Manipulation of Cassava Cultivation and Utilization to Improve Protein to Energy Biomass for Livestock Feeding in the Tropics

M. Wanapat
Department of Animal Science, Faculty of Agriculture, Khon Kaen University, Khon Kaen 40002, Thailand

ABSTRACT : Cassava *(Manihot esculenta,* Crantz*),* an annual tropical tuber crop, was nutritionally evaluated as a foliage for ruminants, especially dairy cattle. Cultivation of cassava biomass to produce hay is based on a first harvest of the foliage at three months after planting, followed every two months thereafter until one year. Inter-cropping of leguminous fodder as food-feed between rows of cassava, such as *Leucaena leucocephala* or cowpea *(Vigna unculata),* enriches soil fertility and provides additional fodder. Cassava hay contained 20 to 25% crude protein in the dry matter with good profile of amino acids. Feeding trials with cattle revealed high levels of DM intake (3.2% of BW) and high DM digestibility (71%). The hay contains tannin-protein complexes which could act as rumen by - pass protein for digestion in the small intestine. As cassava hay contains condensed tannins, it could have subsequent impact on changing rumen ecology particularly changing rumen microbes population. Therefore, supplementation with cassava hay at 1-2 kg/hd/d to dairy cattle could markedly reduce concentrate requirements, and increase milk yield and composition. Moreover, cassava hay supplementation in dairy cattle could increase milk thiocyanate which could possibly enhance milk quality and milk storage, especially in small holder-dairy farming. Condensed tannins contained in cassava hay have also been shown to potentially reduce gastrointestinal nematodes in ruminants and therefore could act as an anthelmintic agent. Cassava hay is therefore an excellent multi-nutrient source for animals, especially for dairy cattle during the long dry season, and has the potential to increase the productivity and profitability of sustainable livestock production systems in the tropics. ***(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 3 : 463-472)***

Key Words : Cassava Hay, Ruminant, Dairy, Protein, Condensed Tannins, Feed, Tropics, Sustainable System

INTRODUCTION

Cassava or tapioca (*Manihot esculenta,* Crantz*)* is an annual tuber crop grow widely in tropical and sub-tropical areas. It can easily thrive in sandy-loam soil with low organic matter, receiving low rainfall and high temperatures. It is therefore a cash crop cultivated by small-holder farmers within the existing farming systems in many countries (Wanapat, 1999).

Cassava tubers contain high levels of energy and minimal levels of crude protein and have been used as readily fermentable energy in ruminant rations. Cassava leaves have been used as a protein source when collected at tuber harvesting time. However, the intake and digestibility was low due to the high level of condensed tannins (Reed et al., 1982; Onwuka 1992). The role of tannins in tropical animal production has been currently presented (Brooker et al., 2000; Norton, 2000). Harvesting of cassava at an early growth stage (3 months) to make hay could reduce the condensed tannin content and increase protein content (25% of DM) resulting in a higher nutritive value (Wanapat et al., 1997).

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* Reprint request to: M. Wanapat. Department of Animal Science, Faculty of Agriculture, Khon Kaen University, Khon Kaen 40002, Thailand. Tel: +66-43-23-9749, Fax: +66-43-24-4474. E-mail: metha@kku1.kku.ac.th

PLANTING, CUTTING AND CULTIVATION FOR CASSAVA HAY (CH) MAKING

The studies by Wanapat et al. (1997, 2000a, 2000b, 2000c, 2000d) have revealed the details of planting and cassava hay making. Planting cassava for hay making was aimed to increase the whole crop digestible biomass and the tuber root as a by-product. Earlier work by Wanapat et al.(1997) demonstrated that planting cassava at 60x40 cm between rows and intercroppd with cowpea or leucaena could enrich soil fertility and used as food and feed for human and livestock, respectively. The initial cutting at 3 months was made and followed by subsequent cutting at every two months by hand breaking of the stem about 20-30 cm above the ground (with 3-5 remaining branches). The fresh whole crop was directly sun-dried or chopped before sun-drying to obtain dry matter 80-90%. This might take 2-3 days but chopping helps shorten the drying process. Sun-drying also eliminated hydro-cyanic acid (HCN) more than 90% and enhanced the palatability and long-term storage. Intercropping cassava with leguminous crop such as cowpea could improve soil fertility and to provide as food for human consumption and the residue used as supplemental feed especially during the dry season (Polthanee et al., 2001). Planting space and frequent cuttings have been shown to affect on combined yield of the cassava hay (Petlum et al., 2001). Furthermore, planting pattern either with non-ridging or ridging as well as manure fertilization could affect cassava hay production (Puangchompoo et al., 2001) (Table 1). Protein yield of CH

Table 1. Effects of planting method and fertilization on cassava hay yield[1]

Item	With ridge		Unridge		SEM
	Without manure	With manure	Without manure	With manure	
Fresh yield, kg/ha					
First cutting	3.7	4.0	3.8	3.5	0.26
Second	3.7	3.1	3.1	3.3	0.31
Third,	6.0	7.7	5.7	7.8	0.54
Fourth	5.6	4.7	5.6	4.6	0.27
Five	2.7	3.0	2.8	3.5	0.19
Six	0.7	0.8	0.4	0.9	0.11
Total	21.8	23.3	21.4	23.5	0.54
Dry matter yield, kg/ha					
First cutting	1.1	1.2	1.1	1.1	0.08
Second	1.0	0.9	1.0	1.0	0.09
Third	1.8	2.3	1.5	2.2	0.17
Fourth	1.7	1.4	1.6	1.3	0.08
Five	0.9	1.0	0.9	1.1	0.05
Six	0.3	0.3	0.2	0.3	0.05
Total	6.7	7.1	6.3	7.0	0.17
CP kg/ha	1.5	1.7	1.5	1.7	-

ns: non significantly different (p>0.05). (Puangchompoo et al., 2001)

[1] There were no significant interactions

has been reported to range from 1.5-1.7 ton/ha for six collective harvest (Wanapat et al., 2002)

Table 2 revealed dry matter yield of leaf, petiole and stem when harvested at 4 months after growing. Significant DM yield/ha have been obtained (Wanapat, 2002, unpublished data).

Chemical compositions of leaf and hay are presented in table 3. As could be seen that cassava leaf/hay contained high levels of nutrients especially protein content. Harvesting of whole crop at earlier stage and followed by 2 month subsequent cuttings resulted in higher protein to energy ratio (Tables 3, 4).

CASSAVA HAY NUTRITIVE VALUE

It has been found that cassava hay harvested at younger stage of growth (3 months) contained protein up to 25% CP and with a good profile of amino acids. As presented in table 3 and figure 1, cassava leaf and cassava hay contained relatively high value of nutrients particularly those of protein and amino acid profiles. When compared cassava leaf (CL) and cassava hay (CH) with soybean meal (SBM) and alfalfa hay (AH), these amino acid profiles were relatively comparable. Lysine, glutamine, asparagine and

Table 2. Fresh yield of cassava foliage (Rayong 72)[1/] harvested at 4 months after planting

		% DM	Fresh weight (g)	Dry weight (g)	% of total cut DM	Kg DM / ha/cut
Leaf	P1	27.5	16.7	4.7	13.6	120
	P2	30.5	41.9	13.0	37.9	336
	P3	37.9	44.4	16.6	48.8	430
	Total		103.0	34.3	61.1[2/]	880
Petiole	P1	14.1	7.7	1.2	11.0	32
	P2	20.4	21.8	4.5	40.1	116
	P3	22.1	25.5	5.5	49.0	142
	Total		55.0	11.2	20.1[2/]	290
Stem	P1	10.5	4.5	0.5	5.2	14
	P2	17.4	14.9	2.5	24.5	65
	P3	20.1	35.1	7.2	70.3	185
	Total		54.5	10.2	18.3[2/]	264
	Grand total		212.5	55.7		1434

[1/] Cassava top harvested approximately 40 cm above ground and were separated into 3 portions (P1 = light green and reddish color leaf, top; P2 = intermediate green, medium leaf; P3 = dark green color leaf, lower)

[2/] Percentage of total biomas / cut. (Wanapat et al., unpublished data)

Table 3. Chemical compositions of dried cassava leaf and hay

Item	Dried cassava leaf	Cassava hay
DM, %	90.0	86.3
	-------% of DM---------	
Digestible protein, DP	18.3	22.0
Total digestible nutrient, TDN	60.0	65.0
Crude protein, CP	20 - 30	25.0
Neutral detergent fiber, NDF	29.6	44.3
Acid detergent fiber, ADF	24.1	30.3
Acid detergent lignin, ADL	4.7	5.8
Ether extract, EE	5.9	6.2
Nitrogen free extract, NFE	44.2	48.0
Ash	10.0	12.5
Ca	1.5	2.4
P	0.4	0.03
Secondary compounds		
Condensed tannins, %	4.3	3.9
Hydrocyanic acid, mg/kg DM	46	38

* Leaf and hay harvested at 3 - 4 months of growth.

(Wanapat, 1999; Wanapat, 2001; Wanapat et al., 2000a)

arginine were higher in SBM but in CH were higher with methionine and leucine. Condensed tannins and hydrocyanic acid (HCN) concentrations were low in both CL and CH. Sun-drying could remarkably reduced HCN (Wanapat, 2000a, Wanapat, 2002). Digestibility and intake studies in cattle resulted in relatively high values which demonstrated that cassava hay was palatable and digestible. Condensed tannins(CT) were generally found in higher value in matured cassava leaf but was lower in cassava hay harvested at younger stage. Barry and Manley (1984) and Reed (1995) reported that if condensed tannins in the feeds exceeded 6% of dry matter, it would reduce feed intake and digestibility. If CT contained between 2-4% DM of condensed tannins, it would help to protect protein from rumen digestion thereby to increase by-pass protein.

Cassava hay contained condensed tannins(CT) or proanthocyanidin(PC) which were common in tropical plants. CT are polyphenolics which can casily be solubilized in water and can precipitate protein. The presence of condensed tannins and protein could form tannin-protein complex (TPC) by hydrogen-bonding especially at alkaline pH condition. TPC will maintain its complex in pH 3.5-7 and will dissociate under pH<3.0 and >8.0 (Jones and Mangan, 1977). Condensed tannins have been found to increase N-recycling in the rumen and salivation (Reed, 1995) and moreover to improve rumen microbial protein synthesis (Makkar, 2000). While McSweeney et al. (2000) found lower rumen cellulolytic bacteria in sheep fed tannin-containing diets but microbial

Table 4. Comparison of energy and protein obtained from traditional cassava cultivation and new method

	Method of cultivation	
	Traditional	New Paradigm
CP	550	3125 kg/ha
TDN	21250	18125(1062+ 7500)kg/ha
CP/TDN	0.02 (10%)	0.17 (90%)
		Efficiency P/E

(Wanapat, 2001)

protein synthesis was not affected. However, mode of action of CT on rumen fermentation is yet to be elucidated.

EFFECT OF RESIDUAL HYDRO-CYANIC ACID (HCN) AS THIOCYANATE IN CASSAVA HAY AS MILK PRESERVATIVE

As has been reported by Claesson (1994) that milk thiocyanate was required in the lactoperoxidase system in milk to help preserve the shelf-life and the optimal range of milk thiocyanate should not exceed 20 ppm. Feeding dairy cows with cassava hay as a supplement, has been shown that milk thiocyanate was 19.5 ppm, however, more researches need to further conducted in order to pin-point the role of residual HCN in cassava on milk thiocyanate.

EFFECT OF CT AS A GASTROINTESTINAL ANTHELMINTIC AGENT

Gastrointestinal (GI) parasites or nematodes have been found widely and resulting on poor performance of ruminants in the tropics. Common GI nematodes found were those of *Trichostrongylus colubriformis, Ostertagia circumcincta, Haemonchus centortus and T. vitrinus.* These nematode-infected animals exhibited higher requirement of protein and mineral requirements due to loss of endogenous nitrogen (blood, plasma, mucin and sloughed cells) and lowered P adsorption (Poppi et al., 1985, Kahn and Diaz-

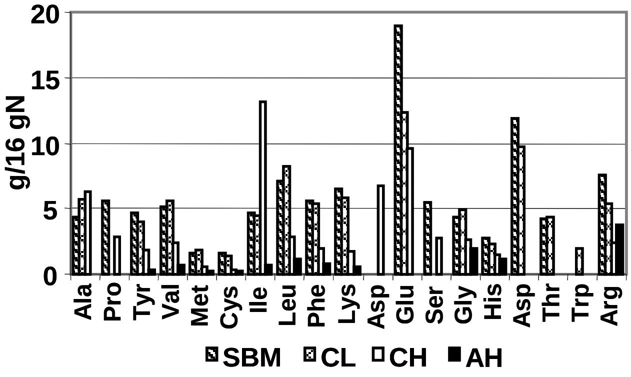

Figure 1. Amino acid profiles in cassava leaf (CL), cassava hay (CH), soybean meal (SBM) and alfalfa hay (AH) (Wanapat, 2002)

Hernandez, 2000). The preliminary work by Netpana et al. (2001) showed that the fecal parasitic egg counts in cattle and buffaloes were significantly lower when fed with cassava hay which contained condensed tannins and were similar to the group with drenching. Recent work by Granum et al. (2002) revealed that supplementation of CH at 1 kg/hd/d significantly reduced fecal egg counts in both buffaloes and cattle (Table 5). The reasons could possibly be that the animals received supplemental protein and/or CT could have a direct affect on the internal parasites. Possible mechanisms thorough which CT may reduce larval migration and development remain to be elucidated but may be mediated through ingestion of CT interactions of CT with external surface of larvae (Kahn and Diaz-Hernandez, 2000).

FEEDING TRIALS USING CASSAVA HAY (CH)

Cassava hay has been used successfully as a source of high protein roughage in lactating dairy cows (Wanapat et al., 2000a; Wanapat et al., 2000b). Wanapat et al. (2000b) (Table 5) found that increasing levels of CH from 0.6 to 1.7 kg/hd/d could reduce levels of concentrate from 0.1 to 1.6 kg/hd/d, respectively, without changing levels of milk yield. Moreover, feeding CH on ad lib resulted in similar result and could further reduce concentrate use. The study was conducted to examine the supplementation levels of cassava hay (CH) in dairy cows. Six multiparous Holstein-Friesian crossbreds were paired and randomly assigned in a change-over design to receive three levels of CH supplement at 0, 0.8 and 1.7 kg DM/hd/d. Concentrate was supplemented at the same level (1:2; concentrate: milk yield) while urea-treated (5%) rice straw was offered on ad libitum basis. The results revealed that supplementation of CH could significantly reduce concentrate use resulting in similar milk yield (12.5, 12.12 and 12.6 kg/hd/d) and significantly enhanced 3.5% FCM (14.21, 15.70 14.9 kg/d, respectively). Moreover, CH supplementation significantly increased milk fat and milk protein percentages especially at 1.70 kg/hd/d. Concentrate use could be significantly reduced by 27% at 1.7 kg/hd/d CH supplementation. In a later experiment (Wanapat et al., 2000b), supplementation of cassava hay to replace concentrate use was studied in lactating-Holstein Friesian crossbreds grazed on Ruzi grass. Six multiparous cows in mid-lactating periods were paired and randomly assigned according to a change-over-design to receive three dietary treatments, T1=0 kg cassava hay (CH) in 1:2 concentrate supplementation (CS) to milk yield (MY), T_2=1.0 kg DM CH/hd/d in 1:3 CS to MY, T_3=1.7 kg DM CH/hd/d in 1:4 CS to MY, respectively. The results were found that milk yield were similar among treatments while protein, lactose and solids-not-fat percentages were highest ($p<0.05$) in cows receiving CH at 1.0 kg/hd/d. Most

Table 5. Effects of cassava hay (CH) supplementation levels on ruminal pH, NH_3-N, milk yield and milk compositions in late lactating cows fed urea-treated rice straw (UTRS) as a roughage

	T1	T2	T3	T4	T5	SEM
Cassava hay DM intake, kg/d	-	0.56	1.13	1.70	5.2	0.20
Condensed tannin intake, g/hd/d	0	1.44	2.90	4.37	13.36	5.26
Conc. Saving, kg/hd/d	-	0.10	1.30	1.60	3.1	-
Urea-treated rice straw						
DM intake						
kg/d	6.8	6.4	6.7	8.0	-	0.28
g/kgW$^{.75}$	86	69	84	98	-	2.82
%BW	2.0	1.8	2.0	2.3	-	0.06
Ruminal pH	7.2	7.0	7.0	7.0	6.8	0.13
Ruminal NH_3-N, mg%	17	13	13	16	7.0	0.52
Milk yield, kg/d	6.3	6.1	5.4	6.1	5.4	0.24
3.5% FCM,kg/d	6.8^{ac}	6.2^{ab}	6.0^{b}	7.1^{c}	6.4^{ab}	0.13
Milk fat, %	4.0^{a}	3.6^{b}	4.2^{a}	4.5^{c}	4.6^{c}	0.11
Milk protein, %	4.4^{a}	4.0^{a}	3.8^{a}	4.1^{a}	5.3^{b}	0.17
Solids-not-fat, %	8.6	8.8	8.4	8.6	8.4	0.12
Total solids, %	12.6	12.3	12.0	12.2	12.6	0.18

abc Values on the same row with different superscripts differ ($p<0.05$). (Wanapat et al., 2000b)

T1= Urea-treated rice straw (UTRS0 ad lib.+ Conc: Milk yield(1:2) + 0 CH.

T2= UTRS ad lib. + Conc: Milk (1:2)+ CH at 0.56 kg DM/hd/d.

T3= UTRS ad lib. + Conc: Milk (1:3)+ CH at 1.13 kg DM/hd/d.

T4= UTRS ad lib. + Conc: Milk (1:2)+ CH at 1.70 kg DM/hd/d.

T5= Cassava hay ad lib. + Cassava (cassava chip + 3% urea) at 2 kg/d.

* Concentrate mixture in this treatment contained 95% cassava chip, 3% urea, 1% sulfur and 1 % mineral mix.

significant improvement from CH supplementation was the ability to reduce concentrate use by 42% which could provide a higher income for small-holder dairy farmers. In addition, milk thiocyanate was enhanced from 5.3 to 17.8 ppm ($p<0.05$) in the control and in the CH supplemented group (1.7 kg/hd/d), respectively. Moreover, CH supplementation could significantly reduce concentrate evel for dairy feeding thus resulted in more economical return. These results were in agreement with the work by Woodward et al. (1999) who reported that dairy cows fed

Table 6. Effect of level of chopped cassava hay on milk yield and composition of Holstein Friesian crossbreds fed urea-treated (5%) rice straw on ad labium basis

Item	Chopped cassava hay, kg/d			SEM
	0	0.8	1.70	
Concentrate DM intake, kg/d	5.53	5.00	4.03	0.25
Concentrate saving, kg (%control)	0	0.53(10%)	1.50(27%)	0.30
Milk yield, kg/d	12.50	12.12	12.62	0.57
3.5% FCM, kg/d	14.21[a]	15.70[c]	14.93[b]	0.67
Milk compositions				
Fat, %	4.06[a]	4.15[a]	4.61[b]	0.19
Protein, %	3.40[a]	3.34[b]	3.50[c]	0.08
Lactose, %	4.64[a]	4.82[b]	4.62[a]	0.05
Solids-not-fat, %	8.74	8.80	8.81	0.09
Total solids, %	13.56	13.18	13.76	0.32

[a,b,c] Values with different superscipts differ ($p<0.05$). (Wanapat et al., 2000a)

Table 7. Effect of cassava hay (CH) supplementation on concentrate use, milk yield and compositions

Conc : milk CH suppl. kgDM/d	1:2	1:3	1:4	SEM
CH suppl. kgDM/d	0	1.0	1.7	
Concentrate DM Intake, kg/d	4.56[a]	3.20[b]	2.64[c]	0.25
Concentrate saving, kg (%control)	0	1.36(30)	1.92(42)	-
Milk yield, kg/d	10.72	10.19	10.42	0.58
3.5% FCM, kg/d	12.65	12.51	12.64	0.75
Milk compositions				
Fat, %	4.61[a]	4.98[b]	4.80[ab]	0.13
Protein, %	3.36[a]	3.60[b]	3.45[ab]	0.10
Lactose, %	4.47[a]	4.66[b]	4.53	0.07
Solids-not-fat, %	8.80[a]	8.95[b]	8.68[c]	0.09
Total solids	13.41	13.54	13.50	0.24
Thiocyanate, ppm	5.3[a]	13.3[b]	17.8[b]	0.77

[abc] Values with different superscripts differ ($P<.05$). (Wanapat et al., 2000a)

Table 8. Effect of cassava hay supplementation on economical return of milk yield

Conc : milk	1:2	1:3	1:4
CH suppl, kgDM/d	0	1.0	1.7
3.5% FCM, kg/d	12.65	12.51	12.64
Milk sale, Baht	141.68	140.11	141.57
Concentrate intake, kg/d	5.15	3.62	2.97
Concentrate cost, B/d	60.90	21.72	17.82
Cassava hay intake, kg/d	0	2.85	4.02
Cassava hay cost, B/d	0	1.92	2.01
Total feed cost	30.90	23.64	19.83
Income over feed, B/hd/d	110.78	116.47	121.74
B/hd/m	3,324	3,494	3,652
$US	92.3	97.1	101.4

1 kg milk = 11.20 B, kg conc = 6.00 B, kg Cassava hay = 0.50 B 36B = 1 $US. (Wanapat et al., 2000a)

Table 9. Effect of local feed supplements on milk yield and compositions in farmers lactating dairy cows conducted as on an on-farm trial

	HQFB		HQFP		DCL		DLL		CSM	
	P	D	P	D	P	D	P	D	P	D
Milk yield, kg/d	9.80 ±2.95	10.46 ±2.78	11.05 ±3.21	12.08 ±4.55	9.08 ±2.16	10.11 ±2.53	9.76 ±1.78	10.77 ±2.15	11.76 ±2.80	13.06 ±3.10
3.5%FCM.kg/d	10.75 ±1.80	11.99 ±2.10	11.94 ±2.80	13.97 ±2.25	10.26 ±2.30	11.75 ±2.40	10.56 ±2.15	12.34 ±2.90	10.90 ±2.65	12.63 ±3.40
Fat, %	4.1	4.4	4.0	4.2	4.3	4.5	4.0	4.4	3.05	4.20
Protein, %	3.3	3.4	3.2	3.3	3.2	3.3	3.2	3.3	3.20	3.30
Lactose, %	5.1	5.1	5.0	5.0	5.0	5.0	5.1	5.0	4.90	5.00
Solids-not-fat, %	9.1	9.2	8.8	9.0	8.8	9.0	9.0	9.0	8.85	8.90
Total solids, %	13.2	13.4	12.8	12.8	13.1	13.3	13.0	13.4	11.90	12.65

* Three farms within each group, 30 farms in all, with similar lactation and condition were ranomly selected for these values.
P = pre-trial; HQFB = high-quality feed block; D= during trial, HQFB= High-qualtiy feed pellet; DCL = dried cassava leaf/hay DLL= dried leucaena leaf; CSM= cottonseed meal. (Wanapat et al., 2000c)

with *Lotus corniculatus* which contained condensed tannins had contributed to 42% improvement in milk yield and 57% increase in protein percentage without changing feed intake. (Tables 6, 7, 8 and 9).

Table 10. Ingredients mixture of high-quality feed block (HQFB)

Ingredient	HQFB1	HQFB2
	..……% by weight……..	
Molasses	40	42
Course rice bran	30	0
Cassava hay	0	30
Urea	13	11
Sulphure	1	1
Mineral mixed	1	1
Salt	1	1
Tallow	2	2
Cement	12	12

(Koakhunthod et al., 2001)

Recent trials in Vietnam, Nguyen et al. (2002) found similar results with earlier reports by Wanapat et al. (1997, 2000a, 2000b) that cassava hay could be produced at initial 4 months after planting and subsequently harvested at 1 month. Supplementation of cassava hay could lower concentrate use and improve milk yield and milk compositions. (Tables 16, 17, 18).

Koakhunthod et al. (2001) used CH as a major source of protein in high – quality feed block and supplemented to lactating dairy cow. The results were found that rumen ecology, milk yield and milk compositions were improved (Table 10, 11, 12, 13, 14).

CONCLUSIONS AND RECOMMENDATIONS

Cassava could be cultivated to produce cassava hay with high nutritive value. Intercropping cassava with food-feed could further increase biomass yield and enrich soil fertility.

Condensed tannins contained in cassava hay demonstrated potential role as a tannin-protein complex thus to increase rumen by-pass protein and to reduce GI nematodes egg count. Feeding cassava hay as a supplemental high protein source could increase milk yield and compositions and could significantly reduce concentrate use. On-fram research with small-holder farmers show a promising establishment and development of cassava hay production on farm. Harvesting of whole crop at earlier stage and subsequent cuttings to produce hay resulted in increasing protein to energy ratio in animal feeding. However, further researches relating to role of condensed tannins in cassava hay on rumen ecology and for livestock feeding for dairy cattle as well as the utilization levels especially with other low-quality roughage deserve immediate undertakings. Cassava hay could contribute to the sustainable livestock-crop production systems in the tropics.

Table 11. Chemical composition of urea-treated rice straw (UTRS), concentrate and feed block with (HQFB-CH) or without (HQFB) cassava hay (CH) (as % of dry matter)

	Dry matter	Organic matter	Crude protein	NDF	ADF
UTRS	55.2	83.6	6.8	83.0	58.1
Concentrate	85.0	92.2	13.6	24.3	10.7
HQFB	79.8	76.4	36.0	26.2	20.2
HQFB-CH	80.2	76.1	33.2	23.2	17.2

(Koakhunthod et al., 2001)

Table 12. Effect of cassava hay in a high-quality feed block on feed intake and dry matter digestibility in lactating dairy cows fed a basal diet of urea-treated rice straw

Item	Control	HQFB – CH	HQFB	SEM
UTRS DM intake				
kg/ day	5.44	6.20	5.61	0.17
% of BW	1.44	1.57	1.55	0.03
HQFB DM intake				
kg/ day		0.79	0.65	0.03
% of BW		0.20	0.18	0.01
Total DM intake				
kg/ day	9.18[a]	11.1[b]	10.1[ab]	0.31
% of BW	2.43	2.78	2.82	0.07
	48.4 [a]	53.4 [b]	51.1[ab]	0.76

SEM=standard error of means. (Koakhunthod et al., 2001)

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

Table 13. Effect of cassava hay in the feed block on rumen pH, NH_3

	Dietary treatments			
	Control	HQFB	HQFB - CH	SEM
pH	6.64	6.50	6.59	0.07
NH3-N (mg %)	7.95	8.61	9.14	0.71
Bacteria (X 10^9 cells/ml)	6.56	6.74	7.25	3.05
Protozoa(X10^5 cells/ml)	6.30	6.20	6.10	0.34
-holotrich(X10^5 cells/ml)	2.30	2.30	2.40	0.52
-entodiniomorp(X10^5 cells/ml)	4.00	3.90	3.70	0.83
Fungal zoospore(X10^7 cells/ml)	3.02	3.75	4.16	3.87
Total viable count(X10^{10} CFU/ml)	2.51	2.86	3.16	0.23
Cellulolytic bacteria X(10^9 CFU/ml)	3.04	3.21	3.48	0.27
Amylolytic bacteria(X10^8 CFU/ml)	1.60	2.22	2.19	0.15
Proteolytic bacteria(X10^8 CFU/ml)	1.71	2.02	2.13	0.19

SEM=standard error of the means. (Koakhunthod *et al.*, 2001)

Table 14. Effect of cassava hay (CH) in the feed block (HQFB) on milk yield and milk composition in lactating dairy cows fed urea-treated rice straw

	Dietary treatments			
	Control	HQFB	HQFB – CH	SEM
Yield, kg/day				
Milk	7.58[a]	8.85[b]	9.36[b]	0.44
3.5%FCM	7.66[a]	8.43[b]	9.94[c]	0.46
Fat	0.27[a]	0.29[a]	0.37[b]	0.02
Protein	0.23[a]	0.25[a]	0.31[b]	0.02
Milk compositions, %				
Fat	3.39[a]	3.53[ab]	4.08[b]	0.16
Protein	2.87	2.96	3.32	0.11
Lactose	5.01	4.85	5.00	0.04
SNF	7.98	8.01	8.01	0.42
Total solids	12.11[a]	12.03[a]	13.09[b]	0.25

SEM=standard error of the means, SNF=solids-not-fat. (Koakhunthod et al., 2001)

[ab] The values in the same rows with different superscripts differ ($p<0.05$).

Table 15. Effect of cassava hay supplementation on fecal egg counts (FEC)

Parasitic egg counts/g DM feces	Buffaloes		Cattle		SEM
	C	S	C	S	
Prel. period (grazing only)	1552	1243	1189	1462	82.2
Experim. period	918 [a]	579 [b]	951 [a]	747 [c]	77.4
Reduction from prel. period (%)	31.7 [a]	57.6[b]	24.7 [a]	45.0 [c]	6.2

[a, b, c,] Values on the same row with different superscripts differ (P<0.05). (Granum et al., 2002)
Values are the mean of 6 animals; C=control; S=cassava hay supplementation;
Prel.=preliminary Experim.=experimental; SEM=standard error of the mean

Table 16. Fresh, dry fodder and protein yield of cassava in different cuttings (t/ha)

Item	T1	T2	T3	T4	SEM	Contrast		
						IC	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	**

SEM=Standard error of mean. (Nguyen et al., 2002)
Mean in the same row with different superscripts differ (p<0.05).
FM=Fresh matter, IC=Initial cutting, SC=Subsequent cutting, X=Interaction between IC and SC.
*, **=Significant at 0.05 and 0.001 probability level, respectively, NS=Non significant.
T1: IC=2 months and SC=1 month; T2: IC=2 months and SC=2 months.
T3: IC=4 months and SC=1 month; T4: IC=42 months and SC=2 months.

Table 17. Effects of different cuttings on chemical compositions of cassava foliage

Items	T1	T2	T3	T4	SEM
DM, %	16.41[a]	18.80[b]	18.89[b]	22.40[c]	0.60
	---------------------% of DM -------------------------				
NDF	42.70[a]	48.27[b]	49.16[b]	56.04[c]	1.26
ADF	25.93[a]	31.02[b]	32.06[b]	37.97[c]	0.14
ADL	10.44[a]	11.83[b]	12.59[b]	13.60[c]	0.32
CP	28.51[a]	24.23[b]	28.65[a]	20.79[c]	0.87
Total Ash	7.72[a]	6.66[b]	6.97[b]	5.21[c]	0.25
Condensed tannin	5.00	5.15	4.87	5.48	0.85

SEM=Standard error of mean; (Nguyen et al., 2002)
Mean in the same row with different superscripts differ (p<0.05)
IC=Initial cutting, SC=Subsequent cutting.
T1: IC=2 months and SC=1 month; T2: IC=2 months and SC=2 months
T3: IC=4 months and SC=1 month; T4: IC=4 months and SC=2 months

Table 18. Effect of cassava hay supplementation on milk yield and composition

Item	T1	T2	T3	T4	T5	SEM
Milk yield, kg	7.48	8.42	7.70	8.00	7.90	0.12
4% FCM, kg	7.79	9.53	8.76	9.10	8.87	0.16
Milk DM, %	12.72	13.52	13.76	13.60	13.86	0.13
Milk fat, %	4.32	4.90	4.90	5.04	4.90	0.09
Milk CP, %	3.46[a]	3.76[b]	3.78[b]	3.94[b]	3.74[b]	0.03
Milk SNF, %	8.40	8.62	8.86	8.56	8.96	0.07

SEM=standard error of mean; Mean in the same row with different superscripts differ (p<0.05). (Nguyen et al., 2002)
FCM=fat corrected milk, 4% FCM=0.4x(kg of milk)+15×(kg of fat)
T1: No cassava hay supplementation, supplementation of concentrate at 1:2 milk yield. T2: Supplementation of 1kgDM of CH/h/d, supplementation of concentrate at 1:2 milk yield. T3: Supplementation of 1kgDM of CH/h/d, supplementation of concentrate at 1:3 milk yield. T4: Supplementation of 2kgDM of CH/h/d, supplementation of concentrate at 1:2 milk yield. T5: Supplementation of 2kgDM of CH/h/d, supplementation of concentrate at 1:2 milk yield.

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