanthes guianensis*), Jackfruit (*Artocarpus heterophyllus*) or Cassava (*Manihot esculenta* Crantz).

Stylosanthes is a leguminous species, which occurs naturally in the tropical, subtropical and temperate regions of the Americas, Africa and Southeast Asia. The CP concentration of Stylosanthes is on average 170 g/kg DM, the variation mainly being due to age at harvesting (Tarawali et al., 2005). Phengsavanh and Ledin (2003) indicated that the growth rate of goats was 64–70 g/day when fed a diet consisting of grass and 30–40% of the DM intake (DMI) as Stylosanthes. According to Mupangwa et al. (2000), the DMI and apparent DM digestibility of *Stylosanthes guianensis* hay by Dorper wethers were 50.9 g/kg $W^{0.75}$ and 0.58, respectively.

Cassava is a tropical feed resource with a high biomass production of which the roots are used for human consumption and the leaves can be used as a feed for animals. The CP concentration in cassava leaves ranges from 160 to 250 g/kg DM, with 85% of the CP as true protein (Ravindran, 1993). Phengvichith and Ledin (2007) indicated that the daily live weight gain of growing goats ranged from 52 to 54 g/day when given 30–40% of the DMI in the form of wilted cassava foliage. Seng and Rodriguez (2001) showed that the growth rate of confined goats was higher and nematode infestation lower, when the forage supplement was cassava foliage.

Jackfruit is a fruit tree used to produce fruit for human consumption and for making live fences in SEA. The foliage is used as a feed for animals. The live weight gain (LWG) of growing goats and sheep was high when Jackfruit foliage was used as a protein supplement in the diets (Mui et al., 2001, 2002; Van et al., 2006). The leaves contain 330 g DM/kg and the CP concentration is 171 g/kg DM (Lin et al., 2003). The total tannin in leaves and 35–45 cm stem of Jackfruit was found to be 33.2 g/kg DM according to Mui et al. (2002). The voluntary feed intake by goats is high, 38.5–49.7 g DM/kg BW and LWG was 43.9 g/day (Mui et al., 2001; Kouch, 2003).

Leaves or foliages of multipurpose tree species often contain secondary compounds, especially tannins, which in low amounts may increase the productivity of the animals by binding with the dietary proteins during mastication and protecting the protein from microbial attack in the rumen. The protein–tannin complex will then be digested and utilised in the lower part of the digestive tract, thus acting as a by-pass protein source (Barry and McNabb, 1999; Norton, 2000). When feeding foliages and UTR the proteins with low ruminal degradability provide essential amino acids to the host animal, while molasses acts as fermentable carbohydrates for the ruminal microorganisms that can digest UTR (Galina et al., 2005). Tannins from some foliages have also been introduced in practice for the control of parasites in ruminants (Mui et al., 2005). According to Athanasiadou et al. (2001) and Lin et al. (2003) cassava or Jackfruit in the diet of cattle, goats and sheep reduced the number of parasite eggs in the faeces with time.

The objectives of the present study were to evaluate the effect of supplementing a basal diet of urea treated rice straw with protein rich forage species (Cassava, Stylosanthes or Jackfruit) on intake, growth rate, digestibility and nitrogen retention of growing lambs and the effect of tannins in the foliages on number of parasite eggs in the faeces.

2. Material and methods

2.1. Location and climate

The experiments were conducted in The Goat and Rabbit Research Center, Sontay, Hatay, Vietnam, 40 km West of Hanoi, longitude E 105°25 and latitude N 21°06. The altitude is about 220 m above sea level. The climate in this area is tropical monsoon with a wet season between April and November and a dry season from December to March. Average annual rainfall is 1850 mm. The two trials were conducted during March to September 2006.

2.2. Animals and management

The animals used were weaned lambs, bought at the Goat and Rabbit Research Centre. The breed was the local Phan Rang breed, which is used for meat production only, a wool type sheep with thin tail and a mature body weight (BW) of 39–45 kg for males and 34–38 kg for females. The mean initial BW was 14.9 kg (S.D. = 1.34) kg and the age around 3.5 months. Before starting the experiments, the lambs were treated against parasites with injections of Ivermectin solution (1 ml per 4 kg BW) and were vaccinated against Pasteurellosis, Pox, Foot and Mouth Disease and Enterotoxaemia.

Water was supplied in plastic buckets and the water consumption was recorded every day. Mineral lick blocks [730 g minerals (700 stone meal, $Ca_3(PO_4)_2$ and 300 g bone meal/kg mineral) plus 170 g cement as a binding agent and 100 g salt/kg mineral] were available *ad libitum*.

The animals were allowed to exercise once daily for 1 h in the afternoon at 14–15 h (for the growth trial only). During the exercise time, males and females were separated to avoid mating. They were weighed in the morning before feeding at the start and end of the experiments, and at 2-week intervals for the growth trial. For the digestibility trial the animals were weighed at the start of the adaptation period, at the start of the collection period and at the end of the collection period.

2.3. Experimental feeds and feeding

The feeds used in the experiments were UTR, molasses, concentrate and forages from Cassava, Stylosanthes and Jackfruit.

To produce UTR the straw was chopped into pieces of 7–10 cm in length before treatment. The formula for treatment was 100 kg rice straw + 50 kg water + 4 kg urea + 1 kg salt + 1 kg lime. The urea, salt and lime were dissolved in water before mixing with the rice straw. After mixing, the rice straw was stored in plastic bags under anaerobic conditions for 10–15 days before feeding. The quality of the UTR was estimated according to colour and smell (bright-yellow colour and good smell).

The concentrate was a commercial concentrate produced by Guyomach feed company based mainly on fish meal, soybean meal, maize and rice bran, and the nutritive value according to the producer was 180 g CP and 11.7 MJ ME/kg DM. All concentrate for the experiment was bought at the same time to avoid variations in feed composition.

Cassava, Stylosanthes and Jackfruit were harvested by cutting or breaking from the fields around the centre 1–2 h before feeding. If it was raining, the forages were harvested the day before feeding to limit the effects of low DM content. The Stylosanthes was harvested at an approximate age of 50–60 days. Before the start of the experiment, the area with the Stylosanthes was divided into 6 plots, each plot big enough to provide feed for 10 lambs during 1 week. The plots were harvested one by one with 1-week delay to be able to provide the Stylosanthes at the same age during the experiment. The Cassava foliage was harvested at an age of 3–4 months when the length of the Cassava stems was about 50–60 cm.

The animals were fed concentrate and foliage twice per day at 7:00 and 14:00 h. Molasses was added at a level of 20% of the fresh weight of the UTR and mixed thoroughly before feeding 4 times per day, the same times as the concentrate and foliage but also at 10:30 and 16:30 h. The UTR–molasses and the concentrate were put in separate troughs. The forages were offered tied in bunches hanging in the front above the trough.

2.4. Experimental design

In the growth trial 32 lambs were randomly allocated to 4 treatments with 3 males and 5 females per treatment. The length of the trial was 12 weeks. Before the start of the experiment, the lambs were adapted to the feeds for 10 days. The lambs were given UTR + molasses supplemented with concentrate (Control), Stylosanthes (UTR-S), Cassava foliage (UTR-C) or Jackfruit foliage (UTR-J).

At the start of the experiment the animals were offered diets based on requirements according to Paul et al. (2003). Lambs at 15 kg of BW and a LWG of 50 g/day require 4.94 MJ ME and 74 g CP/day. When the experiment was running the UTR–molasses and forages were fed *ad libitum* and supplied at a level of 150% of the individual average consumption in the previous weeks. The concentrate was fixed to 1.5% of BW. The amount of concentrate was changed according changes in BW every 2 weeks after weighing.

In the digestibility trial eight weaned male lambs with the same age and BW as the lambs in the growth trial were used in a 4 × 4 Latin square design replicated once. The lambs were allocated to individual metabolic cages. The diets offered and the feeding regimes were the same as in the growth trial and. In each period of observation, the lambs were adapted to the experimental diets for 14 days and the next 7 days were used for collecting data. Between periods the lambs were allowed 7 days in pens with a normal diet of UTR–molasses, 100 g concentrate, Guinea grass and Jackfruit foliage.

2.5. Measurements and analyses

Feeds offered were weighed and recorded daily. The feed refusals were collected and weighed every day in the morning before feeding. Water offered and refused was also measured daily during the data collection period for both the growth and the digestibility trial. In the growth trial, samples of feed offered and refused were taken weekly for analysing DM, then pooled to monthly samples for further analysis. The refusals of mixed UTR and molasses were assumed to have the same proportion of molasses as the feed offered.

The faecal samples of individual animals were taken directly from the rectum in the morning for counting gastrointestinal parasite eggs (Nematodes, Coccidia oocysts and Cestodes). Faecal egg count (FEC) was determined using a modified McMaster method (MAFF, 1977) with a lower limit of detection of 50 eggs/g of faeces. The samples of faeces (4 g) were ground and mixed with 56 ml of flotation fluid (360 g NaCl and 1 l of water). After filtering through a tea strainer, a sub-sample was transferred to both sides of a McMaster counting chamber and allowed to stand for 5 min. Nematodes and Cestodes eggs and Coccidia oocysts was counted under a microscope at 10 × 10 times magnification (Hansen and Perry, 1994). FEC was recorded every 10 days after the treatment against parasites to the end of the experiment.

In the digestibility trial, the samples of feed offered and refused were taken daily during the collection periods for analysing DM, and one portion of each sample was taken and pooled to an individual weekly sample. The faeces and urine excreted by each animal was recorded twice a day at 7:00 and 18:00 h. At each collecting time, 10% of the faeces was sampled and frozen at −20 °C. Urine was collected in a jar containing 10% sulphuric acid (urine pH < 3) to preserve the nitrogen (Chen and Gomes, 1992) and 10% of the total urine was also sampled every day and stored at 4 °C.

The feed offered and the refusals in both experiments and manure in the digestibility experiment were analysed for DM, ash, CP, neutral detergent fiber (NDF) and acid detergent fiber (ADF) and the urine for N according to the standard methods of AOAC (1990). Dry matter content of the UTR–molasses and forages was evaluated weekly, and daily in the rainy period. NDF and ADF were determined by the methods of van Soest et al. (1991). Total tannins in the feeds and the refusals were analysed according to AOAC (1975). The costs of the diets were calculated using prices at the Goat and Rabbit Research Center and the local markets around the center during the experimental period.

2.6. Statistical analysis

The data was analysed statistically by using the GLM procedure of Minitab Software, version 13.31 (Minitab, 2000). Treatment means which showed significant differences at the probability level of $P < 0.05$ was compared using Tukey's pairwise comparison procedures.

The statistical model used in the analysis of the growth trial was: $Y_{ij} = \mu + T_i + \beta W_j + e_{ij}$, where Y_{ij} is the dependent variable, μ is the overall mean, T_i is the effect of treatments (diets), initial weight (W_j) was used as a covariate and e_{ij} is the random error, independent and normally distributed. The statistical model used in the analysis of digestibility trial was: $Y_{ijk} = \mu + T_i + P_j + A_k + e_{ijk}$, where Y_{ijk} is the dependent variable, T_i is the effect of treatments (different diets), P_j is the effect of period, A_k is the effect of animal and e_{ijk} is the random error.

The number of Nematode eggs was analysed by a variance analysis using $\log_{10}$ transformation, while Coccidia oocysts and Cestode eggs were analysed using $\log_{10}$ [Coccidia oocysts (or Cestodes) + 1] transformation due to the fact that the data contained many zeros and were not normally distributed. The results were back-transformed by taking anti-logarithms of the least squares means and standard error of Nematodes and were presented as geometric means, and Coccidia oocysts and Cestodes were presented as geometric means-1. All statistical tests were applied to the transformed data.

3. Results

3.1. Chemical composition of the feeds

The chemical composition of the experimental feeds is shown in Table 1. The DM content of UTR–molasses, Stylosanthes forages and Jackfruit foliages were 614, 226, 372 g/kg, respectively, and of 184 g/kg in cassava foliage. The CP content in the concentrate was 171 g/kg DM, and in the Cassava, Stylosanthes and Jackfruit foliages, 202, 154 and 148 g/kg DM, respectively. The Jackfruit foliage had the highest content of total tannins, 48 g/kg DM.

3.2. The growth experiment: feed intake, nutrient intake, water consumption, LWG and feed conversion ratio

The feed offered, daily feed intake, and nutrient intake are shown in Table 2. The total DMI recorded for the animals fed the diet UTR-J (739 g) was significantly higher than for the diets UTR-C (573 g) and UTR-S (613 g), but was not significantly different from the control diet (676 g).

The daily DMI ranged from 3.3 to 4.4% of BW. The water consumption was highest in the animals fed the control diet (1920 g) and the UTR-J diet (1090 g) but was

Table 1
Chemical composition of the experimental feeds[a]

Feed[b]	DM (g/kg)	g/kg DM					MJ (ME/kg DM)[c]
		CP	Ash	NDF	ADF	Total tannins	
UTR–molasses	614 (42)	113 (8)	134 (4)	576 (33)	355 (29)	–	7.6
Concentrate	920 (5)	171 (2)	62 (9)	380 (17)	167 (15)	–	11.7
Stylosanthes	226 (19)	154 (4)	83 (5)	556 (44)	385 (47)	16 (4)	10.1
Cassava	184 (11)	202 (13)	65 (5)	358 (46)	270 (57)	23 (3)	11.3
Jackfruit	372 (18)	148 (8)	90 (8)	460 (59)	330 (64)	48 (8)	9.7

UTR (urea treated rice straw) and molasses estimated from 20% molasses per kg fresh weight of UTR.
[a] Mean and standard deviation (S.D.).
[b] Three samples in the Exp. 1 and 4 samples in the Exp. 2.
[c] Calculated based on table values (NIAH, 2007) ME (MJ/kg DM) = 0.016DOMD (g digestible organic matter per kg DM) (AFRC, 1998).

Table 2
Exp. 1—feed offered, feed intake, nutrient intake and daily gain and feed conversion ratio of diets containing urea treated rice straw and molasses supplemented with protein rich forages in replacement of a concentrate ($n = 8$)[a]

	Control	UTR-S	UTR-C	UTR-J	S.E.
Feed offered (g DM/day)					
UTR–molasses	566	386	356	439	
Concentrate	310	–	–	–	
Foliages	–	560	521	664	
Total DM offered	877	946	878	1103	
Feed intake (g DM/day)					
UTR–molasses	376^{a}	253^{b}	228^{b}	293^{ab}	25.6
Concentrate	300	–	–	–	–
Foliages	–	360^{b}	345^{b}	446^{a}	25.7
Total	676^{ab}	613^{b}	573^{b}	739^{a}	28.9
DM intake in % of BW	3.8	3.4	3.3	4.4	0.2
Water intake (g/day)	1920^{a}	790^{b}	630^{b}	1090^{a}	83.2
Nutrient intake (g/day)					
CP	108^{a}	101^{b}	104^{ab}	118^{a}	3.6
NDF	328^{a}	303^{a}	242^{b}	338^{a}	15.3
ADF	175^{b}	181^{ab}	158^{b}	214^{a}	9.9
Total tannins	–	9.7^{b}	12.1^{b}	25.7^{a}	0.7
ME intake (MJ/day)	6.3	5.9	6.0	6.5	0.25
Initial BW (kg)	15.1	15.5	14.8	14.3	0.5
Final BW (kg)	21.1	21.3	21.4	20.2	0.5
Daily gain (g/day)	73.3	70.0	77.7	70.2	3.7
Feed conversion ratio					
kg DM/kg LWG	9.3^{ab}	9.0^{ab}	7.5^{b}	10.4^{a}	0.5
kg CP/kg LWG	1.5^{b}	1.5^{b}	1.4^{b}	1.7^{a}	0.07

Urea treated rice straw with 20% molasses and Cassava foliage (UTR-C), Stylosanthes forage (UTR-S) or Jackfruit foliage (UTR-J). ^{a,b}Means within rows with different superscripts differ significantly ($P < 0.05$).
[a] Least squares means and S.E.

significantly lower for the diets UTR-S (790 g) and UTR-C (630 g), which were not significantly different. The CP intake was significantly lower in the UTR-S diet compared to the UTR-J (118 g) and control (108 g), but was not significantly different from the UTR-C (104 g). The intake of total tannins in the UTR-J diet was 25.7 g/day, significantly higher compared to the UTR-C (12.1 g/day) and UTR-S (9.7 g/day) and resulted in lower number of Nematode eggs in the faeces. The estimation of energy intake showed that there was no significant difference in energy intake among treatments and that energy intake ranged from 5.9 to 6.5 MJ/day.

There was no difference in initial and final BW. The LWG ranged between 70.0 and 77.7 g/day and was not significantly different among diets (Table 2). The FCR of DM was significantly lower for the UTR-C diet compared to the UTR-J diet but was similar to the other diets and the FCR of CP was significantly higher for the UTR-J diet compared to the other diets.

3.3. The growth experiment: effect of the different experimental diets on internal parasites

The experimental diets had no significant effect on the number of eggs from Cestodes or coccidian oocysts in the faeces but the diets UTR-C and UTR-J reduced the number of Nematode eggs compared to the control and the UTR-S diets ($P < 0.05$) (Fig. 1). In general, the number of parasite eggs from internal parasites was low for all diets. In the diets without or with low content of total tannins (control diet and UTR-S), the number of Nematode eggs increased gradually during the time of the experiment.

3.4. The digestibility experiment

The digestibility of DM was similar for the control (0.63) and the UTR-C (0.60) diets (Table 3), but

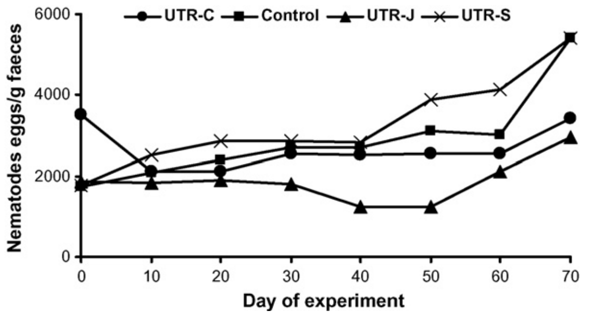

Fig. 1. Effect of different diets on number of Nematode eggs in the faeces of growing lambs. UTR-C, urea treated rice straw with 20% molasses + Cassava foliage; UTR-S, urea treated rice straw with 20% molasses + Stylosanthes forage; UTR-J, urea treated rice straw with 20% molasses + Jackfruit foliage.

was significantly higher than for the UTR-S (0.55) and UTR-J (0.54), diets. The CP digestibility of the UTR-J diet was significantly lower than for the other diets, which were not significantly different from each other.

The N intake was significantly higher in the diets UTR-J, UTR-C and control compared to the UTR-S diet. The N retention was positive in all diets, ranging from 9.8 to 10.9 g/day, and was not significantly different between diets. The N efficiency varied from 41.2 to 46.8% of total N intake and was not significantly different among treatments.

The cost/kg LWG of the control diet (2.3 USD) was higher than for all the experimental diets. If the cost/kg LWG of the control treatment was fixed to 100% the costs of the diets UTR-S, UTR-C and UTR-J were 90.1, 69.6 and 62.5%, respectively.

Table 3

Exp. 2—feed intake, digestibility, N balance and N efficiency of diets containing urea treated rice straw and molasses supplemented with protein rich forages in replacement of a concentrate ($n = 8$)[a]

	Control	UTR-S	UTR-C	UTR-J	SE
Feed offered (g DM/day)					
UTR–molasses	630	637	670	772	
Concentrate	460	–	–	–	
Foliages	–	663	552	745	
Total	1090	1300	1222	1517	
Feed intake (g DM/day)					
UTR–molasses	425^{b}	431^{b}	441^{b}	547^{a}	29.9
Concentrate	460	–	–	–	–
Foliages	–	422^{b}	369^{c}	510^{a}	32.6
Total	985^{b}	853^{c}	810^{c}	1057^{a}	20.8
Nutrient intake (g/day)					
CP	144^{a}	135^{b}	140^{a}	150^{a}	2.7
NDF	402^{ab}	414^{ab}	357^{b}	477^{a}	13.4
ADF	249^{b}	259^{ab}	220^{b}	321^{a}	10.4
Digestibility					
DM	0.63^{a}	0.55^{b}	0.60^{a}	0.54^{b}	0.01
OM	0.67^{a}	0.58^{b}	0.63^{a}	0.57^{b}	0.01
CP	0.64^{a}	0.65^{a}	0.67^{a}	0.52^{b}	0.02
NDF	0.58^{a}	0.58^{a}	0.58^{a}	0.53^{b}	0.02
ADF	0.32	0.30	0.31	0.31	0.03
ME intake (MJ/day)[b]	10.4	9.8	10.2	10.1	0.17
Nitrogen balance					
N-intake (g/day)	23.1^{a}	21.6^{b}	23.2^{a}	24.0^{a}	0.4
N-faeces (g/day)	7.8^{b}	8.2^{b}	7.7^{b}	10.0^{a}	0.4
N-urine (g/day)	4.9^{a}	3.5^{b}	4.6^{a}	4.2^{a}	0.3
N-retained (g/day)	10.4	9.9	10.9	9.8	0.5
N retained/N-intake	0.43	0.46	0.47	0.41	0.2

Urea treated rice straw with 20% molasses and Cassava foliage (UTR-C), Stylosanthes forage (UTR-S) or Jackfruit foliage (UTR-J). [a,b]Means within row with different superscripts differ significantly ($P < 0.05$).

[a] Least squares means and S.E.

[b] Calculated as ME (MJ/kg DM) = 0.016 DOMD (g digestible organic matter per kg DM) (AFRC, 1998).

4. Discussion

4.1. Chemical composition of the feeds

The CP of UTR with 4% of urea was 113 g/kg DM similar to the results reported by Selim et al. (2004). The variation in CP concentration in the urea treated rice straw can depend on the rice straw varieties used, fertilisation and harvesting period (Shen et al., 1998). The CP content of the Stylosanthes forage was 154 g/kg DM, lower than reported by Phengsavanh and Ledin (2003) and Mupangwa et al. (2000) (190 g/kg DM). The CP concentration in the Stylosanthes forage is mainly affected by the harvesting frequency. According to Tarawali et al. (2005) the CP concentration of Stylosanthes can decrease very fast from 188 g at a harvesting frequency of 2 months to 94 g/kg DM at 4 months. The Cassava foliage had a CP content of 202 g/kg DM in the present study. This value is lower than the results reported by Vongsamphanh and Wanapat (2004) (230–258 g/kg DM) in different Cassava varieties and by Phengvichith and Ledin (2007) (211 g). The CP content in the Jackfruit foliage was 148 g/kg DM. This result is in agreement with values obtained by Mui et al. (2001), Mui et al. (2002) and Van et al. (2005), but it is higher than the 129 g reported by Das and Ghosh (2007). The difference in CP concentration of the foliages could be a result of differences in the proportion of leaves and stems in the harvested material, or in the method of sampling. It also could be affected by the harvest stage, since CP is normally higher in young compared to mature foliages.

The content of total tannins in the Jackfruit in this study was 48 g/kg DM. This is in agreement with the values reported by Van et al. (2005) and Van et al. (2006) of 40–42 g/kg DM. The total tannins in the Cassava foliage was 23 g, lower compared to the results reported by Netpana et al. (2001) and Dung et al. (2005) with 33 and 39 g/kg DM, respectively. The different content of total tannins could be due to stage of plant growth, season of collection or proportions of the foliage materials sampled (Makkar and Becker, 1998; Salem et al., 2006). Mupangwa et al. (2000) found 15.6 g/kg DM of total tannins in Stylosanthes hay, and the Stylosanthes forage in this study contained 16 g/kg DM. The total concentration of tannins in the forages did not seem to have any negative effects on intake or performance of the lambs. Barry and McNabb (1999) concluded that the concentration of condensed tannins in *Lotus corniculatus* (30–40 g/kg DM) in the diet of sheep increased the absorption of essential amino acids without affecting voluntary feed intake and feed conversion ratio but the performance of sheep was depressed at the level of 75–100 g/kg DM of condensed tannins in the diet.

4.2. Effect of supplementation with protein rich forages on DMI, LWG, digestibility and economic efficiency

Using protein rich forages (Stylosanthes, Cassava and Jackfruit) as a replacement for the concentrate in the diet of sheep resulted in no significant differences between the experimental and control treatments in relation to g DMI per kg BW. The total DMI in g/kg BW of lambs fed the diets UTR-S, UTR-C and UTR-J, were 34, 33 and 44 g, respectively. Similar DMI in g/kg BW of lambs compared to the present study was indicated by Van et al. (2007), when offering diets of Jackfruit, sugarcane and concentrate. According to NRC (1985) the DMI of sheep normally ranges from 15 to 30 g/kg BW, but in good feeding conditions and with feeds with high intake characteristics, the DMI of sheep could reach 40–50 g/kg BW. The DMI from Stylosanthes and Cassava was 19 g/kg BW and from Jackfruit 26 g/kg BW. Forage from Stylosanthes, Cassava and Jackfruit made up 58, 56 and 59%, respectively, of the total DMI. If judged by the DMI it can be concluded that Jackfruit has better intake characteristics than Cassava and Stylosanthes. Mui et al. (2001), Kouch (2003), Van et al. (2005) and Das and Ghosh (2007) also concluded that foliage from Jackfruit is an excellent feed for ruminants, with high intakes. However, the DM content in Jackfruit in the present study was 2.0 and 1.6 times higher than in Cassava and Stylosanthes, respectively. The higher water content could have had a negative effect on the feed intake from Cassava and Stylosanthes. The differences in water content in the forages resulted logically in significantly different water consumption, higher in the diets UTR-J and control.

The LWG of the lambs was not significantly different among the treatments in spite of the protein sources being different and the total CP intake being lower in the diet UTR-S compared to the other diets. The LWG was similar to the result obtained by Binh et al. (2005), who found that the LWG of Phan Rang lambs were 68–73 g/day.

The CP digestibility was significantly higher in the diets UTR-C, UTR-S and control compared to UTR-J and the N content in the urine and faeces was higher in the diet UTR-J, so even if the CP intake was high in the UTR-J diet this did not result in any higher N-retention or better growth. The CP and the estimated MJ ME consumed were similar in all treatments so unless there were appreciable differences in the utilization of the nutrients no differences in LWG could be expected. The

N efficiency was high and the intake of CP higher than the requirement (Paul et al., 2003) for the growth obtained. This could be due to the fact that the UTR–molasses was sampled at feeding and some N may have been lost as ammonia during the day. This meant that the difference between N content in the feed and in the refusals was too high and the estimate of intake higher than the true intake.

The economic efficiency was highest when feeding the diet UTR-J. The costs of the diets were based on the prices of the feeds at the experimental site, which means that the relation between the diets may be different in other conditions. However, according to ILRI (1998) a new technology can be recommended if net income increases and variables costs remain the same or decrease.

4.3. Effect of total tannins on faecal egg count

The number of Nematode eggs/g faeces of the sheep was reduced during the time of the experiment after 10–60 days for animals fed the diets containing total tannins. Athanasiadou et al. (2001) found that FEC in sheep faeces was lower when the sheep were drenched with extract from condensed tannins. Total tannins include hydrolysable tannins (gallotannins and ellagitannins) and condensed tannins (flavolans). According to Mui et al. (2005) forages containing condensed tannins have the potential to control anthelmintic-resistant gastro-intestinal parasites by direct or indirect biological effects. The direct effect might be mediated through interaction between condensed tannins and nematodes, affecting physiological functions of gastro-intestinal parasites through interference with parasite hatching and development of infective stage larvae (Nieze et al., 1998; Molan et al., 2002). Barry et al. (2001) and Nieze et al. (2002) also illustrated that the indirect effect of condensed tannins may enhance resistance of gastro-intestinal parasite infection through increases in protein supply, which are prioritised for tissue repair and immune response. Condensed tannins and binding of nutrients directly inhibit nutrient availability for larval growth or decrease gastro-intestinal parasites through inhibition of oxidative phosphorylation (Scalbert, 1991). The viability of the larval stages of several nematodes in goats and sheep was decreased by condensed tannins extracted from forages (Kahn and Diaz-Hernandez, 2000; Molan et al., 2000). The research by Min and Hart (2003) also concluded that condensed tannins reduced larval development by 69% in ruminants fed fresh temperate forages. In this study the animals were de-wormed at the start of the experiment, fed a presumably clean basic feed (UTR) and the forages were cut, not grazed, so high levels of parasite eggs would not be expected.

5. Conclusions

Stylosanthes forage and Cassava and Jackfruit foliage could be used as protein sources in a diet based on urea treated rice straw and replace a commercial concentrate without any effect on the live weight gain of the sheep.

Feeding Stylosanthes forage and Cassava and Jackfruit foliage is very easy to apply for farmers, and a reduced price of products will lead to an improvement of the economical efficiency compared to concentrate supplementation.

Using forages containing total tannins such as Jackfruit or Cassava can reduce the number of internal parasites with time.

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