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Full Length Research Paper

Utilization of steam-processed oil palm (*Elaeis guineensis*) frond by ruminants in Malaysia: Investigations for nitrogen supplementation

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Two experiments were undertaken using lambs and cows fed steam-treated oil palm frond (SOPF). In the first experiment, 8 lambs received SOPF supplemented with 4 levels of urea: 0 (U0), 8 (U8), 16 (U16) and 24 g urea/kg SOPF (U24) in a replicated 4 x 4 Latin square design. When the lambs were given the above diets, all the measurements for intake and digestibility (dry matter, organic matter and nitrogen) increased in a linear ($P < 0.001$) manner up to the level of U16, except for intake of nitrogen (N); no further benefits were obtained when more urea was added. Giving 16 g urea per kg could provide sufficient fermentable N for SOPF utilization. Three ruminally cannulated non lactating cross-bred Charolais x Kedah-Kelantan cattle were used in the second experiment to determine the effective degradability of N from cassava foliage (CF), cassava leaves (CL) and soybean meal (SM) suspended in the rumen. The animals were fed with amount of dry matter (DM) that was equivalent to 1.5% of body weight of SOPF supplemented with 16 g of urea per kg. The effective degradability of N from CF, CL and SM was calculated from their residues after incubation in the rumen for 2, 4, 8, 16 and 24 h. Increasing the rate of outflow of particulate matter (from 2, 5 to 8%/ h) from the rumen, resulted in a greater disappearance of N ($P < 0.05$) from CF than from CL or SM. Because of its relative faster rate of degradation, CF in addition to the provision of fermentable N may also contribute easily degradable cellulose and hemicellulose to SOPF-based diets. The nylon bag technique appeared to be a powerful tool for screening protein supplements.

Key words: Degradability, nitrogen, oil palm frond, ruminant, steam treatment, supplementation.

INTRODUCTION

Malaysia leads the world in palm oil production and 24.4 million metric tons (DM basis) of oil palm frond (OPF) (the petiole plus the leaflet) are harvested annually from its 2.5 millions hectare of oil palm plantation (Islam, 1999). Due to the shortage of grazing land for its ruminant production, OPF has been advocated as an alternative feed resource for ruminants in Malaysia (Oshio et al., 1990). However, the high fibre (60 to 70%) and the low nitrogen (N) [5% crude protein (CP)] contents of OPF limit its effective utilization by rumen microbes and consequently by the host animal.

Steam treatment increased the potential degradability of OPF incubated in nylon bags by 40% (Bengaly et al., 2004). There is considerable evidence (Ørskov and Grubb, 1978; Hettiarachchi et al., 1999) that the advantage of making more fermentable low quality roughage by a processing technique can be fully exploited if the rumen microbial needs for fermentable N are met. However,

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rumen protein sources must be provided in the diet to enhance the productivity of the host animal (Ørskov, 1992). Conventional proteins and energy concentrates such as soybean meal, fish meal and cereal grains have a very limited potential utilization in many livestock production systems of developing countries due to scarcity and cost in addition to their inhibitory effect on cellulolytic activity of rumen microbes at high levels of supplementation (e.g. cereal based concentrates). Leng and Preston (1976) suggested that forage supplements would stimulate nutrient intake and improve animal performance when ruminants are fed poor quality tropical crop residues. The improved utilization of poor quality basal roughages due to forage supplementation has generally been explained by the faster rate of degradation of the supplement in the rumen, resulting in an increase in intake and a low substitution rate of the basal diet (McMeniman et al., 1988; Bonsi et al., 1994b). Nsahlai et al. (1995) also suggested that the degree of substitution could be related to the extent of DM degradability of the forage supplement in the rumen.

This study reports the results of 2 experiments. In the first, the amount of urea (as fermentable N source) required to supplement steam-processed OPF [steam-treated oil palm frond (SOPF)]-based diet was determined. The second experiment was designed to investigate the merits of cassava foliage [(CF): the stem plus the leaflet], the leaflet portion alone (cassava leaves, CF) and soybean meal (SM) as protein and energy supplements by use of the nylon bag technique.

MATERIALS AND METHODS

Experiment 1

Animals and diets

Eight entire Dorset x Malin lambs that weighed 10 to 20 kg were used. Freshly pruned fronds were chopped to 2 to 3 cm length and steam treated. They were pre-dried to moisture content of 25 - 30% before steam treatment at a pressure of 10 kg cm^{-2} for 20 min (Bengaly et al., 2004). The treated OPF was subsequently mixed with molasses (3%) and dicalcium phosphate (1%) and supplemented with 4 levels of urea, namely; 0 (U0), 8 (U8), 16 (U16) and 24 g/kg SOPF (U24), corresponding to 4 dietary treatments. Anhydrous sodium sulphate was added to 0.13 g/g urea (McDonald et al., 1995) to provide sufficient sulphur. The final N contents of the dietary treatments were: 5.2, 9.2, 12.5 and 16.3 g/kg DM for diet U0, U8, U16 and U24, respectively.

Experimental design and management

The 8 lambs were allocated to the treatments using a replicated 4 x 4 Latin square design. Each test period consisted of 28 days, during which, the last 7 days, the faeces were collected for the determination of apparent digestibility of DM, organic matter (OM) and N. Each morning, the urea mixture was sprayed onto the daily ration, which was then separated into 2 equal portions. Half of the ration was fed in the morning (08.00 h) and the remaining half at 16.00 h. The animals were fed *ad libitum* to ensure 20% residues daily and they had free access to clean water. The residues were dried to constant weight for DM determination. Voluntary intake was measured during the last 15 days of each experimental period.

Chemical analyses

Samples of feeds and faeces were ground before been analysed to determine DM by the oven drying method, OM by muffle furnace incineration and N by Kjeldahl method (AOAC, 1990).

Statistical analysis

The data were analysed using the GLM procedure of SAS (1989) for a replicated 4 x 4 Latin square design. Since a missing value occurred, significant differences between treatment means, if any, were tested using the Tukey's t-test (Steel and Torrie, 1980).

Experiment 2

Animals, diets and management

Three matured non-lactating cross-bred Charolais x local Kedah-Kelantan cattle that weighed between 280 and 340 kg and each fitted with a permanent rumen cannula were used. They were housed in individual pens, fed SOPF twice daily in equal meals at 08:00 and 16:00h and had free access to water. Steam-treated OPF was prepared and mixed with urea, molasses, dicalcium phosphate and anhydrous sodium sulphate as in experiment 1. The animals were offered the diet at an amount of DM equivalent to 1.5% body weight for 2 weeks before the measurements were made.

Samples preparation

Samples of cassava were from 8 week's regrowth plants obtained from a plot established in 1999. They were separated into 2 portions, the stem plus the leaflet (cassava foliage, CF) and the leaflet portion alone (cassava leaves, CL), then chopped and sun-dried. For the nylon bag incubation study, the samples were ground, except for SM, through a hammermill fitted with 2.5 mm screen.

Nylon bag incubation study

Degradability of CF, CL and SM was studied according to the procedure described by Ørskov et al. (1980). Samples from each feedstuff were incubated in nylon bags suspended in the rumen of each animal. Approximately 5 g of each sample were put into each bag incubated for 2, 4, 8 16 and 24 h, and there was one bag per incubation time. Zero-hour bags were not incubated but were washed by hand under running tap water with other bags (to determine solubility). The bags were dried to a constant weight at 60°C for 48 h. Dried residues of each sample were pooled over animals on the basis of incubation period before analysing for N.

Chemical analyses

Samples from the incubated feedstuffs were analysed for DM and N, as described in experiment 1. They were also analysed to determine neutral detergent fibre (NDF), acid detergent fibre (ADF) and lignin (Soest et al., 1991).

Statistical analyses

The degradability data for DM and N were fitted to the exponential model of McDonald (1981); Dhanoa (1988) with a discrete lag phase:

$P = a + b\,(1 - e^{-c*(t-L)})$ for $t > L$

Where, *P* is the degradability of DM or N at time *t*, *a* is the soluble or rapidly degradable fraction, *b* represents the insoluble but fermentable fraction, *c* is the rate of degradation of *b* and *L* is the lag time for the beginning of the degradation process. The constants *a*, *b*, *c* and *L* were calculated using the non-linear least square program of Marquardt procedure (SAS, 1989). The effective degradability of N (*EDN*) in the rumen was calculated using the 4 constants and the assumed rate of particulate outflow from the rumen (*k*) according to McDonald (1981):

$EDN = a + [(b*c) / (k + c)*\exp(-(c + k)*L)]$

Chosen values of *k* were 2, 5 and 8%/h, which may be representative of low, medium and high feeding level, respectively (ARC, 1984). Data were subjected to analysis of variance using the procedures of SAS (1989). Effects of changing rumen outflow rates on the effective N degradability from the feedstuffs were evaluated with animals treated as random blocks and the significance of treatments was tested against animals x feedstuffs. When F values were significant ($p < 0.05$), effects of rumen outflow rates were compared using the *lsd* test.

RESULTS

Experiment 1

The results for the daily intake of DM, OM and N are given in Table 1. The differences between the unsupplemented diet and the diet containing the first increment of urea (8 g/kg) were highly significant ($P < 0.001$) for DM intake, DM, OM digestibility and digestible organic matter intake (DOMI). In fact, DOMI increased by 47%. There appeared to be a levelling off in response and none of the differences between the diets containing 16 and 24 g urea/kg approached significance. There was a linear increase in the apparent digestibility of N.

Experiment 2

The chemical composition of the basal diet and the incubated feedstuffs are reported in Table 2. The disappearance values for DM and N from the feedstuffs are reported in Table 3. Except for SM, the pattern of N disappearance was very similar to that of DM up to 8 h of incubation, and thereafter, the N degradability was much greater than that of DM. The constants from fitted exponential; a, b, c and L are reported in Table 4. The mean value of feed N that was immediately degraded in the rumen fraction *a*, differed ($P < 0.001$) between feedstuffs. Cassava foliage had the highest value (39.6%) followed by CL (27.3%) and SM had the lowest value (19.7%). The size of the slowly degradable N fraction *b* was similar ($p > 0.05$) across feedstuffs. However, the mean degradation rates *c* of *b* for CF (10.5%/h) and for CL (9.3%/h) were higher than that for SM (4.7%/h).

The lag time preceding N disappearance was about 1.3 units longer ($P < 0.05$) for SM than for CF and CL. The effective N degradability of each feedstuff was highly affected ($P < 0.001$) by the rate of particulate outflow from the rumen. An increase in ruminal outflow from 2 to 8%/h was associated with a decrease in the effective degradability of about 18% in CF, 23% in CL and 33% in SM. At each outflow rate, the effective N degradability varied among feedstuffs, but the values for CF and CL were identical ($P > 0.05$) at ruminal outflow rate of 2%/h, whereas SM had the lowest value. At ruminal outflow rates of 5 and 8%/h, the effective N degradability was highest for CF followed by CL, and SM had the lowest value.

DISCUSSION

It is a well-known fact that the major limitation to the use of fibrous crop residues is their low digestibility. The ammonia generated in the rumen from degraded protein is often too low to ensure an efficient digestion process, leading to a substantial reduction in feed intake (Ørskov, 1995). Fermentable N supplementation as urea would be of immediate advantage raising the intake and digestibility potential of low N diets.

The results of experiment 1 clearly illustrate that in order for intake and digestibility potential of steam-treated OPF to be realized, additional fermentable N must be provided for the bacterial growth. Microbial growth was presumably limiting on the U0 diet and the lambs responded positively to the first increment of urea supplementation (Table 1). The negative coefficient of apparently digested N in animals given this diet may be as a result of urea recycling. Ruminant animals can survive on diets containing very low N, because N, mainly in the form of urea, is continuously recycled into the rumen from the blood for re-utilization as N source for rumen microbial growth (Satter and Roffler, 1981; Norton, 1984). It is quite possible that the limited extent of digestibility of the unsupplemented diet resulted in the passage of more potentially digestible carbohydrates (Ørskov et al., 1972) along with some bacterial matter (Soest, 1994) to the large intestine. Microbial protein synthesized in the large intestine, in part from recycled urea-N, would then be lost in the faeces. The apparent digestibility of N in the U0 diet was -32.8%, which was higher than the value of -64.5% reported by Ørskov and Grubb (1978) in sheep given sodium hydroxide treated straw without urea. One animal in the control group died, suggesting that the recycled urea could not meet the N requirements of the rumen microbes for maintenance or production (Preston and Leng, 1987).

The Agricultural Research Council (ARC) system of

Table 1. Voluntary intake and apparent digestibility of dry matter (DM), organic matter (OM) and nitrogen (N) by lambs fed steam-treated oil palm frond supplemented with incremental levels of urea.

Parameter	Urea supplementation (g/kg)[a]				SE[b]
	U0	U8	U16	U24	
DM intake (g/d)	317	479	582	555	21
DM digestibility (g/kg)	370	446	472	482	13
OM digestibility (g/kg)	348	419	456	461	14
DOM intake (g/d)	99	186	237	241	10
Nitrogen digestibility (g/kg)	-328	65	463	560	39

[a]; Levels of urea supplementation: U0, no urea; U8, 8 g/kg; U16, 16 g/kg; U24, 24 g/kg of oil palm frond. [b]SE; standard error of difference between means.

Table 2. Chemical composition (g/kg DM) of steam-treated oil palm frond fed to the animals and of cassava foliage, cassava leaves and soybean meal incubated in the nylon bags.

Parameter	SOPF*	Cassava foliage (CF)	Cassava leaves (CL)	Soybean meal (SM)
Dry matter (g/kg)	949	932	918	836
Crude protein	42	229	266	519
Neutral detergent fibre	609	460	438	nd**
Acid detergent fibre	581	377	311	nd
cid detergent lignin	100	26	24	nd
Hemicellulose	28	83	127	nd
Cellulose	481	351	287	nd

*SOPF, steam-treated oil palm frond; **nd, not determined.

Table 3. Degradability values (%) of dry matter and nitrogen from cassava foliage, cassava leaves and soybean meal in the rumens of cattle given steam-treated oil palm fronds.

Incubation time (h)	Dry matter			Nitrogen		
	Cassava foliage	Cassava leaves	Soybean meal	Cassava foliage	Cassava leaves	Soybean meal
2	29.92	34.85	20.08	33.29	25.20	0.92
4	35.46	35.10	21.88	40.96	31.48	7.71
8	43.81	47.52	23.43	53.91	48.13	20.98
16	66.67	73.57	52.29	87.17	83.38	41.85
24	71.58	82.46	71.83	92.30	93.77	62.88

protein evaluation proposed that the amount of degradable N required by rumen microbes is 19.5 g N per kg of digestible OM (ARC, 1984). If we assume that the potential digestibility of the OM was 460 g/kg (Table 1), then the degradable N required per kg of digestible OM would be 9.0 or 8.1 g (after adjusted for OM content of 898 g/kg DM). A ruminal degradability factor for dietary protein for hays and urea of about 0.8 has been proposed. Assuming this applies to crop residues and straw and that the entire N in these feeds was in protein, then the total N required per kg of DM according to the ARC system would be:

8.1 / 0.80 = 10.1 g

Since N content of OPF was only 5.2 g/kg DM, a significant effect of N supplementation is therefore, expected. The lambs responded positively in terms of intake and digestibility as a result of urea supplementation and an optimum level was reached between 8 and 16 g urea/kg OPF, providing an equivalent of 9 to 12 g N/kg DM. This result was, therefore, close to the predicted level of ARC. Efforts have been made to estimate *in vivo* ruminal protein degradability by use of the nylon bag technique (Ørskov and McDonald, 1979).

Table 4. Fitted exponential constants for nitrogen degradability, effective degradability of nitrogen (g/kg DM) of cassava foliage, cassava leaves and soybean meal in the rumen of non-lactating cross-bred cows fed steam-treated oil palm frond.

Feedstuff	Wash[1] value	Fitted exponential constant				Degradability[3]		
		a[2]	*b*	*c* (h^{-1})	*L* (h)	*EDN2*	*EDN5*	*EDN8*
Cassava foliage	347	396[a4]	523[a]	0.105[a]	2.27[b]	820[a]	728[a]	669[a]
Cassava leaves	260	273[b]	613[a]	0.093[a]	2.33[b]	771[a]	664[b]	596[b]
Soybean meal	71	197[c]	687[a]	0.047[b]	3.63[a]	671[b]	526[c]	450[c]
SE[5]		15.2	76.4	0.015	0.16	33.6	21.1	20.0

[1]Zero-hour washing loss; *a*[2]*, b, c, L:* Fitted exponential constants for nitrogen degradability; *EDN;* [3]Effective degradability of nitrogen at ruminal outflow rates of 2, 5 and 8%/h; 4; means in the same column with different superscripts differ significantly ($P < 0.05$); [5]SE, standard error of difference between means.

However, the rate of N degradation from feeds suspended in the rumen has been shown to vary with the nature of the protein source, (whether it is fibrous or concentrate) (Ganev et al., 1979), the composition and particle sizes of the basal diet and the level of feeding (Weakley et al., 1983; Elimam and Ørskov, 1984ab; Susmmel et al., 1989; Zhao et al., 1993).

The differences in effective degradability of N in the rumen may result from the differences in the structural functions of the leaflets and the stem parts of cassava plant and the compact structure of unground SM (Table 3). Effective degradability of CF that had the highest soluble N fraction was affected a little by changes in rumen outflow rates, while SM was greatly affected, corroborating Ørskov's observation (1992) that protein supplemented with a substantial soluble fraction *a*, relative to *b*, tend to be little affected by changes in outflow rates or feed intake, whereas those having a large *b* fraction and a low degradation rate *c* are more affected. Differences in the pattern of N degradation presumably reflect the deficiency in fermentable energy relative to the N content of SM compared to CL and CF.

Conclusion

It can be concluded that 16 g urea/kg would provide sufficient fermentable N for an efficient digestion of steam-treated OPF. Having assessed the needs for fermentable N, the provision of a rumen undegradable N supplement may be required to improve animal performance given steam-treated OPF-based diet. Differences among feedstuffs N degradability in the rumen reported in experiment 2 are not totally understood. The effect of particle size was apparent on disappearance measurements of incubated feeds. Moreover, it was observed that DM and N degradation from cassava foliage and cassava leaves proceeded at the same rates especially during the earliest periods of incubation, suggesting that N degradation from these feedstuffs was not hindered by any specific constituents. The data further suggest that cassava foliage, a locally available resource, could be a potential protein supplement in animals given steam-treated OPF because of its faster rate of degradation. Further studies should examine the effect of supplementing OPF with these protein sources on the rates of passage of particulate matter along the gut.

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