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Original Article

Effect of oil palm meal on nutrient utilization and milk production in lactating dairy cows fed with urea-treated rice straw

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ABSTRACT

Five Holstein-Friesian crossbred dairy cows were randomly assigned according to a 5 × 5 Latin square design to study the effects of different inclusion levels of oil palm meal (OPM) at 0%, 10%, 20%, 30% and 40% in the concentrate on feed intake, nutrient digestibility, rumen fermentation and milk production in lactating dairy cows. Cows received urea-treated rice straw *ad libitum* as a roughage source. The results showed that the concentrate intake and total dry matter intake were significantly ($p < 0.05$) highest in cows fed with 10–20% oil palm meal (OPM) in concentrate, while roughage intake was not significantly ($p > 0.05$) different among treatments. Similarly, dry matter, organic matter, and natural detergent fiber were significantly ($p < 0.05$) higher in cows fed with 10% OPM in the concentrate than those in other treatments, resulting in the highest nutrient intake ($p < 0.05$). Feed intake, nutrient digestibility and nutrient intake significantly ($p < 0.05$) decreased with increasing levels of OPM up to 30–40% in the concentrate. Blood-urea nitrogen, ruminal temperature, ruminal pH, NH_3–N, total volatile fatty acids, acetic acid and butyric acid were similar among treatments ($p > 0.05$), whereas, propionic acid decreased with increasing levels of OPM in the concentrate, which was lowest in cows fed 40% OPM, resulting in the significantly ($p < 0.05$) highest acetic acid to propionic acid ratio and methane production. Furthermore, milk yield was significantly ($p < 0.05$) the highest in cows fed concentrate with 10–20% OPM, while feeding cows OPM did not affect milk composition ($p > 0.05$). In conclusion, the optimum level of OPM in the concentrate for lactating dairy cows fed with urea-treated rice straw as a roughage source in this study should not exceed 20%.

Introduction

An increase in feed price for livestock production has encouraged nutritionists to intensify research into the feeding values of potentially useful, attractive, cheaper and readily available protein and energy sources from unconventional crop products (Chanjula et al., 2011). One of these is agro-industrial by-products, which could provide alternatives for cheap and sustainable feed for livestock such as by-products from the oil palm industry. The oil palm industry produces annually large amounts of biomass available as potential animal feed, such as oil palm frond (OPF), oil palm meal (OPM), palm oil decanter cake (DC) and palm kernel cake (PKC). These by-products are obtained either during harvesting of the fruits, extraction of palm oil or refining of palm kernel oil (Wan Zahari and Alimon, 2014), and represent an alternative, as they are readily available and represent sustainable feed resources for ruminants and other farm animals (Abubakr et al., 2015). For example, PKC, resulting from the extraction of palm oil, is a good alternative feed for ruminant animals. This ingredient has a high concentration of fiber and protein, thus it can reduce costs and achieve satisfactory animal performance (Fereira et al., 2012).

Moreover, OPM, is a by-product obtained after milling and extraction of oil from the oil palm fruits, which consists of husk, shell and kernel cake; it contains 30% crude fiber and 7% crude protein (Fetuga et al., 1977), which is suitable for ruminant feed and can have a major influence on reducing the production cost. However, the information available on the use of OPM as ruminant feed is very scarce. Therefore, the objective of this study was to investigate the effect of different inclusion levels of OPM in concentrate on feed intake, nutrient utilization, rumen fermentation characteristics, milk yield and milk composition in lactating dairy cows.

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Materials and methods

All procedures involving animals were approved by the Ubon Ratchathani Rajabhat University Animal Care and Use Committee according to the guidelines of Ethical Principles for the Use of Animals for Scientific Purposes of the National Research Council of Thailand.

Animals, diet and experimental design

Five Holstein-Friesian (HF) crossbred dairy cows (75% HF with 25% Thai native breed) with 498 ± 17.0 kg of body weight (BW), 102 ± 15.0 days in milk and daily milk production of 12 ± 2.0 kg/day, were randomly assigned according to a 5 × 5 Latin square design to receive OPM at 0, 10%, 20%, 30% and 40% in concentrate.

The experiment lasted for five periods and each period lasted 21 d. The first 14 d were for feed adaptation while the last 7 d were for sample collection. Cows received the concentrate diet at a ratio of milk yield to concentrate of 2:1 and urea-treated rice straw (5% urea) was offered *ad libitum* as a roughage source. The concentrate diet was offered to the animals at 0700 h, 1200 h and 1600 h feeding times. All cows were individually penned, and water and a mineral-salt block were available at all times. The body weight of each cow was weighed on the first and last day of each period for feed offered calculation. Milk yield was recorded during the 21-day period and samples were collected during the last 7 d of each period. Feed ingredients and the chemical compositions of concentrate, rice straw, and oil palm meal are presented in Table 1. Concentrate diets were formulated to be 17% CP (crude protein on a dry matter (DM) basis) using available local feed resources. All concentrate diets contained similar concentrations of DM, organic matter (OM) and CP, whereas amounts of ether extract (EE), neutral detergent fiber (NDF) and acidic detergent fiber (ADF) were slightly higher as the level of OPM increased in the diets. Moreover, OMP had 8.0% CP content and UTRS contained 7.1% CP as well as high fibrous fractions (NDF and ADF) in UTRS.

Data collection, sampling procedure, and analysis

Feed intakes were measured and refusals recorded. Samples of feed (concentrate and urea-treated rice straw) were collected daily during the collection period and composited by period and stored at 4 °C for later chemical analysis. The samples were divided into two parts; the first part was analyzed for dry matter (DM) while the second part was for analyses of ash, ether extract (EE), crude protein (CP) and acidic detergent fiber (ADF) according to Association of Official Analytical Chemists (1997). Neutral detergent fiber (NDF) in samples was estimated according to Van Soest et al. (1991).

Fecal samples were collected during the last 7 d of each period. Fecal samples were collected at 0900 h or 1200 h using rectal sampling. The fecal samples were divided into two parts; the first part was for DM analysis (Association of Official Analytical Chemists, 1997) every day during the collection period and the second part was kept in a refrigerator and pooled by cows at the end of each period for chemical analysis. Composited samples were dried at 60 °C, ground through a 1 mm screen using a Grinding Machine (Lockpin 200Ag; Zhejiang, China), and then analyzed for DM, ash, CP and ADF (Association of Official Analytical Chemists, 1997) as well as NDF in samples which was estimated according to Van Soest et al. (1991). Acid-insoluble ash (AIA) was analyzed and used to estimate the digestibility of nutrients (Van Keulen and Young, 1977).

Milk yields were recorded daily at each milking, and milk samples were composited daily, according to yield, for both the morning and afternoon milking time, preserved with 2-bromo-2 nitropropane-1, 3- dial, and stored at 4 °C until analysis for chemical composition of fat, protein, totals solids and solids-not-fat using a Lacticheck milk analyzer (LC-01RR; Massachusetts, United States). Milk urea nitrogen (MUN) was determined using Sigma kits #640 (Sigma Diagnostics, St. Louis, MO, USA).

At the end of each period, rumen fluid was collected at 0 h and 4 h post feeding. Approximately 200 mL of rumen fluid were obtained anaerobically from different sites within the rumen via the esophagus using a stomach tube (outside diameter 1 cm, inside diameter 0.8 cm, length 300 cm) connected to a vacuum pump. When the tube was employed, a back and forth action was used to facilitate obtaining large quantities of rumen contents from different areas of the rumen. Rumen fluid was immediately measured for pH and temperature using a glass electrode pH meter and temperature meter (HI 8424 microcomputer (microprocessor-based pH/mV/°C meter with HI 1230B combination, double-junction, gel pH electrode and HI 7669AW temperature probe); Hanna Instruments, Singapore), respectively. Rumen fluid samples were then filtered through four layers of cheesecloth and 45 mL of rumen fluid sample was collected in a plastic bottle to which 5 mL of 1M H_2SO_4 was added to stop the fermentation process of microbial activity, before centrifuging at 16,000 × *g* for 10 min. About 20–30 mL of supernatant was collected and frozen at −20 °C for analysis of volatile fatty acid (VFA) using high performance liquid chromatography (HPLC) according to Samuel et al. (1997) and NH_3–N using a Kjeltec Auto 8100 Analyzer (Tecator; Hilleroed, Denmark) according to Association of Official Analytical Chemists (1997).

A blood sample (about 10 mL) was collected from a jugular vein (at the same time as rumen fluid sampling) and processed using a commercial test kit for analysis of blood-urea nitrogen (BUN) in a Rosche Cobas C501 Analyzer (Photometric measuring unit (incl. ISE), Rotkreuz, Switzerland).

Statistical analysis

All data were subjected to ANOVA according to a 5 × 5 Latin square design using the General Linear Models (GLM) procedures (SAS, 1998). Data were analyzed using the model: $Y_{ijk} = \mu + M_i + A_j + P_k + \varepsilon_{ijk}$; where Y_{ijk} is the observation from animal *j*, receiving diet *i*, in *j* = 1, 2, 3, 4 or 5 treatment groups; P_k is

Table 1
Feed ingredients and chemical composition of experimental diets on dry matter (DM) basis.

Ingredient	OPM levels (%DM)					OPM	UTRS
	0	10	20	30	40		
Oil palm meal	0.0	10.0	20.0	30.0	40.0		
Cassava chip	57.0	50.0	40.0	32.0	24.0		
Palm kernel cake	6.5	6.5	6.5	6.5	6.5		
Soybean meal	13.5	13.0	13.0	11.0	10.0		
Fine rice bran	13.5	13.0	13.0	13.0	13.0		
Urea	2.5	2.5	2.5	2.5	2.5		
Molasses	2.0	2.0	2.0	2.0	2.0		
Salt	0.5	0.5	0.5	0.5	0.5		
Sulfur	0.5	0.5	0.5	0.5	0.5		
Mineral mixture	1.0	1.0	1.0	1.0	1.0		
Di-calcium phosphate	1.0	1.0	1.0	1.0	1.0		
Total	100.0	100.0	100.0	100.0	100.0		
Chemical composition, %DM (analysis values)							
DM (%)	84.3	84.8	85.1	84.6	85.8	88.2	70.6
Organic matter	86.8	87.2	87.6	88.1	88.4	96.4	83.3
Crude protein	17.2	17.3	17.7	17.6	17.8	8.0	6.1
Ether extract	4.8	5.1	5.7	6.3	6.7	7.4	1.2
Neutral detergent fiber	20.3	23.1	26.6	29.8	32.1	48.4	76.3
Acid detergent fiber	10.6	12.0	14.3	17.7	20.3	28.6	52.5

OPM = oil palm meal, UTRS = urea-treated rice straw.

the effect of period $k = 1, 2, 3, 4, 5$; ε_{ijk} is the residual effect in period k; μ is the overall of mean; M_i is the mean effect of different levels of OPM in the concentrate for i = 0%, 10%, 20%, 30% or 40%; and A_j **is** the effect of animal. Treatment means were compared using Duncan's new multiple range test (Steel and Torrie, 1980). Differences among means with $p < 0.05$ were accepted as representing statistically significant differences.

Results

Feed intake and nutrient digestibility

The effects of dietary inclusion of OPM on feed intakes and nutrient digestibility are presented in Table 2. The data indicated that inclusion of OPM had no effect on roughage intake, while concentrate intake and total DM intake decreased with increasing levels of OPM >20% in the concentrate, which was lowest in cows fed with 40% OPM. The greatest concentrate and total DM intake were observed in cows fed on 10% OPM, but the results were similar with cows fed on 0% and 20% OPM.

Digestibility of DM, OM, and NDF significantly decreased as dietary OPM increased, resulting in a significantly decreased nutrient intake (Table 2), which was lowest in cows fed 40% OPM. In contrast, digestibility and nutrient intake of EE significantly increased as dietary OPM increased, which was highest in cows fed 40% OPM. No significant differences in CP and ADF digestibility were obtained from feeding different OPM levels in the concentrate. In addition, the results of feed intake, nutrient digestibility, and nutrient intake were highest in cows fed 10–20% OPM.

Rumen fermentation characteristics and blood urea nitrogen

The results of rumen ecology and BUN are illustrated in Tables 3 and 4. There was no significant difference in the effect of OPM levels on ruminal temperature, ruminal pH, NH_3–N, BUN, acetic acid and butyric acid at 0 h and 4 h post feeding as well as for the overall mean, total volatile fatty acids (VFA) at 0 h post feeding and the overall mean. On the other hand, rumen VFA in terms of propionic acid at 4 h post feeding and mean values were significantly

Table 2
Effects of oil palm meal on feed intake and nutrient digestibility in lactating dairy cows fed with urea-treated rice straw (UTRS).

Item	OPM levels (g/kg DM)					SEM
	0	10	20	30	40	
Dry matter intake						
UTRS intake						
kg/d	10.4	10.5	10.4	10.0	10.1	0.18
%BW	2.1	2.2	2.1	2.0	2.0	0.05
Concentrate intake						
(kg/d)	6.5[a]	6.6[a]	6.5[a]	5.6[b]	5.3[b]	0.23
(%Body weight)	1.3[a]	1.3[a]	1.3[a]	1.1[b]	1.1[b]	0.05
Total intake						
(kg/d)	16.8[a]	17.0[a]	16.9[a]	15.6[b]	15.3[b]	0.30
(%Bodyweight)	3.4[ab]	3.5[a]	3.4[ab]	3.2[bc]	3.1[c]	0.02
Nutrient intake (kg/d)						
Organic matter	13.7[a]	13.7[a]	13.8[a]	12.9[b]	12.5[b]	0.19
Crude protein	1.8[a]	1.8[a]	1.8[a]	1.6[b]	1.5[b]	0.03
Natural detergent fiber	9.8[ab]	10.2[a]	10.1[ab]	9.7[b]	9.8[ab]	0.14
Acid detergent fiber	6.1	6.3	6.4	6.3	6.4	0.10
Ether extract	0.42[c]	0.45[b]	0.47[ab]	0.48[ab]	0.49[a]	0.000
Nutrient digestibility, %						
Dry matter	72.1[a]	72.8[a]	69.3[ab]	66.7[bc]	64.9[c]	1.12
Organic matter	70.3[ab]	72.6[a]	70.5[ab]	65.9[b]	65.3[b]	1.77
Crude protein	60.0	60.2	58.6	57.8	56.4	1.14
Natural detergent fiber	55.6[ab]	58.5[a]	57.6[a]	54.2[bc]	51.2[c]	1.03
Acid detergent fiber	48.7	51.3	46.9	44.2	44.4	2.61
Ether extract	69.4[b]	71.8[ab]	74.9[ab]	76.8[a]	77.3[a]	2.18

OPM = oil palm meal, DM = dry matter, SEM = standard error of the means.
[a, b, c] = values in the same row with different lowercase superscripts differ ($p < 0.05$) significantly.

Table 3
Effects of oil palm meal on rumen fermentation and blood metabolites in lactating dairy cows fed with urea-treated rice straw.

Item	OPM level (g/kg DM)					SEM
	0	10	20	30	40	
Ruminal pH						
Hours post feeding						
0	6.7	6.8	6.7	6.6	6.6	0.06
4	6.6	6.6	6.6	6.5	6.5	0.06
Mean	6.6	6.7	6.6	6.6	6.5	0.05
Ruminal temperature (°C)						
Hours post feeding						
0	38.4	37.3	39.8	37.7	38.7	0.90
4	39.6	40.6	40.3	40.9	39.8	0.57
Mean	39.1	39.0	40.0	39.3	39.2	0.49
NH_3–N, mg/dL						
Hours post feeding						
0	13.1	13.1	13.2	12.4	13.5	0.96
4	17.7	20.0	19.4	18.3	18.2	1.11
Mean	15.4	16.6	16.3	15.3	16.1	0.70
Blood urea-N (mg/dL)						
Hours post feeding						
0	15.6	15.2	15.4	13.8	13.2	0.97
4	16.6	16.2	16.2	16.0	16.0	1.19
Mean	16.4	16.0	16.2	15.2	15.0	0.96

OPM = oil palm meal, DM = dry matter, SEM = standard error of the means.

Table 4
Effect of oil palm meal in on ruminal volatile fatty acids (VFA) concentration in lactating dairy cows fed with urea-treated rice straw.

Item	OPM level (g/kg DM)					SEM
	0	10	20	30	40	
Total VFA (mmol/L)						
Hours post feeding						
0	84.2	83.8	82.8	77.2	88.3	6.26
4	117.9[a]	123.2[a]	124.2[a]	100.2[b]	96.2[b]	5.66
Mean	98.6	100.7	99.8	92.1	91.9	4.28
Acetic acid (mmol/L)						
Hours post feeding						
0	65.8	65.5	66.3	66.2	66.5	0.50
4	62.0	61.8	61.6	62.6	62.7	0.56
Mean	63.6	63.3	63.5	64.2	64.6	0.42
Propionic acid (mmol/L)						
Hours post feeding						
0	25.2	26.0	25.1	24.8	24.8	0.39
4	28.6[ab]	29.3[a]	29.2[a]	27.4[b]	27.4[b]	0.51
Mean	27.2[ab]	28.0[a]	27.6[a]	26.3[bc]	26.1[c]	0.33
Butyric acid (mmol/L)						
Hours post feeding						
0	9.0	8.5	8.6	9.0	8.7	0.39
4	9.4	8.9	9.2	10.0	9.9	0.35
Mean	9.2	8.7	8.9	9.6	9.3	0.34
Acetic:Propionic acid ratio						
Hours post feeding						
0	2.6	2.5	2.6	2.7	2.8	0.06
4	2.2[ab]	2.1[b]	2.1[b]	2.2[ab]	2.3[a]	0.05
Mean	2.4[bc]	2.2[c]	2.2[c]	2.5[ab]	2.6[a]	0.04
Methane*, (mmol/L)						
Hours post feeding						
0	29.6	29.0	29.7	29.9	29.9	0.30
4	26.9[ab]	26.4[b]	26.5[b]	27.8[a]	27.8[a]	0.39
Mean	28.3[ab]	27.7[b]	28.1[ab]	28.8[a]	28.8[a]	0.27

OPM = oil palm meal.
* = methane = (0.45 × acetic acid) − (0.275 × propionic acid) + (0.40 × butyric acid) (Moss et al., 2000).
[a, b, c] = values in the same row with different lowercase superscripts differ ($p < 0.05$) significantly.

decreased with increasing levels of OPM in the concentrate. The greatest propionic acid concentration was observed in cows fed 10–20% OPM and the least propionic acid concentration was in cows fed 40% OPM, resulting in the significantly highest acetic acid to propionic acid ratio and methane production (Table 4). Moreover, at 0 h post feeding, there was no significant difference among treatments regarding propionic acid, acetic acid to propionic acid ratio and methane production.

Milk production and compositions

Milk production and composition as affected by different OPM levels in the concentrate are presented in Table 5. Feeding cows with OPM at 10–20% in the concentrate produced the highest milk yield while increasing levels of OPM up to 30–40% significantly decreased milk yield. Moreover, there were no differences due to varying OPM in the diets on 3.5% fat collected milk (FCM), milk fat yield and milk protein as well as milk composition and MUN.

Discussion

Cows receiving concentrate containing more than 20% OPM had lower concentrate intake and total DM intake than those on 0% and 10% OPM. This result may have been due to the high fibrous fraction (NDF and ADF) and EE content of the concentrate, which had comparatively low palatability and also due to the rancidity of concentrate containing more than 20% OPM. Fereira et al. (2012) reported that a linear decrease in dry matter intake (DMI) was observed in cattle fed different levels of palm kernel cake in concentrate (0%, 7%, 14%, 21%, and 28%, respectively) due to the lower palatability and higher fiber content of the palm kernel cake, and the content of NDF in the diet could reduce consumption primarily because of physical limitations. Moreover, reduction in feed intake may be related to an EE content of more than 20%, when OPM inclusion was high enough to reduce digestibility, especially fiber digestion and rumen microbial fermentation (Palmquist and Jenkins, 1980; National Research Council, 2001), which resulted in reduced feed intake and digestibility when feeding high levels of OPM. In this experiment, digestibility of nutrient and nutrient intake of DM, OM and NDF as well as the CP intake by cows fed with 30–40% OPM in concentrate were lower than those for cows fed with 10–20% OPM. This result may have been due to the EE content from the inclusion of 30–40% OPM (6.3–6.7%) being high enough to reduce the digestibility of nutrient. Similarly, Seephueak et al. (2011) found that cattle feed concentrate containing 40% palm oil sludge (POS) tended to have lower DM and OM digestibility than the cow fed with 0–30% POS; furthermore, cattle fed concentrate containing 40% POS had lower CP digestibility than for the other treatments. The data indicated that high POS levels with high EE content in the diets affected feed intake and digestibility. Feeding excess fat in the ruminant diet has been found to inhibit microbial activity during ruminal fermentation, thereby leading to depressed digestibility (Orskov and Ryle, 1990). Similarly, Palmquist and Jenkins (1980), Doreau and Chilliard, 1997, and National Research Council (2001) indicated that feeding large amounts of dietary fat to ruminants (above 6–7%) can negatively affect digestibility, bacterial growth and rumen fermentation, resulting in decreased overall DMI and nutrient digestion. Furthermore, a reduction in the digestibility of nutrient may be related with the high digestibility of EE and EE intake when feeding high levels of OPM in concentrate (30–40% OPM). In addition, it is possible that low digestibility could have been attributed to a high fibrous fraction in the diets (Van Soest, 1994); the current study found that composition of NDF and ADF increased with increasing levels of OPM in the concentrate, which resulted in reduced digestibility when feeding a high level of OPM.

Table 5
Effects of oil palm meal on milk yield and milk composition in lactating dairy cows fed with urea-treated rice straw.

Item	OPM level (g/kg DM)					SEM
	0	10	20	30	40	
Milk yield (kg/d)	14.3[ab]	14.8[a]	14.8[a]	12.6[b]	12.4[b]	0.64
3.5% FCM (kg/d)*	15.1	16.4	16.2	14.3	14.5	1.26
Milk fat yield (kg/d)	0.54	0.62	0.60.	0.54	0.55	0.06
Milk protein yield (kg/d)	0.49	0.52	0.51	0.41	0.42	0.04
Milk composition (%)						
Fat	3.8	4.2	4.0	4.4	4.5	0.34
Protein	3.4	3.5	3.4	3.3	3.4	0.12
Solids-not fat	8.8	9.5	9.3	8.8	9.2	0.38
Total solids	12.6	13.7	13.4	13.2	13.7	0.64
Milk urea-N (mg/dL)	15.8	14.0	14.6	16.2	16.0	0.95

[1]OPM = oil palm meal, FCM = fat collected milk.
* 3.5% FCM (fat collected milk) = 0.432 (kg of milk/d) + 16.23 (kg of fat).
[a, b] = values in the same row with different lowercase superscripts differ ($p < 0.05$) significantly.

There were no effects of OPM in the concentrate for lactating dairy cows on ruminal temperature, ruminal pH, NH_3–N and BUN. Ruminal pH and temperature at 0 h and 4 h post feeding and the overall mean were similar among treatments and the values were quite stable within normal ranges reported as optimal levels (pH 6.0–7.0 and temperature 39–40 °C) for microbial growth and digestion by Van Soest (1994). In addition, NH_3–N and BUN were close to the normal levels reported by Preston and Leng (1987) of an optimal level of NH_3–N within the range 5–25 mg/dL of rumen liquor recommended as being adequate for microbial growth, with more efficient microbial activity improved by higher levels where there is a continuous supply of high levels of NH_3–N. Furthermore, Roseler et al. (1993) reported that balanced diets with energy and protein for lactating dairy cows were associated with an average BUN concentration of 15 mg/dL. The current study had mean values of NH_3–N and BUN of 15.3–16.6 mg/dL and 15.0–16.4 mg/dL, respectively.

Although the molar proportion of VFA in terms of acetic acid, butyric acid was not affected by dietary treatments at any sampling time, the concentration of total VFA and propionic acid at 4 h post feeding were lower in cows fed 30–40% OPM in the concentrate compared with other treatments, probably as a result of the lower feed intake and apparent digestibility. Chanjula et al. (2010) found that the concentration of total VFA was slightly lower for goats fed 45–55% PKC compared with 15–35% PKC. This result may have been due to the EE content of the diets as reported by Oldick and Firkins (2000) who found that proportion of propionic acid increased and of butyric acid decreased with increasing fat levels in the concentrate. Boggs et al. (1987) reported that increasing the level of fat in diets tended to decrease concentrations of total VFA in rumen fluid and also decreased ($p < 0.01$) acetic acid and increased propionic acid. In the current study, the highest concentrations of total VFA and propionic acid were observed in cows fed 10–20% OPM in the concentrate, which resulted in the lowest acetic acid to propionic ratio and methane production in the rumen. The change in the methane concentration in the rumen is consistent with the reduced acetate to propionate ratio which often improves the efficiency of feed utilization since relatively higher propionate production is associated with less methane production and so less energy from gas (Machmueller et al., 1998).

Oil palm meal (OPM) inclusion at 10–20% in the diets of lactating dairy cows produced the highest milk yield, while the milk composition was not affected by the inclusion of OPM in the diets. It would seem that feeding cows with 10–20% OPM could enhance feed intake, nutrient digestibility, and rumen fermentation, resulting in an increased milk production. In addition, MUN in this study was in the range 14.0–16.2 mg/dL, which was related to efficient utilization of dietary protein in ruminants. Hwang et al. (2000) reported that cattle producing milk that contains a level of MUN within the standard reference range (11–17 mg/dL) was indicative of a balanced protein and energy intake.

It can be concluded from the results of this study that increased levels of OPM (up to 30–40%) in the concentrate for lactating dairy cows adversely affected feed intake nutrient digestibility, rumen fermentation, and milk production. To obtain the most beneficial effect on feed intake, nutrient digestibility, rumen fermentation, and milk production, the use of OPM in the concentrate for lactating dairy cow fed with urea-treated rice straw should not exceed 20%.

Conflict of interest

The authors declare that there are no conflicts of interest.

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