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Effects of Sunflower Oil Supplementation in Cassava Hay Based-diets for Lactating Dairy Cows

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ABSTRACT : Twenty-four, lactating dairy cows were randomly assigned according to a Rrandomized complete block design (RCBD) to investigate the effect of sunflower oil supplementation (SFOS) with cassava hay based-diets on feed intake, digestibility of nutrients, rumen fermentation efficiency and milk production. The treatments were as follows: T1 = Control, using commercial concentrate as a supplement (CON); T2 = Concentrate with cassava hay (CHSO-0); T3 = Concentrate with cassava hay and 2.5% sunflower oil (CHSO-2.5); T4 = Concentrate with cassava hay and 5% sunflower oil (CHSO-5). The cows were offered concentrate feed at a ratio of concentrate to milk production of 1:2 and urea-treated rice straw was fed *ad libitum*. The results revealed that feed intake, digestibility of nutrients and ruminal pH were similar among all treatments, while ruminal NH_3-N was lower ($p<0.05$) with SFOS. Blood urea-N (BUN) and milk urea-N (MUN) were not significantly affected by SFOS. The ruminal concentrations of volatile fatty acids were significantly different among the treatments. Sunflower oil supplementation significantly increased concentrations of unsaturated fatty acids, and ratio of unsaturated to saturated fatty acids in the milk, particularly the conjugated fatty acids, was significantly enhanced. Furthermore, production costs of treatments with sunflower oil supplementation were lower than for the control. Based on this study, SFOS in cassava hay based-diets improves rumen ecology, milk yield and milk quality, especially in terms of conjugated linoleic acids.
(**Key Words :** Sunflower Oil, Cassava Hay, Conjugated Linoleic Acid (CLA), Rumen Fermentation, Urea-treated Rice Straw, Dairy Cows, Ruminant)

INTRODUCTION

Cows in early lactation and high-producing cows are typically in a negative energy balance. In order to balance the ration, the use of fat or fat-rich feedstuffs is a logical step to increase the energy content of rations. Fat has good potential, because of its high energy, to meet the energy requirements of high-producing dairy cows and for early lactation. It increases the energy density of the diet by increasing the fat content which increases milk yield and milk quality. Sunflower oil is one source of fat that can be used as a supplement. It contains 12% saturated fatty acids and 88% unsaturated fatty acids (Grant and Kubik, 1990). Palmquist (1988) reported that sunflower oil consists of 8% palmitic ($C_{16:0}$), 3% stearic ($C_{18:0}$), 13.5% oleic ($C_{18:1}$), 75% linoleic ($C_{18:2}$) and 0.5% linolenic ($C_{18:3}$) acid. In addition, sunflower oil supplementation increases milk yield and the proportion of unsaturated fatty acids in milk fat. Furthermore, it increases the concentrations of *trans*10, *cis*12 ($C_{18:2}$) and *cis*9, *trans*11 ($C_{18:2}$) in the rumen (Loor et al., 2004). However, feeding sunflower oil did not affect DMI and apparent ruminal DM, NDF and ADF digestibilities when supplemented at 2-4% (Kalscheur et al., 1997). However, there have not been any studies of sunflower oil supplementation with cassava hay based-concentrate in lactating dairy cows. Since cassava hay can be used as a good source of protein in ruminant (Wanapat and Khampa, 2006; Phengvichith et al., 2007) or dairy cattle (Wanapat et al., 2000a; Hong et al., 2003; Wanapat, 2003; Kiyothong and Wanapat, 2004)

Therefore, the objective of this experiment was to investigate the effect of supplementation of sunflower oil and cassava hay based-concentrate with urea-treated rice straw as basal roughage on ruminal fermentation efficiency, and milk productivity in lactating dairy cows.

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Table 1. Ingredients and composition of experimental concentrates

Item	CON	CHSO-0	CHSO-2.5	CHSO-5
Ingredient (% DM)	--------------- % Dry basis ------------			
Sunflower oil		-	2.5	5
Cassava chip		50	50	50
Wheat bran		5.5	3	0.5
Chopped cassava hay		20	20	20
Sunflower meal		10	10	10
Brewer's grain		8	8	8
Molasses		1.5	1.5	1.5
Urea		2.5	2.5	2.5
Sulphur		0.5	0.5	0.5
Mixed minerals		2	2	2
Total		100	100	100

CHSO-0 = Concentrate with cassava hay.
CHSO-2.5 = Concentrate with cassava hay+2.5% sunflower oil.
CHSO-5 = Concentrate with cassava hay+5% sunflower oil.

MATERIALS AND METHODS

Animals, diets and experimental design

Twenty-four, Holstein-Friesian crossbred cows (75%) in their first lactation at 50-55 days-in-milk were used in this experiment. The average milk yield before the experiment was 10-12 kg/day and the average body weight was 390±10 kg. Cows were randomly assigned according to a Randomized complete block design (RCBD) with 4 treatments and 6 replications to study ruminal fermentation efficiency, digestibility of nutrients and milk production. The dietary treatments were as follows: T1 = control, using commercial concentrate (containing cassava chip, wheat bran, soybean meal, ground mungbean, sunflower meal, palm kernel cake, brewers' grain, kapok seed meal, molasses, urea, sulphur, mixed minerals and vitamin ADE) as a supplement (CON); T2 = concentrate with cassava hay (CHSO-0); T3 = concentrate with cassava hay and 2.5% sunflower oil (CHSO-2.5); T4 = concentrate with cassava hay and 5% sunflower oil (CHSO-5). The composition of dietary treatments used is shown in Table 1.

Cows were housed in individual pens and individually fed concentrate feed at a ratio of 1:2 according to the milk yield twice daily after milking at 06.00 am and 04.00 pm. They were fed the experimental diets for 14 days to adapt and for 3 months during the experimental period. All cows were fed urea-treated rice straw (UTS) *ad libitum* with water and a mineral-salt block. Feed intake of concentrate and roughage were measured separately and refusals recorded. In the morning and in the evening the daily milk yield of each individual cow was recorded. During the last 14 days of each month, daily feed intake was recorded. Once a month, two consecutive milk samples of each cow were taken and analysed for milk composition, milk-urea nitrogen (MUN) and fatty acid content by using Milko-Scan, a Sigma diagnostics procedure and gas chromatography, respectively.

The UTS was prepared by using 5% (W/W) urea mixed with 100 kg of water and 100 kg batches of rice straw (RS) (50:50, water to straw). The mixture was poured over a stack of straw and then the rice straw was covered with a plastic sheet for a minimum of 10 days before feeding to animals (Wanapat, 1990).

Data collection and sampling procedures

The UTS and concentrate were sampled daily during the collection period and were composited prior to analyses. Feed, fecal and urine samples were collected during the last seven days of each period. Fecal samples were collected by rectal sampling. Composited samples were dried at 60°C, ground (1 mm screen using Cyclotech Mill, Tecator, Sweden) and analyzed for DM, ether extract, ash and CP content (AOAC, 1990), NDF, ADF and ADL (Goering and Van Soest, 1970) and acid insoluble ash (AIA). AIA was used as internal marker to estimate digestibility of nutrients (Van Keulen and Young, 1977). In brief, AIA was prepared by drying and ashing the sample, and boiling the ashed sample in 2 M hydrochloric acid for 5 min. The ash content was determined gravimetrically after the hot hydrolysate had been filtered, washed free of acid and then re-ashed.

Cows were milked twice daily, and milk weights were recorded at each milking during each period. Milk samples (morning and afternoon milk) were composited daily, preserved with 2-bromo-2 nitropropane-1, 3-dial and stored at 4°C until analyzed for fat, protein, lactose, total solids and solids-not-fat content by infrared methods using Milko-Scan 33 (Foss Electric, Hillerod, Demark). Milk urea nitrogen (MUN) was determined using Sigma kits #640 (Sigma Diagnostics, St. Louis, MO) (Valladares et al., 1999).

Rumen fluid samples were collected at 0 h (pre-concentrate feeding) and 4 h after the feeding of concentrates for each individual cow. On the last day of each period approximately 200 ml rumen fluid was taken from the middle part of the rumen with a stomach tube which was connected to a vacuum pump Rumen fluid was measured immediately after withdrawal for pH and temperature using a microcomputer (HANNA instruments HI 8424). Rumen fluid samples were filtered through four layers of cheesecloth and divided into two portions. One portion was used for NH_3-N analysis, after 5 ml of H_2SO_4 solution (1 M) was added to 50 ml of rumen fluid. The mixture was centrifuged at 16,000 g for 15 minute and the supernatant stored at -20°C until NH_3-N analysis, using the micro Kjeldahl method (AOAC, 1990), and volatile fatty acid (VFA) analysis, using HPLC according to Zinn and Owens (1986). The second portion was fixed with10% formalin solution in normal saline (Galyean, 1989).

A blood sample (about 10 ml) was drawn from the jugular vein at the same time as rumen fluid sampling; after

Table 2. Chemical compositions and price of experimental concentrates

Item	CON	CHSO-0	CHSO-2.5	CHSO-5
Chemical compositions (%)				
DM	89.2	88.9	88.9	89.5
CP	19.5	19.1	19.6	19.1
Fat	3.2	2.7	5.3	7.0
Ash	8.7	6.8	6.7	6.8
NDF	27.8	26.4	31.8	27.3
ADF	16.3	18.8	23.1	20.9
ADL	2.7	6.7	8.8	8.0
Price/kg Baht (fed basis)	6.13	4.99	5.80	6.61
$ US	0.15	0.12	0.14	0.16

DM = Dry matter, CP = Crude protein, NDF = Neutral-detergent fiber.
ADF = Acid-detergent fiber, ADL = Acid-detergent lignin.
1 US = 40 Baht.
CON = Control (using commercial concentrate as a supplement).
CHSO-0 = Concentrate with cassava hay.
CHSO-2.5 = Concentrate with cassava hay + 2.5% sunflower oil.
CHSO-5 = Concentrate with cassava hay+5% sunflower oil.

separation by centrifugation at 5,000 g for 10 minutes, the blood plasma was stored at -20°C until the analysis of blood urea nitrogen (BUN) according to the method of Crocker (1967).

Statistical analysis

Various data were subjected to Analyses of variance (ANOVA) according to a Randomized complete block design using the General Linear Models (GLM) of the SAS System for Windows (SAS, 1998). Treatment means were compared using Duncan's New Multiple Range Test (DMRT) (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Chemical composition of feeds

Ingredients and composition of experimental concentrates are shown in Table 1. The CP content was similar for all treatments and in the range recommended by NRC (2001).

Effect on feed intake and digestibility

The effect of sunflower oil in cassava hay based-diets on feed intake and body weight is presented in Table 3. UTS and concentrate dry matter intakes were not significantly different among the treatments. This result was similar to the observation of Wanapat (2001) who found that UTS intakes were similar in diets fed with and without cassava hay supplementation. However, UTS intakes in the cassava hay based-diet treatments tended to be higher, while intakes of concentrate tended to be lower as compared to the control treatment. This result agreed with studies of Wanapat (2001) and Kiyothong and Wanapat (2004) who reported that supplementation of cassava hay reduced concentrate use without affecting the milk yield. Supplementation of sunflower oil resulted in slightly lower total dry matter intake (DMI) than that recommended by NRC (2001); however, total DMI was not significantly different among treatments which agreed with the work of Sackmann et al. (2003). Others have reported no reduction in DMI when supplementing yellow grease (Zinn et al., 2000), 0.5-4% soybean oil or 1% linseed oil (Dhiman et al., 2000) or high-corn oil (Duckett et al., 2002). However, DMI expressed as % BW tended to be lowered by increasing sunflower oil supplementation. Feeding more fat could result in reduced rumen microbial activities, reduced digestibility (McDonald et al., 2002) and might result in low dry matter intake. This study found that digestibilities of all nutrients (DM, OM, NDF and ADF) tended to be reduced as fat content of feed increased.

Digestion of nutrients and energy intakes were similar among treatments (Table 4). However, all of the cassava hay based-diet treatments tended to be higher in nutrient digestion than the CON. However, increasing sunflower oil in the diets tended to lower nutrient digestion. According to

Table 3. Effect of sunflower oil in cassava hay based-diets on feed intake and live weight changes of cattle

Item	CON	CHSO-0	CHSO-2.5	CHSO-5	SEM
UTS DMI (kg/day)	6.7	7.0	6.9	6.8	0.20
% BW	1.6	1.8	1.7	1.6	0.05
g/kg $W^{0.75}$	82.4	86.5	85.1	83.4	2.44
Concentrate DMI (kg/day)	5.9	5.2	4.9	5.1	0.33
% BW	1.4	1.3	1.2	1.2	0.07
g/kg $W^{0.75}$	72.1	64.4	61.0	63.5	4.00
Total DMI (kg/day)	12.6	12.3	11.9	12.0	0.43
% BW	3.1	3.2	3.0	2.9	0.09
g/kg $W^{0.75}$	154.5	150.9	146.1	146.9	5.22
Live weight (kg)					
Initial	408	386	389	401	8.76
Final	429	418	400	435	8.69
Live weight change (kg/day)	0.26	0.25	0.12	0.26	0.04

ADG = Average daily gain, UTRS = Urea-treated rice straw, DMI = Dry matter intake, BW = Body weight, SEM = Standard error of mean.
CON = Control (using commercial concentrate as a supplement). CHSO-0 = Concentrate with cassava hay.
CHSO-2.5 = Concentrate with cassava hay+2.5% sunflower oil. CHSO-5 = Concentrate with cassava hay+5% sunflower oil.

Table 4. Effect of sunflower oil in cassava hay based-diets on nutrient digestibility and digestible nutrient intake

Item	CON	CHSO-0	CHSO-2.5	CHSO-5	SEM
Digestion coefficients (%)					
DM	56.4	57.9	57.6	56.3	0.74
OM	61.7	62.9	62.9	61.6	0.71
CP	55.6	56.8	54.7	51.2	0.95
NDF	61.1	59.3	60.4	56.2	1.98
ADF	24.2	33.0	31.8	28.6	2.06
Estimated digestible nutrient intake (kg/d)					
DM	7.1	7.1	6.8	6.7	0.25
OM	6.7	6.8	6.6	6.5	0.24
CP	0.9	0.8	0.8	0.8	0.04
NDF	3.9	3.9	4.0	3.6	0.09
ADF	0.9	1.3	1.3	1.2	0.09
Estimated energy intake[1]					
Mcal ME/d	25.8	26.0	25.2	24.7	0.89
ME/kg DM	2.0	2.1	2.1	2.0	0.02

[1] 1 kg of digestible organic matter (DOM) = 3.8 Mcal ME (Kearl, 1982).

DM = Dry matter, OM =Organic matter, CP = Crude protein, NDF = Neutral-detergent fiber, ADL = Acid-detergent fiber.

Mcal = Mega calorie, ME = Metabolism energy, SEM = Standard error of mean.

Table 5. Effect of sunflower oil in cassava hay based-diets on rumen ecology, blood-urea nitrogen and milk-urea nitrogen

Item	CON	CHSO-0	CHSO-2.5	CHSO-5	SEM
pH					
0 h post feeding	7.1	7.0	7.0	7.1	0.02
4 h post feeding	6.9	6.8	7.0	7.0	0.04
Mean	7.0	6.9	7.0	7.0	0.03
NH_3-N (mg/dl)					
0 h post feeding	4.8	5.8	4.7	5.5	0.23
4 h post feeding	18.6[a]	18.7[a]	16.4[ab]	12.8[b]	1.03
Mean	11.7[a]	12.2[a]	10.5[ab]	9.0[b]	0.52
BUN (mg/dl)					
0 h post feeding	16.1	15.2	14.3	13.7	0.64
4 h post feeding	17.7	17.2	16.3	14.8	0.64
Mean	16.9	16.2	15.3	14.3	0.63
MUN (mg/dl)	16.0	15.2	14.9	14.6	0.31

[a, b] Means in the same row with different superscripts differ ($p<0.05$).

NH_3-N = Ammonia nitrogen, VFA = Volatile fatty acid, BUN = Blood-urea nitrogen, MUN = Milk-urea nitrogen, SEM = Standard error of mean.

Church (1977), in practice 2-4% fat is commonly added to diets for lactating dairy cows. The supplementation of sunflower oil up to 5% in this study did not affect nutrient digestion. Kalscheur et al. (1997) reported no changes in apparent ruminal NDF digestibility in dairy cows supplemented with 3% sunflower oil or vegetable oil. Similarly, Sackmann et al. (2003) reported that dietary sunflower oil levels (2 and 4%) did not alter apparent ruminal DM, NDF and ADF digestibility. The results of DM digestion were also similar to those of Nowak et al. (2003). However, increasing sunflower oil in the diet tended to lower digestion coefficients. Therefore, adding oils at high level to the rumen caused a depression in digestibility of fibrous components (Church, 1976; Preston and Leng, 1987).

Characteristics of ruminal fermentation, blood metabolites and milk urea-nitrogen (MUN)

Data on rumen ecology, blood-urea nitrogen (BUN) and milk-urea nitrogen (MUN) are presented in Table 5. The ruminal pH was similar among the treatments. The mean values of VFA concentration were also similar among treatments except for acetate which was significantly the lowest ($p<0.05$) in CHSO-5. This result agreed with Church (1976) who pointed out that adding fats to diets influenced the pattern of rumen fermentation and resultant VFA production, particularly a reduced percentage of acetate. The reason was that high fat content could reduce fiber digestibility (high fiber digestion could result in high acetic acid production in the rumen). Based on this study it was found that NDF and ADF digestibilities were lowest for the CHSO-5 treatment.

The average values of ammonia nitrogen (NH_3-N) in this study were 9.0 to 12.2 mg/dl. Preston and Leng (1987) reported that the optimum NH_3-N concentration in ruminal fluid for microbial growth was from 5 to 25 mg/dl and 8.5 to over 30 mg/dl (McDonald et al., 1996; Wanapat and Pimpa, 1999). The average values of NH_3-N in the present

Table 6. Effect of sunflower oil in cassava hay based-diets on milk yield and milk composition

Item	CON	CHSO-0	CHSO-2.5	CHSO-5	SEM
Milk production (kg/day)					
Milk yield	10.2[a]	10.4[ab]	11.5[b]	10.8[ab]	0.66
4% FCM	10.9[a]	11.1[ab]	12.3[b]	11.6[ab]	0.73
Milk composition (%)					
Fat	4.1	3.9	3.8	3.8	0.12
Protein	3.3	3.1	3.0	3.1	0.05
SNF	9.0	8.6	8.5	8.7	0.09
Lactose	5.0	4.7	4.7	4.7	0.05
Total solids	13.2	12.5	12.3	12.5	0.18

[a, b] Means in the same row with different superscripts differ ($p<0.05$).

FCM = Fat corrected milk, 4% FCM = 0.432×(kg of milk)+15×(kg of fat), SNF = Solids-not-fat, SEM = Standard error of mean.

study were within the ranges reported above. Increasing sunflower oil supplementation tended to decrease NH_3-N concentration, which was significantly lower ($p<0.05$) in CHSO-5 compared to the CON and CHSO-0 treatments. This result agreed with the work of Church (1976) and Preston and Leng (1987) who reported that adding high levels of fat affected microbe activities. The rumen microbe activity was lower because the fat intake is rapidly hydrolyzed in the rumen to long chain fatty acids which are absorbed onto the fiber; this decreases the accessibility for microbial attack (Leng, 1987) or renders a direct toxic effect on the ruminal microorganisms (Jenkins, 1993). Normally, lipid content of ruminant diets is low (<50 g/kg) and if it increases above 100 g/kg the activities of rumen microbes are reduced (McDonald et al., 2002). In the present study the lipid content in the concentrate was highest at 70 g/kg for CHSO-5. Under this study protozoal population was not measured; however, the possibility of lower rumen NH_3-N concentration was found in cows fed high sunflower oil suggesting that a high fat diet could reduce protozoal population. The reduction in ruminal ammonia concentration when fat is included in dairy diets has been associated with reduced numbers of protozoa (Ikwuegbu and Sutton, 1982; Broudiscou et al., 1994). As Leng and Nolan (1984) reported, up to 50% of the microbial protein synthesized is degraded to NH3-N in the rumen. Recycling of microbial N in the rumen occurs as a result of both protozoal and bacterial lysis and degradation. From *in vitro* studies it was suggested that the presence of protozoa in the rumen would result in engulfing of bacteria and this would affect the turnover of bacterial N in the rumen (Coleman, 1975). A decrease in rumen ammonia-N levels was found following defaunation of animals (Abou Akkada and el-Shazly, 1964; Christiansen et al., 1965).

The values of BUN and MUN in this study ranged from 14.3 to 16.9 and from 14.6 to 16.0 mg/dl, respectively. BUN and MUN are known to be related to inefficient utilization of dietary CP in ruminants (Lewis, 1957; Broderick and Clayton, 1997; Hwang et al., 2000; Schroeder, 2002; Promkot and Wanapat, 2005). Balanced diets for lactating dairy cows were associated with average BUN concentrations of 15 mg% (Roseler et al., 1993) and average MUN concentrations of 15 to 16 mg% (Baker et al., 1995) or 11-17 mg% (Hwang et al., 2000). Hwang (2000) summarized that cattle producing milk that contains a level of MUN within the standard reference range of 11-17 mg% and 3.0% milk protein was regarded as indicative of a balanced protein and energy intake. BUN and MUN lower than the above reference values could be due to insufficiency in CP per unit of energy; on the other hand, values higher than the reference range could be due to excess CP per unit of energy. In the present study, the BUN and MUN of all treatments were within the reference range and exhibited adequate protein intakes according to the above named references.

Milk production and composition

Yields and composition of milk are shown in Table 6. Adding sunflower oil tended to increase milk yield, and the 2.5% oil treatment resulted in significantly increased milk yield. This result could be attributed to the presence of cassava hay and a suitable level of fat as an energy source. Cassava hay has relatively low rumen degradation (48.8%) (Promkot et al., 2007) due to the presence of condensed tannins, which would result in higher ruminal by-pass protein (Wanapat et al., 1997). Supplementing cassava hay for lactating dairy cows tended to increase milk yield, similarly to the work of Wanapat (2001) and Kiyothong and Wanapat (2004). Higher milk yield was found in cows fed concentrate containing cassava hay and 2.5% sunflower oil as compared with the control group. This level of fat inclusion did not show any adverse effect. This finding accords with those of Amaral et al. (1997) and Avila et al. (2000), who reported that feeding fat to dairy cows can increase milk yield and milk quality.

Milk composition was not significantly different among treatments. Based on this study, supplementation of cassava hay did not affect milk composition, contrary to Wanapat et al. (2000a) who found that cassava hay improved milk fat, protein, lactose and solids-not-fat. Possible reasons may include differences in the ingredients and composition of concentrate and the level of supplemented cassava hay. In

Table 7. Effect of sunflower oil in cassava hay based-diets on fatty acid composition, conjugated linoleic acid in milk fat and the proportion of unsaturated to saturated fatty acids

Item	CON	CHSO-0	CHSO-2.5	CHSO-5	SEM
Fatty acid (mg/g fat)					
$C_{14:0}$	113.8^{a}	102.1^{b}	94.2^{bc}	92.9^{c}	2.01
$C_{16:0}$	332.0^{a}	334.7^{a}	273.0^{b}	257.2^{b}	7.74
$C_{18:0}$	111.0^{a}	80.8^{b}	127.8^{a}	175.8^{c}	7.92
Other SFAs	149.8^{a}	132.9^{b}	121.5^{b}	136.2^{ab}	2.81
$C_{18:1}$ (*cis*-9)	93.7^{a}	111.8^{a}	156.2^{b}	195.9^{c}	8.52
$C_{18:1}$ (*trans*-9)	12.6^{a}	8.6^{a}	15.8^{a}	24.4^{b}	1.44
$C_{18:2}$ (*cis*-6)	14.2^{a}	10.8^{b}	13.0^{a}	16.3^{c}	0.48
$C_{18:2}$ (*trans*-6)	0.5^{a}	0.5^{a}	0.4^{a}	0.8^{b}	0.03
$C_{18:2}$ (*cis*-9, *trans*-11) CLA	2.1^{a}	2.4^{a}	4.3^{b}	5.9^{c}	0.34
Total CLA	2.6^{a}	2.8^{a}	5.2^{b}	7.3^{c}	0.42
Other UFAs	14.0^{a}	24.5^{b}	18.9^{c}	20.7^{d}	0.83
UFAs:SFAs	0.20^{a}	0.25^{b}	0.34^{c}	0.40^{d}	0.02

[a, b, c, d] Means in the same row with different superscripts differ ($p<0.01$).

CLA = Conjugated linoleic acid, SFAs = Saturated fatty acids, UFAs = Unsaturated fatty acids, SEM = Standard error of mean.

Table 8. Effect of sunflower oil in cassava hay based-diets on economic returns

Item	CON	CHSO-0	CHSO-2.5	CHSO-5	SEM
4% FCM (kg/hd/d)	10.9	11.1	12.3	11.6	2.13
Milk sales (US/hd/d)	3.0	3.0	3.3	3.1	0.59
Concentrate intake (kg/hd/d[1])	6.6	5.9	5.6	5.8	0.98
Concentrate cost (US/hd/d)	1.0	0.7	0.8	0.9	0.53
UTS intake (kg/hd/d[1])	13.6	14.3	14.0	13.8	0.69
UTS cost (US/hd/d)	0.341	0.358	0.352	0.345	0.13
Income over feed					
US/kg of milk	0.15	0.17	0.18	0.16	0.07
US/hd/d	1.65	1.95	2.22	1.89	0.89
US/hd/month	49.50	58.50	66.60	56.70	7.63

[1] on fed basis.

FCM = Fat corrected milk, 4% FCM = 0.432×(kg of milk)+15×(kg of fat), UTS = Urea-treated rice straw,
1 kg milk = 0.275 US, kg UTS = 0.025 US, concentrates price are shown in Table 2. 1 US = 40 Baht.

the above work, cassava hay was supplemented at 0, 2.85 and 4.02 kg DM/d with the ratio of concentrate to milk of 1:2. 1:3 and 1:4, respectively. In the present study, the concentrate comprised cassava hay at 20% (Table 1) and it was supplemented to cows at the ratio of concentrate to milk of 1:2. Supplementation of sunflower oil in the diet did not affect milk composition, similarly to the work of LaCount et al. (1995) who reported that milk yield and composition were not affected by feeding high-oil corn grain. However, increasing sunflower oil supplementation in the diets tended to decrease milk fat, and, as Jenkins and Lundy (2001) stated, unsaturated oils could cause milk fat depression when fed to dairy cows.

Table 7 shows that fatty acid composition of milk and unsaturated fatty acids (UFAs) were increased while saturated fatty acids (SFAs) were decreased when cows were fed cassava hay. Furthermore, UFAs were more enhanced by adding sunflower oil. Jenkins and Lundy (2001) reported that a typical fatty acid composition of milk fat was 70-80% saturated and 20-30% unsaturated. Of the UFA, the majority (>70%) was oleic acid. Normally, conjugated linoleic acid (CLA) is formed in the rumen as an intermediate product in the biohydrogenation to by which autotrophic bacteria utilize dietary fatty acids (Hazlewood and Dawson, 1979). Plant oils, which are high in $C_{18:2}$ and $C_{18:3,}$ appear to be particularly effective in increasing the amount of $C_{18,}$ especially milk CLA (Dhiman et al., 2000; Chouinard et al., 2001). The CLA found in milk fat originates from two sources, *trans*-11 $C_{18:1}$, which is absorbed and used for endogenous synthesis of CLA, and from CLA that is absorbed and used directly (Griinari et al., 2000). Commonly, CLA is found in whole milk at about 4.5 to 5.5 mg/g fat (approximately 0.45 to 0.55%) (Song and Kennelly, 2002). In addition, Martin and Jenkins (2002) observed that ruminal pH influenced biohydrogenation so that low pH decreased the biohydrogenation of *cis*-$C_{18:2}$ and *cis*-$C_{18:3}$ with a decrease of *trans*-$C_{18:1}$ and CLA. Troegeler et al. (2003) also suggested that CLA content in milk could be obtained with diets leading to a ruminal pH that is nearly neutral, and with feeds containing a high amount of *cis*-$C_{18:2}$. Confirming the report above, the average ruminal pH in the present study in animals fed on urea-treated rice straw as basal roughage was 6.9 to 7.0, which could be a suitable ruminal pH to enhance CLA content in milk.

Economic returns

Approximately 60% of the cost of milk production can be attributed to concentrate feed (Office of Agricultural Economics, 1997; Wongnen et al., 1998). Therefore, reduction of feed costs is important for higher profitability in dairy farming. Based on the current price of concentrate (Table 2), all cassava hay-based dietary treatments when compared to the control could reduce feed costs by 19, 14 and 3%, while income over feed costs was higher by 18, 33 and 15% for CHSO-0, CHSO-2.5 and CHSO-5, respectively (Table 8). This result is similar to that of Wanapat (2000a; 2000b) who reported that cassava hay supplementation resulted in reduction of concentrate use which leads to a higher income. The result also agreed with Hong et al. (2003) and Kiyothong and Wanapat (2004); however, increasing sunflower oil in cassava hay based-diets tended to reduce income over feed due to the high price of sunflower oil.

CONCLUSIONS AND RECOMMENDATIONS

Based on this experiment, it could be concluded that supplementation of sunflower oil and cassava hay based-diets could improve efficiency of ruminal fermentation. The production of daily milk yield tended to be higher with supplementation of cassava hay based diets, while increasing sunflower oil level from 2.5 to 5% in these diets tended to decrease milk yield. These results suggest that supplementation of sunflower oil can be used at 2.5% in cassava hay based-diets with high potential improvement on income over feed costs, milk yield and composition, especially the enhancement of conjugated linoleic acid (CLA) concentration in milk fat in lactating dairy cows fed urea-treated rice straw as a roughage source.

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