Supplementation of Cassava Hay and Stylo 184 Hay to Replace Concentrate for Lactating Dairy Cows

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ABSTRACT : Sixteen multiparous Holstein-Friesian crossbred cows in mid-lactation were blocked according to days in milk (DIM) and previous lactation and randomly assigned according to a Randomized Complete Block (RCB) design with four replications to receive four dietary treatments. The dietary treatments consisted of T1: No cassava hay (CH) or stylo 184 hay (SH) supplementation, supplementation of concentrate to milk yield at 1:2 (control), T2: Supplementation of 1 kg of CH/hd/d, supplementation of concentrate to milk yield at 1:2, T3: Supplementation of 1 kg of CH+SH/hd/d, supplementation of concentrate to milk yield at 1:2, T4: Supplementation of 2 kg of CH+SH/hd/d, supplementation of concentrate to milk yield at 1:3. All animals received Ruzi grass from a cut-and-carry system as roughage source. The feeding trial lasted for 9 weeks. The results revealed that DMI of concentrate of supplemented treatments were significantly lower ($p<0.05$) than those in the control, but there was no significant difference between T2 and T3. There was no significant difference in forage DM intake between the control and supplemented treatments. CP and NDF digestibility of supplemented treatments were significantly ($p<0.05$) greater than the control and there were no significant differences among supplemented treatments. Milk yield and 3.5% FCM (14.3, 14.5, 14.7 and 14.8; 13.9, 14.3, 14.3 and 14.6 kg/hd/d, respectively) were not significantly different among treatments. Milk protein percentage of supplemented treatments was significantly ($p<0.05$) higher than the control, but there were no significant differences among supplemented treatments. There was no significant difference in milk fat percentage between the control and supplemented treatments. However, milk fat percentage tended to be higher for supplemented animals as compared to the control group. There were also no significant differences in lactose, solids-not-fat and total solids percentages among treatments. Cows in supplemented treatments gave incomes over supplement cost (IOSC) of 2.72, 2.74 and 2.93 US$/hd/d, respectively which were greater than for cows on control treatment. Furthermore, IOSC were greatest for cows in T4 as compared to other treatments. Based on this study it was concluded that, feeding cassava hay solely or in combination with stylo 184 hay as a supplemental protein source could be a potential valuable strategy in small-holder dairy farming systems in the tropics. This strategic supplementation significantly reduced concentrate use, which resulted in improved milk yields and milk quality for the supplemented cows. Moreover, it resulted in higher economical returns through increased productivity and lower ratios of concentrate to milk yield, from 1:2 to 1:3. ***(Asian-Aust. J. Anim. Sci. 2004. Vol 17, No. 5 : 670-677)***

Key Words : Cassava Hay, Stylo 184 Hay, Concentrate, Milk Yield, Milk Composition,Tropics

INTRODUCTION

Presently, concentrate supplementation for lactating dairy cows has been practiced by small-holder farmers in the tropics by using a ratio 1:2 concentrate to milk yield/head/day, as a rule of thumb, without taking into account the basal roughage use and actual requirements (Wanapat and Devendra, 1992). In some areas of Thailand, concentrate use was found to be even higher than 1:1 concentrate to milk yield, which could possibly result in rumen acidosis especially when effective fiber was unavailable. High concentrate use eventually resulted in higher production costs of 70% of the total production cost (Wanapat, 1990; Chantalakhana, 1994; Office of Livestock Extension, 1998). It is, hence, imperative to find means to reduce feed cost. Cassava hay was reported to be a good source of high protein roughage and was used as a supplement to improve milk production and quality (Wanapat et al., 1997; Wanapat, 2003). Providing a good source of roughage like cassava hay could possibly increase ratio of protein to energy, hence could increase productivity in ruminants (Leng, 1997). It has been reported that the most economic way to improve energy intake and performance of animals fed on crop residues is to supplement them with good quality forages, including forage legumes (Topps, 1997) such as *Stylosanthes guianensis* CIAT 184, commonly known as "stylo 184" (Horne and Stur, 1999). At the present time it is widely used in tropical countries (Mannetje and Jones, 1992). Stylo 184 was introduced to Thailand in 1993 to evaluate growth and biomass yield, planted at 50×30 cm spacing between rows and plants. It was found that it could grow well and produce 12-17 t DM yield/ha/year with 14-18% CP and could be preserved as hay with high palatability for ruminants (Satjipanon et al., 1995).

The objectives of this experiment were, therefore, to investigate the effect of supplementation of cassava hay and stylo 184 hay to replace concentrate on diet utilization, milk yield and milk composition of crossbred dairy cows fed

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Ruzi grass (*Brachiaria ruziziensis*) from a cut-and-carry system as a basal roughage. Furthermore, research was conducted to demonstrate to participating farmers the use of potential local feed supplements in improving dairy productivity and sustainability of the feeding system.

MATERIALS AND METHODS

Location of the experimental site

The experiment was conducted in Muang District, Mahasarakham, at eight small-holder dairy farms using a participatory approach. Researchers and farmers worked closely during April 2002-December 2002. The experimental site is located 470 km northeast of Bangkok in Northeast Thailand, about 70 km southeast of Khon Kaen, Thailand.

Dairy farmer selection and training for participating farmers

Eight dairy farmers were selected to participate in this research. The selection was based on farmer qualifications (e.g. farmer's willingness, attitude, experience, location, opportunity and potentiality for expansion of technology), their own support and collaboration to participate in the research including the number of milking cow and days in milk (DIM) of milking cow. Prior to the commencement of the experiment, a one-day training program was held by the researchers and extension officers at Mahasarakham Provincial Livestock Office covering details such as how feed supplements should be prepared, and supplemented, how data should be collected, demonstrations of feed preparation, and dairy cow nutrition. Regular visits to the farms by researchers and extension officers followed, and in addition regular discussions and demonstrations were held. Participating farmers were also to visit other farmers during the demonstrations, which offered a real practical perspective and farmer-to-farmer interactions. As a result of this participation and demonstration scheme, the farmers could learn more effectively and accepted the technology more readily, especially the practical details of the feed preparation, feed establishment, feeding method and feeding management.

Demonstration plots

Eight individual plots sized 20×20 m were established at eight participating farms in late May 2002 in order to demonstrate and allow the farmers to participate. Researchers provided planting materials for farmers such as cassava stem, stylo 184 seed and seedlings, and fertilizer. The farmers were also given recommendation management of cassava and stylo 184 on planting, weeding, fertilization, harvesting, hay making and feed supplementation.

Forages hay production

Cassava hay and stylo184 hay were produced from cassava (*Manihot esculenta,* Crantz) variety "Rayong72" and stylo184 (*Stylosanthes guianensis* CIAT184) which were planted in late May 2002 at the Experimental Farm of Khon Kaen Animal Nutrition Research and Development Center. The center is located 449 km northeast of Bangkok in Northeast Thailand (162°N and 102.5°E) at an altitude of 166 m above sea level.

Cassava planting and hay making followed the methods of Wanapat et al. (1997 and 2000a): The cassava crop was planted using stems with 100×30 cm spacing between rows and stems. A basal complete fertilizer (188, 188, 188 kg/ha of N, P and K, respectively) was applied at planting. The entire plot area was kept weed-free with hand hoeing at 20 and 75 days after planting and whenever necessary. The crops were harvested at 3 months after planting in late July 2002 by breaking the cassava stem at 15 cm above the ground.

Planting of stylo 184 and hay making followed the methods of the Department of Livestock Development (2002): Two weeks prior to planting, dolomite was incorporated into plots at the rate of 625 kg/ha. One-month-old seedlings of *Stylosanthes guianensis* CIAT 184 were planted at 100×30 cm spacing between rows and plants. A basal complete fertilizer (188, 188, 188 kg/ha of N, P and K, respectively) was applied at planting, with an additional application of triple superphosphate (125 kg/ha of P) in early July 2002. The entire plot area was kept weed-free using the same methode as cassava. The crops were harvested at 3 months after planting in late July 2002 by cutting 15 cm above the ground.

Prior to drying, both forages were chopped to average length of 5 cm using a tractor mounted "Mizubishi" cutter (PTO rotating at 2,000 rev./min) then sun-dried for 2 days to attain a moisture content less than 10%. Representative samples of cassava hay and stylo 184 hay were taken for chemical analysis. The hay was collected, packaged in plastic bags and allocated to participating farmers according to treatments to use as supplement for selected lactating dairy cows during August- October 2002.

Animal management

Prior to the commencement of the experiment, sixteen multiparous Holstein-Friesian crossbred dairy cows (2 cows/farmer), in mid-lactation (98±19 days in milk) and with a mean live weight of 420 kg at the beginning of the experiment were selected and used in the study. The experiment lasted for nine weeks. The first week was used for diet adaptation and the following eight weeks were used for measurements of milk yield and composition. In the last three days of the experiment, forage DM intakes were measured and whole-tract diet DM digestibility were also

Table 1. Chemical composition of feedstuffs fed during the experiment

Item	Chemical composition							
	DM[1] (%)	OM	Ash	CP	NDF	ADF	ADL	CT
		(% DM)						
Ruzi grass	94.8	90.5	9.5	8.2	77.9	38.7	11.5	ND
Concentrate	89.4	93.5	6.5	16.1	21.1	14.2	8.9	ND
Cassava hay	92.3	92.5	7.5	20.6	55.0	38.9	16.8	3.3
Stylo 184 hay	95.6	90.6	9.4	17.1	56.8	39.1	10.5	ND

[1] DM; dry matter, OM; organic matter, CP; crude protein, NDF; neutral detergent fiber, ADF; acid detergent fiber, ADL; Acid detergent lignin, CT; condensed tannins, ND; not determined.

measured using acid-insoluble ash (AIA) as an internal indicator.

Experimental design and measurements

The experiment was a Randomized complete block design (RCBD) with four dietary treatments and four animals per treatment. At the beginning of the experiment, the cows were blocked according to their days in milk and previous lactation into four blocks of four animals each. Within a block, the animals were each randomly allotted to one of the four dietary treatments. The diets comprised a basal roughage, Ruzi grass (*Brachiaria ruziziensis*) from a cut-and-carry system fed ad libitum and supplemented with four dietary treatments as followings:

T1: No CH or SH supplementation, supplementation of concentrate to milk yield at 1:2 (control).
T2: Supplementation of 1 kg of CH/hd/d, supplementation of concentrate to milk yield at 1:2.
T3: Supplementation of 1 kg of CH+SH/hd/d, supplementation of concentrate to milk yield at 1:2.
T4: Supplementation of 2 kg of CH+SH/hd/d, supplementation of concentrate to milk yield at 1:3.
(CH=cassava hay, SH=stylo 184 hay; ratio of CH and SH is 1:1).

Feeding of the cows was done by participating farmers. Cows were hand milked twice daily, at 07:00 h in the morning and 16:00 h in the evening. The daily morning and evening milk yields of individual cows were recorded. About 100 ml samples of thoroughly mixed composite of milk (morning and afternoon) of individual cows were taken weekly. Concentrate was given according to the respective treatments in two equal amounts during milking time. Cows were supplemented according to treatments twice daily during milking time. The animals had free access to water and mineral blocks. During the last three days prior to termination of the experiment, daily basal diet offered was fed in amounts based on the previous day's intake, allowing for a 20% refusal. Daily forage intakes and refusals were weighed each morning and recorded individually before fresh material was given to the animals; fecal samples were collected daily from rectum for the last three days from each cow, composited, dried and ground. The health condition of the cows was observed daily. Samples of concentrate were taken during the last week of the feeding period.

Chemical analyses

Samples of grass fed by a cut-and-carry system, hay and faeces were dried in a forced-air oven (60°C) for 48 h and ground in a Wiley mill to pass a 2 mm screen and then analysed for dry matter (DM), organic matter (OM), ash and nitrogen (Kjeldahl-N) by the AOAC (1990) procedures. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin (ADL) were determined by the methods of Van Soest and Robertson (1991). Acid-insoluble ash (AIA), measured by the procedure of Van Keulen and Young (1977), was used as an internal indicator to calculate digestion coefficients of the feed. In addition, samples of cassava hay were analyzed for condensed tannins using the vanillin-HCl method (Burns, 1971 as modified by Wanapat and Poungchompu, 2001). The milk samples were analyzed for fat, protein, lactose, solids-not-fat (SNF), and total solids by using a 'Milko-Scan' (Model 133 V37 GB).

Milk quality analyses were carried out in the Milk Quality Control Laboratory of the Dairy Farming Promotion Organization of Thailand (DPO), in the Northeast Region. Fecal and feed sample analyses were carried out in the Animal Nutrition Laboratory of the Khon Kaen Animal Nutrition Research and Development Center and the Ruminant Nutrition Laboratory of the Department of Animal Science, Faculty of Agriculture, Khon Kaen University.

Statistical analyses

The various data were subjected to the analyses of variance (ANOVA) procedure for Randomized complete block design experiment using the general linear models (GLM) of the SAS System for Windows (SAS 6.12, TS level 020, SAS Institute, 1998). Probabilities less than 0.05 were considered significant. Treatment means were compared using Duncan's New Multiple Range test (Steel and Torries, 1980). The statistical model is

$$y_{ij}=m+tx_i+bl_j+e_{ij}$$

where m is the grand mean, tx_i the *i*th treatment effect, bl_j

Table 2. Effects of cassava hay (CH) and stylo 184 hay (SH) supplementation on feed intake

Item	T1	T2	T3	T4	SEM
DM intake of forage					
kg/d	4.5	4.6	4.6	4.7	0.61
% of BW	1.1	1.1	1.1	1.2	0.14
g/kg $W^{0.75}$	48.0	48.8	48.3	48.9	3.73
DM intake of concentrate					
kg/d	7.2[a]	6.3[b]	6.2[b]	5.4[c]	0.23
% of BW	1.7[a]	1.5[b]	1.5[b]	1.3[c]	0.06
g/kg $W^{0.75}$	77.5[a]	66.8[b]	66.2[b]	59.9[c]	2.90
DM intake of supplement					
kg/d	0.0[a]	0.90[b]	0.91[b]	1.82[c]	0.61
% of BW	0.0[a]	0.21[b]	0.22[b]	0.43[c]	0.45
g/kg $W^{0.75}$	0.0[a]	9.75[b]	9.79[b]	19.91[c]	0.64
Total DM intake					
kg/d	11.6	11.6	12.9	13.3	0.71
% of BW	2.8	2.8	2.8	2.9	0.13
g/kg $W^{0.75}$	125.5	125.5	125.3	125.9	4.86

[a, b, c] Means with different superscripts in the same row are significantly different ($p<0.05$). BW; body weight, g/kg $W^{0.75}$=g/kg metabolic weight.
SEM; standard error of the mean.
T1: No CH or SH supplementation, supplementation of concentrate to milk yield at 1:2 (control).
T2: Supplementation of 1 kg of CH/hd/d, supplementation of concentrate to milk yield at 1:2.
T3: Supplementation of 1 kg of CH+SH/hd/d, supplementation of concentrate to milk yield at 1:2.
T4: Supplementation of 2 kg of CH+SH/hd/d, supplementation of concentrate to milk yield at 1:3.
(CH; cassava hay, SH: stylo 184 hay; ratio of CH and SH is 1:1).

Table 3. Effects of cassava hay (CH) and stylo 184 hay (SH) supplementation on nutrient digestibility

Item	T1	T2	T3	T4	SEM
Apparent digestibility, %					
DM[1]	65.7	67.8	66.7	67.9	2.48
OM	69.8	73.4	73.7	75.1	2.15
CP	68.3[a]	73.4[b]	72.6[b]	73.9[b]	1.12
NDF	52.5[a]	58.6[b]	57.2[b]	58.0[b]	1.51
ADF	43.9	50.1	43.1	51.7	2.35
Digestible nutrient intake, kg/d					
OM	8.1	8.5	9.5	10.0	2.01
CP	7.9[a]	8.5[b]	9.4[b]	9.8[b]	1.11
NDF	6.1[a]	6.8[b]	7.4[b]	7.7[b]	1.41
ADF	5.1	5.8	5.6	6.9	1.65
Estimated energy intake [2]					
Mcal ME/d	30.8	32.4	36.1	38.0	1.01
ME/kg DM	2.7[a]	2.8[b]	2.8[b]	2.9[b]	1.05

[a, b] Means with different superscripts in the same row are significantly different ($p<0.05$). SEM; standard error of the mean.
[1] DM; dry matter, OM; organic matter, CP; crude protein, NDF; neutral detergent fiber, ADF; acid detergent fiber.
[2] 1 kg DOM=3.8 Mcal ME/kg (Kearl, 1982).
T1: No CH or SH supplementation, supplementation of concentrate to milk yield at 1:2 (control).
T2: Supplementation of 1 kg of CH/hd/d, supplementation of concentrate to milk yield at 1:2.
T3: Supplementation of 1 kg of CH+SH/hd/d, supplementation of concentrate to milk yield at 1:2.
T4: Supplementation of 2 kg of CH+SH/hd/d, supplementation of concentrate to milk yield at 1:3.
(CH: cassava hay, SH: stylo 184 hay, ratio of CH and SH is 1:1).

the *j*th block effect, and e_{ij} is the experimental error of treatment *i* in block *b*.

RESULTS

Chemical composition of the experimental feeds

Chemical composition of the experimental feeds is shown in Table 1. Crude protein (CP) and neutral detergent fiber (NDF) of Ruzi grass, concentrate, cassava hay and stylo 184 hay were 8.2, 16.1, 20.6, 17.1% and 77.9, 21.1, 55.0, 56.8%, respectively.

Feed intake

The results of the effects of cassava hay and stylo 184 hay supplementation on feed intake are presented in Table 2. There was no significant difference in forage DM intake between the control treatment and supplemented treatments. DMI of concentrate of supplemented treatments was significantly lower ($p<0.05$) than the control treatment, but there was no significant difference between T2 and T3. DMI of supplement of supplemented treatments was significantly higher ($p<0.05$) than the control treatment, but there was no significant difference between T2 and T3. There were no significant differences in total DMI among treatments. However, DM intake of forage and total DMI tended to be higher for supplemented treatments than for cows on the control treatment.

Nutrient digestibility and digestible nutrient intake

Apparent nutrient digestibilities and digestible nutrient intake of diets are presented in Table 3. CP and NDF digestibilities of supplemented treatments were significantly ($p<0.05$) higher than the control treatment, but there were no significant differences among supplemented treatments. Digestibilities of DM, OM and ADF were not significantly different among treatments, ranging from 65.7 to 67.9, 69.8 to 75.1 and 43.1 to 51.7%, respectively. Likewise CP and NDF digestible nutrient intake of supplemented treatments were significantly ($p<0.05$) higher than the control treatment, but there were no significant differences among supplemented treatments. Digestible nutrient intake of OM and ADF were not significantly different among treatments, ranging from 8.1 to 10.0 and 5.1 to 6.9%, respectively.

Milk yield and milk composition

Milk production and milk composition are shown in Table 4. Milk yield and 3.5% FCM were not significantly different among treatments. Nevertheless, both milk yield and 3.5% FCM tended to be higher for supplemented treatments than for cows on the control treatment. Milk protein percentage of supplemented treatments was significantly ($p<0.05$) higher than the control treatment, but there were no significant differences among supplemented treatments. There was no significant difference in milk fat percentage between the control treatment and supplemented treatments. However, milk fat percentage tended to be higher for supplemented treatments as compared to the control treatment. There were no significant differences in lactose, solids-not-fat and total solids percentages among treatments, ranging from 4.91 to 5.13, 8.51 to 8.86 and

Table 4. Effects of cassava hay (CH) and stylo 184 hay (SH) supplementation on milk yield and milk composition

Item	T1	T2	T3	T4	SEM
Milk production, kg/hd/d					
Milk yield	14.3	14.5	14.7	14.8	1.36
3.5% FCM[1]	13.9	14.3	14.3	14.6	1.31
Milk composition, %					
Fat	3.81	3.93	3.83	3.89	0.64
Protein	3.32[a]	3.85[b]	3.79[b]	3.77[b]	0.13
Lactose	5.13	4.99	4.94	4.91	0.17
Solids-not -fat	8.53	8.86	8.51	8.59	0.22
Total solids	12.41	12.32	12.91	12.84	0.80

[a, b] Means with different superscripts in the same row are significantly different ($p<0.05$). SEM; standard error of the mean.

[1] FCM; fat corrected milk, 3.5% FCM=0.4×(kg of milk)+15×(kg of fat).

T1: No CH or SH supplementation, supplementation of concentrate to milk yield at 1:2 (control).

T2: Supplementation of 1 kg of CH/hd/d, supplementation of concentrate to milk yield at 1:2.

T3: Supplementation of 1 kg of CH+SH/hd/d, supplementation of concentrate to milk yield at 1:2.

T4: Supplementation of 2 kg of CH+SH/hd/d, supplementation of concentrate to milk yield at 1:3.

(CH; cassava hay, SH; stylo 184 hay; ratio of CH and SH is 1:1).

Table 5. Effects of cassava hay (CH) and stylo 184 hay (SH) supplementation on economical returns

Item	T1	T2	T3	T4
3.5% FCM[1], kg/hd/d	13.9	14.3	14.3	14.6
Milk income, US$/hd/d	3.61	3.72	3.72	3.80
Concentrate intake, kg/hd/d	8.05	7.05	6.94	6.04
Concentrate cost, US$/hd/d	1.13	0.99	0.97	0.85
CH and SH hay intake, kg/hd/d	0.00	1.00	1.00	2.00
CH and SH hay cost, US$/hd/d	0.00	0.01	0.01	0.02
Total supplement cost, US$/hd/d	1.13	1.00	0.98	0.87
Income over supplement cost				
US$/hd/d	2.48	2.72	2.74	2.93
US$/hd/month	74.52	81.54	82.14	87.78

Price: 1 kg milk=0.26 US$, 1 kg concentrate=0.14 US$, 1 kg cassava hay (CH) and stylo 184 hay (SH)=0.01 US$.

[1] FCM; fat corrected milk, 3.5% FCM=0.4×(kg of milk)+15×(kg of fat).

T1: No CH or SH supplementation, supplementation of concentrate to milk yield at 1:2 (control).

T2: Supplementation of 1 kg of CH/hd/d, supplementation of concentrate to milk yield at 1:2.

T3: Supplementation of 1 kg of CH+SH/hd/d, supplementation of concentrate to milk yield at 1:2.

T4: Supplementation of 2 kg of CH+SH/hd/d, supplementation of concentrate to milk yield at 1:3.

12.32 to 12.91%, respectively.

Economical returns

Feed and feeding is one of important factors in dairy production. Feed cost usually accounts for 60 to 70% of the total cost of production (Office of Agricultural Economics, 1997). Thus, this analysis can have a significant importance when determining the profitability of milk production. Based on current costs of concentrate, CH and SH, and assuming that there is available land to grow Ruzi grass at no cost, income over supplement cost (IOSC) was calculated and simply compared among treatments (Table 5). Cows in the supplemented groups had an IOSC of 2.72, 2.74 and 2.93 US$/hd/d greater than cows in the control group, respectively. Furthermore, IOSC was greatest for T4 as compared with other treatments.

DISCUSSION

The level of CP in Ruzi grass (8.2% CP) was lower than the range of 11-12% CP required for moderate levels of ruminant production (ARC, 1980). However, these CP concentrations in the forage was higher than the limiting level (6-8% CP) below which appetite and forage intake are depressed (Minson, 1982). The supplements (concentrate, CH and SH) had the higher CP and lower NDF concentrations relative to the basal forage. The CP and condensed tannin (CT) contents of cassava hay were found in a similar range to those reported by Wanapat et al. (1997). Likewise CP percentages of stylo 184 hay were found to be in similar to those reported by Satjipanon et al. (1995). Dry matter (DM), organic matter (OM), ash and acid detergent lignin (ADL) of all feeds were similar.

Supplementation of CH solely or in combination with SH did not increase total DM and forage intake of dairy cows. This result disagreed with those of Khang and Wiktorsson (2000), Wanapat et al. (2000a) and Nguyen et al. (2002). The reasons could possibly be the difference in the basal diet, as in the above work only urea-treated rice straw (UTRS) was provided as a basal diet. In the present study, cows were provided with Ruzi grass from a cut-and-carry system and fed ad libitum. However, DM intake of forage and total DMI tended to be higher for supplemented treatments than for cows on the control treatment. As levels of CH solely or in combination with SH supplementation increased from 0 to 0.90, 0.91 to 1.82 kg DM/hd/d, concentrate levels decreased from 7.2 to 6.3, 6.2 and to 5.4 kg/hd/d or 14, 16 and 33% of the control treatment, respectively (Table 2). This result was in accordance with Wanapat et al. (2000a),who reported that as levels of CH supplementation increased from 0 to 1.0 and to 1.7 kg DM/hd/d, concentrate supplement decreased from 4.56 to 3.20 and to 2.64 kg/hd/d or 30 and 40% of the control treatment, respectively.

The result showed that supplementation of CH solely or in combination with SH resulted in increased CP digestibility, which could lead to higher milk protein percentage (Table 4). Supplementation of CH solely or in combination with SH in this study provided tannins to feed. The higher level of milk protein of supplemented treatments attributed from the effect of tannins in feed. This result was in agreement with the work by Wanapat et al. (2002), who reported that a major benefit of tannins in feed has been thought to be the protection of plant proteins from digestion in the rumen, and their subsequent release as protein available for digestion and utilisation in small intestine. This also in accordance with Norton and Ahn (1997) who reported that while the tannins of *Calliandra calothyrsus* (2.5 to 3.7% CT) do also protect proteins from digestion in the rumen, and increase the flow of N to the small intestine. Suties with *Lotus spp* of varying CT content (2.2 and 5.5%) have confirmed that tannins do protect dietary proteins from digestion in the rumen, increase the flux of essential amino acids (EAA) to small intestine, and at low CT concentrations, increase the apparent absorption of EAA in the intestines (Waghorn, 1990). However, at high CT concentrations, the efficiency of EAA absorption was significantly decreased from 78 to 63%.

The results in this study showed that supplementation of SH in combination with CH could have been responsible for the improvement of NDF digestibility. Leguminous forages are known to improve rumen environment by providing ammonia (Bonsi et al., 1995) as well as contributing available cellulose and hemicellulose, which are known to stimulate fiber digestion (Silva and Ørskov, 1988). The enhanced NDF digestibility obtained in the present study may therefore be attributed to the high ammonia concentrations and VFA molar proportions as a result of supplementation with SH. Leguminous forages improve animal productivity from grasslands by increasing total edible biomass. The production increases can also be related to the high mineral concentrations in leguminous forages and to higher protein levels. Many of the responses to leguminous forages are undoubtedly attributable to supplementation of the rumen microbial ecosystem, ensuring an efficient fermentative digestion (Leng, 2003). In this experiment, also showed that ME (Mcal/d) meet requirement of lactating dairy cow, which tended to be positive energy balance. According to NRC (2001), standard requirement of ME (Mcal/d) for lactating dairy cow with a mean live weight of 450 kg is in the range of 22.0-24.0 Mcal ME/d.

As levels of CH solely or in combination with SH supplementation increased, concentrate supplement decreased as discussed previously, it still resulted in similar milk yield and improved milk compositions (Table 4). The use of CH solely or in combination with SH could reduce concentrate levels and resulted in similar milk yield and 3.5% FCM (14.3, 14.5, 14.7 and 14.8 kg/hd/d; 13.9, 14.3, 14.3 and 14.6 kg/hd/d for T1, T2, T3, and T4, respectively). These results were in agreement with the work by Wanapat et al. (2000a) who reported that cassava hay could provide additional volatile fatty acids, necessary for fatty acid synthesis. A significant enhancement of milk protein was obtained for the supplemented animals. A similar finding was reported by Nguyen et al. (2002), who reported that cows receiving diets with CH produced milk with significantly higher protein contents as compared to those fed diets without CH. The present result was also in accordance with the previous findings of Wanapat et al. (2000a,b). The higher milk protein content could be due to CH providing more absorbed protein to the animals as mentioned above, which may have provided more precursors for milk protein synthesis. From the results in Table 4, it can also be seen that milk fat percentage tended to be higher for supplemented animals as compared to the control group. Cassava hay may have provided a substrate which would improve rumen fermentation efficiency, as earlier reported by Wanapat et al. (1997). The higher level of fat of supplemented treatments in this study probably resulted from the better utilization of dietary NDF fiber (Table 3) from which the precursors for mammary lipid synthesis are derived. In addition, the high milk fat concentrations in this study could have been due to the increased acetate: propionate ratio in the rumen (Mpairwe, 1998) which is known to result in higher milk-fat concentration (Sutton et al., 1986). The results also showed that supplementation with CH solely or in combination with SH reduced concentrate use, which did not effect the level of lactose, SNF and total solids. This is in accordance with a report of Wanapat et al. (2000b).

Supplementation with CH+SH at 2 kg/hd/d could reduce concentrate use from a ratio of 1:2 to 1:3 concentrate to milk yield per day and improved IOSC up to 2.93 US$/hd/d. This result was similar to the work of Nguyen et al. (2002), who reported that supplementation of CH at 2 kg/hd/d could reduce concentrate use from a ratio of 1:2 to 1:3 concentrate to milk yield per head per day, and hence could increase income from milk sales by 5 US$/hd/d. This result was also similar to a previous finding by Wanapat et al. (2000b). Moreover, if farmers can produce CH and SH using families's labour, the cost of CH and SH would be lower, and subsequent higher incomes of small-holder dairy farmers could be obtained. This in accordance with Wanapat et al. (2000b), who reported that lower concentrate cost would be of utmost importance in providing income for small-holder dairy farmers in Thailand and for the sustainable dairy farming system in the tropics.

CONCLUSION AND RECOMMENDATIONS

The use of CH solely or in combination with SH could reduce concentrate levels and resulted in similar milk yield and 3.5% FCM (14.3, 14.5, 14.7 and 14.8 kg/hd/d; 13.9, 14.3, 14.3 and 14.6 kg/hd/d for T1, T2, T3 and T4 respectively). Based on this research, it was concluded that feeding cassava hay solely or in combination with stylo 184 hay as a supplemental protein source could be a potential valuable strategy in small-holder dairy farming systems in the tropics. This strategic supplementation resulted in improved milk yield and milk quality and higher economical returns through increased productivity and lower ratios of concentrate to milk yield, from 1:2 to 1:3. However, the on-farm situation of small-holder farmers needs to be further investigated to increase attention and justify an expansion of this dairy feeding strategy among dairy farmers, which would lead to increased sustainability of the feeding system at farm level.

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