Effects of Timing of Initial Cutting and Subsequent Cutting on Yields and Chemical Compositions of Cassava Hay and Its Supplementation on Lactating Dairy Cows

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ABSTRACT : Two experiments were conducted to examine the production and quality of cassava hay and its utilization in diets for dairy cows. In experiment I, a 2×2 Factorial arrangement in a randomized complete block design with 4 replications was carried out to determine the effects of different initial (IC) and subsequent cutting (SC) on yield and composition of cassava plant. The results revealed that cassava could produce from 4 to 7 tonne of DM and 1.2 to 1.6 tonne of CP for the first six months after planting. CP content in cassava plant ranged from 20.8 to 28.5% and was affected by different SC regimes. Condensed tannin in cassava foliage ranged from 4.9 to 5.5%. Initial cutting at 2 months with subsequent cutting at 2 month intervals was the optimal to obtain high dry matter and protein yield. In the second experiment, five crossbred Holstein-Friesian cows in mid lactation with an initial live-weight of 505±6.1 kg and average milk yield of 10.78±1.2 kg/d were randomly assigned in a 5×5 Latin square design to study the effects of 2 levels of CH (1 and 2 kg/hd/d) and concentrate (1 to 2 kg of milk and 1 to 3 kg of milk) on milk yield and milk composition. The results showed that cassava hay increased rumen NH_3-N and milk urea nitrogen (MUN) ($p<0.05$). Cassava hay tended to increase milk production and 4% FCM. Milk protein increased in cows fed cassava hay ($p<0.05$). Moreover, cassava hay could reduce concentrate levels in dairy rations thus resulting in increased economic returns. Cassava hay can be a good source of forage to reduce concentrate supplementation and improve milk quality. ***(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 12 : 1763-1769)***

Key Words : Cassava Hay, Cutting, Foliage, Milk Yield and Compositions, Concentrate, Rumen Environment, Dairy Cows

INTRODUCTION

Demand for livestock products, especially meat and milk has been increasing rapidly throughout SE Asia including Vietnam because of the improvement in the standard of living. Since the 1990s, dairy production in Vietnam has been increasing but has not yet met the local milk demand. Recently, the Vietnamese Government has formally decided to develop dairy production so as to be less reliant on imported milk products. However, dairy production in Vietnam has to cope with several problems such as low productivity, high risk of disease, poor management and particularly the lack of quality forage. The dairy population in Vietnam is concentrated around the big cities where transportation and market conditions are convenient but where there is limited grassland. For this reason, forage supply is a problem, especially in the dry season. One strategy often employed by farmers is to increase the use of concentrates and brewery grains in dairy rations. This results in high feed costs and low milk fat contents (Cai et al., 2000).

Cassava hay has shown excellent potential as a forage source for dairy cattle fed rations based on urea-treated rice straw (Wanapat et al., 1997; Wanapat, 2000; Wanapat et al., 2000a, 2000b). However, the effects of different initial stage of cutting and subsequent harvesting interval on yield and nutritive value of cassava hay have not yet been fully investigated and there is no available information about using cassava hay for dairy cows in Vietnam. The objectives of this experiment were to study the effects of initial cutting and subsequent cutting on yield and chemical composition of cassava hay and also the effects of different levels of cassava hay and concentrate supplementation on milk yield and composition in dairy cows.

MATERIALS AND METHODS

Effects of different initial stage of cutting and subsequent harvesting interval on yield and nutritive value of cassava hay

The study was conducted on grey sandy soil on the farm of the Dairy Research and Training Center, Vietnam. Characteristics of the soil were as follows: pH (4.6), C% (1.12), N% (0.018), P_2O_5% (0.019) and K_2O% (0.021), etc. The experiment consisted of two initial stage of cutting (IC) times, 2 months and 4 months after planting, and two second cutting times (SC), 1 month and 2 months after IC. The treatment combinations were assigned into a 2×2 Factorial arrangement in a Randomized complete block design (RCBD) with 4 replications.

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Received February 3, 2003; Accepted March 25, 2003

Table 1. Chemical composition of feedstuffs in the Experiment 2

	Urea-treated rice straw	Elephant grass	Cassava hay	Concentrate
DM, %	47.3	11.6	86.9	88.0
	------------------------% DM-------------------------------			
Ash	15.8	12.4	6.6	3.70
CP	8.6	11.7	24.2	16.0
NDF	69.8	68.6	48.2	38.1
ADF	44.4	40.0	31.0	9.0
ADL	21.7	18.0	11.8	5.4

Land was ploughed once without harrowing, weed roots removed and divided into 16 plots with a size of 3×7 m. The stems of cassava variety KM 60 about 20 cm in length were planted with a row spacing of 30×40 cm in all plots.

The cassava crop was harvested according to respective treatments with a common harvesting height of 10 cm, which thus included leaf petiole and stem material. All cassava fodder from each plot was weighed to determine the fresh yield and dry matter yield. DM, CP and total ash were analyzed by the procedure of AOAC (1990). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were analyzed by the method of Van Soest et al. (1991). Total condensed tannin content was analyzed by the method of Burns (1971).

Data were statistically analyzed using General Linear Model Procedure of SAS (1998). Treatment means were compared by using Duncan's Multiple Range Test. The interaction between the two factors was examined by orthogonal contrast.

Effects of different levels of cassava hay and concentrate supplementation on ruminal parameters and performance of dairy cows

Five crossbred (50-75%, Holstein Friesian) cows in mid-lactation with an initial live-weight of 505±6.1 kg and average milk yield of 10.78±1.3 kg/d were used in a 5×5 Latin square design. The treatment combinations were as follows:

T1 0, 1:2: No cassava hay (CH) supplementation, supplementation of concentrate at 1:2.

T2 1, 1:2: Supplementation of 1 kgDM of CH/hd/d, supplementation of concentrate at 1:2.

T3 1, 1:3: Supplementation of 1 kgDM of CH/hd/d, supplementation of concentrate at 1:3.

T4 2, 1:2: Supplementation of 2 kgDM of CH/hd/d, supplementation of concentrate at 1:2.

T5 2, 1:3: Supplementation of 2 kgDM of CH/hd/d, supplementation of concentrate at 1:3.

The feeding trial lasted for 105 days, during which cows were individually housed and fed 30 kg of Elephant grass daily together with *ad libitum* urea-treated rice straw. Commercial concentrate containing 16% CP was provided at milking times in the morning and in the afternoon with the amount according to respective treatments and previous milk yield. Cassava hay (CH) was prepared by the procedure of Wanapat et al. (1997) and fed to animals 2 times per day after milking. Fresh water was available all day. The composition of feedstuffs is presented in Table 1.

Feed offered and feed refusals were weighed daily to determine feed intake. On the last day of each period, at 4 h post feeding, 10 ml of blood was taken from the jugular vein and centrifuged to obtain the supernatant for blood urea analysis using Sigma diagnosistics (Sigma Company) and rumen fluid was taken by a stomach tube. Ruminal pH was measured immediately by pH meter and NH_3-N in the fluid was determined using the Kjeltec 1002 system. Milk production was recorded daily and in each period, milk samples were taken on the third day of both second and third week for composition analysis. Milk fat was analyzed using a Gerber Machine supplier. Milk crude protein was determined by using Kjeldahl procedure (Kjeltec 1002 system). On the last day of each period, milk samples were taken in the morning and in the afternoon, mixed thoroughly and centrifuged to take the supernatant for determining milk urea concentration by using Sigma diagnosistics (Sigma Company).

Data were statistically analyzed using General Linear Model Procedure of SAS (1998) according to a 5×5 Latin square design. Treatment means were compared by using Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Effects of different initial stage of cutting and subsequent harvesting interval on yield and nutritive value of cassava hay

Table 2. Fresh, dry fodder and protein yield of cassava in different time of cutting (tonne/ha) at 6 m after planting

Item	T2, 1[2]	T2, 2	T4,1	T4,2	SEM	Contrast		
						IC[1]	SC	X
Fresh fodder	27.89[a]	37.58[b]	33.51[b]	35.91[b]	1.14	NS	*	*
Dry fodder	4.25[a]	6.86[b]	6.49[b]	7.90[c]	0.35	**	**	*
Protein	1.16[a]	1.60[b]	1.55[b]	1.54[b]	0.06	**	NS	**

[a-c] Mean in the same row with different superscripts differ ($p<0.05$). SEM=Standard error of mean.
*, ** Significant at 0.05 and 0.001 probability level, respectively, NS=Non significant.
[1] IC=Initial cutting, SC=subsequent cutting, X=interaction between IC and SC.
[2] T2, 1: IC=2 months and SC=1 month; T2, 2: IC=2 months and SC=2 months; T4, 1: IC=4 months and SC=1 month; T4, 2: IC=4 months and SC=2 months.

Table 3. Effects of different cuttings on chemical composition of cassava foliage

Items	T2, 1[1]	T2, 2	T4, 1	T4, 2	SEM
DM, %	16.4[a]	18.8[b]	18.9[b]	22.4[c]	0.60
	------------------------- % DM	-------------------------			
NDF	42.7[a]	48.3[b]	49.2[b]	56.0[c]	1.26
ADF	25.9[a]	31.0[b]	32.1[b]	38.0[c]	0.14
ADL	10.4[a]	11.8[b]	12.6[b]	13.6[c]	0.32
CP	28.5[a]	24.2[b]	28.7[a]	20.8[c]	0.87
Ash	7.7[a]	6.7[b]	7.0[b]	5.2[c]	0.25
Condensed tannin	5.0	5.1	4.9	5.5	0.85

[a-c] Mean in the same row with different superscripts differ ($p<0.05$). SEM=standard error of mean; IC=initial cutting, SC=subsequent cutting.
[1] T2, 1: IC=2 months and SC=1 month; T2, 2: IC=2 months and SC=2 months;
T4, 1: IC=4 months and SC=1 month; and T4, 2: IC=4 months and SC=2 months.

Fresh, dry matter and protein yields of cassava at different initial and subsequent cuttings are presented in Table 2.

Dry matter production (in 6 months after planting) ranged from 4.3 to 7.9 t/ha. This result is higher than the figures of 3.2 to 4.8 t/ha found by Tung et al. (2001). The difference in DM productivity could be due to the difference in IC and SC as well as the interaction. DM yield was higher for the treatments with IC of 4 months. The results show that the later the IC and the longer the SC interval the higher the dry matter yield. Previous studies (Wanapat et al., 1997; Petlum et al., 2001) reported that the initial cutting (at 3 months) and frequent cutting (every 2 months) have been increased the whole crop biomass.

Protein yield in this study ranged from 1.2 to 1.6 t/ha (at 6 months after planting), higher than the levels reported by Tung et al. (2001). The difference between these studies might be due to the different study site and cutting schedule. The difference in protein productivity between the two studies was associated with differences in IC. In the current study, the medium DM yield and the medium CP (Table 3) content from with treatment was associated with T2, 2 resulted in the highest protein yield (1.6 tonne/ha) (Table 2).

The chemical composition of cassava foliage were presented in Table 3. The DM values were similar to the value of 18.7% obtained by Moore and Cock (1985). Variations in fibre components of cassava foliage were NDF (42.7 to 56.0%), ADF (25.9 to 38.0%) and ADL (10.4 to 13.6 %), respectively. The values of NDF, ADF and ADL in the present study were higher than those reported by Wanapat et al. (1997) but were lower than those of Poungchompu et al. (2001). The differences were probably due to differences in cassava variety, study site and seasonal conditions. Moreover, NDF and ADF values of cassava foliage were lower than those of tropical grasses (Wanapat and Devendra, 1999) and much lower than rice straw (-77.0% NDF, -54.0% ADF). Fibre fractions increased with later IC and SC; the lowest values were in T2, 1 and the highest value was in T4, 2. The high fibre components in T4, 2 were mainly due to the plant composition at 4 months after planting, cassava stems were quite mature and contained high fibre components. The differences could be attributed to age of plant because the amount of NDF and ADF in whole plants increased linearly with age of plant.

Crude protein content in cassava hay in the present study varied between 20.8-28.7%. Moore and Cock (1985) reported that CP in cassava whole plant was 25.5% and Wanapat et al. (1997) reported that a CP value in cassava hay of 24.9% compared with values from 20.6-22% obtained by Poungchompu et al. (2001). CP values in the present study were similar to these earlier references. Cassava hay contained almost double the content of CP of tropical grasses (Wanapat and Devendra, 1999). In addition, except for T4, 2, CP values of cassava foliage in the present study were higher than typical values for alfalfa 16.6–21.8% (Buscaglia et al., 1994).

Ash content in cassava hay in this study ranged from 5.2 to 7.7%. This result was consistent with the previous findings of Moore and Cock (1985), Phuc et al. (1996), Wanapat et al. (1997) and Poungchompu et al. (2001).

In this study, condensed tannin (CT) levels ranged from 4.9% to 5.5% and were not significantly different between treatments. These values are higher than those of 3.8 to 4.2% reported by Poungchompu et al. (2001). The difference between the two studies could be due to the difference in cassava variety. Barry (1989) reported that concentration of condensed tannin differs significantly between genotypes.

T2, 1 provided the best quality hay in terms of being high in CP and ash content and low in fibre components but DM yield and protein yield were very low and the crop suffered from weed competition. T4, 2 produced the highest DM and T2, 2; T4, 1; T4, 2 have equal CP yield but the cassava hay at the first harvest in this treatment was quite woody, high in fiber and low in protein and minerals. Therefore, when making hay, the whole cassava plant needs to be chopped into small pieces (less than 2 cm) in order to prevent animals from sorting out the stem. Cassava in T2, 2 produced high DM and protein yields, was low in fibre components and high in protein content, and the nutritive value was consistent between different cuttings. This treatment of initial and subsequent cutting times of 2

Table 4. Effect of cassava feeding on rumen pH, NH_3-N, blood urea nitrogen (BUN) and milk urea nitrogen (MUN)

Items	T1 0, 1:2 [1]	T2 1,1:2	T3 1, 1:3	T4 2, 1:2	T5 2, 1:3	SEM
pH	6.8	6.9	6.8	6.9	6.9	0.04
NH_3-N, mg/dl	16.4^{a}	21.7^{b}	21.1^{b}	21.6^{b}	23.2^{b}	0.52
BUN, mg/dl	9.0^{a}	9.6^{a}	10.5^{ab}	11.7^{b}	9.2^{a}	0.44
MUN, mg/dl	7.6^{a}	8.3^{ac}	9.6^{bc}	10.4^{b}	8.4^{ac}	0.42

[a-c] Mean in the same row with different superscripts differ (p<0.05). SEM=standard error of mean.

[1] T1 0, 1:2: No cassava hay supplementation, supplementation of concentrate at 1:2. T2 1, 1:2: Supplementation of 1 kgDM of CH/hd/d, supplementation of concentrate at 1:2. T3 1, 1:3: Supplementation of 1 kgDM of CH/hd/d, supplementation of concentrate at 1:3. T4 2, 1:2: Supplementation of 2 kgDM of CH/hd/d, supplementation of concentrate at 1:2. T5 2, 1:3: Supplementation of 2 kgDM of CH/hd/d, supplementation of concentrate at 1:3.

Table 5. Effect of cassava hay (CH) supplementation on total dry matter, roughage and urea-treated rice straw (UTRS) intake of experimental dairy cows (kg/hd/d)

	T1 0, 1:2[1]	T2 1, 1:2	T3 1, 1:3	T4 2, 1:2	T5 2, 1:3	SEM
Total DM	12.2^{a}	13.4^{b}	12.6^{c}	13.6^{b}	12.3^{ac}	0.06
Roughage, DM	8.6^{a}	9.5^{b}	10.2^{c}	9.9^{c}	10.0^{c}	0.06
UTRS, DM	5.5^{a}	5.1^{b}	6.0^{c}	5.1^{b}	5.2^{b}	0.05

[a-c] Mean in the same row with different superscripts differ (p<0.05). SEM=standard error of mean. UTRS=urea-treated rice straw.

[1] T1 0, 1:2: No cassava hay supplementation, supplementation of concentrate at 1:2. T2 1, 1:2: Supplementation of 1 kg DM of CH/hd/d, supplementation of concentrate at 1:2. T3 1, 1:3: Supplementation of 1 kg DM of CH/hd/d, supplementation of concentrate at 1:3. T4 2, 1:2: Supplementation of 2 kg DM of CH/hd/d, supplementation of concentrate at 1:2. T5 2, 1:3: Supplementation of 2 kg DM of CH/hd/d, supplementation of concentrate at 1:3.

months provided a good cutting option for harvesting cassava to making hay for dairy cattle.

Effects of different levels of cassava hay and concentrate supplementation on ruminal parameters and performance of dairy cows

Supplementation of CH did not change the pH in the rumen (Table 4). The values are in agreement with the previous findings of Wanapat et al. (2000a); Khang and Wiktorsson (2000).

Ruminal NH_3-N concentrations are shown in Table 4. The NH_3N concentration of all cows which received CH supplementation was higher than that of cows which did not receive CH (p<0.05). The optimal level of ruminal ammonia concentration for efficient digestion ranges from 8.5 to over 30.0 mg N/dl (McDonald et al., 1996) and from 5.0 to 25.0 mg N/dl (Preston and Leng, 1987). Recent studies have found that when ammonia concentration in the rumen falls below 20 mg N/dl, the rumen micro-organisms are inefficient (Leng, 1999). In the present study, ammonia concentration in the control diet was 16.4 mg N/dl. The ruminal ammonia concentration of all CH supplementation cows was higher than 20 mg N/dl. Therefore, the micro-organisms in the rumen of CH supplemented cows might be expected to more efficient and CH supplementation could improve the efficiency of micro-organisms and digestion in the rumen. This finding efficiency may explain the higher intake and tendency toward increasing milk in CH supplemented cows (which is shown later).

Blood-urea nitrogen (BUN) values are shown in Table 4. BUN has been known to be related to dietary protein intake (Song and Kennelly, 1989; Song and Kennelly, 1990). In the present study, although NH_3-N concentration in the rumen was significantly higher in cows which received CH supplement, the increase in BUN was not significant, except in T4 2, 1:2. Urea concentration in blood is also determined by protein catabolism rather than just ammonia concentration in the rumen (DePeters and Ferguson, 1992). The trend of increasing BUN in the present study might be due to the increase in absorbable protein from the small intestine. Moreover, BUN also depends on protein/energy (P/E) balance. For diets balanced in P/E, BUN concentration was 12.7 mg/dl and BUN value lowers than this reference could be due to an insufficiency in CP per unit of energy (Hwang et al., 2001). BUN values in the current study were lower than the value suggested by Hwang et al. (2001) which indicates that CP supply was very poor.

The concentration of milk urea nitrogen (MUN) in cows, which were supplemented with CH, were higher than compared the control. However, only T3 1, 1:3 and T4 2, 1:2 differed significantly. The MUN is closely correlated to protein in the diet, particularly with the amount of protein per unit of energy (Oltner and Wiktorsson, 1983; Oltner et al., 1985; Hof et al., 1997). MUN concentration is poorly associated with ruminal ammonia concentration but closely related to absorbable protein (Broderick and Clayton, 1997; Cannas et al., 1998). The increase in MUN in the present study suggests that cassava hay contributed a higher amount of absorbable protein to the small intestine thus it might be speculated that CH supplementation has elevated ruminal ammonia concentration mating the micro-organisms more efficient and produced more microbial protein. Moreover, condensed tannin in the CH could result in a high proportion of by-pass protein to the small intestine (Wanapat et al., 1997; Wanapat et al., 2000a, 2000b). It is suggested that the optimal level of MUN should be 10.3 mg/dl and MUN below this level indicate insufficient CP

Table 6. Milk yield and milk compositions of dairy cows

Item	T1 0, 1:2[2]	T2 1, 1:2	T3 1, 1:3	T4 2, 1:2	T5 2, 1:3	SEM
Milk yield, kg	7.5	8.4	7.7	8.0	7.9	0.12
4% FCM[1], kg	7.8	9.5	8.8	9.1	8.9	0.16
Milk fat, %	4.3	4.9	4.9	5.0	4.9	0.09
Milk CP, %	3.5[a]	3.8[b]	3.8[b]	3.9[b]	3.7[b]	0.03
Milk SNF, %	8.4	8.6	8.9	8.6	9.0	0.07
Total solids %	12.7	13.5	13.8	13.6	13.9	0.13

[a-c] Mean in the same row with different superscripts differ (p<0.05). SEM=standard error of mean.

[1] FCM=fat corrected milk, 4% FCM=0.4×(kg of milk)+15×(kg of fat).

[2] T1 0, 1:2: No cassava hay supplementation, supplementation of concentrate at 1:2. T2 1, 1:2: Supplementation of 1 kg DM of CH/hd/d, supplementation of concentrate at 1:2. T3 1, 1:3: Supplementation of 1 kg DM of CH/hd/d, supplementation of concentrate at 1:3. T4 2, 1:2: Supplementation of 2 kg DM of CH/hd/d, supplementation of concentrate at 1:2. T5 2, 1:3: Supplementation of 2 kg DM of CH/hd/d, supplementation of concentrate at 1:3.

Table 7. Effect of cassava hay supplementation on economic return of milk yield

Item	T1 0, 1:2[1]	T2 1, 1:2	T3 1, 1:3	T4 2, 1:2	T5 2, 1:3
Milk sale, US$/d	1.6	1.8	1.7	1.7	1.7
Concentrate, US$/d	0.6	0.6	0.4	0.6	0.3
Cassava hay cost, US$/d	-	0.07	0.07	0.14	0.14
Total supplement cost, US$/d	0.6	0.7	0.4	0.7	0.5
Income over supplement, US$/d	1.1	1.1	1.2	1.0	1.2
Income over supplement, US$/m	31.7	34.0	36.7	30.0	36.7

Price: milk=0.21 US$/kg, concentrate=0.15 US$/kg, cassava hay=0.07 US$/kg. 15,200 dong=1 US$.

[1] T1 0, 1:2: No cassava hay supplementation, supplementation of concentrate at 1:2. T2 1, 1:2: Supplementation of 1 kg DM of CH/hd/d, supplementation of concentrate at 1:2. T3 1, 1:3: Supplementation of 1 kg DM of CH/hd/d, supplementation of concentrate at 1:3. T4 2, 1:2: Supplementation of 2 kg DM of CH/hd/d, supplementation of concentrate at 1:2. T5 2, 1:3: Supplementation of 2 kg DM of CH/hd/d, supplementation of concentrate at 1:3.

per unit of energy (Hof et al., 1997). When milk protein was higher than 3.0%, optimal MUN level ranged from 11-17 mg/dl, MUN below 11.0 mg/dl indicated a protein deficiency and energy balance or slight surplus (Hwang et al., 2000). Most MUN values obtained from the present study were lower than these reports, especially in the control diet.

Lower concentration of BUN and MUN in this study as compared to standard levels could be interpreted as showing that the current practical feeding regime (supplement 1 kg of commercial concentrate to 2 kg of milk) was inappropriate in terms of P/E balance. The diets could be deficient in high quality protein .Therefore supplementation of high quality protein sources could be a good tool to overcome this problem.

The feed intake of the dairy cows is presented in Table 5. Supplementation of CH increased total DM of dairy cows (p<0.05). This result agreed which those of Khang and Wiktorsson (2000), Wanapat et al. (2000a). Supplementation with CH only increased UTRS intake in T3 1, 1:3 and decreased in all other treatments compared to the control. This result differs from that reported by Wanapat et al. (2000a). These authors found that feeding CH to dairy cows increased UTRS intake of dairy cattle. The difference between the two studies was probably due to the difference in the basal diet. In the previous study, only UTRS was provided as the basal diet whilst in the present study, cows were provided with 30 kg fresh Elephant grass daily. Cassava hay plus Elephant grass might have an effect on the intake of UTRS because of limited rumen volume. However, T3 1, 1:3 when the cows received only 1 kg of CH along with a reduction in concentrate feed intake UTRS increased.

The data of milk yield and milk composition are presented in Table 6. Milk yield, 4% FCM and milk fat content tended to be higher when cows received CH supplementation even though CH supplementation reduced the provision of concentrate supplementation. Cassava hay could provide additional volatile fatty acids in the rumen, which are necessary for short chain fatty acid synthesis in milk (Wanapat et al., 2000a).

Milk protein content was 3.5% for the control and varied between 3.7-3.9% for the treatments. Cows receiving diets with CH produced milk with significantly higher protein as compared to those fed diets without CH (p<0.05) despite a reduction in concentrate supplementation. This result agrees with the previous finding of Wanapat et al. (2000a, 2000b). The higher milk protein content could be due to CH providing more absorbed protein to the animals as mentioned above. Therefore, the animals had more precursors for milk protein synthesis. Moreover, supplementation with CH to reduce concentrate usage did not have any adverse effect on total solids and SNF as also reported earlier by Wanapat et al. (2000b).

A simple calculation of economics is presented in Table 7. Supplementation with CH at 1 or 2 kg/hd/d could reduce concentrate use from 1 kg concentrate per 2 kg milk to 1 kg concentrate per 3 kg milk yield (T3 1, 1:3 and T5 2, 1:3) and increase the income from milk sales by 5 US$ per cow per month. This result agrees with the previous findings by

Wanapat et al. (2000b). Moreover, in the present study, the cost for hiring labour to plant, harvest and make CH was included in the cassava cost. In practical situations, if farmers can produce CH using family labour, the cost of CH will be lower and the resultant income higher. Therefore, using cassava hay in dairy production could contribute more employment opportunities to farmers. Besides, using cassava hay in dairy production could provide a source of on-farm high quality protein contributing to more sustainable feeding systems.

ACKNOWLEDGEMENTS

The senior author would like to express the sincere thanks to the Belgian Technical Cooperation for the financial support under the Project Development of dairy support activities in Southern Vietnam (VIE/00/002) for a Master degree study. The authors also would like to express the gratitude to all who have supported the research activities, particularly the Institute of Agricultural Science of South Vietnam, Dairy Research and Training Center and Khon Kaen University.

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