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Sago pith meal based diets in sheep containing different sources of nitrogen: Feed preparation, growth performance, digestibility and carcass quality

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ABSTRACT

The present research work was designed to evaluate sago pith meal (SPM) as feed for ruminants. A particle size distribution (Experiment 1) was determined in SPM prepared from sago logs by use of three different rasping sizes (large, medium and small). The large rasping produced a negligible amount of fine particles and a large amount of large particles, while small rasping produced a negligible amount of large particles and a smaller amount of fine particles than the medium rasping. Since both large and fine particles are not desirable, the SPM produced by the small rasping was considered the best as feed for ruminants and was used in two experiments with sheep (Experiments 2 and 3) to determine the digestibility and growth performance/carcass quality, respectively. Sheep were divided in each experiment into three treatments and each group was fed one of three SPM based diets: (1) control diet (CNT) contained SPM and soybean meal, (2) USM diet contained SPM, soybean meal and urea, while (3) UFM diet contained SPM, fish meal and urea. In the Experiment 2, the digestibility of dry matter was not different ($P>0.05$) among the diets, but the digestibility of neutral detergent fiber was lower ($P<0.05$) for the USM and UFM diets than for the CNT diet. However, there was no difference ($P>0.05$) between the USM and UFM diets. In Experiment 3, the means for the average daily gain, feed intake, carcass weight, dressing percentage and lean meat were not different ($P>0.05$) between the USM and UFM diets, but all were higher ($P<0.05$) for the CNT diet than for both the USM and UFM diets. It was concluded that the small rasping is best for preparation of SPM as feed for ruminants, and that a highly soluble and rumen degradable protein supplement is more efficient than urea to support the maximum microbial growth in the rumen of sheep fed diets based on SPM supplemented with soybean meal or fish meal.

1. Introduction

Sago belongs to a group of starch-bearing palms found in the Malay Archipelago that stretches from the Philippines to Papua New Guinea. The most common and productive species that is grown in the Borneo part of Malaysia, mainly Sarawak, is *Metroxylon sagu*. It is used commercially for production of starch. However, there is abundance of sago in Malaysia and

Abbreviations: ADF, acid detergent fiber; ADL, acid detergent lignin; AIA, acid insoluble ash; CNT, control diet; CP, crude protein; EE, ether extract; FM, fish meal; NDF, neutral detergent fiber; NPN, non-protein nitrogen; OM, organic matter; RDP, rumen degradable protein; RUP, rumen undegradable protein; SBM, soybean meal; SPM, sago pith meal; UFM, diet contained sago pith meal fish meal and urea; USM, diet containing sago pith meal soybean meal and urea.

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Table 1
Mean particle size distribution and chemical composition (g/kg dry matter unless otherwise stated) of sago peat meal produced by large, medium or small rasping of split sago logs.

Item	Pore equivalent of sieves (μm)[a]	Particles retained on mesh (g/kg)					
		Large rasping[b]		Medium rasping[b]		Small rasping[c]	
		Mean	SE	Mean	SE	Mean	SE
Sieve screens mesh							
Large (2 sieves)	8060; 4822	623	35	12	1	2	1
Medium (3 sieves)	2858; 2015; 1019	360	31	414	4	561	1
Small (3 sieves)	504; 299; 250	8	4	422	1	382	9
Fine (3 sieves)	106; 53; 0.05	9	0	152	4	55	4
Chemical analysis							
Dry matter		941	1	930	12	925	3
Crude protein		12	0	12	0	11	0
Ether extract		5	1	5	0	7	1
Ash		35	1	66	1	47	3
Acid detergent fiber		95	3	93	3	92	4
Neutral detergent fiber		135	4	126	6	128	5
Acid detergent lignin		21	0	21	0	26	3
Acid insoluble ash		11	2	18	3	20	2
Hemicellulose		40	4	33	9	36	5
Cellulose		74	4	72	0	66	7
Starch		751	12	740	32	722	13
Gross energy (MJ/kg dry matter)		181	02	173	0	175	1

[a] Based on Tyler mesh equivalents (Pfost and Headley, 1976).
[b] Two runs on the batch.
[c] Two butches and two runs on each batch.

dried rasped sago pith has been used for feeding animals since 1873 (Burkhill, 1966). Together with sago flour, the whole sago pith meal (SPM) may be grouped into an energy feed based on an international classification standard (Harris et al., 1968). The use of feed sources containing highly fermentable carbohydrate such as SPM is important in optimizing livestock production in Malaysia as the lack of energy in commonly available feeds is more critical than the lack of other nutrients. Several studies have been conducted on the use of SPM in diets of pigs and poultry, but very few with feeding SPM to ruminants. The ensiled sago fiber with molasses and urea resulted in poor growth in lambs (Yardav and Mahyuddin, 1991), but when supplemented with corn grain and fish meal the growth of lambs was greatly improved (Yardav et al., 1991). There is no recent information on feeding SPM to sheep, especially the type of dietary protein supplement such as rumen degradable protein (RDP), rumen undegradable protein (RUP) and/or non-protein N (NPN) required to obtain a reasonable growth, feed utilization and carcass quality in sheep. Also, there are numerous commercial factories in Malaysia that produce SPM from sago logs using different sizes of rasping, which can produce different rasping sizes of SPM. The feed particle size dynamics affects the nutritive value of feeds (Murphy and Kennedy, 1993); the relatively large particles affect the normal passage from the rumen (Faichney and Brown, 1991), while fine particles formed lumps in the stomach resulting in lower digestion in the intestinal tract of pigs (Ivan and Farrell, 1976) and grinding too finely corn grain had negative effect on gain and feed conversion efficiency in feedlot cattle (Corona et al., 2005). Therefore, it was hypothesized that different sizes of rasping may produce different distribution of sizes of particles and, therefore, not all rasping sizes may be suitable to produce SPM for use in diets of ruminants. Consequently, the first objective of the present study was to test the hypothesis by the determination of the particle size distribution and chemical composition from use of different rasping sizes to prepare SPM from sago logs by a factory in Sarawak; a rasping size that produced the largest proportion of desirable medium and small size particles and smallest proportion of undesirable large and fine size particles in SPM was then selected. The second objective was to use the selected rasping size SPM as dietary base in combination with supplements of soybean meal (SBM) as RDP, fish meal (FM) as RUP and urea as NPN to assess the potential of SPM based diets in terms of the digestibility, growth performance and carcass quality in sheep.

2. Materials and methods

2.1. Particle size distribution—Experiment 1

Three routinely used rasping sizes (large, medium and small) were used to prepare SPM from split sago logs by a commercial factory in Sarawak, Malaysia. One batch of each large and medium rasping and two batches of small rasping were prepared and used in the present Experiment 1 to determine the particle size distribution. Approximately 130 g sample from each batch was each placed on the top of a series of 11 sieve pens fixed on a particle test-sieve shaker (Endecotts Model EFL2 mk3, Chelmsford, Essex, UK). The pen with the largest mesh openings was placed on the top, followed down with the decreasing mesh openings, with a collection pen on the bottom. There were two different mesh size sieves for the large mesh sieve group and three for each medium, small and fine mesh sieve group (Table 1). Seven larger mesh size sieve pens were

Table 2
Mineral composition of small rasping sago pith meal (mg/kg dry matter).

Mineral element	Mean[a]	SE
Calcium	1400	0
Phosphorus	400	0
Iron	219	21
Potassium	528	5
Sodium	219	3
Manganese	87.5	3.2
Copper	2.96	0.39
Cobalt	0.88	0.03
Cadmium	0.12	0.02
Zinc	0.05	0.01

[a] Mean of 5 samples.

Table 3
Composition (g/kg dry matter unless otherwise stated) of sago pith meal based diets supplemented with soybean meal (control; CNT), urea and soybean meal (USM), and urea and fish meal (UFM).

Item	CNT		USM		UFM	
	Mean	SE	Mean	SE	Mean	SE
Ingredient composition						
Sago pith meal	643.8		861.1		866.1	
Soybean meal	339.1		82.5		–	
Fish meal	–		–		77.5	
Urea	–		39.3		39.3	
Vitamin–mineral mix	10.0		10.0		10.0	
Ammonium sulfate	7.1		7.1		7.1	
Chemical composition						
Dry matter (g/kg)	734	18	701	27	724	26
Organic matter	948	11	959	11	943	12
Crude protein	174	11	170	8	172	4
Ether extract	49	4	45	2	56	6
Acid detergent fiber	78	1	83	5	70	1
Neutral detergent fiber	102	5	136	6	129	3
Ash	52	1	41	1	57	2
Gross energy (MJ/kg dry matter)	160	0	160	0	170	0

manufactured by the N.V. Metaagaas, Hangelo, Holland, while the remaining smaller size mesh sieve pens were supplied by the Endecotts, Chelmsford, Essex, UK. Each sample was shaken for 5 min. The particles retained on each sieve and on the bottom collection pen were weighed. The weights on the sieves assigned to large, medium, small and fine mesh groups were combined and their percentage of the sample weight was calculated. The chemical composition was determined for each rasping (Table 1), while the mineral composition was determined only for the small rasping (Table 2).

2.2. Housing (Experiment 2 and 3)

Sheep used in the two experiments were housed in individual pens with automatic drinking nipples and slatted floor in an open wooden sheep barn raised above the ground. All sheep were drenched with Systamex (Welcome Foundation Ltd., London, UK) to control internal parasites. The care of the experimental animals was in accordance with the country standards (including halal slaughter) and the experimental protocol was reviewed by the Institutional Animal Care and Use Committee.

2.3. Diets (Experiment 2 and 3)

Three experimental total mixed diets were prepared using the small rasping SPM (determined in Experiment 1 to be the most appropriate for feeding ruminants as discussed bellow), and three sources of the dietary N; SBM as RDP, FM as RUP and urea as soluble NPN (Table 3). The diets were (1) CTN-control diet containing SPM and SBM, (2) USM diet containing SPM, SBM and urea, and (3) UFM diet containing SPM, FM and urea.

In the control diet (CNT) SBM provided most of the dietary crude protein (CP), while in the other two diets majority of the CP was as NPN in the form of urea and SPM and the rest of CP was either SBM (diet USM) or FM (diet UFM). All three diets were approximately isonitrogenous (2.7 to 2.8 g N/kg dry matter (DM)) and isocaloric (16 to 17 MJ gross energy/kg DM). Ammonium sulfate provided required dietary sulfur, while the vitamin–mineral premix (Vifosmin 2, Lazuli Sdn. Bhd., Kuala Lumpur, Malaysia) provided required dietary vitamins and minerals. The total mixed diets were prepared at approximately 2-weekly intervals and a small amount was taken from each mixed diet as a sample.

2.4. Digestibility—Experiment 2

Nine one-year old male sheep were shorn and randomly assigned to three treatment groups in a Latin square experiment with three diets (Table 3) and three periods replicated over three squares. Over 30 days prior to the start of the experiment the sheep were fed a sheep commercial diet (based on rice bran and SBM) and occasionally placed into metabolism crates for training. All sheep were weighed before the start of the experiment. The experiment consisted of three test periods, each of two weeks adaptation and 5 days collection of feces. Dietary rations were weighed and fed twice daily in equal portions at 08:30 and 16:30. Before feeding, all rations were mixed with 15% water by weight to prevent waste and dustiness. During the adaptation the amount of feed offered to individual sheep was adjusted to minimize refusals. The total fecal output was collected, weighed and sampled (10%) daily before the morning feeding. The feed intakes and refusals were recorded and sampled (10%) daily. Samples of feces, feed and refusals were accumulated in plastic bags. All samples were stored at −20 °C for chemical analysis.

2.5. Growth performance and carcass quality—Experiment 3

Twenty one approximately four months old male sheep were used in a feeding experiment lasting 91 days. The sheep were weighed and blocked into seven groups of three animals each in descending order of their initial weights. The sheep in each group were then randomly assigned to three dietary treatments based on a randomized block design (Cox, 1980) and fed the diet CNT, USM or UFM *ad libitum* in excess (10%) of individual intakes. Feed refusals were collected weighed and sampled each morning before feeding. Individual feed intakes were recorded daily. The sheep were allowed to adapt to the assigned experimental diet for two weeks prior to the start of the 91-day experiment. Thereafter they were sheared and weighed on two consecutive days after feed and water was withdrawn for overnight. The same shearing and weighing procedure was used at the end of the experiment. The average of the two consecutive weighing was considered as the initial or final live body weight. The sheep were also weighed monthly during the experiment.

After the end of the feeding experiment two heaviest sheep from each treatment were starved for 24 h, weighed and slaughtered (halal method). This procedure was repeated every 2 days until all lambs were slaughtered. Dead weights were recorded immediately after slaughter. Thereafter they were skinned, eviscerated and the heads and shanks removed. Each carcass was split into halves through the middle of the spine by an electric saw. The warm carcass weight was taken as the sum of the two halves, while the chilled carcass weight was the weight of the two halves after 24 h chilling at 4 °C. Other measurements made on the chilled carcass include the kidney fat, channel fat and the back fat thickness. The thickness was measured at the 12th rib incision of the left carcass side. The left side of the chilled carcass was manually separated into lean meat, bones, and subcutaneous and intramuscular fats (separable fats). The weights of these components were multiplied by two to obtain their estimated total weights in the whole carcass and to calculate the meat:bone ratio. The calculations were as follows:

$$\text{Dressing \%} = \text{hot carcass weight} \times \frac{100}{\text{starved live weight}}$$

$$\text{Renal–pelvic fat} = (\text{kidney fat weight} + \text{channel fat weight}) \times \frac{100}{\text{chilled carcass weight}}$$

For the right half of each carcass, about 3 cm slice of rib chop was taken as sample between the 10th and 12th rib, wrapped in aluminum foil to prevent formation of ice crystals, sealed in plastic bags and stored at −20 °C for analysis.

2.6. Chemical analysis

All samples of SPM, diets, refusals and feces were dried in an oven at 60 °C for 48 h and ground to pass 1 mm screen in a Wiley Mill (Model 4; Thomas Scientific, Swedesboro, NJ, USA). Analytical DM was determined by overnight drying at 103 °C. The samples were stored in air tight glass containers.

Concentrations of ash and organic matter (OM) (method no. 7.009), and ether extract (EE) (method no. 13.033) were determined according to AOAC (1984). The determination of fiber fractions, neutral detergent fiber (aNDFom) and acid detergent fiber (ADFom), without sodium sulfide and expressed free of ash was based on the procedure of Van Soest et al. (1991). However, it was noted that aNDFom extraction from SPM using normal strength aNDFom solution did not dissolve all the starch present, which caused difficulty in filtration. Therefore, the samples were pre-digested by incubation at 38 °C overnight in amylase (EC 3.2.1.1, Type I-A; Sigma, St Luis, USA) solution (1 ml enzyme suspension in 1 L of distilled water containing 3.56 g KH_2PO_4 and 7.22 g Na_2HPO_4 at pH 7.0). This was followed by digestion in a more concentrated aNDFom solution (Close and Menke, 1986). Determination of ADFom was similar to that for aNDFom; the ADFom digestion solution contained 11 N H_2SO_4 and 20 g acetylthrimethylammonium bromide. The lignin with ash residue left after ADFom procedure was ashed in a muffle furnace at 550 °C for 4 h to determine the concentration of acid insoluble ash (AIA). The concentration of the acid detergent lignin (ADL) was then calculated by subtracting AIA from the lignin with ash residue, while the concentration of cellulose was determined by subtracting the concentrations of hemicelluloses, ADL and AIA from the concentration of aNDFom. All the above procedures were sequential on the same samples. The starch concentration in

SPM samples was determined according to previously reported procedures (Woods and Aurand, 1976; Aurand et al., 1987). Crude protein was determined by micro-Kjeldahl procedure, while bomb calorimetry (Adiabatic Oxygen Bomb Calorimeter, Par Instrument Co., Moline, IL, USA) was used to determine gross energy.

For determination of mineral elements the SPM samples were digested in a solution comprising of 12 ml 65% HNO_3, 12 ml 70% $HClO_4$ and 1 ml 98% H_2SO_4. After appropriate dilution with deionized water the concentrations of Ca, Na, K, Fe, Cu, Co, Mn, Zn and Cd were determined using atomic absorption spectrophotometer (Shimadzu model AA-680, Kyoto, Japan). The concentration of phosphorus was determined colorimetrically using autoanalyzer (Technicon Instrument Co., Tarryton, NY, USA).

The rib chop samples were defrosted and prepared for EE based on the method no 13.033 of AOAC (1984). The meat was separated from the vertebral bone and minced in a blender. About 3 g of the meat was transferred in a previously tarred and dried cellulose extraction thimble containing a small portion of purified sand and glass rod. The sample was thoroughly mixed with the sand in the thimble by using the glass road, placed in a 50 ml beaker for drying at 125 °C for 1.5 h. Thereafter, crude lipids were extracted with ether in a Soxhlet apparatus (Narang Medical Limited, New Delhi, India).

2.7. Statistical analysis

Data from the 3 × 3 multiple Latin square design with three replicated squares (Experiment 2) were analyzed by general linear model procedure (SAS, 2004). Each cell was replicated with three animals over 5 day repeated measurements. The linear model used was as follows:

$$Yi_{jk1} = \mu + S_i + D_j + P_k + A_1 + (PA)_{jk} + \varepsilon_{i1k1}$$

where $i = 1, 2, 3$; $j = 1, 2, 3$; $k = 1, 2, 3$; $l = 1, 2, 3, \ldots 9$; Y_{ijkl} is the observed parameter for i-th square, j-th diet, k-th period and l-th animal; μ is the population mean; S_i is the effect of i-th square; D_j is the effect of j-th diet; P_k is the effect of k-th period; A_1 is the effect of l-th animal; $(PA)_{kl}$ is the interaction between k-th period and l-th animal; and ε_{ijkl} are all other influences on cell mean, including random experimental error and various components of any interactions that exist that are not accounted for in the other model terms.

The degrees of freedom for the squares, diet, period, animal and error term were 2, 2, 2, 8, and 122, respectively. When the main effects were significant the Bonferonni's multiple range test was used to evaluate differences among means; significance was declared at $P<0.05$. Except for the interaction between period and animal, no other two-way or three-way interactions were detected.

Data from the feeding experiment (Experiment 3) were analyzed according to randomized block design using general linear model:

$$Y_{ij} = B_i + D_j + \varepsilon_{ij}$$

where $i = 1, 2, 3, \ldots, 7$; $j = 1, 2, 3$; Y_{ij} is the observed parameter for diet j in block i; B_i is the mean yield for block i; D_j is the treatment effect on the observed parameter for diet j; and ε_{ij} represents the random unit variation within a block.

When the main effects were significant the Bonferonni's test was used to evaluate differences among means; significance was declared at $P<0.05$.

3. Results

3.1. Particle size distribution and chemical composition

The large rasping of split sago logs produced the largest percentage (62.3) of large size and smallest percentage (0.9) of fine size SPM particles (Table 1). The medium and small rasping produced very little of the large particles, but although the percentages of the medium and small particle sizes were similar, the small rasping produced a 3-fold less of the fine particles than the medium rasping. The chemical composition of the large, medium and small rasping SPM samples was similar. The concentration of starch in SPM showed the highest values (722–751 g/kg DM), followed by aNDFom (126–135 g/kg DM).

3.2. Digestibility

The apparent DM digestibility (Table 4) of the three experimental diets based on SPM (CNT, USM and UFM) was similar ($P>0.05$). However the digestibility of OM was higher ($P<0.05$) for the UFM diet than for the USM diet, but there was no difference between the CNT diet and the USM diet ($P>0.05$). There were differences ($P<0.05$) among the diets in the digestibility of CP, which ranked UFM > USM > CNT. The digestibility of aNDFom was not different ($P>0.05$) between the diets USM and UFM, but it was higher ($P<0.05$) for the diet CNT than for the other diets (USM and UFM). The digestibility of EE was lower ($P<0.05$) for the diet USM than for the diets CNT and UFM, while there was no difference ($P>0.05$) between the diets CNT and UFM.

Table 4
Apparent digestibility coefficients in sheep fed sago pith meal based diets supplemented with soybean meal (control; CNT), urea and soybean meal (USM), and urea and fish meal (UFM).

Item	CNT	USM	UFM	SEM
Dry matter	0.792	0.786	0.800	0.007
Organic matter	0.813^{ab}	0.807^{a}	0.829^{b}	0.006
Crude protein	0.680^{a}	0.711^{b}	0.753^{c}	0.010
Neutral detergent fiber	0.540^{a}	0.230^{b}	0.250^{b}	0.011
Ether extract	0.853^{a}	0.815^{b}	0.848^{a}	0.010

Means within rows followed with different superscript letters are statistically different (P<0.05).

Table 5
Growth performance of sheep fed sago pith meal based diets supplemented with soybean meal (control; CNT), urea and soybean meal (USM), and urea and fish meal (UFM).

Item	CNT	USM	UFM	SEM
Initial body weight (kg)	17.8	17.3	17.6	0.3
Final body weight (kg)	28.9^{a}	21.9^{b}	24.6^{b}	0.9
Total weight gain (kg)	11.1^{a}	4.6^{b}	7.0^{c}	1.0
Average daily gain (g)	122^{a}	50^{b}	77^{c}	11
Average daily feed intake (g)	763^{a}	543^{b}	608^{b}	40
Feed conversion ratio (g feed/g gain)	6.25^{a}	10.9^{b}	7.90^{ab}	0.85

Means within rows followed with different superscript letters are statistically different (P<0.05).

Table 6
Carcass composition of sheep fed sago pith meal based diets supplemented with soybean meal (control; CNT), urea and soybean meal (USM), and urea and fish meal (UFM).

Item	CNT	USM	UFM	SEM
Starved live weight (kg)	28.7^{a}	21.7^{b}	24.2^{c}	0.7
Hot carcass weight (kg)	16.0^{a}	11.3^{b}	12.6^{b}	0.4
Chilled carcass weight (kg)	15.6^{a}	11.0^{b}	12.2^{b}	0.4
Dressing (%)	55.7^{a}	52.1^{b}	52.1^{b}	0.9
Lean meat (kg)	8.8^{a}	6.4^{b}	6.8^{b}	0.3
Separable fat (kg)	2.7	1.9	2.5	0.3
Bone (kg)	3.3^{a}	2.6^{b}	2.9^{ab}	0.1
Meat:bone ratio	2.7	2.5	2.3	0.1
Back fat (mm)	4.2	3.3	3.2	0.4
Renal–pelvic fat (g)	650^{a}	316^{b}	447^{ab}	67
Deboned rib cut EE (g/kg DM)	650^{a}	570^{b}	670^{a}	20

EE, ether extract.
Means within rows followed with different superscript letters are statistically different (P<0.05).

3.3. Growth performance

The average initial body weight of sheep was not different (P>0.05) among the dietary treatments (Table 5). However, the average final body weight, total weight gain, daily gain and daily feed intake were all higher (P<0.05) for the diet CNT than for the diets USM and UFM. There was no difference (P>0.05) between the diet USM and UFM in the average final body weight, but the total weight gain and average daily gain were higher (P<0.05) for the diet UFM than for the diet USM. However, the feed conversion ratio was higher (P<0.05) for the diet USM than for the diet CNT, but there were no differences (P>0.05) between the diets CNT and UFM and between the diets USM and UFM.

3.4. Carcass composition

There were no differences (P>0.05) among the experimental diets in the separable fat, meat:bone ratio and back fat (Table 6). There were though differences (P<0.05) in the starved live weight among the diets, which ranked CNT > UFM > USM. However, the hot carcass weight, chilled carcass weight, dressing percentage and lean meat were higher (P<0.05) for the diet CNT than for the diets USM and UFM, but there were no differences (P>0.05) between the diets USM and UFM. The renal–pelvic fat was higher (P<0.05) for the diet CNT than for the diet USM, but there were no differences (P>0.05) between the diets CNT and UFM and between the diets USM and UFM. The deboned rib cut EE was lower (P<0.05) for the diet USM than for the diets CNT and UFM, but there were no differences between the diets CNT and UFM.

4. Discussion

The results on the SPM particle size distribution from different rasping sizes clearly showed that for ruminant feeding the use of the small rasping of sago logs produced the best type of SPM. This is because the small rasping produced a negligible amount of large particles and lower amount of fine particles in comparison with the medium rasping. Although the large rasping also produced a negligible amount of fine particles it also produced a very large amount (62%) of large size particles that affect normal passage from the rumen (Faichney and Brown, 1991). Reduced size of corn grain increased daily gains (Galyean et al., 1979; Turgeon et al., 1983) and starch digestibility (Ouellet et al., 2010) in finishing steers. On the other hand, fine size particles were found to produce lumps in the stomach of pigs, which did not permit good penetration and mixing with digestive substances, resulting in a lower digestibility of the diet (Ivan and Farrell, 1976). Also, too fine grinding of corn grain had negative effects on daily gains and feed conversion efficiency in finishing steers (Corona et al., 2005). Clearly, the feed particle size dynamics affects the nutritive value of feeds in ruminants (Murphy and Kennedy, 1993) and the size of rasping did not appreciably affect the chemical composition of SPM in the present study (Experiment 1). Therefore the small rasping preparation of SPM appears to be the most suitable as ruminant feed and was selected for the follow-up experimental work with sheep in the present study (Experiments 2 and 3).

The CNT diet comprised of approximately two thirds SPM and one third SBM, and resulted in a reasonably good growth performance (gain, feed intake and feed:gain ratio) of sheep. However, when approximately 76% of the SBM portion in the CNT diet was replaced by an equivalent amount of N in the form of NPN (urea; diet USM) and increased amount of SPM the growth performance of sheep decreased. This was in spite of approximately the same apparent digestibility of DM and OM in the two diets. It is though interesting to note that the digestibility of aNDFom and the feed intake of lambs fed the USM diet decreased. Although the feed palatability might have been negatively affected somewhat by the extra dietary SPM and the urea supplement, the lower digestibility of aNDFom was most probably responsible for the lower feed intake. This is in agreement with the suggestion of Leng (1990) that the voluntary feed intake may be stimulated by higher digestibility. This would indicate that the rumen microbial activity was negatively affected by the increased dietary SPM and urea supplement, resulting in the lower digestibility of aNDFom and increased rumen fill in the present experiment. A lower feed intake and growth of goats was reported when SPM replaced 60% of a commercial concentrate diet (Tuen, 1994). However the dietary SPM had a positive effect on the nutrient utilization, while the growth performance and digestibility was not affected when SPM replaced corn grain in the diet of cattle (Chanjula and Ngampongsai, 2009; Ngampongsai and Chanjula, 2009).

The replacement of SBM in the diet USM with FM (diet UFM *vs* diet USM) resulted in only a small improvement in the growth performance of sheep. In addition to poorer growth performance and digestibility there was also indication for poorer carcass composition in sheep fed urea in combination with SBM or FM (diets USM and UFM *vs* diet CNT). This was especially so in the case of dressing percentage and lean meat yield. It therefore appears that although the level of N in the form of ammonia available to rumen bacteria might have been adequate for all three diets, there was probably shortage of available amino acid/peptide N for maximal growth of bacteria in sheep fed the diets USM and UFM. In addition, SPM contains high percentage of rumen fermentable starch that would contribute to higher rate of energy release in the rumen. A greater amount of available energy in the rumen leads to a requirement for more RDP (Cooper at al., 2002). Rooke and Armstrong (1989) drew attention to the importance of a supply of RDP, such as casein, rather than NPN, such as urea, in stimulating rumen microbial N synthesis. Indeed Satter and Armstrong (1975) pointed out that dietary urea is rapidly hydrolyzed in the rumen, but rumen carbohydrate degradation and microbial growth is slower process than the releasing of ammonia N, thus, urea is inefficiently used by microorganisms. Also, it was reported (Chen et al., 1987) that rumen bacteria have a preference for peptide N, which might be supplied by RDP. A sufficient amount of RDP must be present in the diet to support maximum bacterial growth yield and fermentation in the rumen (Ivan et al., 1996). It is apparent that the supplements of urea with SBM or FM have not fulfilled this requirement in the present experiment. Additional research is conducted in this laboratory to gain more information on the effects of the present SPM based diets on rumen fermentation, microbial synthesis of protein and duodenal flow of the dietary components.

5. Conclusion

A properly prepared SPM appears to be acceptable source of the dietary energy for ruminants and the small rasping size is most appropriate for its preparation from the sago logs. Such preparation results in good distribution of sizes of particles, without excessive amounts of large and fine particles that negatively affect digestion of the diet by ruminants.

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