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Original Article

Effects of palm oil sludge in concentrate on nutrient utilization and rumen ecology of thai native cattle fed with hay

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Abstract

This experiment aimed to study the effects of palm oil sludge (POS) in concentrate on nutrient utilization and rumen ecology of Thai native cattle. Five ruminally fistulated Thai native bulls with average live weight of 361.80±15.74 kg were arranged according to 5x5 Latin square design. The cattle were fed with Plicatulum hay *ad libitum* and supplemented with concentrate containing 0, 10, 20, 30 and 40% POS at 1.5 %BW. A metabolism trial lasted for 22 days, with the first 16 days an adaptation period and the last 6 days the sample collection period. There was no significant difference (p>0.05) among treatments regarding hay and concentrate intake. Digestibility coefficient of DM, OM and ADF of all treatments were not significantly different (p>0.05) while CP digestibility coefficient was significantly lower (P<0.05) when 40% POS was incorporated into concentrate diet. Rumen parameters (ruminal pH, temperature and microbial populations) were similar among treatments (p>0.05) whereas ruminal NH_3-N concentration of cattle fed 0 and 20% POS were higher (p<0.05) than those of cattle fed 40 % POS. Total VFA in rumen fluid, C_2, C_3, isobutyrate, isovalerate, n-valerate and C_2:C_3 were not significantly different (p>0.05) while the proportion of C_4 of cattle fed 0% POS was higher (p<0.01) than those fed 20, 30 and 40% POS. Blood parameters (PCV, glucose and NEFA concentration) were similar among treatments (p>0.05) while, BUN concentration of cattle fed 40% POS was significantly lower (p<0.01) than those of cattle fed 0, 10, 20 and 30% POS. These results indicate that the optimum level of POS in concentrate for Thai native cattle fed Plicalum hay as a roughage source should not exceed 30%.

Keywords: palm oil sludge, nutrient utilization, rumen ecology, Thai native cattle

1. Introduction

Feed cost is not only an important concern in the management of national economy but also a major cost burden of livestock farm. Thus a major strategy to develop the livestock industry in developing countries should be increasing the use of indigenous feed resource to reduce the cost of imported feed (Goh and Rajion, 2007). The palm oil industry plays an important role in Thailand's economy. Palm oil occupies 70% of the Thai vegetable oil market, and is estimated to be worth 40,000 million baht per annum and has an average annual growth rate of 15% during the last decade (Chavalparit *et al*., 2006). Most palm oil mills are located in the southern part of the country. All 71 palm oil mills, had a more or less similar production process (wet process) and the crude palm oil (CPO) yield was about 17-20% of fresh fruit bunch (FFB) (Paepatung *et al*., 2009).

CPO production from FFB, generates large amount of process residues. Palm oil sludge (POS) or decanter cake is a by-product obtained after dehydration of palm oil mill effluent

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(POME). During the process, most of the solid in the final effluent is decanted in a decanter and passed to a filter press before being dried in a rotary drier (Devendra *et al.*, 1981). Chavalparit *et al.* (2006) reported that average values of 42 kg POS per ton FFB, was generated from palm oil mills in Thailand. In 2009, approximately 8,162,379 tons of FFB was available (Office of Agricultural Economics, 2010). Therefore, the production of POS was estimated to be 342,820 tons a year. POS is characterized by considerable variability in chemical composition i.e., high fat, high mineral and medium crude protein contents. Currently, most POS is used as fertilizer and soil cover materials in oil palm plantation area or biogas production (Chavalparit *et al.*, 2006; Paepatung *et al.*, 2009), while its utilization in animal feed is minimal. Bamikole and Babayemi (2008) reported that POS has good potential as feed source and could be directly used in ruminant feeding as an energy source. Therefore, this research was conducted to evaluate the effects of different POS levels in concentrate on nutrient utilization and rumen ecology of Thai native cattle.

2. Materials and Methods

2.1 Animals and experimental diets

Five Thai native male cattle (approximately 5 years old) with average 361.80±15.74 kg initial body weight were randomly assigned to dietary treatments according to 5x5 Latin square design. Five concentrate diets containing 0, 10, 20, 30 and 40% POS with similar CP contents of 14% and metabolizable energy (ME) of 2.5 Mcal/kg were formulated (Table 1).

Each cattle was kept individually in a metabolism crate in well ventilated sheds where water was available at all times. Each experimental period lasted for 22 days, with the first 16 days an adaptation period and the last 6 days the sample collection period. During the adaptation period, the animals received a concentrate diet at 1.5% body weight (as fed basis) and were allowed to consume Plicatulum hay *ad libitum*, with 10% refusal allowance. Feed were provided twice daily in two equal portions at 08.30 and 16.30 h daily. Feed refusals were weighed and recorded daily at 08.00. Fresh ort samples were bulked by pen and dried at 65°C and sub samples were used for dry matter determinations. This information was used for the calculation of concentrate and Plicatulum hay intake. Feed samples obtained each time were oven dried at 65°C for 72 hours and ground through a 1-mm sieve, and composited by period on equal weight basis for further analyses. Cattle were weighed at the beginning of each experimental period before the morning feeding.

2.2 Sampling techniques

In the sample collection period, feed intake was restricted to 90% of the previous voluntary feed intake. Dietary feed offered, orts, 24 hours feces voide by individual animal during the 6 days of collection period were recorded and representative samples were taken for further analyses. At the end of each period, rumen temperature were measured via canula using thermometer at the same time as rumen fluid sampling. Rumen fluid samples were collected via canula at 0 and 4 hours post feeding. Then, the pH of the rumen samples was measured immediately by pH meter (pH electrode MP 125 LE 413, Switzerland). Rumen fluid samples were then strained through four layers of cheesecloth. Samples were divided into two portions. One portion was used for NH_3-N and volatile fatty acids (VFAs) analyses where 1 ml H_2SO_4 (1M) was added to 10 ml of rumen fluid. The mixture was centrifuged at 3,500 rpm for 15 minutes and supernatant stored at -20°C prior to NH_3-N and VFAs analyses. Another portion was fixed with 10% formalin solution in normal saline (0.9%NaCl) for total direct count of the bacteria, protozoa

Table 1. Ingredients and chemical composition of concentrate used in the experiment.

Feedstuffs, %air dry basis	0%POS	10%POS	20%POS	30%POS	40%POS
Palm kernel Cake	40.0	29.8	18.0	4.6	0.0
Ground Corn	8.6	17.2	20.9	27.3	32.9
Soybean Meal	2.5	3.9	6.3	7.9	8.9
Palm Oil Sludge (POS)	0.0	10.0	20.0	30.0	40.0
Cassava Chip	46.0	33.4	29.2	22.6	10.9
Premixed[1]	0.5	0.5	0.5	0.5	0.5
Molasses	0.0	3.0	3.0	5.0	5.0
Sulfur	0.2	0.2	0.2	0.2	0.2
Urea	1.7	1.5	1.4	1.4	1.1
DCP	0.5	0.5	0.5	0.5	0.5

[1] 1 kg of premixed consisted of vitamin A, 2,160,000; vitamin D_3; 400,000 and vitamin E; 5,000 IU; Mn, 8.5; Zn, 6.4; Fe, 8.0, Cu, 1.6; Co, 320.0; I, 800.0; Mg, 16.0, Se, 32.0; feed preservative, 6.6 g. Adjust the weigh up to 1 kg by adding more filler.

and zoospore. Blood samples (about 10 ml) were collected via jugular vein at the same time as rumen fluid sampling. Blood samples were divided into four portions. The first portion was collected into an EDTA coated tube for packed cell volume (PCV) analysis. The second portion was collected into a NaF coated tube for glucose analysis. The third portion was collected into an empty tube for blood urea nitrogen (BUN) analysis. The fourth portion was collected into an empty tube and centrifuged at 2,500 rpm for 5 minutes, then serum was separated and frozen at -20°C prior to non-esterified fatty acid (NEFA) analysis.

2.3 Laboratory analyses

Feed, refusal and feces were analyzed in duplicate for dry matter (DM), ash, ether extract (EE) and Kjedahl N using AOAC (1990) 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). Mineral content in POS was measured using atomic absorbtion (GBC avanta, GBC Scientific Equipment Pty LTD). Apparent digestibility were calculated by using the formula given by Schneider and Flatt (1975). Ruminal VFA analyses using a gas Chromatograph (GC 6890, Agilent Technologies) according to the method of Bartley *et al.* (1979) and for NH_3-N using macro Kjedahl method (AOAC, 1990). The total direct count of bacteria, protozoa and zoospores was made using the methods of Galyean (1989) based on the use of haemacytometer (Boeco) under a light microscope (Olympus BX51TRF, Olympus Optical Co. Ltd.). BUN was measured using diagnostic kits (Stanbio Urea Nitrogen (BUN) Liqui-UV®, Stanbio Laboratory). Plasma glucose was measured using diagnostic kits (Enzymetic colorimetric Test, Human Gesellschaft fÜr Biochemica und Diagnostica mbH) and PCV was measured by centrifuge (Haematocrit 24). NEFA in the blood serum was measured using diagnostic kits (NEFA C-Test WAKO, WAKO Pure Chemical Industries, Ltd.).

2.4 Statistical analyses

All data obtained from the experiment were subjected to Analysis of Variance (ANOVA) for 5x5 Latin square design. Data were analyzed using the model

$$Y_{ijk} = \mu + T_i + A_j + P_k + \Sigma_{ijk}$$

μ = overall mean
T_i = treatment
A_j = animal
P_k = period
Σ_{ijk} = error

The treatment means were statistically compared using Duncan's New Multiple Range Test (DMRT) (Steel and Torrie, 1980).

3. Results and Discussion

3.1 Chemical composition of feeds

The chemical composition of POS, hay and concentrate are presented in Table 2. The POS contained 92.5%DM with 6.7%CP and 58.9%EE. The proximate analysis of POS showed that POS contained very high fat and low protein content when compared with the report of Pimpa *et al.* (2009) who surveyed and collected sample by-products from 26 palm oil mills in the south of Thailand. They found that POS comprised of 14%CP and 11%EE. The nutritive values of POS are variable depending on oil palm varieties (Bamikole and Ikhatua, 2009) and oil extraction process. POS from the palm oil mill with a wet processing is low in fat. In contrast, the POS from the palm oil mill with a dry processing with a high fat content which is a POS were used in this experiment from dry processing. In Nigeria, EE content was similar high value (33.9-38.84%; Bamikole and Ikhatua, 2009; Bamikole and Babayemi, 2008) with this study. The reported in Malay-

Table 2. Chemical composition of Plicatulum hay, POS and concentrate containing different levels of POS (%DM basis)

Diet/Composition	DM	Ash	CP	EE	NDF	ADF	ADL
Plicatulum hay	87.00	5.74	2.51	1.27	81.77	49.26	6.65
POS[1]	92.50	0.18	6.66	58.88	-	-	-
Concentrate							
%POS	89.26	4.73	14.44	5.23	40.52	25.74	6.34
10%POS	88.88	5.81	14.57	9.06	28.69	22.21	6.79
20%POS	89.46	7.49	14.83	13.63	23.13	19.70	7.62
30%POS	89.62	8.92	14.91	16.18	18.03	16.28	5.55
40%POS	90.02	8.83	14.17	20.37	17.55	15.61	5.19

[1]Minerals content of POS : Ca, 0.74; P, 0.19; S, 0.16; Na, 0.02; K, 0.71 and Mg, 0.37%; Fe, 2,700.12; Cu, 29.33; Mn, 111.19 and Zn, 33.08 ppm

sia, EE content of POS 6.33-8.8% (Shibata and Osman, 1988; Vadiveloo, 1986) was lower than the earlier mentioned values. This is indicative of variation in the efficiency of oil extraction methods (Bamikole and Babayemi, 2008). Some mineral contents of POS such as Fe had similar high values to those in the report of Bamikole and Ikhatua (2009) and Bamikole and Babayemi (2008). Therefore, the use of POS in ruminant feed should be careful, regarding toxicity of these minerals. The Plicatulum hay contained 87% DM with 2.5% CP, 82% NDF, 49% ADF and 6.7% ADL. Similar values for Plicatulum hay have been previously reported by Pechkhan (2008). Regarding chemical composition of concentrate, the CP content was similar among treatments, ranging from 14.2 to 14.8%, while EE content increased with increased levels of POS in concentrate.

3.2 Effects on feed intake and apparent digestibility

There was no significant difference among treatments regarding concentrate intake, roughage intake and total dry matter intake (DMI). However, cattle receiving concentrate containing 40% POS tended to have lower concentrate and total DMI than other treatments (Table 3). The high EE content in this ration probably limited the appetite of the animal. In addition, feedstuffs in the experiment were kept a long time with this effect of deteriorating the quality of feedstuffs especially palm kernel cake and POS, and thereby lowering the appetite for concentrate to lower than 1.5%BW. However, Sudin (1988) reported the different levels of POS in concentrate (0, 15, 30 and 65%) did not affect total DMI in Sahiwal-Friesian growing heifers because POS used in the ration had low EE content (12.1%).

Digestibility of DM, OM and ADF did not significantly different (P>0.05) among treatments but cattle fed concentrate containing 40%POS tended to have lower DM and OM digestibility than those on other treatments. Furthermore, cattle fed concentrate containing 40% POS had lower CP digestibility than the other treatments. Regarding NDF digestibility, increasing levels of POS in the concentrate significantly decreased NDF digestibility when compared with the treatment of 0% POS (Table 4). The data indicated that high POS levels in the diets affected feed intake and digestibility. Feeding excess fat in ruminant diet has been found to inhibit microbial activity during ruminal fermentation, thereby leading to depressed digestibility (Orskov and Ryle, 1990). Similarly, Boggs *et al*. (1987) reported that an increasing level of fat in diets decreased DM and ADF digestibility in the rumen. In addition, Oldick and Firkins (2000) reported that ruminal NDF digestibility decreased when fat was fed. Byers and Schelling (1988) recommended that the use of fat in feeds in an attempt to prevent rumen fermentation problems should not exceed 5% of the total ration.

Digestible DOM intake, digestible ADF intake and metabolizable energy of all treatments were not significantly different (p>0.05). Cattle fed concentrate containing 40% POS had lower digestible CP intake than the other treatments (p<0.05), while cattle fed concentrate containing 0%POS had higher digestible NDF intake than other treatments (p<0.01) (Table 4). This was due to the lower DM intake and lower CP and NDF digestibility which had been shown in the previous table.

3.3 Effects on rumen fermentation and microbial populations

There was no significant difference (p>0.05) in effect of POS levels on ruminal fluid pH and temperature. Overall mean of ruminal fluid pH and temperature (Table 5) was

Table 3. Effect of different POS levels in concentrate on dry matter intake of Thai native cattle fed with hay

Attributes	POS levels (%)					SEM
	0	10	20	30	40	
Concentrate intake						
kg/head/day	1.90	2.11	2.00	1.93	1.68	0.12
%BW	0.53	0.60	0.58	0.55	0.47	0.03
g/BW$^{0.75}$	23.21	25.87	24.79	23.98	20.43	1.35
Roughage intake						
kg/head/day	2.18	2.09	1.95	2.10	2.18	0.06
%BW	0.62	0.60	0.57	0.61	0.61	0.02
g/BW$^{0.75}$	26.71	25.99	24.38	26.12	26.68	0.66
Total intake						
kg/head/day	4.09	4.20	3.96	4.04	3.86	0.15
%BW	1.15	1.20	1.14	1.16	1.09	0.04
g/BW$^{0.75}$	49.92	51.87	49.17	50.09	47.11	1.65

Table 4. Effect of different POS levels in concentrate on nutrient digestibility and digestible nutrient intake of Thai native cattle

Attributes	POS levels (%)					SEM
	0	10	20	30	40	
Digestibility, %						
DM	47.72	50.42	50.40	52.08	46.48	1.05
OM	52.00	54.22	54.10	55.46	50.24	0.97
CP	52.66[a]	52.22[a]	49.64[a]	51.52[a]	40.85[b]	1.56
NDF	48.10[a]	43.16[b]	43.97[b]	41.03[b]	40.82[b]	0.84
ADF	42.83	42.54	45.10	44.49	42.22	0.72
Digestible Nutrient Intake						
OM						
g/head/day	1.58	1.61	1.44	1.62	1.40	0.10
g/$BW^{0.75}$	19.16	19.62	17.89	20.11	17.05	1.05
CP						
g/head/day	155.42[a]	154.58[a]	121.26[a]	147.69[a]	97.61[b]	12.44
g/$BW^{0.75}$	1.86[a]	1.87[a]	1.51[a]	1.83[a]	1.18[b]	0.14
NDF						
g/head/day	933.15[A]	697.96[B]	658.26[B]	621.38[B]	638.06[B]	39.39
g/$BW^{0.75}$	11.38[A]	8.60[B]	8.19[B]	7.34[B]	7.82[B]	0.45
ADF						
g/head/day	510.78	451.57	442.84	445.80	427.80	21.94
g/$BW^{0.75}$	6.22	5.55	5.51	5.55	5.23	0.24
Estimated metabolizable energy intake[1/]						
KJ/$BW^{0.75}$	304.86	312.04	284.62	319.89	271.26	16.74

[AB] Means with different superscripts within the same row are highly significantly different (p<0.01)

[ab] Means with different superscripts within the same row are significantly different (p<0.05)

[1/] 1 kg DOM = 3.8 McalME/kg (Kearl, 1982)

within normal ranges which have been reported as optimal for microbial digestion of protein and fiber (6.0-7.0 and 39-40°C) (Van Soest, 1982). In addition, Grant and Mertens (1992) reported that the optimal pH for microbial digestion of fiber is between 6.5-6.8 while Kopency and Wallace (1982) reported that the optimal pH for microbial digestion of fiber is between 5.5-7.0. In this study ruminal fluid pH values were similar to those reported by Grant and Mertens (1992). This might be due to the high roughage intake of all treatments. NH_3-N concentration in rumen fluid of cattle fed concentrate containing 40% POS was significantly lower than that of 0% and 10% POS groups. Cattle receiving concentrate containing 40% POS had the lowest NH_3-N concentration due to low concentrate intake and CP digestibility. However, ruminal NH_3-N concentration in this study was optimal for microbial protein synthesis. The optimal NH_3-N concentration in ruminal fluid for maximum microbial protein synthsis is between 5-8 mg/dl (Satter and Slyter,1974; Slyter *et al*., 1979; Pisulewski *et al*., 1981).

The mean ruminal microbial populations of cattle receiving POS at different levels (Table 6) were not significantly different (p>0.05). Overall bacteria, zoospore and protozoa population (2.84-3.49x10^{10}, 8.25x10^{6} and 5.02-6.27x10^{6} cells/ml, respectively) were within normal range which have been reported by Hungate (1966). However, Oldick and Firkins (2000) reported that fat supplementation in the diets decreased ruminal protozoa counts by 30%, and caused increased propionate and decreased butyrate concentrations.

Overall mean of total VFA concentration, proportion of C_2, C_3 isobutyrate, isovalerate, n-valerate and C_2:C_3 ratio in the rumen were not different (P>0.05) among treatments (Table 7). Meanwhiles, the proportion of C_3 was slightly increased when the level of POS in diet was increased. Oldick and Firkins (2000) also reported that proportion of C_3 increased and C_4 decreased when increasing fat level in the concentrate. Boggs *et al*. (1987) reported that increasing level of fat in diets tended to decrease concentrations of total VFA in rumen fluid and also decreased (p<0.01) C_2 and increased

Table 5. Effect of different POS levels in concentrate on ruminal temperature, ruminal pH and NH_3-N of Thai native cattle fed with hay.

Attributes	POS levels (%)					SEM
	0	10	20	30	40	
Ruminal pH						
0 h, post feeding	6.86	6.84	6.80	6.98	6.94	0.03
4 h, post feeding	6.68	6.56	6.52	6.58	6.64	0.03
average	6.76	6.71	6.67	6.77	6.79	0.02
Ruminal temperature						
0 h, post feeding	38.30	38.20	38.30	38.00	38.30	0.08
4 h, post feeding	38.60	38.80	38.50	38.90	38.70	0.12
average	38.45	38.50	38.40	38.45	38.50	0.08
NH_3-N, mg/dl						
0 h, post feeding	14.11	15.12	12.43	14.11	11.42	0.65
4 h, post feeding	11.76^{AB}	13.44^{A}	10.42^{BC}	11.09^{BC}	9.07^{C}	0.55
average	12.94^{ab}	14.28^{a}	11.42^{bc}	12.60^{abc}	10.25^{c}	0.55

^{ABC} Means with different superscripts within the same row are highly significantly different (p<0.01)

^{abc} Means with different superscripts within the same row are significantly different (p<0.05)

Table 6. Effect of different POS levels in concentrate on ruminal microbial populations

Attributes	POS levels (%)					SEM
	0	10	20	30	40	
Bacteria (x10^{10} cell/ml)						
0 h, post feeding	2.59	3.36	2.93	3.82	3.48	0.29
4 h, post feeding	3.10	3.03	2.81	3.17	2.68	0.31
average	2.84	3.19	2.87	3.49	3.08	0.26
Zoospore (x10^{6} cell/ml)						
0 h, post feeding	7.80	10.56	7.92	11.88	9.90	0.65
4 h, post feeding	9.90^{A}	5.94^{B}	9.24^{A}	9.50^{A}	11.88^{A}	0.66
average	8.85	8.25	8.58	10.69	10.89	0.48
Protozoa (x10^{6} cell/ml)						
Holotrich protozoa						
0 h, post feeding	4.42	5.02	5.28	4.82	3.96	0.38
4 h, post feeding	5.68	5.94	7.26	6.28	6.08	0.48
average	5.05	5.48	6.27	5.55	5.02	0.38
Entodiniomorphs protozoa						
0 h, post feeding	8.58	8.46	7.46	8.12	8.06	0.33
4 h, post feeding	9.24	5.94	8.12	7.86	7.72	0.49
average	8.91	7.20	7.79	7.99	7.89	0.33
Total protozoa						
0 h, post feeding	13.00	13.48	12.74	12.94	12.02	0.55
4 h, post feeding	14.92	11.88	15.38	14.14	13.80	0.69
average	13.96	12.68	14.06	13.54	12.91	0.48

^{AB}Means with different superscripts within the same row are highly significantly different (p<0.01)

Table 7. Effect of different POS levels in concentrate on ruminal volatile fatty acid profiles of Thai native cattle fed with hay.

Attributes	POS levels (%)					SEM
	0	10	20	30	40	
Total volatile fatty acid (TVFA), mm/l						
0 h, post feeding	155.60	151.81	163.64	140.13	142.02	6.18
4 h, post feeding	172.95	162.00	178.53	170.34	159.78	6.03
average	164.28	156.91	171.09	155.23	150.90	4.70
Acetic acid (C_2), %total volatile fatty acid						
0 h, post feeding	74.60	74.01	72.96	73.75	73.76	0.64
4 h, post feeding	72.98	72.79	74.49	71.08	75.12	0.93
average	73.79	73.39	73.73	72.41	74.44	0.55
Propionic acid (C_3), %total volatile fatty acid						
0 h, post feeding	13.42	14.12	16.16	15.03	17.44	0.51
4 h, post feeding	14.76	15.71	15.79	18.30	17.28	0.75
average	14.09	14.92	15.98	16.66	17.36	0.48
Butyric acid (C_4), %total volatile fatty acid						
0 h, post feeding	9.04[a]	8.47[a]	7.61[ab]	7.53[ab]	6.03[b]	0.34
4 h, post feeding	10.07[A]	9.38[AB]	7.60[BC]	8.46[AB]	5.91[C]	0.44
average	9.55[A]	8.93[AB]	7.60[B]	8.00[B]	5.97[C]	0.36
Isobutyric acid, %total volatile fatty acid						
0 h, post feeding	1.33	1.42	1.36	1.51	1.32	0.04
4 h, post feeding	1.26	1.05	0.94	1.03	0.91	0.06
average	1.30	1.23	1.15	1.27	1.12	0.04
Isovaleric acid, %total volatile fatty acid						
0 h, post feeding	1.04	1.29	1.23	1.56	0.95	0.08
4 h, post feeding	0.46	0.53	0.60	0.63	0.38	0.04
average	0.75	0.91	0.91	1.09	0.67	0.06
n-Valeric acid, %total volatile fatty acid						
0 h, post feeding	0.58	0.68	0.69	0.62	0.50	0.03
4 h, post feeding	0.47	0.54	0.58	0.50	0.40	0.03
average	0.53	0.61	0.63	0.56	0.45	0.03
C_2:C_3						
0 h, post feeding	5.58	5.32	4.71	4.98	4.30	0.17
4 h, post feeding	5.02	4.70	4.84	4.10	5.72	0.43
average	5.30	5.01	4.78	4.54	5.01	0.22

[ABC] Means with different superscripts within the same row are highly significantly different ($p<0.01$)

[ab] Means with different superscripts within the same row are significantly different ($p<0.05$)

C_3. In addition, Onetti *et al*. (2001) found that adding fat caused a trend of decline in total VFA and that the C_2:C_3 ratio declined because of decreased C_2 and increased C_3 proportions as fat increased from 2 to 4% in dairy cow diets, since fat supplied in ruminant diets often has a negative effect on fiber digestion (Zinn, 1989). The concentration of ruminal total VFA concentration in all treatments in this study was, however, higher than normal concentrations of 70-130 mmol/l, the range suggested by France and Siddons (1983).

3.4 Effect on blood metabolites

Table 8 presents blood metabolites of Thai native cattle fed concentrate containing different levels of POS. PCV

Table 8. Effect of different POS levels in concentrate on blood metabolites of Thai native cattle fed with hay.

Attributes	POS levels (%)					SEM
	0	10	20	30	40	
Plasma glucose, mg/dl						
0 h, post feeding	60.98^{B}	59.28^{E}	60.86^{C}	67.70^{A}	60.66^{D}	1.86
4 h, post feeding	62.50	59.60	62.86	58.30	66.28	1.25
average	61.08	58.88	61.86	62.21	63.47	1.28
Blood urea nitrogen, mg/dl						
0 h, post feeding	9.78^{a}	10.46^{a}	9.16^{ab}	10.15^{a}	7.16^{b}	0.51
4 h, post feeding	10.78^{A}	11.44^{A}	9.56^{A}	10.64^{A}	6.72^{B}	0.55
average	10.28^{A}	10.96^{A}	9.35^{A}	10.63^{A}	6.94^{B}	0.52
Packed cell volume, %						
0 h, post feeding	39.60	39.40	40.00	39.00	40.00	0.55
4 h, post feeding	39.40	39.60	39.20	37.60	38.80	0.72
average	39.50	39.50	39.60	38.30	39.40	0.55
Non-esterified fatty acid (NEFA), mEq/L						
0 h, post feeding	0.92	0.82	0.84	0.79	0.82	0.08
4 h, post feeding	0.73	0.71	0.68	0.86	0.71	0.08
average	0.82	0.77	0.76	0.82	0.77	0.07

^{A,B,C,D,E} Means with different superscripts within the same row are highly significantly different (p<0.01).

^{a,b} Means with different superscripts within the same row are significantly different (p<0.05).

and blood glucose were similar (P>0.05) among dietary treatments and the values of all treatments were within the normal range, 24-46% for PCV (Jain, 1993), 50-75% for glucose (Kaneko, 1989), respectively. NEFA concentrations were not different (p>0.05) among treatments (0.76-0.82 mEq/L). NEFA concentration indicates the breakdown of tissue from the animal's body to use as energy source. Results clearly showed that energy mobilization from animal tissue were not affected by POS levels in concentrate diets. The results are consistent with Elliott *et al*. (1996) who reported that concentrations of NEFA and glucose were not affected by fat supplementation. The data indicated that inclusion of POS in the diet did not affect the energy status of the cattle. BUN levels of cattle fed concentrate with 40%POS was significantly (P<0.01) lower than that of 0, 10, 20 and 30%POS groups. Lewis (1975) reported that concentrations of BUN was highly correlated with protein intake and reflected the level of NH_3-N production in rumen. In this study the lowest rumen NH_3-N levels were found when cattle were fed with concentrate containing 40%POS .

4. Conclusions

These results show that increased POS in concentrate up to 40% affected intake, digestibility, ruminal fermentation and blood metabolites of Thai native cattle fed with hay. Therefore, the optimum level of POS in concentrate for Thai native cattle fed Plicatulum hay as a roughage source should not exceed 30%.

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