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Effects of Supplementing Gamba Grass (*Andropogon gayanus*) with Cassava (*Manihot esculenta* Crantz) Hay and Cassava Root Chips on Feed Intake, Digestibility and Growth in Goats

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ABSTRACT : The effects of supplementing Gamba grass (*Andropogon gayanus*) with varying levels of hay from cassava (*Manihot esculenta* Crantz) and dried cassava root chip on growth and diet digestibility were studied using local male goats with an average initial body weight of 14.0 kg. Thirty-two animals were allocated to a completely randomized 2×2 factorial design with eight animals per treatment. The factors were two levels of cassava hay (25% and 35% of an expected dry matter (DM) intake of 3% of body weight) and cassava root chips (0 or 1% of body weight) on an individual basis with grass offered *ad libitum*. Another four animals were assigned to a 4×4 Latin square design to study digestibility, and were given the same four diets as in the growth experiment. Total DM intake was significantly higher in the group fed diets with cassava hay and root while the DM intake of Gamba grass was not significantly different between treatments. The supplementation with cassava hay and root increased the apparent digestibility of DM, organic matter and N and resulted in a higher N-retention. The apparent digestibility of neutral detergent fibre and acid detergent fiber was not affected significantly. The average daily gain of animals fed diets supplemented with both cassava hay and root was significantly higher than for the animals supplemented with cassava hay alone. The highest daily gain recorded was 70 g/day. In conclusion, supplementing a basal diet of Gamba grass with cassava hay and root chips improved DM intake, digestibility, N-retention and weight gain. In order to minimize the waste of cassava hay, the inclusion level of cassava hay can be recommended to be 25% of expected DM intake, which would give acceptable intake and growth performance when cassava root is included in the diet. (**Key Words** : Goats, Cassava Hay, Cassava Root, Gamba Grass, Intake, Digestibility, Growth)

INTRODUCTION

Smallholder goat production in the tropics and sub-tropics is mainly based on feeds from native pastures, crop residues and edible parts of shrubs and trees, which are generally high in fiber and low in crude protein (CP) as well as in metabolisable energy (ME) (Aregheore and Perera, 2004b; Baumann et al., 2004). Feed intake and the nutrient absorption from such diets are insufficient to even meet the maintenance requirements of the animals and thus they are prone to lose weight if not receiving additional nitrogen, energy and mineral supplements (Aregheore and Perera, 2004a). Supplementation of low quality diets with forage legumes or grains has been reported to increase intake, digestion and growth performance (Ondiek et al., 1999; Mupangwa et al., 2000). Several studies have shown that adding an energy supplement to the protein supplement further improved dry matter (DM) intake and digestibility coefficients of low quality diets (Shem et al., 2003; Aregheore and Perera, 2004b).

Despite the fact that there are potential economic benefits of using cereal grains for supplementation to ruminants, the availability, the costs and the value as a food for humans limits their use under small farm conditions. Cultivation of cassava (*Manihot esculenta* Crantz) to produce roots for human consumption is very common in smallholder farms in the tropical regions. The cassava foliage is a possible source of protein in the diet of growing goats and the roots can be used as an energy supplement. The leaf of cassava has a high protein concentration. The CP content of cassava foliage normally ranges from 190 g to 250 g/kg DM, and with almost 85% of the CP fraction as true protein (Ravindran, 1993; Khang and Wiktorsson,

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2004; Dung et al., 2005). The dried cassava root contains mainly starch (Lakpini et al., 1997). Large quantities of cassava foliage are available at the root harvesting and it is also possible to grow cassava as a forage crop. The foliage can be processed or preserved as an animal feed, through several processing methods, including chopping, air wilting, sun drying for hay making or production of leaf meal, and ensiling (Wanapat et al., 2000; Khang and Wiktorsson, 2004; Dung et al., 2005). The cassava root may be processed as cassava root chip or root meal or can be ensiled for feeding to both monogastric and ruminant animals.

The overall objective of this research was to find locally available feed resources to use in goat production systems for smallholders. The specific objective of this study was to determine the effect of supplementing a basal grass diet with varying levels of cassava hay, and with or without dried cassava root chip, on feed intake, digestibility and live weight gain of growing goats.

MATERIAL AND METHODS

Location and climate of the study area

The experiment was conducted in the Livestock Research Centre, which is located about 40 km from Vientiane, Laos, at an altitude of 150 m above sea level. The climate in this area is tropical monsoon, with a wet season from May to October and a dry season from November to April. Annual rainfall averages 1,600 mm and the peak rainfall occurs in the period July to August. Temperatures and relative humidity ranges during the study were 25°C to 30°C and 70% to 80%, respectively. The experiment was conducted in the wet season (i.e. mid June to October, 2004).

Experimental feeds

The feeds used in the experiment were Gamba grass (*Andropogon gayanus*), cassava hay and dried cassava root chip. The Gamba grass was obtained from existing pastures near the experimental unit. The pasture was divided into 10 plots, which were mechanically cut at 4-day intervals at the beginning of the wet season before the start of the experiment. Goat manure and nitrogen fertilizer (urea) were applied at the same time at the rate of 500 kg/ha and 50 kg of urea ha^{-1}, respectively, and subsequent fertilization with urea was applied after each cutting with an amount of 100 kg of urea ha^{-1} at each occasion. The forage was manually harvested about 25 to 30 cm from the ground every morning at 06:00 h and afternoon at 14:30 h. Before feeding, the grass was wilted in the shade for 1 h, and chopped into 20 to 30 cm pieces to avoid excessive waste.

The cassava hay was obtained from several foliage harvests undertaken before and during the experimental period. In order to avoid differences in nutritive value at different stages of maturity at the time of harvesting the cassava crop was divided into 10 small plots. The stems were cut stepwise with 7 days cutting interval 60 days before the start of the experiment. Goat manure was collected from the experimental unit and applied at the rate of 800 kg/ha at cutting time and with subsequent fertilization with urea at the rate of 100 kg ha^{-1} after each foliage harvesting. The foliage was manually harvested 60 days after the stem cuttings. The aerial parts, 30 to 40 cm from the top, including leaves, petioles and young stems, were collected, mechanically chopped into 5-7 cm pieces and sun dried for 2 to 3 days, depending on the intensity of sunlight to a moisture content of less than 12%. The cassava hay was stored in bags until used for feeding. The dried cassava root chips were purchased from farmers before the start of the experiment. A mineral salt-lick block containing Ca 145 g, Cl 375 g, Na 242 g, Fe 320 mg, Cu 295 mg, Mn 185 mg, Co 80 mg, Zn 280 mg, Se 20 mg, I 300 mg and Mg 2,400 mg per kg block was supplied to each pen. Goats had free access to drinking water, which was provided in a plastic bucket in each pen. The feeding troughs were divided into two sections, making it possible to feed cassava hay at the same time as the cassava root, and grass 2 h later. The forages were offered twice a day, at 08:00 h and 16:30 h, in equal proportions.

Animals and management

In total 36 local growing male goats were purchased from farmers in the central part of Laos. The local goats (*Capra spp.*) have a small body size reaching mature body weight of 30 to 35 kg at the age of about 18 months. Thirty two goats, weighing 14.0 kg (SD = 1.10 kg) and 5 to 6 months old were used for the growth performance study, and another 4 male goats about 7 to 8 months old and weighing 20.2 kg (SD = 1.50 kg) were assigned to the digestibility study. The animals were housed in individual pens (1.5 m×0.80 m) in an open-sided type of house with corrugated aluminium sheet roofing and concrete floor. The animals were vaccinated against haemorrhagic septicaemia, treated against internal and external parasites by oral drenching, using mebendazole (500 mg per 10 kg body weight (BW)) followed by i.m. injection of ivermectin (1 ml per 10 kg BW) 10 days after oral drenching. The animals were adapted to the feeds and the pens over 15 days. In the digestibility experiment the animals were kept in simple metabolism cages (1.5 m×0.8 m), with floors made of rounded bamboo and fitted with plastic mesh and plastic sheet, which allowed separation of faeces and urine. Feeding and management routines were the same as in the growth experiment.

Table 1. Chemical composition of the dietary components[a]

	Gamba grass	Cassava hay	Cassava root
DM g/kg	206 (10.2)	918 (10.2)	917 (11.0)
g/kg DM			
Ash	60 (8.7)	89 (2.3)	16 (3.0)
CP	103 (5.4)	227 (10.8)	28 (4.4)
NDF	716 (22.0)	394 (14.0)	53 (3.2)
ADF	417 (30.0)	298 (14.4)	26 (1.3)
HCN (mg/kg DM (fresh))	-	320 (12.0)	-
HCN (mg/kg DM (hay))	-	129 (11.4)	-
ME (MJ/kg DM)	6.7[b]	10.61[c]	13.18[c]
No of samples	21	13	13

[a] Means and SD. [b] Evitayani et al. (2005). [c] Dung et al. (2005).

Experimental design

The growth experiment was carried out for 90 days, with an extra 15 days for adaptation. The animals were assigned to a completely randomized 2×2 factorial design, with eight animals per treatment. The factors were: two levels of cassava hay (25% and 35%), with or without cassava root. The hay was fed as 25% or 35% of expected DM intake (3% of BW). The grass was offered *ad libitum* at 120% of the average daily consumption of grass in the previous week. Dried cassava root chip was fed at a level of 1% of BW. The amounts of feeds were calculated on an individual basis. The amounts of cassava hay and root and grass offered were adjusted weekly after weighing the animals. The nutrient requirements were estimated to be 5 MJ ME and 40 g digestible CP (approximately 60 to 65 g CP) per day for a goat weighing 15 kg and growing 50 g/day (Peacock, 1996). In the digestibility experiment four goats were assigned to the same four diets as given in the growth experiment in a 4×4 Latin square design. Each experimental period consisted of 25 days: 14 days for adaptation, 7 days for measurement and an extra 4 days allowing animals free grazing in a confined pasture area.

Data collection and analyses

The animals in the growth experiment were weighed when the experiment started and then once per week, always at 6:00 h in the morning before feeding. Feeds offered and refused were recorded individually daily. Dry matter content of the feeds offered and refused was determined every day using a microwave oven to be able to record the daily DM consumption, as well as to feed the correct amount of DM the following day. Samples of grass were taken once per week or more often when the climate changed or the harvest of grass changed from one plot to another. During the harvesting of cassava foliage and processing hay, samples of fresh cassava foliage were taken for hydrogen cyanide (HCN) analysis. In addition, during the experimental period, samples of cassava hay and root chips were taken daily during the feeding and pooled weekly, and two sub-samples of each feedstuff were taken for chemical analysis. Refusals from individual animals in each group were pooled weekly, and two sub samples from each group were taken for chemical analyses.

During the collection period of the digestibility experiment, the feeds offered and refused were recorded. Samples were taken daily and then pooled for the whole collection period. Faeces and urine were collected from individual animals and recorded daily. Urine was collected in a glass jar containing 50 ml of 1 N sulphuric acid to preserve the nitrogen. Samples of faeces and urine were taken daily and frozen. The samples were later pooled for the whole collection period. Dry matter content of feed offered and refused and of faeces from individual animals was determined daily. The animals were weighed before the commencement of the adaptation period and before feeding on the first and last days of each collection period. Samples of feeds, refusals and faeces were pre-dried at 60°C in an oven for 48 h before grinding using a hammer mill with a 1 mm screen. The samples were analyzed for DM, ash, nitrogen (N), neutral detergent fiber (NDF) and acid detergent fiber (ADF). Hydrogen cyanide in both fresh cassava foliages and hay, and N in urine were also determined. Dry matter, N, ash and HCN were analyzed according to standard methods of AOAC (AOAC, 1990). Analyses of NDF and ADF were done following the procedures of Van Soest et al. (1991). Crude protein was calculated as N×6.25.

Statistical analyses

The data concerning feed intake and live weight gain from the experiment were analyzed statistically by a variance analysis (ANOVA) using the General Linear Model (GLM) of Minitab Software version 13.31 (Minitab, 2000). Treatment means showing significant differences at the probability level of $p<0.05$ were compared using Tukey's pairwise comparison procedures. The following model was used for all variables in the growth experiment, with the exception of initial weight where the covariate was not included: $Y_{ijk} = \mu+CH_i+CR_j+(CH\times CR)_{ij}+\beta X_{ijk}+e_{ijk}$; where Y_{ijk}: feed intake or growth, μ: general mean, CH_i: effect level of cassava hay, CR_j: effect of level of cassava root, $(CH\times CR)_{ij}$: effect of interaction between level of hay

Table 2. Feed offered[1] and feed and nutrient intakes[2]

	CH 25%		CH 35%		SE	Significance level		
	NR	R	NR	R		CH	R	CH×R
Feed offered (g DM/day)								
Gamba grass	402	376	419	362				
Cassava hay	125	130	170	190				
Cassava root	0	170	0	180				
Total	527	676	589	732				
Feed intake (g DM/day)								
Gamba grass	326	314	347	293	12.2	NS	NS	NS
Cassava hay	99	100	131	127	5.2	***	NS	NS
Cassava root	0^b	163^a	0^b	175^a	1.4	***	***	***
Total intake	425^b	576^a	478^b	596^a	15.3	*	***	NS
Nutrient intake (g/day)								
CP	57	58	66	67	2.4	***	NS	NS
NDF	281	273	296	278	10.8	NS	NS	NS
ADF	173	168	184	175	6.7	NS	NS	NS
ME (MJ/day)	3.3^b	5.3^a	3.6^b	5.7^a	0.18	NS	***	NS
Intake (% of BW)	2.6^b	3.4^a	2.9^b	3.5^a	0.10	NS	***	NS
Intake (g/kg $W^{0.75}$)	45^b	58^a	49^d	59^c	1.6	NS	***	NS
Intake of CH (% of diet)	23.6^a	17.3^b	27.4^a	21.4^b	0.66	***	***	NS

[1] Means. [2] Least squares means (LS-means). SE: Standard error. CH: Cassava hay. R: Cassava root. NR: No cassava root.
* $p<0.05$, *** $p<0.001$, NS: Non significant.
Means within rows and levels of cassava hay with different superscripts are significantly different. [a-b] $p<0.001$. [c-d] $p<0.01$.

Table 3. Effect of feeding varying levels of cassava hay with or without dried cassava root in the diet on daily weight gain of goats[1] (LS means and SE)

	CH 25%		CH 35%		SE	Significance level		
	NR	R	NR	R		CH	R	CH×R
Initial weight	14.3	14.0	13.4	14.6	0.38	NS	NS	NS
Final weight	18.4^b	20.0^a	19.0^b	20.4^a	0.22	*	***	NS
ADG (g/day)	48^b	65^a	55^b	70^a	2.5	*	***	NS

[1] LS means and SE: CH: cassava hay; R: cassava root; NR: no cassava root; * $p<0.05$, *** $p<0.001$.
NS = Non significant: Means within rows and levels of cassava hay with different superscripts are significantly different [a-b] $p<0.001$.

and level of root, βX_{ijk}: effect of initial weight as a covariate, e_{ijk}: random error. For the digestibility experiment the model was: $Y_{ijkl} = \mu+D_i+P_j+A_k+e_{ijk}$; where: Y_{ijkl}: the dependent variable, μ: general mean; D_i: effect of diet, P_j: effect of period, A_k: effect of animal, and e_{ijk}: random error.

RESULTS

Growth experiment

Table 1 shows the chemical composition of the cassava hay and root and the Gamba grass. The cassava hay contained 227 g CP/kg DM and CP contents of the Gamba grass and the cassava root were 103 g/kg DM and 28 g/kg DM, respectively. NDF and ADF contents of Gamba grass were high (716 g/kg DM and 417 g/kg DM, respectively). Hydrogen cyanide contents of fresh cassava foliage and cassava hay were 320 mg/kg DM and 129 mg/kg DM, respectively.

Feed offered and feed intake are presented in Table 2. There were no significant interactions between level of cassava hay and level of cassava root in the diets in relation to feed intake and nutrient intake with the exception of intake of cassava root. There were no significant differences in the intake of Gamba grass due to level of hay or root offered. The highest intake of cassava hay, 131 g DM/day, was recorded in the group fed 35% cassava hay and no root. Addition of cassava root had no significant effect on intake of cassava hay. Total DM intake was significantly higher in the groups fed cassava root and also significantly higher in the group fed 35% cassava hay. The highest total DM intake (596 g/day) was recorded in the group fed 35% cassava hay and cassava root. The higher intake of cassava hay at the higher level of supplementation resulted in a significantly higher CP intake. The highest CP intake, 67 g/day, was recorded in the group fed 35% cassava hay and cassava root. There were, however, no significant differences due to level of cassava hay or cassava root in intake of NDF and ADF. Dry matter intake as % of BW and as g/kg $W^{0.75}$ were significantly higher in the groups fed cassava root than in the groups fed no cassava root. The consumption of cassava hay was lower than planned, between 73% and 81% of the amount offered in the different groups. Cassava root was consumed to more than 95% of that offered. Energy intake was estimated to be significantly lower in the diets with no

Table 4. Intake and apparent digestibility, N-balance and N-retention of goats fed varying levels of cassava hay with or without dried cassava root in the diet[1]

	Diet				
	CH25%-NR	CH25%-R	CH 35%-NR	CH35%-R	SE
Feed offered (g DM/day)					
Gamba grass	480	467	502	463	
Cassava hay	150	150	210	220	
Cassava root chip	0	200	0	210	
Total	630	817	712	893	
Intake (g DM/day)					
Gamba grass	400	382	401	372	11.9
Cassava hay	103^{b}	101^{b}	157^{a}	160^{a}	6.7
Cassava root	0	175	0	180	6.7
Feed intake (g/day)					
DM	503^{b}	658^{a}	558^{b}	712^{a}	17.0
OM	470^{b}	623^{a}	519^{b}	671^{a}	16.0
CP	68^{b}	71^{b}	82^{a}	84^{a}	2.0
NDF	326	322	347	338	8.8
ADF	196	192	212	206	5.1
ME (MJ/day)	3.8^{b}	6.0^{a}	4.4^{b}	6.6^{a}	0.16
Apparent digestibility (%)					
DM	67^{b}	74^{a}	68^{b}	75^{a}	0.8
OM	70^{b}	76^{a}	70^{b}	78^{a}	0.9
CP	63^{b}	78^{a}	69^{b}	82^{a}	1.8
NDF	65	69	68	72	3.1
ADF	55	62	57	65	3.2
Nitrogen balance (g/day)					
N intake	11.0^{b}	11.4^{b}	13.1^{a}	13.4^{a}	0.31
N in faeces	4.0^{a}	2.5^{b}	4.0^{a}	2.4^{b}	0.20
N in urine	2.9^{a}	1.7^{b}	3.2^{a}	1.7^{b}	0.16
N retention	4.1^{c}	7.2^{b}	5.9^{bc}	9.3^{a}	0.50
N retention (%)	37^{b}	63^{a}	45^{b}	70^{a}	2.9

[1] LS means and SE.

[a, b, c] Means within rows with different superscripts differ significantly ($p<0.05$).

CH: Cassava hay; R: Cassava root; NR: No cassava root.

cassava root.

The effect of feeding varying levels of cassava hay and cassava root on average daily gain (ADG) is shown in Table 3. There was no significant interaction between levels of cassava hay or cassava root in the diets in relation to ADG. There was a significant difference in ADG due to level of cassava hay, the higher level showing higher ADG and the groups fed cassava root grew significantly better than the groups without cassava root. The highest ADG was obtained by the animals fed 35% cassava hay and root at 70 g/day.

Digestibility experiment

Animal and period had no effect on feed intake, digestibility or N-retention in the digestibility experiment (Table 4) and there was no effect of diet on intake of Gamba grass. The groups fed 35% cassava hay had significantly higher intakes of hay and the groups fed cassava root had significantly higher total DM intakes than the groups fed no roots. The highest total DM intake was 712 g/d. The intake of CP was significantly higher in the groups supplemented with 35% cassava hay than in the groups supplemented with 25% cassava hay. The estimated energy intake was significantly higher in the groups fed cassava root than in the groups fed no roots. The digestibility of DM. OM and CP was significantly higher for the groups fed cassava root than for the groups without cassava root. but the level of cassava hay had no effect on digestibility. The digestibilities of NDF and ADF were not significantly different between treatments. The N-balance was positive in all groups, and the percentage of N retention among treatments varied from 37% to 70%. The lowest value was recorded for the treatment with 25% cassava hay and no cassava root and the highest for the treatment with 35% hay and with root.

DISCUSSION

Chemical composition of the feeds

The DM and CP contents of the Gamba grass used in this trial were similar to values reported by Phengsavanh

(2003), but CP content was higher than the value reported by Evitayani et al. (2005). Differences in chemical composition may be due to the environmental conditions or, more commonly, the stage of cutting. The high CP content of the cassava hay, 227 g/kg DM, is within the range of values reported in the literature, 190 g to 250 g/kg DM (Wanapat et al., 2000; Van and Ledin, 2002; Dung et al., 2005). The HCN content is normally between 200 mg and 900 mg/kg DM in fresh cassava leaves (Ravindran, 1993; Man and Wiktorsson, 2001; Borin et al., 2005). The content of HCN in the fresh cassava foliage and the cassava hay recorded in the present study was 320 mg and 129 mg/kg DM, respectively. The processing to hay (i.e. chopping and sun drying) obviously decreased the content of HCN in the cassava foliage to about 35% of the initial value. A similar result has been reported by Dung et al. (2005). On the diet with highest intake of cassava hay, the animals consumed 27.8 mg HCN per kg DM. The level of HCN that causes toxicity in ruminants is not well defined. It has been suggested that levels below 200 mg/kg DM for grazing animals are harmless. Acute HCN toxicity in ruminants is not common (Stanton and Whittier, 2006).

Feed and nutrient intake

In the growth experiment, increasing levels of cassava hay offered lead to increasing intake of cassava hay. This could be due to the better possibility for selection (Bosman et al., 1995; Van and Ledin, 2002). The cassava root chip had high intake characteristics and was almost completely consumed. The intake of Gamba grass, however, was not significantly affected by either level of cassava hay or addition of cassava root. Consequently there was no substitution effect and the supplements were additional to the basal diet. The supplementation with both cassava hay and root had a significant effect on total DM intake. The increased intake can be explained by the improved supply of both N and readily available carbohydrates to the ruminal microbes, probably improving the rate of degradation of the basal diet, microbial growth and the fractional outflow of liquid matter from the rumen (Shem et al., 2003; Aregheore and Perera, 2004a). Aregheore and Perera (2004b) also reported that the highest DM intake by goats was obtained when maize stover was supplemented with both molasses and forage legumes compared to supplementation with forage legumes alone. Total DM intakes recorded in this study for the groups receiving cassava root were higher than the values obtained by Phengsavanh (2003) and Xaypha (2005) for the same local breed.

Growth performance

Supplementing a low to medium quality forage with degradable protein in the form of forage legumes often results in improved growth performance in ruminants (Mupangwa et al., 2000). The highest ADG, however, will be obtained by supplementation with both forage legumes and an energy source (Ondiek et al., 1999; Shem et al., 2003; Aregheore and Perera, 2004a, b). The diet with 25% cassava hay provided nearly enough CP to meet the requirement (Peacock, 1996) and the diet with 35% cassava hay provided more than the requirement. When comparing the growth rates, however, the animals fed the diets with the addition of cassava root, resulting in higher energy intakes, showed significantly higher growth rates than the animals not fed any cassava root. This suggests that energy and not CP was the limiting factor in the diets. Obviously the animals also had the capacity to grow more than 50 g/day when provided with enough energy and CP. Growth data from the same local breed but with different diets show growth rates from 22 g to 71 g/day (Phimpachanhvongsod, 2002; Phengsavanh, 2003; Xaypha, 2005).

Digestibility

In the digestibility experiment, the pattern of intake was the same as in the growth experiment. Apparent digestibility coefficients of DM, OM and CP were higher in goats fed diets supplemented with both cassava hay and root. Digestibility of fiber, NDF and ADF, did not differ between treatments. The improvement of nutrient digestibility was probably, as discussed earlier, an effect of improved microbial growth in the rumen, and thus enhanced ruminal fermentation (Aregheore and Perera 2004a; Hristov et al., 2005). Similar results have been reported by Ondiek et al. (1999) and Aregheore and Perera (2004b).

In the animals fed no cassava root, N intake increased with increasing level of cassava hay in the diet. This did not, however, lead to increased N retention since the N in urine increased. Lui et al. (2005) concluded that the high urinary N excretion on a diet with low concentrate level was due to the low energy level and the amino acids absorbed being used as energy substrates. In the present study the N retention was higher on the diets supplemented with both cassava hay and root. This could have been due to a better balance between N and energy yielding substrates for ruminal microbes leading to increased capture of degradable N and microbial growth rate and efficiency (Shem et al., 2003; Aregheore and Perera, 2004b; Khang and Wiktorsson, 2004; Hristov et al., 2005). Similar observations with cattle fed wild Napier grass (*Pennisetum macrourum*) supplemented with protein and/or energy rich supplements were reported by Shem et al. (2003).

CONCLUSIONS

Hay and root from cassava (*Manihot esculenta*, Crantz) have potential as a protein and energy sources, respectively, to growing goats fed low or medium quality grasses. Inclusion of both cassava hay and cassava root in a low quality diet resulted in a significant increase in feed intake, digestibility and weight gain. There were no significant differences in DM intake or growth between animals fed diets supplemented with either 25% or 35% of expected DM intake as cassava hay and with cassava root included. This suggests that it would be more economic to feed only 25% of cassava hay to minimize waste and still get acceptable intake and growth performance.

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REFERENCES

AOAC. 1990. Official Methods of Analysis. Association of Analytical Chemists. 15th Edition, Washington, DC.

Aregheore, E. M. and D. Perera. 2004a. Effects of *Erythrina variegata*, *Gliricidia sepium* and *Leucaena leucocephala* on dry matter intake and nutrient digestibility of maize stover, before and after spraying with molasses. Anim. Feed Sci. Technol. 111:191-201.

Aregheore, E. M. and D. Perera. 2004b. Effects of supplementation of a basal diet of maize stover with *Erythrina variegata*, *Gliricidia sepium* and *Leucaena leucocephala* on feed intake and digestibility by goats. Trop. Anim. Health Prod. 36:175-189.

Baumann, T. A., G. P. Lardy, J. S. Caton and V. L. Anderson. 2004. Effect of energy source and ruminally degradable protein addition on performance of lactating beef cows and digestion characteristics of steers. J. Anim. Sci. 82:2667-2678.

Borin, K., J. E. Lindberg and R. B. Ogle. 2005. Effect of variety and preservation method of cassava leaves on diet digestibility by indigenous and improved pigs. J. Anim. Sci. 80:319-324.

Bosman, H. G., C. J. G. M. Versteegden, S. M. Odeyinka and B. J. Tolkamp. 1995. Effect of amount offered on intake, digestibility and value of *Gliricidia sepium* and *Leucaena leucocephala* for West African Dwarf goats. Small Rumin. Res. 15:247-256.

Dung, N. T., N. T. Mui and I. Ledin. 2005. Effect of replacing a commercial concentrate with cassava hay (*Manihot esculenta* Crantz) on the performance of growing goats. Anim. Feed Sci. Technol. 119:271-281.

Evitayani, L. W., Warly, A. Fariani, T. Ichinohe, S. A. Abdulrazak, M. Hayashida and T. Fujihara. 2005. Nutritive value of selected grasses in north Sumatra, Indonesia. Anim. Sci. J. 76:461-468.

Hristov, A. N., J. K. Ropp, K. L. Grandeen, S. Abedi, R. P. Etter, A. Melgar and A. E. Foley. 2005. Effect of carbohydrate source on ammonia utilisation in lactating dairy cows. J. Anim. Sci. 83:408-421.

Khang, D. N. and H. Wiktorsson. 2004. Effects of fresh cassava tops on rumen environment parameters, thyroid gland hormones and liver enzymes of local yellow cattle fed urea-treated fresh rice straw. Trop. Anim. Health Prod. 36:751-762.

Lakpini, C. A. M., B. I. Balogun, J. P. Alawa, O. S. Onifade and S. M. Otaru. 1997. Effects of graded levels of sun-dried cassava peels in supplement diets fed to Red Sokoto goats in first trimester of pregnancy. Anim. Feed Sci. Technol. 67:197-204.

Lui, X., Z. Wang and F. Lee. 2005. Influence of concentrate level on dry matter intake, N balance, nutrient digestibility, ruminal outflow rate, and nutrient degradability in sheep. Small Rumin. Res. 58:55-62.

Man, N. V. and H. Wiktorsson. 2001. Cassava tops ensiled with or without molasses as additive effects on quality, feed intake and digestibility by heifers. Asian-Aust. J. Anim. Sci. 14:624-630.

Minitab. 2000. Minitab User's Guide 2.Data Analysis and Quality tools, Release 13.13 for Windows, Windows 95 and Windows NT. Minitab Inc., Pennsylvania, USA.

Mupangwa, J. F., N. T. Ngongoni, J. H. Topps and H. Hamudikuwanda. 2000. Effects of supplementing a basal diet of *Chloris gayana* hay with one of three protein-rich legume hays of *Cassia rotundifolia*, *Lablab purpureus* and *Macroptilium atropurpureum* forage on some nutritional parameters in goats. Trop. Anim. Health Prod. 32:245-256.

Ondiek, J. O., S. A. Abdulrazak, J. K. Tuitoek and F. B. Bareeba. 1999. The effects of *Gliricidia sepium* and maize bran as supplementary feed to Rhodes grass hay on intake, digestion and liveweight of dairy goats. Livest. Prod. Sci. 61:65-70.

Peacock, C. 1996. Improving Goat Production in the Tropics. Oxfam/Farm Africa Publ, Oxford, UK.

Phengsavanh, P. 2003. Goat production in smallholder farming systems in Lao PDR and the possibility of improving the diet quality by using *Stylosanthes guianensis* CIAT 184 and *Andropogon gayanus* cv Kent. MSc thesis in the programme "Tropical Livestock Systems". SLU, Dept. of Animal Nutrition and Management, P.O. Box 7024, Uppsala, Sweden.

Phimphachanhvongsod, V. and I. Ledin. 2002. Performance of growing goats fed *Panicum maximum* and leaves of *Gliricidia sepium*. Asian-Aust. J. Anim. Sci. 15:1585-1590.

Ravindran, V. 1993. Cassava leaves as animal feed: Potential and limitations. J. Sci. Food Agric. 61:145-150.

Shem, M. N., E. J. Mtengeti, M. Luaga, T. Ichinohe and T. Fujihara. 2003. Feeding value of wild Napier grass *Pennisetum macrourum* for cattle supplemented with protein and/or energy rich supplements. Anim. Feed Sci. Technol. 108:15-24.

Stanton, T. L. and J. Whittier. 2006. Prussic acid poisoning. Colorado State University Cooperative Extension Report 1. 612:1-3. www.ext.colostate.edu/pubs/livestk/01612.html.

Van, D. T. T. and I. Ledin. 2002. Effects of different foliages and sugar cane in the diet in late pregnancy on ewe and lamb performance. Asian-Aust. J. Anim. Sci.15:828-833.

Van Soest, P. J., J. B. Robertson and B. A. Lewis. 1991. Methods for dietary fibre, neutral detergent fibre and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci.

74:3583-3597.

Wanapat, M., T. Puramongkon and W. Siphuak. 2000. Feeding of cassava hay for lactating dairy cows. Asian-Aust. J. Anim. Sci. 13:478-482.

Xaypha, S. 2005. Goat production in smallholder farming systems in lowland Lao PDR and an evaluation of different forages for growing goats. MSc thesis in the programme "Tropical Livestock Systems". Swedish Univ. of Agr. Sci., Dept. of Animal Nutrition and Management, Uppsala, Sweden.