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Original Article

Effects of dietary inclusion of palm kernel cake on nutrient utilization, rumen fermentation characteristics and microbial populations of goats fed *Paspalum plicatulum* hay-based diet

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Abstract

To investigate the effects of inclusion of palm kernel cake (PKC) in the diets on intake, digestibility, rumen fermentation characteristics, nitrogen balance and microbial N supply, five goats (initial BW = 20±1 kg) were randomly assigned to a 5×5 Latin square design to receive five diets, T_1 = concentrate with 15% PKC, T_2 = 25% PKC, T_3 = 35% PKC, T_4 = 45% PKC and T_5 = 55% PKC, of dietary dry matter, respectively. Plicatulum hay was offered *ad libitum* as the roughage. A metabolism trial lasted for 21 days during which live weight changes and feed intakes were measured. Based on this experiment, there were no significant differences (p>0.05) among treatment groups regarding dry matter (DM) intake and digestion coefficients of DM, organic matter, crude protein, neutral detergent fiber and acid detergent fiber, except in T_4 and T_5 (45 and 55% PKC) which had lower (p<0.01) than other treatments. Rumen parameters: temperature, pH, NH_3-N, blood urea nitrogen and blood glucose, packed cell volume, volatile fatty acids, rumen microorganism populations and N retention were similar among treatments (p>0.05), however the concentration of total volatile fatty acids and protozoal populations were slightly lower for goats fed inclusion of 45-55% PKC as compared with other treatments. Based on this experiment, it could be concluded that the optimal level of PKC in concentrate should be 15-35% for goats fed with plicatulum hay and that it may be an effective means of exploiting the use of local feed resources for goat production.

Keywords: palm kernel cake, rumen fermentation, goat, microbial populations

1. Introduction

In recent years, the increase in feed prices and the scarcity of grains and protein plant supplements (e.g., corn grain and soybean meal) are important constrains hampering the goat production sector in Thailand and in other countries. Additionally, the high cost of feed is a sequel to the competition between man and livestock for these feed ingredients. This has forced animal nutritionists to intensify research into the feeding values of potentially useful but unconventional crop products. One of these is oil palm (*Elaeis guineensis* Jacq.), which is abundantly available and its associated industry has been comprehensively described by Hartley (1988). Therefore, abundant amounts of by-products are produced including palm kernel cake (from the kernel) and palm press fiber (from the mesocarp layer) after the extraction of oil from the fruits; the empty fruit branch, oil palm truck and fronds. Of these by-products, Palm kernel cake (PKC), also known as palm kernel meal (PKM) has been found to be a good feed material for some ruminants (Abdullah *et al.*, 1995). They are available at competitive prices and can have a major influence on reducing the production cost.

Palm kernel cake, containing 20.6 MJ metabolisable energy (ME) kg $^{-1}$, has a high nutritive value (O'Mara *et al.*,

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1999). Anonymous (1990) reported that PKC contained 12-23% of crude protein depending on the process used to extract the oil and dry matter digestibility of around 70-80% (Jalaludin *et al.,* 1991), but a high level of fiber, gritty and lowly palatable. Therefore, it is commonly used as animal feed, especially for ruminant diets because of its fibrous nature (Moss and Givens, 1994; Abdullah *et al.,* 1995). It is regarded as a medium quality energy feed for ruminants with a moderate content of crude protein (O'Mara *et al.,* 1999; Carvalho *et al.,* 2005). Earlier studies showed that cattle and buffaloes fed PKC as supplements or basal diets generally result in improving growth performance (Hutagalung and Mahyuddin, 1985; Jelan *et al.,* 1991), but Wan Mohamed *et al.* (1987) reported that it has adverse effects in sheep. Long term feeding with PKC in sheep resulted in problems related to Cu toxicity. However, the information available on the use of high levels of PKC in diets for goats is very scarce. Therefore, this present study was conducted to evaluate the effects of PKC inclusion into the diets based on plicatulum hay upon feed intake, nutrient utilization, rumen fermentation characteristics and nitrogen balance of goats.

2. Materials and Methods

All procedures involving animals were approved by the Ethical Principles for the Use of Animals for Scientific Purposes of the National Research Council of Thailand (NRCT).

2.1 Animals, treatments and experimental design

Five male crossbred (Thai Native x Anglo Nubian) goats (approximately 15 months old) averaging 20±1.0 kg (initial mean BW±SD) were randomly assigned to dietary treatments according to a 5 x 5 Latin square design to study the effects of palm kernel cake (PKC) inclusion into the diets on intake, digestibility, ruminal fermentation, blood metabolites, microbial populations and nitrogen balance. Five isonitrogenous experimental diets were formulated to contain PKC as shown in Table 1. The treatments were as follows: T_1 = concentrate with 15% PKC, T_2 = 25% PKC, T_3 = 35% PKC, T_4 = 45% PKC, and T_5 = 55% PKC.

All goats 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 goat was kept individually in a ventilated metabolism crate in well-ventilated sheds where water and mineral salt were available at all times. The experiment was conducted for five periods, and each period lasted for 21 days. During the first 14 days, 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, whereas during the last 7 days for total collection, they were restricted to 90% of the previous voluntary feed intake of Plicatulum hay. Feeds were provided twice daily in two equal portions at 0800 and 1600 daily. Goats were weighed at the beginning of each experimental period before the morning feeding.

2.2 Data collection and sampling procedures

Feed intake was measured and refusals recorded. Body weights were measured daily during the sampling period prior to feeding. Feeds were sampled; urine and fecal samples were collected from the total collection of each individual goat on each treatment during the last 7 days of each period at the morning and afternoon feeding. Composited samples were dried at 60°C, ground (1-mm screen using Cyclotech Mill, Tecator), and then analyzed for DM, ether extract, ash, CP content (AOAC, 1990), NDF and ADF (Goering and Van Soest, 1970). At the end of each period, rumen fluid samples were collected by a stomach tube and a vacuum pump at 0 and 4 h-post feeding. Then, the pH of the rumen samples was measured immediately by pH and temperature meter (HANNA instruments HI 98153 microcomputer pH meter). 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 VFA analyses where 3 mL of H_2SO_4 solution (1M) were added to 30 mL of rumen fluid. The mixture was centrifuged at 16,000 x *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 jugular vein into heparinized tubes at the same time as rumen fluid sampling (0 and 4 h-post feeding). Then blood samples were centrifuged at 4°C at 3,300 x *g* for 15 minutes and supernatants were separated and frozen at -20°C until analysis.

2.3 Laboratory analyses

Feed, refusal and feces were analyzed in duplicate for DM, ash, CF, ether extract and Kjeldahl 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). Digestion coefficients were calculated by using the formula given by Schneider and Flatt (1975). Blood urea nitrogen (BUN) was determined according to the method of Crocker (1967) and for ruminal NH_3-N using the micro Kjeldahl method (AOAC, 1990) and volatile fatty acid (VFAs) analyses using a HPLC (Instruments by controller water model 600E; water model 484 UV detector; column novapak C_{18}; column size 4 mm x 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). Total

Table 1. Ingredients and chemical compositions of the experimental diets, plicatulum hay and palm kernel cake (PKC) (DM basis).

Item	Palm kernel cake (PKC) levels in concentrate (%)[1]					Plicatulum hay	Palm kernel cake
	T1(15)	T2(25)	T3(35)	T4(45)	T5(55)		
Ingredients composition, %							
Palm cake kernel, PKC	15.00	25.00	35.00	45.00	55.00	-	-
Corn meal, CM	59.75	58.11	50.41	42.25	28.80	-	-
Soybean meal, SBM	15.54	5.64	2.89	0.17	-	-	-
Rice bran, RB	5.00	5.00	5.00	5.00	5.00	-	-
Urea	-	1.00	1.10	1.20	1.20	-	-
Salt	1.00	1.00	1.00	1.00	1.00	-	-
Mineral mix[2]	1.00	1.00	1.00	1.00	1.00	-	-
Dicalcium phosphate	1.00	1.00	1.00	1.00	1.00	-	-
Molasses	1.46	2.00	2.00	2.00	5.00	-	-
Palm oil	-	-	0.35	1.13	1.75	-	-
Sulfur	0.25	0.25	0.25	0.25	0.25	-	-
Chemical composition							
DM[3]	88.54	88.61	88.726	88.876	88.78	92.16	95.90
Ash	5.74	5.43	5.46	5.75	6.41	8.28	3.90
OM	94.26	94.57	94.54	94.25	93.59	91.72	96.10
CP	15.89	15.76	15.83	15.48	15.56	3.04	14.20
EE	3.22	4.19	4.82	6.74	7.80	0.21	9.40
NSC[4]	43.36	36.96	33.03	24.44	19.04	6.28	3.63
NDF	31.79	37.66	40.86	47.59	51.19	82.19	68.87
ADF	13.29	18.69	22.63	28.37	32.72	54.01	52.68
ADL	4.72	6.28	8.20	9.32	11.05	8.84	14.73
Hemicellulose[5]	18.50	18.97	18.23	19.22	18.47	28.19	16.19
Cellulose[6]	8.57	12.41	14.43	19.05	21.67	45.17	37.95
GE MJ/kg DM	-	-	-	-	-	16.35	19.85

[1]T_1 = Level of PKC 15%, T_2 = Level of PKC 25%, T_3 = Level of PKC 35%, T_4 = Level of PKC 45%, T_5 = Level of PKC 55%. [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; ADL: acid detergent lignin; GE: gross energy. [4]Estimated: NSC = 100-(CP+NDF+EE+Ash). [5]Estimated: Hemicellulose = NDF-ADF. [6]Estimated: Cellulose = ADF-ADL.

urine samples were determined according to the method of AOAC (1990).

2.4 Statistical analyses

Statistical analyses were conducted using the GLM procedure of SAS software (SAS, 2000). The model used was: $Y_{ijk} = m+A_i+P_j+T_k+e_{ijk}$, where Y_{ijk} observation from animal i, receiving diet k, in period j; m, the overall of 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 level PKC (k = 1 to 5); and e_{ijk}, the residual effect. Treatment means were statistically compared using Duncan's Multiple Range Test (Steel and Torrie, 1980) to identify differences between means. Significant differences were declared if $p<0.05$. Orthogonal polynomial contrasts were used to estimate the effect of PKC supplement level.

3. Results and Discussion

3.1 Chemical composition of feeds

The ingredient and chemical compositions of roughage, palm kernel cake and experimental feeds are summarized in Table 1. The five experimental diets contained similar concentrations of DM, ash, OM and CP, but varying amount of EE, NSC, NDF, ADF and ADL among those diets. Diets were formulated to be 15% CP (DM basis). Slightly greater concentrations of CP in DM offered may have been because of greater than expected CP levels in some ingredients or inconsistencies in diet mixing or sampling (Table 1). Diets containing PKC-based diets had a slightly lower non-structural carbohydrate (NSC) as the level of Palm kernel cake (PKC) increased in the diets, ranging from 20.41 to 37.97% respectively, whereas amount of EE, NDF, ADF and ADL had a slightly higher as the level of PKC increased in the diets. 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 3.04% CP, 82.19% NDF, 54.01% ADF, and 8.84% ADL (DM basis). Similar values for PH have been previously reported by Humphreys (1980); Chanjula and Ngampongsai (2009). The PKC was contained 14.20% CP and high in OM (96.17%), NDF (68.87%), ADF (52.68%), and ADL (14.73%) contents. The CP and EE contents in PKC in this study were similar to those reported by Abdullah *et al.* (1995); O'Mara *et al.* (1999); Carvalho *et al.* (2005) who found that PKC contained 14.10-16.42% CP and 7.83-9.40% EE. The sample had GE content 19.85 MJ/kg DM. Similar values for PKC have been previously reported by Jalaludin *et al.* (1991); O'Mara *et al.* (1999). However the chemical composition of PKC is variable due to different processing methods and the degree of impurities such as shell content (Jalaludin *et al.,* 1991). In general, the expeller samples had lower contents of CP, CF, NDF, and ADF than the extracted samples. These differences can be mainly attributed to the dilution effect of the oil in the expeller samples (O'Mara *et al.,* 1999).

3.2 Feed intake and apparent digestibility of nutrients

The effects of dietary inclusion of PKC on daily feed intake and apparent digestibility of goats are presented in Table 2. Overall means for daily feed intakes for five diets in terms of roughage, concentrate and total DMI (%BW g/kgBW$^{.75}$) were similar for all dietary treatments as compared between the experimental diets (15-55% PKC). The data indicate that inclusion level of PKC had no effect on feed intake for goats. All diets were accepted well by the goats, as evidenced by similar DMI among goats receiving diets inclusion of PKC. These data support earlier studies (Hutagalung and Mahyuddin, 1985; Jelan *et al.,* 1991) in which inclusion of PKC-based diets or supplements generally resulted in satisfactory animal performance and no negative effects on animal health in finishing crossbred beef cattle and in buffaloes. Another study (Carvalho *et al.,* 2006) reported that solvent-extracted PKM up to 15% in corn silage-based diets did not affect DMI or milk yield of midlactation dairy cows.

In the current study, apparent digestibilities of DM, OM, CP, NDF and ADF were decreased ($p<0.05$) linearly by increasing level of PKC in diets. The apparent digestibilities of DM, OM, CP, NDF, and ADF by goats fed 15-35% PKC were greater than those fed 45 and 55% PKC (Table 2). This trend may be related to high fibrous fraction (ADF and ADL) and EE contents (Table 1). The EE content of inclusion of 45-55% PKC (6.74 and 7.80% EE, respectively) was high enough to reduce digestibility, especially for fiber digestion and rumen microbial fermentation (Jenkins, 1993; NRC, 2001). Similarly, Jenkins (1993), Doreau and Chilliard (1997), and NRC (2001) indicated that feeding large amounts of dietary fat to ruminants (above 5%) can negatively affect digestibility, bacterial growth and rumen fermentation. Furthermore, it is possible that low digestibility could have been attributed to a high fibrous fraction (ADF and ADL) (Hart and Wanapat, 1992). Digestibility appears to be negatively related to fibrous content (Van Soest, 1994; O'Mara *et al.,* 1999), 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. The

Table 2. Effects of palm kernel cake on feed intake and apparent digestibility in goats fed on plicatulum hay as roughage.

Item	Palm kernel cake (PKC) levels in concentrate (%)[1]					SEM	Contrast P-value[2]	
	T1(15)	T2(25)	T3(35)	T4(45)	T5(55)		L	Q
DMI, kg/d								
Plicatulum hay, kg/d	0.256	0.298	0.294	0.244	0.232	0.03	0.29	0.18
Concentrate, kg/d	0.512	0.530	0.514	0.504	0.508	0.01	0.76	0.86
Total DMI, kg/d	0.768	0.828	0.808	0.748	0.740	0.03	0.45	0.41
DMI, %BW	2.82	3.02	3.02	2.80	2.79	0.09	0.30	0.06
DMI, g/kg $W^{0.75}$	64.47	68.99	68.56	63.54	63.30	1.97	0.28	0.10
Apparent digestibility, %								
DM	72.11^{ab}	75.62^{a}	72.11^{ab}	68.27^{bc}	63.77^{c}	1.71**	0.005	0.11
OM	73.48^{ab}	76.78^{a}	74.62^{ab}	69.97^{bc}	65.72^{c}	1.62**	0.005	0.09
CP	69.28^{a}	72.83^{a}	70.18^{a}	63.64^{b}	58.73^{c}	1.55**	0.001	0.03
NDF	64.00^{a}	69.96^{a}	66.18^{a}	63.73^{a}	57.48^{b}	2.01*	0.06	0.05
ADF	54.32^{abc}	62.17^{a}	58.56^{ab}	52.32^{bc}	48.05^{c}	2.47*	0.05	0.04

[1]T_1 = Level of PKC 15%, T_2 = Level of PKC 25%, T_3 = Level of PKC 35%, T_4 = Level of PKC 45%, T_5 = Level of PKC 55%. $^{a-c}$ Within rows not sharing a common superscripts are significantly different ($p<0.05$).
* $p<0.05$; ** $p<0.01$. [2]L = linear, Q = quadratic. SEM = Standard error of the mean (n = 5).

poorly digested components are more concentrated in the ADF than the NDF, resulting in the lower digestibility. The slightly lower CP digestibility at inclusion of 45-55% PKC may have been contributed by lower intake of concentrate that contained slightly lower true protein (soy bean meal, SBM) in the diet (Table 1). Saxena *et al.* (1971) indicated that supplementation of true protein was more effective than that of NPN. Similarly, McAllan (1991) and Huntington and Archibeque (1999) reported that protein digestion in animals supplemented with true protein was greater than those supplemented with urea or NPN.

3.3 Rumen fermentation patterns and blood metabolites

Rumen parameters were measured for pH, NH_3-N and BUN. In addition, BUN was determined to investigate their relationship with rumen NH_3-N and protein utilization. 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 39.3-39.5°C, and all treatment means were within the normal range which has been reported as optimal for microbial digestion (Van Soest, 1994). Rumen fluid pH at 0 and 4 h post feeding and overall means were unchanged by dietary treatments in this study, indicating no specific effect of the inclusion of palm kernel cake, while at 4 h after the onset feeding, rumen pH of goats declined as active fermentation of the newly ingested feed occurred. At this time, the pH values ranged from 6.18-6.31, however, all treatment means were within the normal range and the values were quite stable at 6.22-6.53, which was in optimal level for microbial digestion of fiber (Hoover, 1986; Van Soest, 1994) and also digestion of protein (6.0-7.0).

Ruminal NH_3-N at 0 and 4 h post feeding and overall means were not altered by diets containing PKC-based diets, ranging from 14.14 to 16.71 mg/dL. Concentration of ruminal NH_3-N was higher than 5-8 mg/dL, which is the optimal level of NH_3-N for microbial protein synthesis (Satter and Slyter, 1974). Likewise, BUN concentration and overall means were similar among treatments with inclusion of PKC, ranging

Table 3. Effects of palm kernel cake on rumen fermentation characteristics and blood metabolized characteristics in goats fed on plicatulum hay as roughage.

Attribute	Palm kernel cake (PKC) levels in concentrate (%)[1]					SEM	Contrast P-value[2]	
	T1(15)	T2(25)	T3(35)	T4(45)	T5(55)		L	Q
Temperature, °C								
0 h-post feeding	39.1	39.3	39.4	39.2	39.2	0.33	0.91	0.54
4 h-post feeding	39.8	39.7	39.5	39.4	39.7	0.23	0.52	0.32
Mean	39.4	39.5	39.4	39.3	39.4	0.16	0.83	0.23
Ruminal pH								
0 h-post feeding	6.74	6.78	6.61	6.65	6.66	0.09	0.45	0.74
4 h-post feeding	6.31	6.20	6.21	6.18	6.18	0.04	0.33	0.60
Mean	6.53	6.49	6.41	6.22	6.42	0.10	0.15	0.35
NH_3-N, mg/dl								
0 h-post feeding	18.57	17.43	14.86	17.43	16.29	1.18	0.44	0.46
4 h-post feeding	14.86	16.00	14.00	14.29	12.00	1.48	0.16	0.45
Mean	16.71	16.71	14.43	15.86	14.14	1.13	0.23	0.96
BUN, mg/dl								
0 h-post feeding	17.77	17.26	15.65	15.32	16.00	1.05	0.17	0.43
4 h-post feeding	17.39	17.68	17.01	16.34	16.60	0.86	0.55	0.99
Mean	17.58	17.38	16.33	15.83	16.31	0.86	0.32	0.69
Glu, mg/dl								
0 h-post feeding	59.92	61.46	59.36	63.68	62.46	1.91	0.39	0.92
4 h-post feeding	65.32	66.40	64.86	65.78	64.04	2.13	0.71	0.75
Mean	62.62	63.93	62.11	64.73	63.93	1.90	0.79	0.90
PCV, %								
0 h-post feeding	27.40	2.80	27.00	29.00	29.00	0.82	0.31	0.80
4 h-post feeding	26.60	26.60	26.60	28.20	28.40	0.62	0.06	0.45
Mean	27.00	27.70	26.80	28.60	28.70	0.56	0.08	0.59

[1] T_1 = Level of PKC 15%, T_2 = Level of PKC 25%, T_3 = Level of PKC 35%, T_4 = Level of PKC 45%, T_5 = Level of PKC 55%. [a-c] Within rows not sharing a common superscripts are significantly different ($p<0.05$).
* $p<0.05$; ** $p<0.01$. [2] L = linear, Q = quadratic. SEM = Standard error of the mean (n = 5).

from 15.58 to 17.58 mg/dL, and the values were similar to the appropriate BUN of 15 mg% reported by Baker *et al.* (1995). It was close to the optimal level in normal goats which has been reported in the range of 11.2 to 27.7 mg/dL (Lloyd, 1982).

Blood glucose concentration at 0 and 4 h post feeding and overall means was similar ($p>0.05$) among dietary treatments and ranging from 62.11 to 64.73 mg/dL (3.45 to 3.59 mmol/L) (Table 3). Blood glucose concentration prior to morning feeding of the goats tended to be lower than that taken at 4 h after the onset of feeding. All treatment means were within the normal range which has been reported as ranging from 50 to 75 mg/dL (2.78 to 4.16 mmol/L) (Kaneko, 1980). Observed blood glucose concentrations were similar to those reported by Gelaye *et al.* (1990) and Turner *et al.* (2005). However, the variation in blood glucose could be affected by physiological status (Firat and Ozpinar, 1996) or disease conditions. Moreover, sampling is very important, as prior to morning feed, absorption of nutrients from the digestive tract was at minimum level (Hove and Halse, 1983). Glucose, as a source of energy, is necessary for production and reproduction performance. Blood glucose and BUN level may serve as indicators for a goat's energy status. In the present experiment, these data indicate that goats consuming the diets with palm kernel cake were in a normal energy status. This may be the possible reason for the lack of differences among treatments and there were no deleterious effects on feed intake or the metabolism of the goats. Likewise, packed cell volume (PCV) at 0 and 4 h post feeding and overall mean were similar ($p>0.05$) among treatments and ranging from 26.80 to 28.70%, but all were within the normal range of 22-38% (Jain, 1993). Based on this study, these data indicate that the inclusion of PKC-based diets had no effect on BUN, blood glucose and PCV concentrations. They also showed positive in the energy status. West (1996) reported that serum glucose has been shown to increase in high energy diet, while it dramatically decreases in starvation and low energy diet.

3.4 Volatile fatty acid profiles and rumen microorganism populations

The effect of dietary inclusion of PKC on production of total VFA concentrate, acetic acid proportion, propionic and butyric acid concentrations and acetic to propionic ratio are shown in Table 4. Overall means of total VFAs, acetic, propionate and butyric concentrations in the rumen were not affected by dietary treatments. However, the concentration of total VFAs was slightly lower for goats fed 45-55% PKC as compared with other treatments, probably as a result of lower apparent digestibilities. Ruminal acetate: propionate ratio was similar among dietary treatments. A similar observation was reported by Chanjula *et al.* (2007) and Dayani *et al.* (2007). However, the molar proportion of other VFA (isobutyrate, isovalerate and valerate) tended to be slightly higher for goats fed inclusion of 45-55% PKC as compared with other treatments, but the difference was not statistically significant. The increase in isovaleric acid could be an advantage to the animal as earlier reports showed that the use of isoacids in the diet improved microbial protein synthesis and cellulose digestion (Russell and Sniffen, 1984; Gorosito *et al.,* 1985).

Table 4 presents the rumen microorganism populations. Population of rumen bacteria and fungal zoospores were not affected ($p>0.05$) by treatments, but protozoa population at 0 and 4 h post feeding and overall protozoal populations were decreased ($p<0.01$) by treatments for goats fed inclusion of 45-55% PKC as compared with other treatments, probably as a result of higher level of PKC in diets. This finding similar to that reported by Abdullah and Hutagalung (1988) showed that the adverse effect of PKC on protozoa has been reported in cattle fed a PKC-based diet, but the reason is unknown. Some dietary factors may reduce or eliminate ruminal protozoa. Additionally, Abdullah *et al.* (1995) reported that protozoa population in the rumen fluid of sheep dropped immediately after the consumption of PKC in the first two groups of animals. Another study (Dayani *et al.,* 2007) reported that feeding whole cotton seed (WCS) decreased the total protozoa population approximately from 500,000 to 250,000 cell/ml. Several reports have shown that unsaturated fatty acids reduced protozoa population (Machmüller and Kreuzer, 1999) because unsaturated C18 fatty acids are toxic to protozoa (Newbold and Chamberlain, 1988). Thus, the use of PKC in diets may potentially result in reducing the protozoa population, changing ruminal ecosystem via reducing protozoal number and indirectly increasing bacterial numbers and activity (Kim *et al.,* 2007).

3.5 Efficiency of nitrogen utilization

Whole body N data are summarized in Table 5. Total N intake in this study was affected ($p<0.05$) by treatments, ranging from 13.66 to 15.09 g/d, and was slightly decreased for goats fed inclusion of 45-55% PKC as compared with other treatments. This trend may be related to the lower DMI and CP digestibility of goats fed diets containing 45-55% PKC compared with other treatments.

No differences in urinary N and total N excretion were observed among treatments, whilst fecal N increased ($p<0.05$) linearly as the inclusion of PKC increased in the diet. This pattern of fecal and urinary excretion is indicative of the extremely high N intake for goats fed diets containing PKC. This could be explained by the fact that excess ruminal NH_3-N is 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. The amount of N absorption and retention were similar among treatments, except for treatment 4 and 5 which tended to be slightly lower for goats fed diets containing 45 and 55% PKC. It is now well established that nitrogen retention depends on the intake of nitrogen, and the amount of fermentable carbohydrate of the diet (Sarwar *et al.,* 2003). Differences in N retention in the present study can be attributed to differences in supplemental proteins (Table

Table 4. Effects of palm kernel cake on volatile fatty acid profiles and rumen microbs in goats fed on plicatulum hay as roughage.

Attribute	Palm kernel cake (PKC) levels in concentrate (%)[1]					SEM	Contrast P-value[2]	
	T1(15)	T2(25)	T3(35)	T4(45)	T5(55)		L	Q
Total VFA, mmol/ L								
0 h-post feeding	58.48	59.59	59.09	57.95	57.70	0.96	0.76	0.79
4 h-post feeding	92.69^{ab}	95.11^{a}	91.60^{ab}	87.38^{bc}	83.75^{c}	1.70**	0.02	0.32
Mean	75.58^{a}	77.35^{a}	75.35^{a}	71.76^{b}	70.73^{b}	1.01**	0.01	0.31
Molar proportion of VFA, mol/ 100mol								
Acetate (C_2)								
0 h-post feeding	70.65	69.39	70.62	71.18	71.36	0.64	0.27	0.52
4 h-post feeding	71.95	71.04	72.36	72.15	72.40	0.79	0.48	0.81
Mean	71.31	70.22	71.49	71.66	71.88	0.62	0.24	0.56
Propionate (C_3)								
0 h-post feeding	19.26	20.21	19.15	19.61	19.20	0.51	0.83	0.76
4 h-post feeding	20.19	21.50	20.81	20.75	19.93	0.58	0.67	0.31
Mean	19.72	20.86	19.98	20.17	19.57	0.47	0.69	0.42
Butyrate (C_4)								
0 h-post feeding	7.24^{a}	7.51^{a}	7.53^{a}	6.06^{b}	6.46^{ab}	0.34*	0.16	0.62
4 h-post feeding	6.01	5.63	4.94	5.22	5.51	0.54	0.35	0.87
Mean	6.63	6.58	6.17	5.60	5.98	0.37	0.16	0.72
Other VFA,[3]								
0 h-post feeding	2.83	2.84	2.81	3.20	2.98	0.17	0.28	0.94
4 h-post feeding	1.83	1.82	1.87	1.88	2.14	0.18	0.07	0.25
Mean	2.33	2.33	2.34	2.54	2.56	0.16	0.07	0.60
C2:C3 ratio								
0 h-post feeding	3.70	3.48	3.73	3.69	3.77	0.11	0.64	0.71
4 h-post feeding	3.57	3.31	3.48	3.53	3.71	0.12	0.40	0.27
Mean	3.64	3.39	3.61	3.61	3.74	0.10	0.42	0.39
Total direct count								
Bacteria ($x10^{10}$cell/ml)								
0 h-post feeding	1.60	1.56	1.45	1.35	1.45	1.35	0.50	0.67
4 h-post feeding	1.90	2.20	1.67	1.63	1.56	2.01	0.67	0.80
Mean	1.75	1.88	1.56	1.49	1.51	1.65	0.43	0.89
Fungal zoospores ($x10^{6}$ cell/ ml)								
0 h-post feeding	2.28	1.91	1.67	1.61	1.53	0.27	0.07	0.51
4 h-post feeding	2.36	2.67	2.15	1.51	1.52	0.37	0.11	0.72
Mean	2.32	2.29	1.91	1.56	1.52	0.28	0.06	0.97
Total Protozoa ($x10^{6}$ cell/ml)								
0 h-post feeding	1.75^{a}	1.27^{ab}	2.34^{a}	0.35^{b}	0.28^{b}	0.32**	0.09	0.50
4 h-post feeding	3.54^{a}	1.55^{ab}	2.35^{a}	0.28^{b}	0.27^{b}	0.49**	0.10	0.56
Mean	2.64^{a}	1.41^{ab}	2.34^{a}	0.31^{b}	0.27^{b}	0.36**	0.06	0.95

[1]T_1 = Level of PKC 15%, T_2 = Level of PKC 25%, T_3 = Level of PKC 35%, T_4 = Level of PKC 45%, T_5 = Level of PKC 55%. [a-c] Within rows not sharing a common superscripts are significantly different ($p<0.05$).
* $p<0.05$; ** $p<0.01$. [2]L = linear, Q = quadratic. SEM = Standard error of the mean (n = 5). [3]Sum of isobutyrate, isovalerate, and valerate.

1). Swanson *et al.* (2004) suggested that N retention is higher in ruminants receiving natural protein sources than those receiving supplemental urea. However, the positive N balance observed in this study indicates that the positive influence of inclusion level of PKC in the diets with PH based feeding of goats. With regards to N utilization, Owens and Zinn (1988) stated that N excretion and N retention should reflect differences in N metabolism, because N retention was the most important index of the protein nutrition status of ruminants.

Table 5. Effects of palm kernel cake on nitrogen utilization in goats fed on plicatulum hay as roughage.

Attribute	Palm kernel cake (PKC) levels in concentrate (%)[1]					SEM	Contrast P-value[2]	
	T1(15)	T2(25)	T3(35)	T4(45)	T5(55)		L	Q
N balance, g/d								
Total N intake	15.04[a]	15.09[a]	14.40[ab]	13.66[b]	13.76[b]	0.26**	0.15	0.98
N-concentrate	13.80[a]	13.63[a]	12.96[b]	12.47[b]	12.63[b]	0.17*	0.15	0.76
N-roughage	1.24	1.46	1.44	1.19	1.12	0.11	0.34	0.20
N excretion, g/d								
Fecal N	4.62[b]	3.63[bc]	4.64[b]	4.94[ab]	5.62[a]	0.35*	0.001	0.04
Urinary N	2.24	2.63	2.22	1.70	1.89	0.28	0.23	0.83
Total N excretion	6.86	6.26	6.48	6.65	7.51	0.37*	0.32	0.16
Absorbed N	10.42[ab]	11.46[a]	10.03[b]	8.72[c]	8.13[c]	0.35**	0.02	0.37
Retained N	8.18[a]	8.83[a]	7.91[ab]	7.01[bc]	6.24[c]	0.32*	0.03	0.34
N output (% of N intake)								
Fecal	30.69[bc]	25.23[c]	30.95[bc]	36.36[ab]	41.27[a]	1.82*	0.001	0.06
Urine	15.03	17.27	14.15	12.12	13.60	1.77	0.31	0.96
Absorbed	69.30[ab]	74.76[a]	69.04[ab]	63.63[bc]	58.72[c]	1.82**	0.001	0.06
Retained	54.27[a]	57.50[a]	54.89[a]	51.51[ab]	45.12[b]	2.26*	0.04	0.14

[1]T_1 = Level of PKC 15%, T_2 = Level of PKC 25%, T_3 = Level of PKC 35%, T_4 = Level of PKC 45%, T_5 = Level of PKC 55%. [a-c] Within rows not sharing a common superscripts are significantly different ($p<0.05$).
* $p<0.05$; ** $p<0.01$. [2]L = linear, Q = quadratic. SEM = Standard error of the mean (n = 5).

4. Conclusions

Based on the experimental data, the inclusion of PKC in diets did not show any adverse effect on feed intake, digestibility, rumen fermentation patterns, blood metabolites, volatile fatty acid profiles, rumen microorganism populations, and nitrogen utilization up to 35% inclusion level of PKC. Increasing the inclusion level of PKC (>35% PKC) in the rations decreased the digestibility of DM, protein and fibrous fractions and also decreased the protozoal populations. It could be concluded that the optimal level of PKC in concentrate should be 15-35 % for goat fed with plicatulum hay, and it was a good approach in exploiting the use of local feed resources for goat production. However, further research on the use of diets in finishing goats and dairy goats should be undertaken.

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