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Effects of different harvest intervals on cassava foliage (cassava hay) and root yield

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Abstract

A Randomized complete block design (RCBD) with 4 treatments and 4 replications was conducted to investigate the effect of different harvest intervals of cassava foliage on cassava root and foliage yield under traditional cultivation. The treatments were: cassava foliage (CF) harvested once at root harvest (H_1) as the control treatment, CF harvested two times at 3 months of growth and at root harvest (H_2), CF harvested three times at 3 months of growth, three months thereafter and at root harvest (H_3) and CF harvested four times at 3 months of growth, every three months thereafter and at root harvest (H_4). Root was harvested at one year after planting.

Alteration of soil OM content and pH after root harvest were not significantly different among treatments but frequent harvests of cassava foliage tended to decrease soil OM content while N in the soil was significantly increased. DM, CP and ash in cassava foliage were similar among treatments. NDF and ADF tended to increased by frequent harvesting intervals, while ADL was similar among treatments. Condensed tannin in cassava foliage was not significantly different but tended to be lower by frequent harvests. Cassava foliage yield was significantly increased ($P<0.01$) by frequent harvests of cassava foliage, while cassava root yield was significantly decreased ($P<0.01$) 14 to 48%, as compared with the control treatment. Starch in cassava root was also decreased by frequent harvests of cassava foliage. However, frequent harvests of cassava foliage resulted in greater economical returns by increased total net income from sold cassava foliage (cassava hay) and root production up to 12 and 31% for H_3 and H_4, respectively as compared with the control treatment. Based on the result of this study, it was concluded that different harvest intervals of cassava foliage had no major effect on quality, but affected on quantity of foliage and root yield. Planting cassava for making cassava hay as a protein source could be more potential and profitable in increasing income under small-holder farming system.

Keywords: Cassava foliage; Cassava hay; Cassava root; Harvest interval; Starch

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1. Introduction

Cassava or tapioca (*Manihot esculenta*, Crantz) is grown widely in tropical and sub-tropical countries. This plant is well known to adapt to poor soil condition, drought resistance and

has pest tolerance. Cassava is the one of three most important crop in Thailand (Siroth, 2000) which in 2004, Thailand can produce total cassava root yield of 21.4 million tons with total harvested area 1.08 million hectares (Office of Agricultural Economics, 2004). Cassava roots are utilized for making dry chip, pellets, starch, monosodium glutamate etc. Cassava chip is locally available, it is an excellent energy source for ruminants because of its highly digestible carbohydrate (70-80%), mainly in the form of starch. (Kearl, 1982; Sommart *et al*., 2000; Vearasilp and Mikled, 2001). While, cassava foliage (cassava hay) has been used to supplement as a protein source for ruminants. Recently, Wanapat *et al*. (1997) has paid attention on cassava hay and stated that cassava hay is harvested three months after planting and followed every two to three months thereafter until one year by cutting the whole crop at 15 cm. above the ground (between green and brown part). Then sun-dried one to three days before feeding or for storage. The potential advantages of cassava foliage harvesting at an early growth stage (3 months) reduces condensed tannin (CT) and increase the protein contents resulting in higher nutritive value. In addition, ruminal protein degradation of cassava hay was relatively low (48.8%) since it contained tannin-protein complex which would render higher by-pass protein in small intestine (Wanapat *et al*., 1997). Moreover, Netpana *et al*. (2001) showed that the fecal parasitic egg counts in cattle and buffaloes were significantly lower when fed with cassava hay that contained condensed tannins and were similar to the group that had been drenched. Therefore, cassava chip and cassava hay could be a good supplement to combine with the low protein roughage such as grass, rice straw to improve feed intake, digestibility and production of ruminants, especial in the dry season. Although, the use of cassava chip and cassava hay has been successfully to supplement for ruminants especially in dairy cows to improve production and reduce feed cost. Nevertheless, the study on cassava hay production and it composition under traditional cultivations for more profitable both of root and foliage have been limited. Therefore, the objective of this experiment is to determine the production and quality of cassava hay and cassava root as affected by different harvest intervals of cassava foliage under the traditional cultivation.

2. Materials and methods

2.1 Location and climate of the experimental area

This experiment was conducted as an on-farm trial under rain fed condition during November 2003 – October 2004 at Namphong district, Khon Kaen, Thailand. Annual rainfall is 1,113 mm and average temperature is 27.5°C. The monthly average minimum, maximum temperature and rainfall during experimental period are shown in figure 1.

2.2 Experimental design and treatments

Randomized complete block design (RCBD) with four replications were used to study the effects of different harvestings on yield and chemical compositions of cassava hay and cassava root. The experiment comprised of 4 treatments:

H_1: Cassava foliage (CF) harvested once at root harvest

H_2: CF harvested two times at 3 months of growth and at root harvest

H_3: CF harvested three times at 3 months of growth, three months thereafter and at root harvest

H_4: CF harvested four times at 3 months of growth, every three months thereafter and at root harvest.

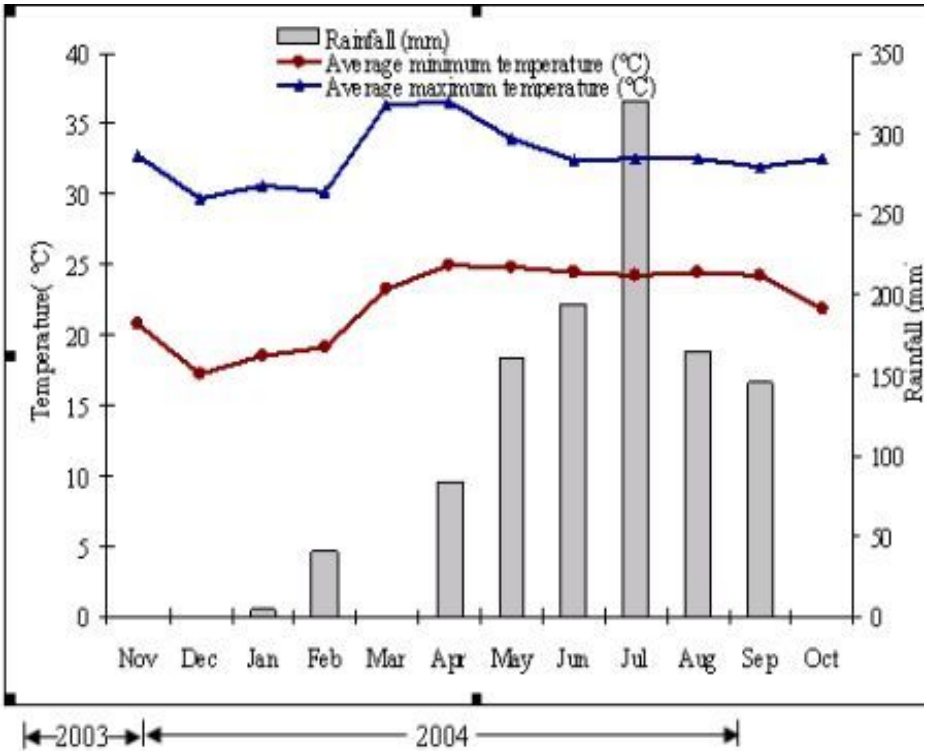

Figure 1. Monthly weather data during the experimental period.
Source : Khon Kaen Meteorological Station, Khon Kaen (2005).

2.3 Land preparation and cassava planting

Soil was ploughed without harrowing. After ploughing, land was ridged and divided into 16 plots with the size of each plot 4.5×6.4 m. The spacing between 2 plots was 1 m. Cassava was planted in rows using stems as planting material. The cassava stakes from the healthy and disease free stems of the local variety Rayong 60 of 15 – 20 cm length were used. A row spacing of 50×80 cm (between stem 50 cm and between row 80 cm) were used in all plots. Weeding was applied to all plots at 3 months after planting and at each harvesting time. Fertilizer was applied by using chemical fertilizer with N-P-K (15-15-15) 150 kg/ha at 3 months after planting.

2.4 Data collection and plant harvesting

Initial and subsequent harvesting of cassava foliage was done according to treatments. The last harvesting of cassava foliage of all treatments was done when harvesting cassava root at one year after planting. Cassava foliage was harvested by breaking the stem at between the green and brown part in accordance with Wanapat *et al*. (1997). Individual plot of fresh cassava foliage were weighed. The cassava foliage samples were randomly sampled and divided into two parts, one for dry matter and one for proximate and condensed tannin analyse. Samples were chopped. Cassava root was harvested at one year after planting, soil-free cassava root in each plot were weighed and samples were randomly taken about 5 kg for starch analysis and about 1 kg chopped for dry matter analysis. Soil samples were taken from 3 locations within each plot at 0 - 20 cm depths at initial experiment and after harvesting the cassava root.

2.5 Chemical analysis

At each harvesting, cassava foliage samples were analysed for dry matter (DM), crude protein (CP) and ash by the AOAC (1990) procedures. Neutral-detergent fiber (NDF), acid-detergent fiber (ADF) and acid-detergent lignin (ADL) were analysed by the methods of Van Soest *et al*. (1991). Condensed tannin was analysed by using the Vanillin-HCl method (Burns, 1971 as modified by Wanapat and Poungchompu, 2001). Cassava root samples were analysed for dry matter (DM) by AOAC (1990) and starch percentage was analysed by using root specific gravity (CIAT, 1975). Soil samples were analysed for organic matter (OM), total nitrogen (N) and pH.

2.6 Statistical analysis

The various data were subjected to the analyses of variance (ANOVA) procedure 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 (Steel and Torrie 1980). The statistical model was:

$$Y_{ij} = \mu + \alpha_i + \beta_j + e_{ij}$$

Where: Y_{ij}: observation in block i (i = 1-4) and treatment j (j = 1-4), μ = overall sample mean, α_i = effect of block i, β_j = effect of treatment j and e_{ij} = error

3. Results

3.1 Soil fertility

Effect of harvest intervals on soil fertility is shown in Table 1. OM and pH in the soil content were not significantly different among treatments but frequent harvests of cassava foliage tended to decrease soil OM content, while nitrogen content was increased by harvesting frequency in which H_4 was significantly higher ($P<0.05$) that in the H_1 treatment.

Table 1. The effects of different harvest intervals of cassava foliage on soil fertility

	Harvest intervals				SEM
	H_1	H_2	H_3	H_4	
Organic matter (OM), %					
Initial experiment	0.24	0.27	0.25	0.25	0.02
After root harvesting	0.23	0.19	0.18	0.08	0.03
Alteration	-0.02	-0.07	-0.07	-0.17	0.04
Nitrogen, %					
Initial experiment	0.014	0.014	0.014	0.014	0.000
After root harvesting	0.012	0.015	0.016	0.017	0.001
Alteration	-0.002^{b}	0.001^{ab}	0.002^{ab}	0.003^{a}	0.001
pH					
Initial experiment	4.6	4.6	4.5	4.5	0.04
After root harvesting	4.6	4.5	4.5	4.4	0.04
Alteration	0.07	-0.08	-0.08	-0.05	0.04

^{a,b,c} Means in the same row with different superscripts differ ($P<0.05$)

SEM = standard error of means

H_1 = Cassava foliage (CF) harvested once at root harvest
H_2 = CF harvested two times at 3 months of growth and at root harvest
H_3 = CF harvested three times at 3 months of growth, three months thereafter and at root harves
H_4 = CF harvested four times at 3 months of growth, every three months thereafter and at root harvest

3.2 Cassava foliage and cassava root yield

Cassava foliage and cassava root yield are shown in Table 2. DM of cassava foliage from fresh foliage was not significantly different among treatments. Fresh and dry matter yield of cassava foliage were significantly increased by frequent harvesting intervals. The result in H_4 was significantly greatest ($P<0.01$) among treatments. H_3 was significantly greater ($P<0.01$) than those in treatments H_2 and H_1, while in treatment H_2 and H_1 were similar.

DM of cassava root from fresh root was declined by increasing harvesting intervals. In H_2 was significantly higher ($P<0.01$) than those in the H_3 and H_4. Fresh and dry matter root yield were significantly decreased ($P<0.01$) by frequent harvesting intervals. Fresh root yield in the H_1 was significantly highest, while in the H_2 was higher ($P<0.05$) than in the H_4. Dry matter root yield in the H_1 and H_2 were higher ($P<0.01$) than those in the H_3 and H_4. Percent starch of cassava root was significantly lower ($P<0.01$) by frequent harvesting intervals. Results in the H_1 and H_2 were greater ($P<0.01$) than those in the H_3 and H_4.

3.3 Chemical composition of cassava foliage

Chemical composition of cassava foliage is shown in Table 3. Dry matter (DM), crude protein (CP) ash and ADL contents were similar among treatments. NDF content in the H_2 was significantly lower ($P<0.05$) than in the H_3, while the others were similar. ADF content was lowest in H_1, as shown frequent harvests resulted in significantly higher ADF content. Condensed tannin (CT) in cassava foliage was not significantly different among treatments but tended to be lower by frequent harvests.

Table 2. The effects of different harvest intervals of cassava foliage on cassava foliage and root yield

	Harvest intervals				SEM
	H_1	H_2	H_3	H_4	
Cassava foliage					
DM from fresh foliage, %	30.2	29.4	29.7	29.1	0.24
Fresh yield, tons/ha	0.8^{c}	3.1^{c}	9.0^{b}	13.8^{a}	1.34
DM yield, tons/ha	0.3^{c}	0.9^{c}	2.7^{b}	4.0^{a}	0.39
Cassava root					
DM from fresh root, %	37.8^{ab}	41.7^{a}	36.3^{bc}	31.9^{c}	1.04
Fresh yield, tons/ha	25.1^{a}	19.8^{b}	17.4^{bc}	15.2^{c}	1.08
DM yield, tons/ha	9.5^{a}	8.2^{a}	6.3^{b}	4.9^{c}	0.51
Starch, %	24.7^{a}	25.3^{a}	20.1^{b}	19.3^{b}	0.72

^{a,b,c} Means in the same row with different superscripts differ ($P<0.01$)

SEM = standard error of means

H_1 = Cassava foliage (CF) harvested once at root harvest
H_2 = CF harvested two times at 3 months of growth and at root harvest
H_3 = CF harvested three times at 3 months of growth, three months thereafter and at root harvest
H_4 = CF harvested four times at 3 months of growth, every three months thereafter and at root harvest

Table 3. The effects of different harvest intervals of cassava foliage on chemical composition of cassava foliage

	Harvest intervals				SEM
	H_1	H_2	H_3	H_4	
DM, %	95.7	95.1	93.4	94.0	0.38
CP, %	23.6	22.7	22.8	23.7	0.19
Ash, %	6.5	7.3	6.5	6.0	0.18
NDF, %	41.3^{ab}	37.1^{b}	44.4^{a}	41.2^{ab}	1.01
ADF, %	21.7^{b}	23.2^{ab}	28.5^{a}	28.4^{a}	0.95
ADL, %	7.9	8.4	7.1	7.8	0.37
Condensed tannin, g/kg	39.7	37.8	32.2	28.9	1.83

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

SEM = standard error of means

H_1 = Cassava foliage (CF) harvested once at root harvest
H_2 = CF harvested two times at 3 months of growth and at root harvest
H_3 = CF harvested three times at 3 months of growth, three months thereafter and at root harvest
H_4 = CF harvested four times at 3 months of growth, every three months thereafter and at root harvest

3.4 Economical returns

Economical returns of sold cassava foliage and root production are shown in Table 4. Based on the data, it reveals that frequent harvesting intervals of cassava foliage in H_3 and H_4 resulted in higher net income (408.2 and 478 USD/ha, respectively) and was lowest in the H_2 (295.4 USD/ha). As compared with the H_1 (control treatment), net income from sold cassava foliage and root were increased by 12 and 31% for H_3 and H_4, respectively, while it was decreased by 19% in H_2.

Table 4. Effect of different harvest intervals of cassava foliage on economical returns

	H_1	H_2	H_3	H_4
Air dry basis cassava foliage yield, ton/ha	0.31	0.95	2.9	4.3
Fresh cassava root yield, ton/ha	25.1	19.8	17.4	15.2
Income, USD/ha				
Cassava foliage	34.9	106.9	326.3	483.8
Cassava root	652.6	514.8	452.4	395.2
Total income	687.5	621.7	778.7	879.0
Cost, USD/ha [1]				
Seedling	17.4	17.4	17.4	17.4
Land preparation	23.4	23.4	23.4	23.4
Planting	20.4	20.4	20.4	20.4
Weed control	106.3	106.3	106.3	106.3
Fertilizer	41	41	41	41
Root harvesting	43.8	43.8	43.8	43.8
Transportation	62.8	49.5	43.5	38
Hay making	8	24.5	74.7	110.7
Total cost	323.1	326.3	370.6	401.2
Net Income, USD/ha	364.4	295.4	408.2	478.0

[1] Not include miscellaneous (reparation, interest) and fixed cost (land rent and depreciation).

SEM = standard error of means, cassava foliage price = 112.5 USD/ton (calculated by

compared with the price of other protein sources concentrate ingredient that similar in %CP), fresh cassava root price = 26 USD/ton, transportation cost = 2.5 USD/ton, hay making cost = 25.75 USD/ton, 1USD = 40 Baht.

H_1 = Cassava foliage (CF) harvested once at root harvest
H_2 = CF harvested two times at 3 months of growth and at root harvest
H_3 = CF harvested three times at 3 months of growth, three months thereafter and at root harvest
H_4 = CF harvested four times at 3 months of growth, every three months thereafter and at root harvest

4. Discussions

4.1 Soil fertility

Frequent harvests of cassava foliage resulted in reduced soil OM content. Soil OM at initial and after experiment ranged from 0.24-0.27 and 0.08-0.23%, respectively. Soil OM in the study site was relatively low as compared with average value (0.6%) in Khon Kaen province and was very low in nutritional requirement of cassava according to Howeler (1996) with OM <1.0%. The pH was in the normal ranged (4.5-7) for cassava growth (Rojanaridpiched, 1976; Howeler, 1996). N content in the soil of present study was 0.014% and 0.012 to 0.017% for prior and after experiment, respectively. The N content in the soil in the H_1 was significantly reduced ($P<0.05$). Frequent harvests of cassava foliage resulted in increased N content in the soil. The reason could possibly be due to the N refusal from chemical fertilizer which was applied to cassava plots at 3 months after planting. Yupadee (1976) reported that cassava root part could uptake N of 30.56 kg/ha, while leaf part's uptake 11.38 kg/ha. Hence, it was evident that N was the most limiting nutrient for soil to grow cassava (Sittibusaya *et al*., 1993).

4.2 Cassava foliage and root yield

Variation of fresh and DM yield of cassava foliage ranged from 0.8 to 13.8 and 0.3 to 4.0 tons/ha, respectively. The result was lower than those reported by Wanapat *et al*. (1997); Vongsamphanh and Wanapat (2003). The differences could be due to the differences of planting space, study site and subsequent harvestings. Fresh and DM root yield ranged from 15.2 to 25.1 and 4.9 to 9.5 tons/ha, respectively. Office of Agricultural Economics (2004) reported that the average of cassava root yield (growing for root production) in Thailand was 20.3 tons/ha and Kiyothong and Wanapat (2003) reported that fresh cassava root was 11.2 tons/ha (with harvesting of foliage). As compared with those earlier references, the cassava root yield of the present study was higher, but tended to be lower than the figures of 22.2 to 36.5 tons/ha of fresh cassava root without foliage harvesting reported by Sinthuprama *et al*. (1983). Frequent harvests of cassava foliage were significantly higher ($P<0.01$) in DM cassava foliage yield of 3, 9 and 13 folds for H_2, H_3 and H_4, respectively as compared with the control treatment. While, DM cassava root yield was significantly deceased ($P<0.01$) by frequent harvesting of cassava foliage. The DM root yield was reduced by 14, 34 and 48% for H_2, H_3 and H_4, respectively as compared with the control treatment. Sinthuprama *et al*. (1983) stated that frequent harvesting intervals resulted in increases of cassava foliage while fresh cassava root was decreased by cutting foliage of 3, 4 and 6 times/year and were markedly reduced on fresh root yield. It was suggested that harvesting of cassava foliage at 4 months thereafter did not affect in root yield. DM and starch content of fresh cassava root ranged from 31.9 to 41.7% and 19.3 to 25.3%, respectively. The values of root specific gravity, DM and starch content in the root were highly correlated with each others (CIAT, 1975). Sinthuprama *et al*. (1983) and Settasuk (1994) reported that percent starch in cassava root harvested at 12 months were 17.7 to 22.2%. The Rayong Field Crops Research

Center (1994) reported that percent starch in cassava root were 18.3 to 35% depending on variety, planting area, planting and harvesting season. The values of starch content of cassava root in the present study were consistent with those earlier reported. Frequent harvests of cassava foliage resulted in reduced DM and starch content in the cassava root. Similarly Tiraporn and Narintaraporn (1983) who found that percent starch in the cassava root was significantly lower when cutting cassava stem from 15 up to 75 days before root harvesting as compared with immediate harvesting.

4.3 Chemical composition of cassava foliage

The DM value of cassava foliage in the present study ranged from 93.4 to 95.7%, and were similar to those reported by Wanapat *et al*. (1997) but were higher than those of Poungchompu *et al*. (2001). The differences were probably due to differences in cassava variety and study site. The CP content in cassava foliage in the present study was similar among treatments ranging from 22.7 to 23.7%. Wanapat *et al*. (1997) reported that CP value in cassava hay (whole crop) was 24.9% and 20.6-22%CP in the work of Poungchompu *et al*. (2001) and compared with the values from 21.6-21.9% of cassava hay sole crop by Kiyothong and Wanapat (2003). The CP value was similar according to these cited above. Ash content in cassava foliage in this study ranged from 6 to7.3%. The result was similar to work of Wanapat *et al*. (1997); Poungchompu *et al*. (2001); Hong *et al*. (2003); Kiyothong and Wanapat (2003). Fibre components of cassava foliage ranged from 37.1 to 44.4, 21.7 to 28.5 and 7.1 to 8.4% for NDF, ADF and ADL, respectively. The values of NDF and ADL in this study were higher than those reported by Wanapat *et al*. (1997) but were lower than those of Poungchompu *et al*. (2001); Vongsamphanh and Wanapat (2003). The differences could possibly be differences in cassava variety, study site and subsequent harvesting times of cassava foliage. The ADF content was consistent with those reported by Wanapat *et al*. (1997) and Hong *et al*. (2003). The NDF content was lowest in the H_2 with initial harvesting at 3 months of growth and without subsequent harvesting until the root harvests. The result was similar with the work of Wanapat and Polthanee (2001) who showed that NDF content in cassava hay was lowest in the first harvesting time but disagreed with those of Kiyothong and Wanapat (2003); Vongsamphanh and Wanapat (2003). The reasons could possibly be the differences in the seasonal planting and initial harvesting, as in the above work, cassava were planted at the beginning of rainy season and were harvested for the first time in the rainy season. In the present study it was planted at late of the rainy season (early of the dry season) and was harvested for the first time in the dry season. Condensed tannins (CT) in this study were from 28.9 to 39.7 g/kg DM. The result was slightly lower than the 30 to 42 g/kg DM reported by Poungchompu *et al*. (2001); Kiyothong and Wanapat (2003); Vongsamphanh and Wanapat (2003). The level of condensed tannin in the present study tended to declined by frequent harvests, it was similar result with the work of Hong *et al*. (2003) and was within the level of 2-4% which would be benefit for ruminants to protect protein from rumen digestion, thereby increasing by-pass protein (Barry and Manley (1984); Reed (1995) cited by Wanapat, 2001).

5. Conclusions and recommendations

Based on the result in this study, it was concluded that different harvest intervals of cassava foliage had no major effect on quality, but affected to quantity of foliage and root yield. Planting cassava for making cassava hay as a protein source for ruminant especially for dairy cows could be more potential and profitable in increasing income under small-holder farming system. Further researches relating to the yield and quality of cassava root and foliage under traditional cultivation should be considered in initial harvesting of cassava foliage more for hay making and will be profitable for both of root and foliage.

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7. References

AOAC, 1990. Association of Official Analytical Chemists, Official methods of analysis.15th ed., Washington DC, USA.

CIAT., 1975. Annual report. Centro Internacional de Agricultura Tropical, CIAT cassava office for Asia, Department of Agriculture, Ministry of Agriculture and Cooperatives. Thailand.

Hong, N.T.T., Wanapat, M., Wachirapakorn, C., Pakdee, P., Rowrinson, P., 2003. Effects of timing of initial cutting and subsequent cutting on yield and chemical compositions of cassava hay and its supplementation on lactating dairy cows. Asian-Aust J Anim Sci 16,12:1701-1769.

Howeler, R.H., 1996. Diagnosis of nutritional disorders and soil fertility maintenance of cassava. Tropical tuber crops. Problem, prospects and future strategies. Oxford and IBH Plublishing Co. Pvt. Ltd, New Delhi, India. pp. 181-193.

Kearl, L.C., 1982. Nutrient requirment of ruminants in developing countries. Longan: International Feedstuffs Institute. Utah State University, Utah.

Kiyothong, K., Wanapat, M., 2003. Supplementation of cassava hay and stylo 184 hay to replace concentrate for lactating dairy cows. Cassava-legume intercropping: A potential feed production system for small holder dairy farming. MSc thesis in the programme "Tropical Livestock Systems". SLU, Dept of Animal nutrition and management, Uppsala, Sweden.

Netpana, N., Wanapat, M., Poungchompu, O., Toburan, W., 2001. Effects of cassava hay supplementation on internal parasitic egg counts in swamp buffalo and cattle. In: Preston, T.R., Ogle, B., Wanapat, M. (Eds.), In: International Workshop Current Research and Development on Use of Cassava as Animal Feed. Khon Kaen, Thailand. July 23-24, 2001. pp. 41-43.

Office of Agricutural Economics., 2004. Cassava : Area, production, yield, farm price and farm value. Ministry of Agriculture and Cooperative, Bangkok, Thailand. www.oae.go.th.

Poungchompu, O., Wanapat, S., Polthanee, A., Wachirapakorn, C., Wanapat, M., 2001. Effects of planting method and fertilization on cassava hay yield and chemical composition. In: Preston, T.R., Ogle, B., Wanapat, M. (Eds.), In: International Workshop Current Research and Development on Use of Cassava as Animal Feed. Khon Kaen, Thailand. July 23-24, 2001. pp. 109-112.

Rayong Field Crops Research Center., 1994. Protential of cassava varieties. Cassava. Rayong Field Crops Research Center, Dept. of Agriculture. (in Thai).

Rojanaridpiched, C., 1976. Cassava cultivation. Cassava. Faculty of Agriculture, Kasetsart University. Bangkok, Thailand. pp. 239. (in Thai).

SAS., 1998. User's Guide: Statistic, Version 6.12th Edition. SAS Inst. Inc., Cary, NC.

Settasuk, J., 1994. Harvesting of cassava root. Cassava. Rayong Field Crops Research Center, Dept. of Agriculture. pp. 84-96. (in Thai).

Sinthuprama, S., Tiraporn, C., Thongklum, A., 1983. Planting and management. Cassava monograph number 7. Department of Agriculture, Ministry of Agriculture and Cooperatives. Bangkok, Thailand. pp. 41-56.

Sittibusaya, C., Tiraporn, C., Tongglum, A., Cenpukdee, U., Vichukit, V., Jantawat, S., Howeler, R.H., 1993. Recent progress in cassava agronomy research in Thailand. Cassava breeding, agronomy research and technology transfer in Asia. Proc. of the fourth regional workshop. Kerala, India. Nov 2-6, 1993. pp. 110-123.

Sommart, K., Wanapat, M., Parker, D.S., Rowlinson, P., 2000. Cassava chip as an energy source for lactating dairy cows fed rice straw. Asian-Aust J Anim Sci 13, 1094-1101.

Sriroth, K., 2000. Cassava industry in Thailand: The status of technology and utilization. Cassava, starch and starch derivatives. Proc. of the International Symposium. Nanning, Guangxi, China. Nov 11-15, 1996. pp. 311.

Steel, R.G.D., Torrie, J.H., 1980. Principles and Procedures of Statistics. A Biometrical Approch. McGraw-Hill, New York, USA.

Tiraporn, C., Narintaraporn, K., 1983. Harvesting of cassava root. Cassava monograph number 7. Department of Agriculture, Ministry of Agriculture and Cooperatives. Bangkok, Thailand. pp. 113-119. (in Thai).

Van Soest, P.J., Robesrtson, J.B., Lewis, B.A., 1991. Method for dietary fiber, neutral detergent fiber and non-starch polysaccharide in relation to animal nutrition. J Dairy Sci 74, 3583-3597

Vearasilp, T., Mikled, C., 2001. Site and extent of cassava starch digestion in ruminants. In: Preston, T.R., Ogle, B., Wanapat, M. (Eds.), In: International Workshop Current Research and Development on Use of Cassava as Animal Feed. Khon Kaen, Thailand. July 23-24, 2001. pp. 73-76.

Vongsamphanh, P., Wanapat, M., 2003. Potential use of local feed resources for ruminants in LAO PDR. MSc thesis in the programme "Tropical Livestock Systems". SLU, Dept. of Animal nutrition and management, Uppsala, Sweden.

Wanapat, M., 2001. Role of cassava hay as animal feed in the tropics. In: Preston, T.R., Ogle, B., Wanapat, M. (Eds.), In: International Workshop Current Research and Development on Use of Cassava as Animal Feed. Khon Kaen, Thailand. July 23-24, 2001. pp. 13-20.

Wanapat, M., Petlum, A., 2001. Feeding cassava chip-based rations to lactating dairy cows. In: Preston, T.R., Ogle, B., Wanapat, M. (Eds.), In: International Workshop Current Research and Development on Use of Cassava as Animal Feed. Khon Kaen, Thailand. July 23-24, 2001. pp. 77-79.

Wanapat, M., Pimpa, O., Petlum, A., Boontao, U., 1997. Cassava hay: A new strategic feed for ruminants during the dry season. Paper presentation at the International Workshop on local feed resources-based animal production. Jan 21-25, 1997. pp. 9.

Wanapat, M., Poungchompu, O., 2001. Method for estimation of tannin by Vanillin-HCL method (a modified method of Burn, 1971). Manual of Laboratory of ruminant nutrition. Khon Kaen University, Thailand.

Wanapat, S., Polthanee, A., 2001. Study on growth, yield and nutritive values of cassava Rayong 5, Rayong 72 and Kasetsart 50. Department of Agronomy, Faculty of Agriculture, Khon Kaen University.

Yupadee, S., 1976. Nutrients stored in cassava. Annual report. Department of Agriculture. (in Thai).