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Original Article

Effect of different levels of sago palm pith on nutrient utilization in Thai native cattle fed with plicatulum hay (*Paspalum plicatulum* Michx.) and soybean meal

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Abstract

The effects of different levels of sago palm pith as energy source on nutrient utilization and rumen fermentation characteristics of Thai native cattle were investigated. Four rumen-fistulated bulls with average body weight (BW) of 263± 10 kg were randomly assigned according to a 4x4 Latin Square Design. Plicatulum hay (*Paspalum plicatulum* Michx.) was offered to each animal *ad libitum* with 0.50 kg/h/d of soybean meal. The dietary treatments were sago palm pith supplementation at the rate of 0, 0.25, 0.50 and 0.75% of BW (T_1, T_2, T_3 and T_4, respectively). The results showed that the total DMI (49.77, 52.61 and 52.83 g/BWkg$^{0.75}$/d, respectively) and OMI (46.40, 49.30 and 49.74 g/BWkg$^{0.75}$/d, respectively) were not significantly different between T_2, T_3 and T_4, but all were significantly ($P<0.05$) higher than T_1 (41.56 and 38.47 g/BWkg$^{0.75}$/d, respectively). Apparent digestibility of DM and OM were lowest in T_1 (43.63 and 48.03%, respectively), followed by T_2 (51.86 and 55.29%, respectively), and T_3 (55.48 and 59.07%, respectively) and highest in T_4 (62.91 and 66.23%, respectively). Higher rumen NH_3-N and BUN levels were found in the T_1 (7.14 and 15.74 mg/dl, respectively) compared to the other treatments, while rumen pH and blood glucose levels were within normal range. Under the conditions of this study, different levels of sago palm pith as a supplementary energy source resulted in a positive effect on nutrient utilization of Thai native cattle.

Keywords: sago palm pith, Thai native cattle, nutrient utilization, rumen fermentation, energy source

1. Introduction

The world demand for livestock product, especially meat and milk, has been increasing annually due to a high rate of population and economic growth and improved standard of living (Leng, 1991; Delgado *et al.*, 1999), especially in developing countries. In Thailand, one of the strategies to improve animal productivity and efficiency is to increase the efficiency of utilization of low quality forages, crop residues and high potential local feed resources through appropriate feed supplementation, thereby balancing the supply of nutrients to the animal.

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Sago palm (*Metroxylon sagu*) covers about 64,000 ha of land in Thailand, particularly in swampy areas of the southern province such as Nakhon Si Thammarat, Phatthalung, Songkhla, Pattani, Yala and Narathiwat provinces (Sriroth, 2003). A single sago palm yields about 100-150 kg of sago starch (Sophanodora, 1987). A typical fresh water swamp can produce 50 palms suitable for felling per hectare each year (Anonymous, 2006), which is high in terms of energy production per hectare. Sago starch is produced from the trunk when the tree is about 10 to 15 years old (Sophanodora, 1987; Hutagalung, 2006). The trunk is cut into sections which are split lengthwise, and the comparatively soft material in the center (sago palm pith) is scooped out. From this material, starch is extracted by washing and straining (Anonymous, 2006). The starch is dried to yield sago meal. Sago meal is low in protein but exceptionally high in non-structural carbohydrate (NSC). Soluble carbohydrate in sago meal ranges from 51 to 92.5% (Flach, 1983). It is highly digestible and can be fed to all classes of livestock. Sundried sago palm pith contains 1.0% crude protein (CP), 23.1% neutral detergent fiber (NDF) and 7.1% acid detergent fiber (ADF) (Tuen, 1992). It gives a similar performance to sago meal when fed to cattle and older pigs (Anonymous, 2006). Therefore, this study was conducted to evaluate nutrient utilization and rumen fermentation characteristics of Thai native cattle given low quality roughage and soybean meal as a protein source with different levels of sago palm pith as an energy source.

2. Materials and Methods

2.1 Animals and diets

Four rumen-fistulated Thai native bulls with average initial body weight (BW) of 263±10 kg were randomly assigned according to a 4 x 4 Latin Square Design experiment. All animals were drenched for internal worms (Albendazole, Valbazen®, Better pharma Co., LTD.) and injected with vitamins A, D_3 and E prior to commencing the experiment. Each animal was kept in an individual pen and received free access to water. The experiment consisted of 4 periods. Each period lasted for 19 days, with the first 14 days an adaptation period and the last 5 days the sample collection period. During each period, plicatulum hay (*Paspalum plicatulum* Michx.) was offered to each animal *ad libitum* to ensure 10 % orts, with soybean meal supplementation at 0.50 kg/head/day. The dietary treatments were sun dried sago palm pith (approximately 10% moisture content) supplementation at 0, 0.25, 0.50 and 0.75% of the BW (T_1, T_2, T_3 and T_4, respectively) at the start of the experiment. Each feed was separately offered twice daily at 08.00 and 16.00 hours. The amounts of feed offered and refused were weighed and recorded daily before the morning feeding. Feed samples were oven-dried at 60°C for 72 h, ground to pass through a 1-mm sieve, and composited by period for further analysis.

2.2 Data collection and chemical analysis

Feed intake was measured on a daily basis during the adaptation period. Dietary feed offered, orts, 24 hour faeces and urine voided by individual cattle during the 5 days collection period were recorded and representative samples were taken. Blood samples were collected from the jugular vein into heparinized tubes at 0 and 4 h-post feeding at the end of the sample collection period. The blood samples were centrifuged at 4°C at 3300 x g for 15 min and the supernatants were separated for further analysis. Rumen fluid samples were collected via the fistula at the same time as the blood samples. The pH of the rumen samples was measured immediately with a pH meter (Index portable meter, ID1000, USA). Rumen fluid samples were then strained through two cheesecloths and the samples were frozen at -20°C until analysis. Cattle were weighed at the beginning of each experimental period before the morning feeding.

The feeds and faeces were chemically analyzed for DM, ash and CP (AOAC, 1990), NDF, ADF and ADL (Goering and Van Soest, 1970). Urine nitrogen was analyzed by the method of the AOAC (1990). Energy in feed, faeces and urine was measured by an automatic adiabatic bomb calorimeter (Gallenkamp-auto bomb calorimeter, BA-350-K). The metabolizable energy (ME) of each treatment was estimated through the NRC equation (NRC, 2000). Blood urea nitrogen (BUN) levels were determined by diagnostic kits (Urea Liquicolor®, Germany) based on an enzymatic method and ruminal NH_3-N was determined using the Kjeldahl method (AOAC, 1990). Plasma glucose was measured by the GOD-PAP method using diagnostic kits (Glucose Liquicolor®, Germany). Statistical analysis focused on the effects of sago palm pith levels on nutrient intake, nutrient digestibility, nitrogen balance, energy utilization and rumen fermentation characteristics of Thai native cattle.

2.3 Data analysis

Statistical analyses were performed using the GLM procedure of the Statistical Analysis System Institute (SAS, 1990). Data were analyzed using the model

$$Y_{ijk} = m + M_i + A_j + P_k + e_{ijk}$$

where Y_{ijk} is the observations of animal *j*, receiving diet *i*, in period *k*; μ , the overall mean, M_i, the mean effect of levels of sago palm pith (*i* = 1, 2, 3, 4), A_j, the effect of animal (*j* = 1, 2, 3, 4), P_k, the effect of period (*k* = 1, 2, 3, 4), e_{ijk} , the residual effect. Means were statistically compared using Duncan's Multiple Range Test (DMRT) (Steel and Torrie, 1980).

3. Results and Discussion

The chemical composition of roughage and experimental diets are presented in Table 1. The plicatulum hay contained 93.37 %DM with 2.53 %CP, 85.56 %NDF, 58.07 %ADF and 16.48 KJ/kg gross energy (GE). Similar CP values for plicatulum hay have been previously reported by Tamchan *et al.* (2007) and Seangkong *et al.* (2007). The protein content in plicatulum hay does not satisfy the requirements for maintenance (6-8%) of ruminants (Minson, 1990). Thus, supplemental protein should be provided for optimal rumen function and microbial protein synthesis (Nocek and Russell, 1988). The CP and OM of the soybean meal was 49.00% and 92.92%, respectively. The sago palm pith contained only 2.07 % CP, but was high in OM (96.04%) and NSC (70.68%) content while the GE content was slightly lower than in the other feeds. The CP content in the sago palm pith in this study was similar to reports by Yadav and Mahyuddin (1991), Tuen (1992) and Chanjula and Ngampongsai (2007) who found that sago palm pith and sago

Table 1. Chemical composition of experimental feeds (DM basis)

Items	DM (%)	CP	EE	CF	OM (% DM)	Ash	NFE[1]	NSC[2]	NDF	ADF	GE (KJ/kg)
Plicatulum hay	93.37	2.53	0.96	38.66	92.54	7.46	50.39	3.49	85.56	58.07	16.48
Soybean meal	93.04	49.00	1.03	9.62	92.92	7.08	33.27	24.57	18.32	12.12	18.75
Sago palmpith	93.09	2.07	0.24	7.04	96.04	2.53	88.12	70.68	24.48	8.25	15.25

[1]NFE = 100-(CP+CF+EE+Ash)
[2]NSC= 100-(CP+NDF+EE+Ash)

Table 2. Nutrient intake and apparent digestibility of Thai native cattle given plicatulum hay and soybean meal with different levels of sago palm pith

Attributes	Sago palm pith level (% BW)				SEM
	T1 (0%)	T2 (0.25%)	T3 (0.50%)	T4 (0.75%)	
DM intake(g/BW kg$^{0.75}$/d)					
Soybean meal	6.64[a]	6.77[a]	6.38[b]	6.35[b]	0.05
Sago palm pith	0.00[d]	8.76[c]	16.75[b]	24.05[a]	0.35
Plicatulum hay	34.93[a]	34.24[a]	29.49[b]	22.44[c]	1.12
Total	41.56[b]	49.77[a]	52.61[a]	52.83[a]	1.34
OM intake (g/BW kg$^{0.75}$/d)					
Soybean meal	6.17[a]	6.29[a]	5.93[b]	5.90[b]	0.05
Sago palm pith	0.00[d]	8.42[c]	16.09[b]	23.09[a]	0.33
Plicatulum hay	32.31[a]	31.69[a]	27.29[b]	20.76[c]	1.05
Total	38.47[b]	46.40[a]	49.30[a]	49.74[a]	1.24
CP intake (g/BW kg$^{0.75}$/d)					
Soybean meal	3.25[a]	3.32[a]	3.12[b]	3.11[b]	0.02
Sago palm pith	0.00[d]	0.09[c]	0.17[b]	0.25[a]	0.00
Plicatulum hay	0.89[a]	0.87[a]	0.75[b]	0.57[c]	0.03
Total	4.14[b]	4.28[a]	4.04[b]	3.93[c]	0.05
NDF intake(g/BW kg$^{0.75}$/d)					
Soybean meal	1.22[a]	1.24[a]	1.17[b]	1.16[b]	0.01
Sago palm pith	0.00[d]	2.14[c]	4.09[b]	5.88[a]	0.05
Plicatulum hay	29.86[a]	29.30[a]	25.24[b]	19.18[b]	0.49
Total	31.08[a]	32.68[a]	30.49[a]	26.22[b]	0.32
Apparent digestibility (%)					
DM	43.63[c]	51.86[b]	55.48[b]	62.91[a]	1.93
OM	48.03[c]	55.29[b]	59.07[b]	66.23[a]	1.89
CP	57.95	56.36	52.47	52.80	2.98
NDF	53.37	47.51	53.05	50.77	2.54
ADF	41.09	36.28	42.65	36.78	3.01

[a-d]Means with different superscripts among treatments are significantly different ($p<0.05$).

residue (a by-product of starch extraction) contained 1.4-3.3 % CP. In an earlier study, it was found that sago palm pith had high effective degradability (ED) of DM in the rumen (62.2%). The ED of DM was higher than ground corn (56.3 % ED), making it a potential energy source in concentrates for ruminants (Chanjula and Ngampongsai, 2007).

Table 2 shows DM, OM, CP and NDF intake on the basis of metabolic body size and apparent nutrient digestibility. The intake of DM (DMI), OM (OMI), CP (CPI) and NDF (NDFI) from soybean meal and plicatulum hay were significantly ($p<0.05$) lower for T_3 and T_4 (0.50 and 0.75% sago palm pith) as compared with T_1 and T_2 (0 and 0.25% sago palm pith). Meanwhile, the total DMI and OMI were not significantly different between T_2, T_3 and T_4, but all were significantly ($p<0.05$) higher than the control group; the values tended to increase with increasing levels of sago palm pith supplementation in the diets.

The data indicated that supplementing sago palm pith had no significant effect on DMI and OMI in Thai native cattle fed with plicatulum hay and soybean meal diet, although the CPI and NDFI was lower for T_4 than in the control group. This was probably due to a lower plicatulum hay intake for the T_4 trials as compared with the control diet. The lower plicatulum hay intake of supplemented sago palm pith based diets may have contributed to high degradation of sago palm pith in substantial decrease in fiber digestibility (Hoover, 1986; Ørskov, 1986; Nocek and Russell, 1988) thus reducing roughage intake. Nevertheless, the total CPI of the cattle in this study (3.93-4.28 g/BWkg$^{0.75}$ or 271.04-277.13 g/d) met the CP requirement for maintenance of Thai native cattle (336 g/d for cattle of 400 kg BW with 6 kg DMI) according to the report of Kawashima *et al.* (2000c).

The apparent digestibility of DM and OM was the lowest in T_1, followed by T_2, and T_3 and it was highest in T_4 (P<0.05). This indicated that increasing the levels of sago palm pith as an energy source with soybean meal as a protein source in the diet for cattle fed with plicatulum hay could improve protein and energy balance, resulting in increased microbial protein synthesis, feed digestibility and voluntary feed intake as has been previously suggested by Van Soest (1994) and Huber and Herrera-Saldana (1994). The apparent digestibility of CP, NDF and ADF were similar (P>0.05) for all treatments, indicating that Thai native cattle have the ability to digest protein and fiber well even without energy source supplementation. Kawashima *et al.* (2000b) also previously found that Thai native cattle seemed to have a high ability to digest fiber and to utilize energy in feed.

The effects of different levels of sago palm pith supplementation on energy metabolism of Thai native cattle given plicatulum hay and soybean meal are shown in Table 3. The total GE intake (GEI), digestible energy (DE) and metabolizable energy (ME) were similar among treatments, except T_1 which was significantly lower (P<0.05) than the other dietary treatments. Huntington *et al.* (2006) reported that the most likely way to increase ME intake is to increase energy density of the diet by including grain or other starch containing feedstuffs. As expected, increasing GEI resulted in increased DE and ME (P<0.05) in line with the increasing level of sago palm pith in the diets. Subsequently, the DMI on the basis of metabolic body size was higher in the supplemented sago palm pith groups as compared with the control group, whereas energy loss into faeces and urine were similar (p>0.05) among treatments.

The DE and ME in the treatment without sago palm pith was the lowest (p<0.05), suggesting that sago palm pith supplementation clearly improved energy utilization in the cattle. Although methane and heat production was not determined in this experiment, the calculated ME in the treatment without sago palm pith (291.4 KJ/BWKg$^{0.75}$/d) met the ME requirement for maintenance of Thai native cattle (245 KJ/BWKg$^{0.75}$/d) reported by Kawashima *et al.* (2000b). The data indicate that Thai native cattle seemed to have a high ability to utilize energy in feed.

Nitrogen utilization in Thai native cattle given plicatulum hay and soybean meal with different levels of sago palm pith supplementation is presented in Table 4. Total nitrogen intake was lower (P<0.05) for cattle in T_3 and T_4. This may be related to the lower nitrogen intake from soybean meal and plicatulum hay in these treatments compared with other treatments, whilst total excretion of faeces and urinary nitrogen was not significantly (p>0.05) different among treatments.

The nitrogen balance was similar among all treatments. It is now well established that nitrogen balance depends on not only the intake of nitrogen, but also the amount of fermentable carbohydrate in the diet (Sarwar *et al.*, 2003). The positive nitrogen balance in all trials in this study indicates that the animals acquired sufficient protein from their

Table 3. Energy metabolism of Thai native cattle given plicatulum hay and soybean meal with different levels of sago palm pith

Attributes	Sago palm pith level (% BW)				SEM
	T1 (0%)	T2 (0.25%)	T3 (0.50%)	T4 (0.75%)	
GE intake (KJ/BWkg$^{0.75}$/d)					
Soybean meal	124.5^{a}	127.1^{a}	119.7^{b}	119.1^{b}	0.9
Sago palm pith	0^{d}	133.9^{c}	255.8^{b}	367.1^{a}	5.4
Plicatulum hay	576.3^{a}	564.8^{a}	486.5^{b}	370.0^{c}	21.9
Total	700.8^{b}	825.8^{a}	861.9^{a}	856.4^{a}	21.9
Energy excretion (KJ/BWkg$^{0.75}$/d)					
Faeces	345.5	385.1	373.0	311.8	26.8
Urine	180.7	134.7	88.8	118.1	30.6
Total	526.2	519.8	461.8	429.9	52.9
DE (KJ/BWkg$^{0.75}$/d)	355.4^{c}	440.7^{b}	488.9^{ab}	544.7^{a}	18.6
ME (KJ/BWkg$^{0.75}$/d)	291.4^{c}	361.4^{b}	400.9^{ab}	446.6^{a}	15.2

[a-c] Means with different superscripts among treatments are significantly different (p<0.05).

Table 4. Nitrogen utilization of Thai native cattle given plicatulum hay and soybean meal with different levels of sago palm pith

Attributes	Sago palm pith level (% BW)				SEM
	T1 (0%)	T2 (0.25%)	T3 (0.50%)	T4 (0.75%)	
Nitrogen intake (g/BWkg$^{0.75}$/d)					
Soybean meal	0.52^{a}	0.53^{a}	0.50^{b}	0.50^{b}	0.00
Sago palm pith	0.00^{d}	0.02^{c}	0.03^{b}	0.04^{a}	0.00
Plicatulum hay	0.14^{a}	0.14^{a}	0.12^{b}	0.09^{c}	0.00
Total	0.66^{b}	0.68^{a}	0.65^{b}	0.63^{c}	0.01
Nitrogen excretion (g/BWkg$^{0.75}$/d)					
Faeces	0.28	0.30	0.31	0.30	0.02
Urine	0.23	0.21	0.18	0.16	0.02
Total	0.51	0.51	0.49	0.46	0.04
Nitrogen excretion/Nitrogen intake (%)	76.41	75.93	74.97	72.61	4.84
Nitrogen balance (g/BWkg$^{0.75}$/d)	0.15	0.17	0.16	0.18	0.03

[a-d] Means with different superscripts among treatments are significantly different (p<0.05).

Table 5. NH_3 concentration, pH in rumen fluid and blood metabolites of Thai native cattle given plicatulum hay and soybean meal with different levels of sago palm pith

Attributes	Sago palm pith level (% BW)				SEM
	T1 (0%)	T2 (0.25%)	T3 (0.50%)	T4 (0.75%)	
Ruminal pH					
0 h post feeding	7.13^{ab}	7.25^{a}	7.05^{b}	6.88^{c}	0.06
4 h post feeding	6.88^{a}	6.83^{a}	6.80^{a}	6.68^{b}	0.06
Mean	6.97^{ab}	7.00^{a}	6.81^{b}	6.83^{ab}	0.05
NH_3-N (mg/dl)					
0 h post feeding	7.15^{a}	7.86^{ab}	4.29^{b}	4.64^{b}	1.15
4 h post feeding	7.15^{a}	3.58^{b}	3.58^{b}	2.86^{b}	0.58
Mean	7.14^{a}	5.71^{a}	3.93^{b}	3.75^{b}	0.47
BUN (mg/dl)					
0 h post feeding	15.20^{a}	9.98^{ab}	7.18^{b}	3.70^{b}	1.82
4 h post feeding	16.29^{a}	11.74^{ab}	7.82^{bc}	4.46^{c}	1.82
Mean	15.74^{a}	10.87^{ab}	7.51^{bc}	4.09^{c}	1.76
Blood glucose (mg/dl)					
0 h post feeding	64.78	67.30	66.98	71.18	2.20
4 h post feeding	62.00^{c}	65.25^{b}	68.20^{a}	69.25^{a}	0.62
Mean	64.38	68.00	75.06	71.38	3.04

[a-c] Means with different superscripts among treatments are significantly different (p<0.05).

feed. Furthermore, the lack of nitrogen balance improvement when sago palm pith level in diet was increased is similar to earlier works (Kawashima *et al.*, 2000b,c) in which it was reported that Thai native cattle seemed to have a high ability to utilize energy in feed and have a lower energy requirement for maintenance. Consequently, more energy became available and the balance of protein and energy was sustained even though the animals did not receive energy source (Kawashima *et al.*, 2000b,c).

Rumen fermentation characteristics were measured by pH and NH_3-N concentrations, and BUN and blood glucose were determined to investigate their relationship with NH_3-N, protein and energy utilization (Table 5). Ruminal pH values of T_4 at 0 and 4 h-post feeding, were significantly lower than the other dietary treatments. At 4 h-post feeding, the ruminal pH of all treatments declined as active fermentation of the newly ingested feed occurred. However, all treatment means were within the normal range and the overall means were quite stable at 6.81-7.00. Similar values for pH have been previously reported by Khampa *et al.*

(2006) and Chanjula *et al.* (2007), as well as values at optimal levels for microbial digestion of fiber (Hoover, 1986) and also digestion of protein (6.0-7.0) (Wanapat, 1999).

Ruminal NH_3-N and BUN concentrations differed significantly ($p<0.05$) with different levels of sago palm pith incorporation in the diets at each hour of sampling. Overall means, higher NH_3-N and BUN levels were found in the control diet. Similar values for NH_3-N have been previously reported by Kawashima *et al.* (2000a) in Red Sindi cattle (1.65-4.19 mg/dl). The differences in NH_3-N and BUN concentrations among treatments may have been related directly to protein and energy levels of the concentrate. Hammond (1983a,b) and Oltner and Wiktorsson (1983) found that a surplus of protein intake or increased solubility and/or degradability of dietary protein can lead to increased ruminal ammonia concentrations, resulting in increased BUN concentrations. Preston *et al.* (1965) and Lewis (1975) reported that concentrations of BUN are highly correlated with protein intake and reflect the level of ammonia production in the rumen.

In this study, decreased ruminal NH_3-N and BUN levels were found ($p<0.05$) with increased levels of sago palm pith supplementation in the diets. Several *in vitro* (Stern *et al.*, 1978; Henning, 1991) and *in vivo* (Casper and Schingoethe, 1989; Cameron *et al.*, 1991) studies demonstrated that infusions of increasing amount of readily fermentable carbohydrate decreased ruminal NH_3-N concentrations due to improved nitrogen uptake by ruminal microbes. Furthermore, Chase *et al.* (1993) who formulated and rationed to provide 75 or 150% of maintenance energy requirement but equal CP intake found that at the high level of energy intake BUN averaged 5.6 mg/dl and at the low level of energy intake BUN averaged 19.7 mg/dl.

Glucose, as a source of energy, is necessary for production and reproduction performance (Radostits *et al.*, 2000). Ruminal conversion of carbon from starch digested in the rumen to blood glucose is 45/70, or approximately 64% as efficient as the conversion in the small intestine (Huntington *et al.*, 2006). In this study, blood glucose was similar ($p>0.05$) among dietary treatments, except for T_3 and T_4 at 4 h-post feeding which had higher ($p<0.05$) blood glucose than the other treatments, but all were within the normal range, around 60 mg/dl (Benjamin, 1978). These data indicate that the inclusion of sago palm pith in diets did not affect blood glucose. The animals also showed positive energy status (Table 3) which may be the reason for the lack of differences among treatments and lack of deleterious effects on feed intake, protein and energy utilization of the cattle.

4. Conclusion

In conclusion, under the conditions of this study, different levels of sago palm pith (0.25-0.75%of BW) as a supplementary energy source resulted in a positive effect on nutrient utilization of Thai native cattle given low quality hay and soybean meal as a primary protein source. However, further studies involving the appropriate soybean meal and sago palm pith ratios on nutrient utilization of Thai native cattle are necessary to establish a feeding strategy and feeding standards for Thai native cattle.

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