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Effects of Sago Palm Pith as Replacement for Corn Grain on Intake, Rumen Fermentation Characteristics and Microbial N Supply of Cattle Fed *Paspalum plicatulum* Hay

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ABSTRACT : To investigate the effects of sago palm pith (SPP) substitution of corn in the diets on intake, digestibility, rumen fermentation characteristics, nitrogen balance and microbial N Supply, five ruminally fistulated Southern indigenous cattle (mean initial BW = 226±5 kg) were randomly assigned to a 5×5 Latin Square Design to receive five diets, T_1 = concentrate with 0% SPP, T_2 = 25% SPP, T_3 = 50% SPP, T_4 = 75% SPP and T_5 = 100% SPP, of dietary dry matter, respectively. Plicatulum hay (PH) was offered *ad libitum* as the roughage. A metabolism trial lasted for 21 days during which liveweight changes and feed intakes were measured. Based on this experiment, there were no significant differences ($p>0.05$) among treatments groups regarding total DM intake (OMI, NDFI and ADFI) and digestion coefficients of nutrients (DM, OM, CP, NDF and ADF), while total DM intake (% BW) was significantly ($p<0.05$) higher as higher levels of SPP were incorporated into diets. Rumen parameters (ruminal temperature, pH, glucose, packed cell volume, volatile fatty acid and rumen microorganism populations) were similar among treatments ($p>0.05$), whereas NH_3-N, blood urea nitrogen and molar proportion of propionate concentrations were significantly ($p<0.05$) higher as higher levels of SPP were incorporated into diets. The amount of N absorption, N retention and microbial protein synthesis were similar among treatments. These results indicate that SPP can be included in diets for Southern indigenous cattle to supply up to 100% of supplemental corn when fed with PH without negative impact on animal performance and it was a good approach in exploiting the use of local feed resources for beef cattle production. (**Key Words :** Sago Palm Pith, Corn, Rumen Fermentation, Southern Indigenous Cattle, Microbial N Supply)

INTRODUCTION

Persistent shortages of conventional feedstuffs for livestock feeding in the developing countries are caused largely by inadequate production of farm crops to meet the needs both of humans and of their domestic animals. As a result, this increases feed costs when feedstuffs are dependent on imported materials. This has forced animal nutritionists to intensify research into the feeding values of potentially useful but unconventional crop products to replace more expensive ingredients, such as corn grain and soybean meal. One of these is sago palm (*Metroxylon sagu*) which is abundantly available and is widespread in south-east Asia and Oceania (FAO, 1983). The sago palm contributes to the socio-economic activity of the equatorial swamplands. In swampy areas of Thailand, the sago palm is a local plant and can be found in many areas in the southernmost provinces like Nahkonsirthommarat, Phathalung, Songkhla, Pattani, Yala and Narathiwas. The most important product of sago and by-products from sago palm includes sago palm pith (SPP), sago starch (SS) which is extracted from the SPP, and residued sago palm pith (RSPP) or sago fiber, a by-product of sago starch extraction.

SPP can be processed into dried form rich in metabolizable energy (3.57 kcal/kg ME) (Rizal et al., 1996) which consists of highly digestible carbohydrate 51-92% (FAO, 1983), but is low in crude protein (0.21-3.3% CP) and mineral content (Yadav and Mahyuddin, 1991; Tuen, 1992). The meal is very digestible and can be fed to all classes of livestock. It has been included up to 50% in pig diets and 25% in poultry diets (Anonymous, 2006). Sundried SPP pith contains 1.0% of crude protein (CP), 23.1% of neutral detergent fiber (NDF) and 7.1% of acid detergent fiber (ADF) (Tuen, 1992).

However, the responses to SPP, which is highly degradable in the rumen, have not been extensively studied in beef cattle. Therefore, this present study was conducted

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to evaluate the effects of SPP inclusion into diets based on Plicatulum hay upon feed intake, nutrient utilization, rumen fermentation characteristics, nitrogen balance and microbial N supply of Southern indigenous cattle.

MATERALS AND METHODS

Animals and experimental diets

Five, ruminally fistulated male Southern indigenous cattle (approximately 24 months old) averaging 226±5 kg (mean initial BW) were randomly assigned to dietary treatments according to a 5×5 Latin square design to study the effects of SPP inclusion into the diets on feed intake, digestibility, ruminal fermentation, blood metabolites, microbial populations, nitrogen balance and microbial N Supply. Five experimental diets were formulated to contain SPP as shown in Table 1. The dietary treatments were; Control T_1 = concentrate containing SPP at 0%; T_2 = SPP at 25%; T_3 = SPP at 50%; T_4 = SPP at 75% and T_5 = SPP at 100%.

All cattle were drenched for internal worms (Ivermectin, IDECTIN®, The British Dispensary, Co., Ltd.) and injected with vitamins A, D_3 and E prior to commencing the experiment. Each animal was housed individually in a 4×7 m pen where water and mineral salt were available at all times. During each period, all animals received a concentrate diet at 2% BW (DM basis) and were allowed to consume Plicatulum hay (PH, *Paspalum plicatulum*, Michx.) *ad libitum*, allowing for 10% refusals. Feeds were provided twice daily in two equal portions at 0800 and 1600 daily. Feed refusals were weighed and recorded daily at 0700. Plicatulum hay samples were bulked by pen and dried at 60°C, and subsamples were used for dry matter determinations. This information was used to calculate Plicatulum hay (PH) intake. Feed samples obtained each time were oven dried at 60°C for 72 h and ground to pass through a 1-mm sieve, and composited by period on an equal weight basis for further analysis. Cattle were weighed at the beginning of each experimental period before the morning feeding.

Sampling techniques

Each experimental period lasted for 21 days; the first 15 days as a period for treatment adaptation and for feed intake measurements while the last 6 days were used to measure digestibility using the total collection method. This comprised of 5 days of total collection of feces and urine, followed by 1 day of rumen fluid and blood collection. At

Table 1. Ingredients and chemical composition of the experimental diets, plicatulum hay and sago palm pith (DM basis)

Replaced corn meal (%)	Sago palm pith (SPP) levels in concentrate (%)[1]					Plicatulum hay	SPP
	T1(0)	T2(25)	T3(50)	T4(75)	T5(100)		
Sago palm pith levels	0.0	13.0	27.0	40.5	54.0		
Ingredients composition (% DM)							
Palm cake kernel (PCK)	36.76	35.45	30.10	25.51	21.87	-	-
Soybean meal (SBM)	-	-	5.02	10.00	12.88	-	-
Ground corn (GC)	54.00	40.50	27.00	13.50	-	-	-
Sago palm pith (SPP)	-	13.50	27.00	40.50	54.00	-	-
Urea	0.92	1.46	1.50	1.50	1.75	-	-
Molasses	2.00	2.00	2.00	2.00	2.00	-	-
Salt	1.00	1.00	1.00	1.00	1.00	-	-
Dicalcium phosphate	1.00	1.00	1.00	1.00	1.00	-	-
Sulfur	0.50	0.50	0.50	0.50	0.50	-	-
Oil plant	2.82	3.59	3.88	3.49	4.00	-	-
Mineral mix [2]	1.00	1.00	1.00	1.00	1.00	-	-
Chemical composition							
DM [3]	89.64	89.45	89.37	88.91	88.90	91.70	86.08
Ash	5.38	5.38	5.87	6.62	6.96	7.99	3.83
OM	94.62	94.42	94.13	93.38	93.04	90.01	96.17
CP	13.45	13.90	13.49	14.09	14.19	3.62	1.44
EE	8.61	8.20	8.19	6.70	6.43	0.74	0.12
NSC [4]	36.80	35.03	38.84	38.27	36.37	6.27	75.34
NDF	35.96	37.49	33.71	34.02	35.60	81.38	19.51
ADF	20.97	21.03	21.00	21.69	19.44	50.02	12.88
Gross energy (kcal/kg DM)	-	-	-	-	-	3.94	3.64

[1] T_1 = Level of SPP 0%, T_2 = Level of SPP 25%, T_3 = Level of SPP 50%, T_4 = Level of SPP 75%, T_5 = Level of SPP 100%.

[2] Minerals and vitamins (each kg contains): Vitamin A: 10,000,000 IU; Vitamin E: 70,000 IU; Vitamin D: 1,600,000 IU; Fe: 50 g; Zn: 40 g; Mn: 40 g; Co: 0.1 g; Cu: 10 g; Se: 0.1 g; I: 0.5 g.

[3] DM = Dry matter; OM: Organic matter; CP = Crude protein; EE = Ether extract; NSC = Non structural carbohydrate; NDF = Neutral detergent fiber; ADF = Acid detergent fiber.

[4] Estimated: NSC = 100-(CP+NDF+EE+Ash).

the end of each period, ruminal fluid was sampled from cattle before the morning feeding and at 4 h after feeding. Approximately 150 ml of rumen fluid was taken from the ventral rumen via the cannula using a 60-ml hand syringe at the end of each period. Rumen fluid was immediately measured for pH and temperature using a portable pH and temperature meter (Orion Research portable meter 200 series, USA) after withdrawal. Rumen fluid samples were then filtered through four layers of cheesecloth. Samples were divided into two portions. One portion was used for NH_3-N and VFA analyses where 5 ml of H_2SO_4 solution (1 M) were added to 50 ml of rumen fluid. The mixture was centrifuged at 16,000×g for 15 min and supernatant stored at -20°C prior to NH_3-N and VFA analyses. Another portion was fixed with 10% formalin solution in normal saline (0.9% NaCl) (Galyean, 1989). The total direct count of bacteria, protozoa and fungal zoospores was made using the methods of Galyean (1989) based on the use of a haemacytometer (Boeco) under a light microscope (Olympus BX51TRF, No. 2B04492, Olympus Optical Co. Ltd., Japan). Blood Samples (about 10 ml) were collected via the jugular vein into heparinized tubes at the same time as rumen fluid sampling (0 and 4 h after feeding). Then blood samples were centrifuged at 4°C at 3,300×g for 15 min and supernatants were separated and frozen at -20°C until analysis.

Laboratory analyses

Feed orts and feces samples were analyzed in duplicate for DM, ash, CF, ether extract and Kjeldahl N was determined according to AOAC (1999) procedures. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) fractions were determined with the procedure of Goering and Van Soest (1970). Digestion coefficients were calculated using the formula given by Schneider and Flatt (1975). Blood urea nitrogen (BUN) was determined according to the method of Crocker (1967), ruminal NH_3-N using the micro kjeldahl method (AOAC, 1999), and volatile fatty acid (VFAs) analyses using a HPLC (Instruments by controller Waters model 600E; Waters model 484 UV detector; column novapak C_{18}; column size 4 mm×150 mm; mobile phase 10 mM H_2SO_4 (pH 2.5), ETL Testing Laboratory, Inc., Cortland, New York, 13045, USA) according to Samuel et al. (1997). Plasma glucose and packed cell volume (PCV) were measured by commercial kits (No. 640, Sigma Chemical Co., St. Louis, USA). Urine samples were analyzed for urinary nitrogen (IAEA, 1997) and allantoin in urine was determined by HPLC (Instruments by controller Waters model 600E; Waters model 484 UV detector; column novapak C_{18}; column size 4 mm×150 mm; mobile phase 10 mM H_2PO_4 (pH 2.5), ETL Testing Laboratory, Inc., Cortland, New York, 13045, USA) as described by Chen et al. (1993).

The amount of microbial purines absorbed (X mmol/day) corresponding to the purine derivatives excreted (Y mmol/day) was calculated based on the relationship derived by Chen and Gomes (1995).

$$Y = 0.85X+(0.385W^{0.75})$$

where Y is the excretion of purine derivatives (mmol/day); X is the microbial purines absorbed (mmol/day). The supply of microbial N in gram per day was estimated as follows:

$$\text{Microbial N (g/day)} = \frac{X \times 70}{0.116 \times 0.83 \times 1{,}000} = 0.727 \times X$$

with X being the absorption of purine derivatives in mmol per day, following the assumptions made by Chen and Gomes (1995).

Digestibility of microbial purine is 0.83.

The N content of purines is 70 mg N/mmol.

The ratio of purine-N: total N in mixed rumen microbes is 11.6:100.

The efficiency of microbial nitrogen synthesis (EMNS) to denote the microbial N supplied to the animal per unit of DOMR was calculated using the following formula:

$$\text{EMNS} = \frac{\text{MN (g/day)} \times 1{,}000\text{ (g)}}{\text{DOMR (g)}}$$

where DOMR = DOMI×0.65 (ARC, 1990), DOMR = digestible organic matter apparently fermented in the rumen and DOMI = digestible organic matter intake.

Statistical analyses

Statistical analyses were conducted using the GLM procedure of SAS (SAS Inst. Inc., Carry, NC). The model used was: $Y_{ijk} = \mu+A_i+P_j+T_k+\varepsilon_{ijk}$, where Y_{ijk} is observation from animal i, receiving diet k, in period j; μ, the overall mean, A_i, the effect of animal (i = 1 to 5); P_j, the effect of period (j = 1 to 5), T_k, the mean effect of SPP level (k = 1 to 5); and ε_{ijk}, the residual effect. Treatment means were statistically compared using Duncan's Multiple Range Test (DMRT) (Steel and Torrie, 1980) to identify differences between means. Significance was declared at $p<0.05$.

RESULTS AND DISCUSSION

Chemical composition of feeds

The ingredient and chemical compositions of roughage, SPP and experimental feeds are shown in Table 1. The five experimental diets contained similar concentrations of DM,

Table 2. Effect of sago palm pith substitution for ground corn on feed intake and apparent digestibility in Southern indigenous cattle fed on plicatulum hay as roughage

Attribute	Sago palm pith (SPP) levels in concentrate (%)[1]					SEM
	T1(0)	T2(25)	T3(50)	T4(75)	T5(100)	
Sago palm pith levels (DM basis)	0.0	13.0	27.0	40.5	54.0	
DMI (kg/d)						
Plicatulum hay (kg/d)	1.35	1.26	1.26	1.23	1.37	0.15
Concentrate (kg/d)	3.32	3.38	3.39	4.09	4.21	0.30
Total DMI (kg/d)	4.67	4.65	4.65	5.32	5.58	0.38
DMI (% BW)	1.92^{b}	1.93^{b}	2.02^{ab}	2.25^{ab}	2.28^{a}	0.10
DMI (g/kg $W^{0.75}$)	75.98	76.12	78.71	88.19	89.67	4.50
OMI (kg/d)	4.38	4.36	4.52	4.95	5.02	0.31
NDFI (kg/d)	2.29	2.30	2.21	2.39	2.48	0.21
ADFI (kg/d)	1.38	1.34	1.37	1.50	1.42	0.09
Apparent digestibility (%)						
DM	65.03	63.75	62.35	67.73	67.92	2.58
OM	67.36	66.17	64.54	70.06	70.76	2.59
CP	62.58	63.25	61.43	66.44	67.95	2.81
NDF	57.92	55.24	51.18	56.20	56.64	3.30
ADF	45.01	42.54	40.16	44.64	36.61	3.83
Estimated energy intake[2]						
ME Mcal/d	11.18	10.86	11.33	13.17	13.48	0.97
ME Mcal/kg DM	2.40	2.35	2.29	2.47	2.49	0.09

[1] T_1 = Level of SPP 0%, T_2 = Level of SPP 25%, T_3 = Level of SPP 50%, T_4 = Level of SPP 75%, T_5 = Level of SPP 100%.

[2] 1 kg DOM = 3.8 Mcal ME/kg (Kearl, 1982).

[a-b] Value within rows not sharing a common superscripts are significantly different ($p<0.05$). SEM = Standard error of the mean (n = 5).

ash, OM, CP and ADF, but varying amounts of NSC and NDF. The concentrates ranged in CP concentration from 13.45 to 14.19% of DM basis. The differences among concentrate mixed diets in NSC, ether extract (EE), fiber components and ash concentrations can be related to differences in the ingredients used in diet formulation (Table 1).

Average chemical composition of plicatulum hay (PH) contained 3.62% CP, 81.38% NDF, and 50.02% ADF (DM basis). Similar values for PH have been previously reported by Humphreys (1980). The SPP was low (1.44% CP) and high in OM (96.17%) and NSC (75.34%) contents. The CP content in SPP in this study was similar to that reported by Yadav and Mahyuddin (1991); Tuen (1992) who found that SPP and sago residue (by-product of starch extraction) contained 1.0-3.2% CP, but its OM content was high (99.79%).

Effect on feed intake and apparent digestibility

The effects of SPP substitution of corn in the diets on feed intake and apparent digestibility of Southern indigenous bulls are presented in Table 2. Overall mean feed intakes for the five diets in terms of roughage, concentrate and total DMI (%BW g/kg $BW^{.75}$), OMI, NDFI and ADFI were not significantly affected for all dietary treatments as compared between the experimental diets (25-100% SPP) with the control diet, and the values tended to dramatically increase as levels of SPP increased in the diets. The data indicate that inclusion of SPP replacing corn at a rate of up to 100% had no effect on feed intake for Southern indigenous cattle. These data support earlier work (Tuen, 1992) in which it was reported that inclusion of rasped sago pith in diets resulted in satisfactory animal performance and no negative effects on animal health in goats and lambs (Yadav et al., 1991). The DMI results presented from our indigenous cattle trial (Table 2) were similar to those of Chanjula et al. (2007), who replaced corn with cassava chip in diets for goats and dairy cattle (Sommart et al., 2000; Kanjanapruthipong et al., 2001). Cassava chip is considered a good source of soluble carbohydrate. However, when compared among groups of SPP inclusion, beef cattle fed 100% SPP had greater ($p<0.05$) DMI (% BW) compared with 25% SPP.

Apparent digestibilities (%) of DM, OM, CP, NDF and ADF were not affected ($p>0.05$) for all diets, whilst apparent digestibilities of NDF and ADF when feeding corn-based diets tended to be greater in NDF and ADF digestibility as compared to diets in which SPP replaced corn, but the difference was not statistically significant. Previous reports (Hoover, 1986) have suggested that providing a source of more degradable carbohydrate can result in a substantial decrease in ruminal pH and fiber digestibility, thus reducing feed intake. Moreover, it is possible that low digestibility could have been attributed to a high fibrous fraction (ADL) (Hart and Wanapat, 1992; Wanapat, 2000), especially the large proportion of lignified

cell walls with low fermentation rate and digestibility, leading to a low rate of disappearance through digestion or passage and limited feed intake. Nevertheless, ME (Mcal/d) and ME (Mcal/kg DM) of host energy metabolism were not affected ($p>0.05$) by dietary treatments. In contrast, high DMI, especially for diets containing more digestible fiber, are usually associated with decreased total tract nutrient digestibilities caused by a reduced ruminal retention time and therefore an increased passage rate. Oba and Allen (1999) indicated that forages with high *in situ* or *in vitro* digestibilities might have a shorter retention time, allowing greater DMI at the expense of total tract NDF digestibility. It is also possible that beef cattle fed the corn diets had greater post-ruminal fermentation than beef cattle fed the SPP diet to compensate for reduced ruminal fiber degradability. Total tract fiber digestibility, however, was not influenced ($p>0.05$) by dietary treatments (Table 2).

Rumen fermentation patterns and blood metabolites

Rumen parameters were measured for temperature, pH, NH_3-N and BUN. The pattern of ruminal fermentation at 0 and 4 h post feeding and overall means are given in Table 3. Rumen temperatures were similar among treatments and the values were quite stable at 39.0-39.6°C, but all treatment means were within the normal range which has been reported as optimal for microbial digestion (France and Siddons, 1993; Van Soest, 1994; Firkins, 1996). Rumen fluid pH at 0 and 4 h post feeding was unchanged by dietary treatments in this study, indicating no specific effect of the inclusion of SPP, while at 4 h after the onset of feeding, rumen pH of beef cattle declined as active fermentation of the newly ingested feed occurred. At this time, the pH values ranged from 6.2-6.4, but all treatment means were within the normal range and the values were quite stable at 6.4-6.6. Similar values for pH have been previously reported by Khampa et al. (2006) and Wanapat and Khampa (2007), which were optimal for microbial digestion of fiber (Hoover, 1986) and also digestion of protein (6.0-7.0). According to the review by Ørskov (1986), cows with rumen fluid of pH above 5.8 are considered normal, while those between 5.0 and 5.8 may be suffering from subclinical acidosis. The relatively high rumen fluid pH observed in our study suggests that beef cattle were not likely suffering from subclinical acidosis.

Ruminal NH_3-N at 4 h post feeding was similar among treatments, except at 0 h post feeding and overall means were affected ($p<0.05$) by treatments, ranging from 4.0 to 6.6 and 3.5 to 5.5 mg/dl, respectively, and were

Table 3. Effect of sago palm pith substitution for ground corn on rumen fermentation and blood metabolized characteristics in Southern indigenous cattle fed on plicatulum hay as roughage

Attribute	Sago palm pith (SPP) levels in concentrate (%)[1]					SEM
	T1 (0)	T2 (25)	T3 (50)	T4 (75)	T5 (100)	
Sago palm pith levels, DM basis	0.0	13.0	27.0	40.5	54.0	
Temperature (°C)						
0 h-post feeding	39.0	39.2	39.0	39.2	39.2	0.15
4	39.6	39.4	39.2	39.2	39.6	0.25
Mean	39.3	39.3	39.1	39.2	39.4	0.15
Ruminal pH						
0 h-post feeding	6.8	6.7	6.7	6.9	6.7	0.13
4	6.2	6.3	6.2	6.4	6.3	0.14
Mean	6.5	6.5	6.4	6.6	6.5	0.12
NH_3-N (mg/dl)						
0 h-post feeding	4.0^{c}	4.9^{bc}	5.0^{abc}	6.6^{a}	5.7^{ab}	0.48
4	3.0	3.0	3.6	4.4	4.6	0.55
Mean	3.5^{b}	3.9^{b}	4.3^{b}	5.5^{a}	5.3^{a}	0.32
BUN (mg/dl)						
0 h-post feeding	5.3^{b}	5.9^{b}	6.8^{ab}	8.6^{ab}	9.6^{a}	0.99
4	7.5^{b}	7.4^{b}	9.3^{ab}	10.7^{a}	11.7^{a}	0.84
Mean	6.4^{b}	6.6^{b}	8.0^{ab}	9.6^{a}	10.6^{a}	0.88
Glu (mg/dl)						
0 h-post feeding	65.0^{b}	63.4^{b}	61.8^{b}	62.0^{b}	68.4^{a}	1.05
4	64.6^{ab}	66.6^{ab}	64.8^{ab}	63.0^{b}	68.4^{a}	1.59
Mean	64.8^{ab}	65.0^{ab}	63.3^{b}	62.5^{b}	68.4^{a}	1.34
PCV (%)						
0 h-post feeding	32.8	32.0	32.8	32.4	30.6	1.21
4	33.2	31.8	33.0	32.4	32.6	1.69
Mean	33.0	31.8	32.9	32.4	31.6	1.34

[1] T_1 = Level of SPP 0%, T_2 = Level of SPP 25%, T_3 = Level of SPP 50%, T_4 = Level of SPP 75%, T_5 = Level of SPP 100%.

[a-b] Values within rows not sharing a common superscripts are significantly different ($p<0.05$). SEM = Standard error of the mean (n = 5).

dramatically increased by diets containing SPP as compared with a corn-based diet (Table 3). Likewise, BUN concentrations were significantly ($p<0.05$) higher as higher levels of SPP were incorporated into diets, ranging from 6.4 to 10.6 mg/dl. The BUN prior to morning feeding of the beef cattle tended to be lower than that at 4 h post feeding. The results agreed with Eggum (1970b) who reported that urea content in the blood reached a maximum 3 h after feeding. The increases in rumen NH_3-N levels also resulted in increasing levels of BUN. Previous studies (Preston et al., 1965; Lewis, 1975) have reported that concentrations of BUN are highly correlated to protein intake and reflect the level of ammonia production in the rumen. This would indicate that available rumen NH_3-N could be used and/or absorbed in the rumen for further synthesis. Differences in NH_3-N concentration between dietary treatments were likely due to the addition of urea to the SPP diet (Table 1). Concentration of ruminal NH_3-N is usually increased when diets of lactating cows are supplemented with urea (Cameron et al., 1991). Nevertheless, NH_3-N and BUN concentrations in all animals were within acceptable physiological ranges and would be adequate for ruminal microbial growth and fermentation (Satter and Slyter, 1974) and likely to vary with species and diet.

Blood glucose and packed cell volume (PCV) were similar ($p>0.05$) among dietary treatments, except for T_3 and T_4 (50 and 75% SPP) which had the lowest ($p<0.05$) blood glucose, but all treatments were within the normal range of 60 mg/dl (Benjamin, 1978; Fahey and Berger, 1988); likewise Kaneko (1989) stated that normal glucose concentrations range from 50 to75 mg/dl (2.77 to 4.16 m*M*). Based on this study, these data indicate that the inclusion of SPP-based diets did not affect blood glucose and PCV. They also showed energy status was positive. West (1996) reported that serum glucose has been shown to increase on a high energy diet, while it dramatically decreases in starvation and on a low energy diet.

Volatile fatty acid profiles and rumen microorganism populations

The effect of SPP substitution of corn in the diets on production of total VFA concentration, acetic acid proportion, propionic and butyric acid concentrations and acetic to propionic ratio are shown in Table 4. Overall means of total VFAs and C_2 and C_4 concentrations in the rumen were not different ($p>0.05$) among dietary treatments. Meanwhile, the concentration of propionic acid was slightly higher in diets with SPP inclusion as compared with corn-based diets; this may be possibly because of greater degradation of starch in these diets. This data was in accordance with the reports by Sutton et al. (1993) that increasing the readily degradable starch content of the concentrate resulted in higher rumen propionate concentrations and decreased rumen acetate production, which in turn could have been caused by low ruminal NH_3-N and the inhibition of fiber fermentation (Van Soest, 1994). The increased proportion of propionate in ruminal fluid accompanied by no change in acetate across treatments explained the decrease in the A:P ratio (Table 4). Moreover, Onetti et al. (2001) found that adding fat caused a trend for declines in total VFA and that the A:P ratio declined because of decreased acetate and increased propionate proportions as fat increased from 2 to 4% in dairy cow diets, because fat supplied in ruminant diets often has a negative effect on fiber digestion (Zinn, 1989b). This effect is more marked with polyunsaturated fatty acids (Palmquist and Jenkins, 1980; Sutton et al., 1983). However, In this study, the total VFA concentration in all diets was present at normal concentrations of 70-130 m*M*, the range suggested by France and Siddons (1993). Moreover, the acetate to propionate ratio was similar ($p>0.05$) among dietary treatments as compared with corn-based diets. Although the acetate to propionate ratio tended to be slightly lower by inclusion of SPP in diets, the replacement of corn increased the daily output of propionate without decreasing ($p>0.05$) the production of acetate.

As shown in Table 4, populations of rumen microbes (bacteria, protozoa and fungal zoospores) were variable and were not affected ($p>0.05$) by treatments, although overall protozoal populations tended to be slightly lower by inclusion of SPP in diets, but the difference was not statistically significant ($p>0.05$). The presence of protozoa in the rumen can also affect rumen fermentation of starch. This agrees with the finding of Jouany and Ushida (1999) who reported that the number of protozoa per ml rumen fluid depends on the level of soluble sugars and starches in the ration and also on the pH.

Nitrogen utilization and urinary excretion of purine derivatives and EMNS

Whole body N data are presented in Table 5. Total N intake in this study was affected ($p<0.05$) by treatments, ranging from 78.09 to 104.94 g/d, and was dramatically increased by diets containing SPP as compared with a corn-based diet (Table 5). This trend may be related to DMI and CP digestibility of Southern indigenous cattle fed diets containing SPP as compared with a corn-based diet. No differences in fecal N excretion were observed among treatments, whilst urinary N and total N excretion increased linearly ($p<0.05$) as the proportion of SPP increased in the diet (Table 5). This pattern of fecal and urinary excretion is indicative of the extremely high N intake for Southern indigenous cattle fed diets containing SPP. This could be explained by the fact that excess ruminal NH_3-N is

Table 4. Effect of sago palm pith substitution for ground corn on volatile fatty acid profiles in Southern indigenous cattle fed on plicatulum hay as roughage

Attribute	Sago palm pith (SPP) levels in concentrate (%)[1]					SEM
	T1 (0)	T2 (25)	T3 (50)	T4 (75)	T5 (100)	
Sago palm pith levels (DM basis)	0.0	13.0	27.0	40.5	54.0	
Total VFA (mmol/ L)						
0 h-post feeding	134.7	93.6	103.8	121.7	131.5	18.76
4	128.9	122.8	137.3	119.8	146.3	15.16
Mean	131.8	108.2	120.5	120.7	138.9	15.50
Molar proportion of VFA (mol/100 mol)						
Acetate (C_2)						
0 h-post feeding	64.4	64.7	61.2	64.6	62.0	1.12
4	64.1	64.1	62.4	63.9	63.3	1.33
Mean	64.2	64.4	61.8	64.3	62.6	0.88
Propionate (C_3)						
0 h-post feeding	29.5^{ab}	27.7^{b}	29.9^{ab}	30.4^{ab}	31.5^{a}	1.09
4	29.4	27.9	30.3	30.5	29.90	0.96
Mean	29.5^{ab}	27.8^{b}	30.1^{ab}	30.4^{a}	30.7^{a}	0.77
Butyrate (C_4)						
0 h-post feeding	6.1	7.6	8.8	5.1	6.4	1.25
4	6.5^{ab}	7.9^{a}	7.3^{ab}	5.5^{b}	6.8^{ab}	0.68
Mean	6.3^{ab}	7.8^{ab}	8.1^{a}	5.2^{b}	6.6^{ab}	0.83
C2:C3 ratio						
0 h-post feeding	2.2^{ab}	2.4^{a}	2.1^{ab}	2.2^{ab}	2.0^{b}	0.10
4	2.2	2.3	2.1	2.3	2.1	0.18
Mean	2.2	2.3	2.1	2.2	2.1	0.08
Total direct count						
Bacteria ($\times 10^{10}$ cell/ml)						
0 h-post feeding	3.30	2.80	3.10	3.80	3.50	0.52
4	4.50	4.1	4.50	4.60	5.30	1.23
Mean	3.90	3.45	3.80	4.20	4.40	0.85
Total Protozoa ($\times 10^{6}$ cell/ml)						
0 h-post feeding	2.28	1.44	1.47	1.81	1.75	0.49
4	2.50	1.68	1.42	1.82	1.99	0.46
Mean	2.39	1.56	1.44	1.82	1.86	0.46
Fungal zoospores ($\times 10^{6}$ cell/ ml)						
0 h-post feeding	0.60	0.50	0.50	0.60	0.70	0.07
4	1.10	1.00	1.00	1.10	1.00	1.56
Mean	0.85	0.75	0.75	0.85	0.85	0.32

[1] T_1 = Level of SPP 0%, T_2 = Level of SPP 25%, T_3 = Level of SPP 50%, T_4 = Level of SPP 75%, T_5 = Level of SPP 100%.

[a-b] Vlues within rows not sharing a common superscripts are significantly different ($p<0.05$). SEM = Standard error of the mean (n = 5).

absorbed and excreted in the urine in the form of urea (Nolan, 1993). Cronje (1992) found that inadequate energy reduced the percentage of N retention in goats fed adequate levels of protein and that N recycling increased as the supply of energy increased. However, there was no change ($p>0.05$) in N absorption and retention as a result of increasing SPP in the feed, but there was a trend for a quadratic relationship between SPP level and N retention (% of N intake), with peak retention being obtained with the 75% SPP diet compared with other treatments (Table 5). Similar values for N retention have been previously reported by Soe et al. (2008), which supplemented cell mass from lysine production (CMLP) to goats (35.9 to 42.3%). It is now well established that nitrogen retention depends on the intake of nitrogen and amount of fermentable carbohydrate in the diet (Sarwar et al., 2003).

In this regard, however, the positive N balance observed in this study indicates the positive influence of different SPP replacement of corn in the diets with plicatulum hay based feeding of Southern indigenous cattle. Although the differences in the quantity and routes of N excretion with consequent influences on N retention could reflect treatment feed differences in N metabolism, N retention is considered as the most common index of the protein nutrition status of ruminants (Owens and Zinn, 1988). The excretion of allantoin in the urine was similar among treatments. The microbial nitrogen supply as calculated from purine derivative excretion using the equation of Chen and Gomes (1995) ranged from 65.18 to 86.09 g N/d/$BW^{0.75}$. Likewise, the efficiency of rumen microbial protein

Table 5. Effect of sago palm pith substitution for ground corn on nitrogen utilization and purine derivatives in Southern indigenous cattle fed on plicatulum hay as roughage

Attribute	Sago palm pith (SPP) levels in concentrate (%)[1]					SEM
	T1 (0)	T2 (25)	T3 (50)	T4 (75)	T5 (100)	
Sago palm pith levels (DM basis)	0.0	13.0	27.0	40.5	54.0	
N balance (g/d)						
Total N intake	78.09^{b}	84.26^{ab}	85.73^{ab}	101.49^{a}	104.94^{a}	6.66
N excretion (g/d)						
Fecal N	29.56	33.93	32.41	33.98	33.78	3.64
Urinary N	16.12^{b}	18.27^{b}	20.40^{ab}	22.52^{ab}	26.49^{a}	2.11
Total N excretion	45.69^{b}	52.21^{ab}	52.81^{ab}	56.50^{ab}	60.27^{a}	3.96
Absorbed N	48.44	50.33	53.32	67.50	71.15	6.75
Retained N	32.40	32.05	32.92	44.98	44.66	5.73
N output (% of N intake)						
Absorbed	62.57	59.98	59.41	66.44	67.86	4.95
Retained	41.86	37.79	35.48	44.09	42.66	5.01
Allantoin excretion (mmol/d)	91.60	86.08	81.11	94.35	105.34	10.63
PD (mmol/d)						
PD excretion[2]	107.77	101.27	95.43	107.53	120.40	12.53
PD absorption	103.21	95.70	89.66	103.27	118.42	14.66
Microbial N supply (g N/d)[3]	75.03	69.57	65.18	75.07	86.09	10.65
EMNS (g N/kg of OMDR)[4]	38.86	38.83	38.94	33.23	37.64	6.22

[1] T_1 = Level of SPP 0%, T_2 = Level of SPP 25%, T_3 = Level of SPP 50%, T_4 = Level of SPP 75%, T_5 = Level of SPP 100%.

[2] Allantoin in urine cattle was 80-85% of total purine (IAEA, 1997).

[3] Microbial N (g N/d) = (X×70)/(0.116×0.83×1,000) = 0.727×X (where, X = total absorption of purine derivatives) (Chen et al., 1993).

[4] EMNS = Efficiency of microbial nitrogen supply (g N/kg OMDR), organic matter digestible in the rumen (OMRD, kg) = 65% of organic matter digestible in total tract (ARC, 1990).

[a-b] Values within rows not sharing a common superscripts are significantly different ($p<0.05$). SEM = Standard error of the mean (n = 5).

synthesis was not influenced by dietary treatment, and the values ranged from 33.32 to 38.86 g N/kg of OMDR. Non-treatment variability in EMNS may be due to various factors like concentration and sources of nitrogen and carbohydrates. Singh et al. (2007) reported that the excretion of urinary purine derivatives were positively correlated with the level of feed intake.

CONCLUSIONS

Sago palm pith was a good source of ruminal degradable starch in replacing corn grain and has the potential to improve beef cattle performance. In conclusion, under the conditions of our study, it can be suggested that the optimal inclusion of SPP-based diets did not affect feed intake, apparent digestibility, rumen fermentation characteristics, nitrogen balance or microbial N Supply. The optimal inclusion of SPP in the diet of Southern indigenous cattle is suggested to be between 25-100% when fed with Plicatulum hay, so that it appears to be an economical and healthy approach to exploiting local feed resources such as SPP, which abounds in the Southern provinces of Thailand, in the process of feeding all kinds of livestock. Additional research is needed to determine the use of SPP in practical rations and the long-term effects of feeding SPP on feedlot performance and/or dairy cows as well as using this approach for on-farm research.

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