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Effects of Replacing Ground Corn with Cassava Chip in Concentrate on Feed Intake, Nutrient Utilization, Rumen Fermentation Characteristics and Microbial Populations in Goats

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ABSTRACT : Ten male crossbred (Thai Native×Anglo Nubian) goats with average live weight of 27±2 kg were randomly assigned according to a 5×5 replicated Latin square design to receive five diets, T_1 = concentrate with 0% cassava chip (CC), T_2 = 25% CC, T_3 = 50% CC, T_4 = 75% CC and T_5 = 100% CC. Fresh elephant grass (FEG) was offered *ad libitum* as the roughage. A metabolism trial lasted for 21 days during which liveweight changes and feed intakes were measured. Based on this experiment, there were no significant differences (p>0.05) among treatment groups regarding DM intake and digestion coefficients of nutrients (DM, OM, NDF and ADF), except for T_5 (100% CC) which was lowest (p<0.05) in digestion coefficient of CP than T_1 and T_3. Rumen parameters (ruminal pH, NH_3-N and volatile fatty acids), blood urea nitrogen, blood glucose and packed cell volume were similar among treatments. Moreover, rumen microorganism populations were not affected (p>0.05) by cassava inclusion. The amount of N absorption and retention were similar among treatments, except for T_5 which tended to be slightly lower. Based on this experiment, it could be concluded that the optimal level of cassava inclusion to replace corn in goat diets was in the range of 25-75% of CC when fed with FEG and it was a good approach in exploiting the use of local feed resources for goat production. (**Key Words :** Cassava Chip, Corn, Goats, Rumen Fermentation, Nitrogen Balance)

INTRODUCTION

The considerable increase in feed costs when based on imported materials has necessitated a search for cheaper energy sources on farm to replace expensive sources, such as corn grain in goat ration. Cassava or tapioca (*Manihot esculenta,* Crantz) is an annual tropical tuber crop grown widely in tropical and sub-tropical countries (Calpe, 1992; Wanapat, 2003). This plant is well easily grown under minimal management and it adapts to poor soil condition, low rainfall, high temperature and pest tolerance. Usually, cassava is grown for root production as energy sources. Cassava tuber can be processed into dried chip and pellet rich in metabolizable energy (2.92 Mcal/kg ME) which consists of soluble carbohydrate 76-81%, but low in crude protein (2.3-2.5% CP) (Gomez and Waldivieso, 1984). Cassava chip has a potential for increased use as animal feeds in ruminant nutrition resulted in faster rate of degradability in rumen as compared to other energy sources (Aroeira et al., 1996; Chanjula et al., 2003). Cassava has a similar digestibility value to steam-flaked corn, but higher than sorghum grain (Zinn and DePeters, 1991; Holzer et al., 1997). It has also been reported that inclusion of cassava to partly replace cereal grains (corn, barley, sorghum) with up to 30-40% in diets resulted in satisfactory animal performance and no negative effects on animal heath in finishing beef cattle (Zinn and DePeters, 1991; Holzer et al., 1997) and dairy cattle (Sommart et al., 2000). Increased daily weight gains and feed efficiency have also been reported when cassava replaced corn up to 20% in concentrates fed to buffalo calves (Etman et al., 1993b). In addition, cassava successfully replaced corn or barley in studies on milk production in dairy cows fed grass silage or rice straw (Brigstoke et al., 1981; Sommart et al., 2000). Moreover, cassava chip can be use as energy source of up to

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Table 1. Ingredients and chemical compositions of the experimental diets and elephant grass (DM basis)

Item	Dietary treatment (% cassava chip levels in concentrate) [1]					Elephant grass
	T1 (0)	T2 (25)	T3 (50)	T4 (75)	T5 (100)	
Cassava chip levels	0.00	12.50	25.00	37.50	50.00	
Ingredients composition (%)						
Cassava chip (CC)	-	12.50	25.00	37.50	50.00	-
Corn meal (CM)	50.00	37.50	25.00	12.50	-	-
Palm cake kernel (PCK)	8.39	8.96	10.12	10.70	10.07	-
Soybean meal (SM)	18.36	16.79	15.13	13.55	13.93	-
Broken rice (BR)	20.00	20.00	20.00	20.00	20.00	-
Urea	0.00	0.50	1.00	1.50	1.75	-
Salt	1.00	1.00	1.00	1.00	1.00	-
Mineral mix[2]	1.00	1.00	1.00	1.00	1.00	-
Dicalcium phosphate	0.50	0.50	0.50	0.50	0.50	-
Molasses	0.50	1.00	1.00	1.50	1.50	-
Sulfur	0.25	0.25	0.25	0.25	0.25	-
Chemical composition						
DM [3]	88.25	87.99	87.95	87.95	87.61	93.27
Ash	5.05	4.87	5.16	5.15	5.55	6.63
OM	94.95	95.13	94.84	94.85	94.45	93.37
CP	16.05	15.26	16.14	15.16	15.03	10.01
EE	3.80	2.84	2.78	2.10	1.46	2.60
NFE [4]	70.57	71.96	70.09	72.05	72.76	46.43
NSC [5]	52.85	56.09	55.17	55.31	57.76	3.20
NDF	21.98	20.60	20.10	22.00	19.94	77.56
ADF	7.25	7.56	8.66	8.98	9.05	43.31
ADL	1.54	1.74	2.32	2.88	2.88	5.99

[1] T_1 = Level of CC 0%, T_2 = Level of CC 25%, T_3 = Level of CC 50%, T_4 = Level of CC 75%, T_5 = Level of CC 100%.
[2] Minerals and vitamins (each kg contains): Vitamin A: 10,000,000 IU; Vitamin E: 70,000 IU.
Vitamin D: 1,600,000 IU; Fe: 50 g; Zn: 40 g; Mn: 40 g; Co: 0.1 g; Cu: 10 g; Se: 0.1 g; I: 0.5 g.
[3] DM = Dry matter; OM = Organic matter; CP = Crude protein; EE = Ether extract; NSC = Non structural carbohydrate.
NDF = Neutral detergent fiber; ADF = Acid detergent fiber; ADL = Acid detergent lignin.
[4] Estimated: NFE = 100-(CP+CF+EE+Ash). [5] Estimated: NSC = 100-(CP+NDF+EE+Ash).

75-80% in concentrate diet in beef cattle (Wanapat and Khampa, 2007) or combined with 3-4% urea in concentrate of dairy cattle (Chanjula et al., 2004; Khampa et al., 2006) fed urea-treated rice straw base diet, could improve rumen fermentation efficiency.

However, the responses to cassava, which is highly degradable in the rumen, have not been extensively studied in growing goats. Therefore, this present study was conducted to evaluate the effects of cassava chip inclusion into the diets based on fresh elephant grass upon feed intake, nutrient utilization, ruminal fermentation, blood metabolites and nitrogen balance of growing goats.

MATERIALS AND METHODS

Animals and experimental diets

Ten male crossbred (Thai Native×Anglo Nubian) goats (approximately 15 months old) averaging 27±2 kg (mean±SD) (initial BW) were randomly assigned to dietary treatments according to a 5×5 replicated Latin square design to study the effects of cassava chips inclusion into the diets on feed intake, digestibility, ruminal fermentation, blood metabolites, microbial populations and nitrogen balance. Five isonitrogenous experimental diets were formulated to contain cassava chip (CH) as shown in Table 1. The dietary treatments were; Control T_1 = concentrate containing cassava chip (CC) at 0%; T_2 = CC at 25%; T_3 = CC at 50%; T_4 = CC at 75% and T_5 = CC at 100%, respectively.

All goats were drenched for internal worms (Ivermectin, IDECTIN®, The British Dispensary, Co., Ltd.) and injected with vitamins A, D_3 and E prior to commencing the experiment. Each goat was kept individually in a ventilated metabolism crate in well-ventilated sheds where water and mineral salt were available at all times. During each period, all animals received a concentrate diet at 2% BW (DM basis) and were allowed to consume chopped (3-5 cm) fresh elephant grass (FEG, *Pennisetum purpureum*) *ad libitum*, allowing for 10% refusals. Feeds were provided twice daily in two equal portions at 0800 and 1600 daily. Feed refusals were weighed and recorded daily at 0700. Fresh orts samples were bulked by pen and dried at 60°C, and subsamples were used for dry matter determinations. This information was used to calculate fresh elephant grass (FEG) intake. Feed samples obtained each time were oven dried at 60°C for 72 h and ground to pass through a 1-mm sieve, and composited by period on equal weight basis for further analysis. Goats were weighed at the beginning of each experimental period before the morning feeding.

Sampling techniques

Each experimental period lasted for 21 days; the first 15 days as a period for treatment adaptation and for feed intake measurements while the last 6 days were used to measure digestibility using total collection method. This comprised of 5 days of total collection of feces and urine, followed by 1 day of rumen fluid and blood collection. At the end of each period, rumen fluid samples were collected by a stomach tube at 0 and 4 h-post feeding. Then, the pH of the rumen samples was measured immediately by pH meter (Orion Research portable meter 200 series, USA). Rumen fluid samples were then strained through four layers of cheesecloth. Samples were divided into two portions. One portion was used for NH_3-N and VFA analyses where 3 ml of H_2SO_4 solution (1 M) were added to 30 ml of rumen fluid. The mixture was centrifuged at 16,000×g for 15 min and supernatant stored at -20°C prior to NH_3-N and VFA analyses. Another portion was fixed with 10% formalin solution in normal saline (0.9% NaCl) (Galyean, 1989). The total direct count of bacteria, protozoa and fungal zoospores was made using the methods of Galyean (1989) based on the use of a haemacytometer (Boeco) under a light microscope (Olympus BX51TRF, No. 2B04492, Olympus Optical Co. Ltd., Japan). Blood Samples (about 10 ml) were collected via jugular vein into heparinized tubes at the same time as rumen fluid sampling (0 and 4 h-post feeding). Then blood samples were centrifuged at 4°C at 3,300×g for 15 min and supernatants were separated and frozen at -20°C until analysis.

Laboratory analyses

Feed, refusal and feces were analyzed in duplicate for DM, ash, CF, ether extract and Kjeldahl N using AOAC (1990) procedures. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) fractions were determined with the procedure of Goering and Van Soest (1970). Digestion coefficients were calculated by using the formula given by Schneider and Flatt (1975). Blood urea nitrogen (BUN) was determined according to the method of Crocker (1967) and for ruminal NH_3-N using the micro kjeldahl method (AOAC, 1990) and volatile fatty acid (VFAs) analyses using a HPLC according to Zinn and Owens (1986). Plasma glucose and packed cell volume (PCV) were measured by commercial kits (No. 640, Sigma Chemical Co., St. Louis, USA).

Statistical analyses

All data obtained from the experiment were subjected to ANOVA for a 5×5 replicated Latin square design using the General Linear Models (GLM) procedure of the Statistical Analysis System Institute (SAS, 1990). Data were analyzed using the model

$$Y_{ijkl} = \mu+S_l+A_{i(l)}+P_j+T_k+\varepsilon_{ijkl}$$

where Y_{ijkl} observation from animal $i(l)$, receiving diet k, in period j; μ, the overall of mean, S_l, the effect of square; A_i, the effect of animal (i = 1, 2, 3, 4, 5); P_j, the effect of period (j = 1, 2, 3, 4, 5), T_k, the mean effect of level CC (k = 1, 2, 3, 4, 5); ε_{ijkl}, the residual effect. Treatment means were statistically compared using Duncan's New Multiple Range Test (DMRT) (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Chemical composition of feeds

The chemical composition of roughage and experimental diets are presented in Table 1. The five experimental diets contained similar concentrations of DM, ash, OM, CP and EE. Cassava-based diets had a slightly higher non-structural carbohydrate (NSC) as the level of cassava chip (CC) increased in the diets, ranging from 52.85 to 57.76%, respectively and with varying amount of NDF, ADF and ADL among those diets. The differences among concentrate mixed diets in NSC, NDF and fibrous components can be related to differences in the ingredients used in diet formulation (Table 1).

Average chemical composition of fresh elephant grass (FEG) is presented in Table 1. Elephant grass contained 10.0% CP (1.7% N). Similar values for FEG have been previously reported by Mpairwe et al. (1998); Kabi et al. (2005). The relatively high levels of CP and low level of ADL in FEG suggest that it is suitable for goat, in terms of feed intake and digestibility, which have a limited rumen capacity to use highly lignified feeds. Nevertheless, the nutritive value of FEG may depend on the combined effects of genetic and environmental factor including cultivar, growth stage, response to environmental factor, plant density, plant part, soil fertility, harvesting frequency, season and climate.

Effect on feed intake and apparent digestibility

The effect of cassava substitution of corn in the diets on feed intake and apparent digestibility of goats are presented in Table 2. Overall means for feed intakes for five diets in terms of roughage, concentrate and total DMI (% BW g/kg $BW^{.75}$) were similar for all dietary treatments as compared between the experimental diets (25-100% CC) with the control diet. The data indicate that inclusion of cassava replacing corn at a rate of up to 100% had no effect on feed intake for goats. These data support earlier works (Zinn and DePeters, 1991; Sommart et al., 2000) in which it was reported that inclusion of cassava in diets resulted in satisfactory animal performance and no negative effects on

Table 2. Influence of cassava substitution for corn meal on feed intake and apparent digestibility in growing goat fed on elephant grass as a roughage

Attribute	Cassava levels in concentrate (%)[1]					SEM
	T1 (0)	T2 (25)	T3 (50)	T4 (75)	T5 (100)	
Cassava chip levels (DM basis)	0.00	12.50	25.00	37.50	50.00	
DMI (kg/d)						
Napier grass(kg/d)	0.272	0.275	0.276	0.288	0.324	0.01
% BW	0.89	0.89	0.90	0.94	1.06	0.05
g/kg $W^{0.75}$	20.90	21.01	20.63	22.09	24.93	1.35
Concentrate (kg/d)	0.485^{ab}	0.544^{a}	0.506^{ab}	0.473^{ab}	0.446^{b}	0.02
% BW	1.63^{ab}	1.76^{a}	1.61^{ab}	1.64^{ab}	1.41^{b}	0.07
g/kg $W^{0.75}$	38.11^{ab}	41.55^{a}	38.03^{ab}	38.51^{ab}	34.36^{b}	1.93
Total DMI (kg/d)	0.757	0.817	0.779	0.786	0.770	0.03
DMI (% BW)	2.52	2.66	2.48	2.58	2.52	0.10
DMI (g/kg $W^{0.75}$)	59.02	62.57	58.28	62.27	61.02	2.25
Apparent total- tract digestibility (%)						
DM	76.70^{ab}	77.49^{a}	76.12^{ab}	75.27^{b}	75.18^{b}	0.66
OM	78.00	78.82	77.75	76.97	76.90	0.85
CP	75.98^{ab}	74.62^{abc}	76.36^{a}	73.21^{bc}	72.63^{c}	1.28
NDF	61.73^{a}	61.51^{ab}	58.97^{b}	59.04^{b}	60.39^{ab}	0.84
ADF	54.87^{a}	55.82^{a}	53.14^{ab}	49.64^{b}	52.09^{ab}	1.24

[1] T_1 = Level of CC 0%, T_2 = Level of CC 25%, T_3 = Level of CC 50%, T_4 = Level of CC 75%, T_5 = Level of CC 100%.
[a-c] Within rows not sharing a common superscripts are significantly different (p<0.05).
SEM = Standard error of the mean (n = 10).

animal health in finishing beef cattle and in lactating dairy cows. Other studies (Brigstocke et al., 1981; Lebzien and Engling, 1995) reported a comparison of cassava with corn, barley, sugar and wheat as sources of starch in non-lactating dairy cow diets, while Kanjanapruthipong et al. (2001) also found no difference in DMI, ruminal pH and total VFA concentration in rumen fluid between varying levels of cassava in dairy cow diets. However, when compared among groups of cassava inclusion, goats fed 25% CC had greater ($p<0.05$) concentrate intake compared with 100% CC.

Apparent digestibilities (%) of OM, NDF and ADF were similar ($p>0.05$) for all diets, whilst apparent digestibilities of DM and CP were affected by inclusion of cassava in replacing corn and tended to be slightly lower for goats fed inclusion of 75-100% CC as compared with other treatments (Table 2). The slightly lower CP digestibility at inclusion of 75-100% CC replacing corn may have been contributed by lower intake of concentrate that contained slightly lower true protein (soy bean meal, SBM) in the diet (Table 1). Saxena et al. (1971) indicated that supplementation of true protein was more effective than that of NPN. Similarly, McAllan (1991); Huntington and Archibeque (1999) reported that protein digestion in animals supplemented with true protein was greater than those supplemented with urea or NPN. Moreover, feeding corn diets tended to be greater in NDF and ADF digestibility as compared to cassava replacing corn in the diets. Previous reports (Hoover, 1986) have suggested that providing a source of more degradable NSC can result in a substantial decrease in ruminal pH and fiber digestibility thus reducing feed intake. Furthermore, it is possible that low digestibility could have been attributed by high fibrous fraction (ADL) (Hart and Wanapat, 1992). Mertens (1977) concluded that changes of composition of cell wall involving lignin and possibly silica limited the potential extent of digestion whereas the rate of digestion is limited by the chemical entities other than by the crystalline or physical nature of fiber.

Rumen fermentation patterns and blood metabolites

Rumen parameters were measured for pH, NH_3-N and BUN. In addition, BUN was determined to investigate their relationship with rumen NH_3-N and protein utilization. The pattern of ruminal fermentation at 0 and 4 h post feeding and overall means are given in Table 3. Rumen fluid pH at 0 and 4 h post feeding were unchanged by dietary treatments in this study, indicating no specific effect of the inclusion of cassava. Zinn and DePeters (1991); Lebzien and Engling (1995) found no effect on ruminal pH when cassava was compared to corn grain, while at 4 h after the onset feeding, rumen pH of goats declined as active fermentation of the newly ingested feed occurred. At this time, the pH values ranged from 6.22-6.36, but all treatment means were within the normal range and the values were quite stable at 6.53-6.61. Similar value for pH has been previously reported by Khampa et al. (2006), which were in optimal level for microbial digestion of fiber (Hoover, 1986) and also digestion of protein (6.0-7.0). According to the review by Ørskov (1986), cows with rumen fluid of pH above 5.8 are considered normal, while those between 5.0 and 5.8 may be suffering from subclinical acidosis. The relatively high

Table 3. Influence of cassava substitution for corn meal on rumen fermentation characteristics and blood metabolized in growing goat fed on elephant grass as a roughage

Attribute	Cassava levels in concentrate (%)[1]					SEM
	T1 (0)	T2 (25)	T3 (50)	T4 (75)	T5 (100)	
Cassava chip levels (DM basis)	0.00	12.50	25.00	37.50	50.00	
Ruminal pH						
0 h-post feeding	6.86	6.84	6.93	6.88	6.87	0.06
4	6.36	6.22	6.22	6.23	6.31	0.05
Mean	6.61	6.53	6.57	6.55	6.59	0.06
NH_3-N (mg/dl)						
0 h-post feeding	14.50[ab]	15.35[a]	12.29[ab]	11.29[b]	11.79[b]	1.05
4	17.86	22.29	17.15	18.15	16.72	1.78
Mean	16.18[ab]	18.82[a]	14.72[b]	14.72[b]	14.26[b]	1.08
BUN (mg/dl)						
0 h-post feeding	20.43	20.07	21.40	20.52	20.50	0.68
4	21.37[b]	22.36[ab]	24.70[a]	22.89[ab]	24.47[a]	0.86
Mean	20.91[b]	21.22[ab]	23.05[a]	21.71[ab]	22.92[ab]	0.65
Glu (mg/dl)						
0 h-post feeding	67.80	64.70	68.50	66.50	68.70	1.46
4	73.90	74.10	77.30	74.30	71.60	2.07
Mean	70.85	69.40	72.90	70.40	70.15	1.45
PCV (mg/dl)						
0 h-post feeding	28.50	29.00	28.80	28.70	29.20	0.68
4	28.60	26.80	27.80	28.80	28.70	0.72
Mean	28.55	27.90	28.30	28.75	28.95	0.61

[1] T_1 = Level of CC 0%, T_2 = Level of CC 25%, T_3 = Level of CC 50%, T_4 = Level of CC 75%, T_5 = Level of CC 100%.
[a-b] Within rows not sharing a common superscripts are significantly different ($p<0.05$).
SEM = Standard error of the mean (n = 10).

rumen fluid pH obsevered in our study suggests that goats were not likely suffering from subclinical acidosis. Moreover, the ruminal pH is partly regulated by the ammonia concentration in the rumen fluid, the variation in pH may be explained by the urea entering the rumen and being hydrolyzed by microbial ureases into CO_2 and ammonia (2-NH_3) (Van Soest, 1994).

Ruminal NH_3-N at 4 h post feeding was similar among treatments, except at 0 h post feeding and overall means were affected by treatments and ranging from 11.3 to 15.4 and 14.3 to 18.8 mg/dl, respectively and were slightly decreased by diets containing cassava as compared with corn diet. Concentrations of NH_3-N in ruminal fluid have been reported to decrease when 1) urea containing diets fed to nonlactating dairy cows were supplemented with molasses and starch (Fadel et al., 1987), 2) the non-structural carbohydrate content of the diet was increased (MacGregor et al., 1983), or 3) the amount of starch digested in the rumen was increased (McCarthy et al., 1989). Nevertheless, the rumen ammonia concentrations in all animals were closer to optimal ruminal NH_3-N (15-30 mg%, Perdok and Leng, 1990; Wanapat and Pimpa, 1999) for improving microbial protein synthesis and digestibility and feed intake.

Meanwhile, BUN concentration and overall means were similar among treatments with inclusion of cassava and corn, ranging from 20.91 to 23.05 mg/dl. It was close to the optimal level in normal goats which has been reported in the range of 11.2 to 27.7 mg/dl (Lloyd, 1982). The BUN prior to morning feeding of the goats tended to be lower than that at 4 h post feeding. The results agreed with Eggum (1970b) who reported that urea content in the blood has been found to reach a maximum 3 h after feeding.

Blood glucose concentration at 0 and 4 h post feeding and overall means was similar ($p>0.05$) among dietary treatments and ranging from 69.40 to 72.90 mg/dl (3.9 to 4.0 mmol/L) (Table 3). Blood glucose concentration prior to morning feeding of the goats tended to be lower than that taken at 4 h after the onset of feeding. All treatment means were within the normal range which has been reported as ranging from 50 to75 mg/dl (2.77 to 4.16 mmol/L) (Kaneko, 1980). Observed blood glucose concentrations were similar to those reported by Gelaye et al. (1990) and Turner et al. (2005). However, the variation in blood glucose could be affected by physiological status (Firat and Ozpinar, 1996) or disease conditions (Ford et al., 1990). Moreover, sampling is very important, as prior to morning feed, absorption of nutrients from the digestive tract was at minimum level (Hove and Halse, 1983). Glucose, as a source of energy, is necessary for production and reproduction performance (Radostits et al., 2000). Blood glucose and BUN level may serve as indicators for a goat’s energy status. In the present experiment, these data indicate that goats consuming the diets with cassava were in a normal energy status. This may

Table 4. Influence of cassava substitution for corn meal on volatile fatty acid profiles in growing goat fed on fed on elephant grass as a roughage

Attribute	Cassava levels in concentrate (%)[1]					SEM
	T1 (0)	T2 (25)	T3 (50)	T4 (75)	T5 (100)	
Cassava chip levels (DM basis)	0.00	12.50	25.00	37.50	50.00	
Total VFA (mmol/L)						
0 h-post feeding	73.0	73.9	69.6	79.2	76.3	4.47
4	78.0	82.3	80.3	79.2	76.3	4.23
Mean	75.5	78.1	75.0	79.2	76.3	4.58
Molar proportion of VFA mol/100 mol						
Acetate (A), C_2						
0 h-post feeding	64.8	63.9	63.2	65.3	67.2	2.54
4	67.5	65.4	66.0	66.8	67.2	1.89
Mean	66.2	64.7	64.6	66.1	67.2	2.32
Propionate (P), C_3						
0 h-post feeding	17.9	19.8	18.9	18.8	17.7	1.56
4	19.6	20.4	19.5	18.5	20.2	2.15
Mean	18.8	20.1	19.2	18.7	19.0	1.86
Butyrate, C_4						
0 h-post feeding	14.2	14.7	15.1	14.2	14.7	1.49
4	15.2	15.6	17.1	16.0	12.4	2.45
Mean	14.7	15.2	16.1	15.1	13.6	2.06
A:P ratio						
0 h-post feeding	3.8	3.3	3.5	3.6	3.8	1.25
4	3.3	3.1	3.2	3.5	3.3	0.96
Mean	3.5	3.2	3.4	3.5	3.6	1.03

[1] T_1 = Level of CC 0%, T_2 = Level of CC 25%, T_3 = Level of CC 50%, T_4 = Level of CC 75%, T_5 = Level of CC 100%.
[a-b] Within rows not sharing a common superscripts are significantly different (p<0.05).
SEM = Standard error of the mean (n = 10).

be the possible reason for the lack of differences among treatments and there were no deleterious effects on feed intake or the metabolism of the goats. Likewise, packed cell volume (PCV) at 0, 4 h post feeding and overall mean were similar (p>0.05) among treatments and ranging from 27.90 to 28.95 mg/dl, but all were within the normal range of 22-38 mg/dL (Jain, 1993). Based on this study, these data indicate that the inclusion of cassava-based diets had no effect on blood glucose and PCV. They also showed positive in energy status. West (1996) reported that serum glucose has been shown to increase in high energy diet, while dramatically decreases in starvation and low energy diet.

Volatile fatty acid profiles

The effect of cassava substitution of corn in the diets on production of total VFA concentrate, acetic acid proportion, propionic and butyric acid concentrations and acetic to propionic ratio are shown in Table 4. Overall means of total VFAs, acetic, propionic and butyric concentrations in the rumen were not affected by dietary treatments. However, the concentration of propionic acid was slightly higher in diets with cassava inclusion as compared with corn diets, but the difference was not statistically significant. This data was in accordance with the reports by Sutton et al.(1993) that increasing the readily degradable starch content of the concentrate resulted in higher rumen propionate concentrations and decreased rumen acetate concentration. In this study, the total VFA concentration in all diets ranging from 70 to 130 mM, similar to that reported by France and Siddons (1993). Thus, although the acetate to propionate ratio tended to be slightly lower by inclusion of cassava in diets, but the inclusion of cassava in replacing corn increased the daily output of propionate without decreasing (p>0.05) the production of acetate.

Rumen microorganism populations

Table 5 presents the rumen microorganism populations. Population of rumen microbes (bacteria, protozoa and fungal zoospores) were not affected (p>0.05) by treatments, but overall protozoal populations tended to be slightly greater between the 0 and 4 h post feeding for goats fed cassava inclusion of 75-100% CC as compared with other treatments (Table 6). Also, *Entodiniomorphs sp.* was higher than *Holotrich sp.* in the same treatment. The presence of protozoa in the rumen can also affect on rumen fermentation of starch. This agrees with the finding of Jouany and Ushida (1999) who reported that the number of protozoa per ml rumen fluid depends on the rate of soluble sugars and starches in the ration and also on the pH. Moreover, Chamberlain et al. (1985); Jouany (1988) reported that starch supplementation favoured the development of protozoal, in particular the entodiniomorphid species. Coleman (1986) showed that the

Table 5. Influence of cassava substitution for corn meal on population of rumen microbes in growing goat fed on fed on elephant grass as a roughage

Attribute	Cassava levels in concentrate (%)[1]					SEM
	T1 (0)	T2 (25)	T3 (50)	T4 (75)	T5 (100)	
Cassava chip levels (DM basis)	0.00	12.50	25.00	37.50	50.00	
Total direct count						
Bacteria ($\times10^{10}$ cell/ml)						
0 h-post feeding	1.60	1.40	1.40	1.50	0.80	1.35
4	1.20	1.31	1.10	0.91	1.10	2.01
Mean	1.41	1.35	1.30	1.21	0.99	1.65
Total protozoa ($\times10^{6}$ cell/ml)						
0 h-post feeding	2.16	3.04	2.99	3.08	3.56	1.52
4	2.65	2.78	3.18	3.25	3.58	3.25
Mean	2.41	2.90	3.08	3.17	3.57	1.12
Holotrich sp. ($\times10^{5}$ cell/ml)						
0 h-post feeding	1.12	1.01	1.25	0.17	1.50	0.89
4	1.38	1.31	1.01	1.23	1.53	0.98
Mean	1.25	1.15	1.12	0.70	1.50	0.61
Entodiniomorphs sp. ($\times10^{6}$ cell/ml)						
0 h-post feeding	2.05	2.94	2.86	3.06	3.41	0.84
4	2.51	2.65	3.07	3.12	3.42	0.78
Mean	2.28	2.79	2.97	3.10	3.42	0.75
Fungal zoospores ($\times10^{6}$ cell/ ml)						
0 h-post feeding	0.80[a]	1.31[b]	1.10[ab]	0.91[ab]	1.00[ab]	0.10
4	1.91	1.60	1.51	1.41	1.41	1.56
Mean	1.35	1.35	1.41	1.15	1.21	1.20

[1] T_1 = Level of CC 0%, T_2 = Level of CC 25%, T_3 = Level of CC 50%, T_4 = Level of CC 75%, T_5 = Level of CC 100%.
[a-b] Within rows not sharing a common superscripts are significantly different ($p<0.05$).
SEM = Standard error of the mean (n = 10).

Table 6. Influence of cassava substitution for corn meal on nitrogen utilization in growing goat fed on elephant grass as a roughage

Attribute	Cassava levels in concentrate (%)[1]					SEM
	T1 (0)	T2 (25)	T3 (50)	T4 (75)	T5 (100)	
Cassava chip levels (DM basis)	0.00	12.50	25.00	37.50	50.00	
N balance (g/d)						
N-concentrate	12.64[a]	13.20[a]	12.99[a]	11.65[ab]	9.97[b]	0.65
N-roughage	4.20	4.42	4.35	4.56	4.70	0.19
Total N intake[a]	16.59[ab]	17.60[a]	17.35[a]	16.19[ab]	14.66[b]	0.69
N excretion (g/d)						
Fecal N	4.28[ab]	4.79[a]	4.51[ab]	4.50[ab]	3.99[b]	0.19
Urinary N	5.02[a]	3.64[b]	3.26[b]	4.08[ab]	3.55[b]	0.38
Total N excretion	9.30[a]	8.44[ab]	7.78[ab]	8.54[ab]	7.30[b]	0.50
Absorbed N	12.79[a]	12.80[a]	12.83[a]	11.79[ab]	10.56[b]	0.57
Retained N	7.76[ab]	9.16[a]	9.56[a]	7.71[ab]	7.11[b]	0.62
N output (% of N intake)						
Absorbed	74.92	72.71	73.69	72.60	72.69	1.09
Retained	44.47[b]	50.76[ab]	53.84[a]	48.67[ab]	49.03[ab]	2.88

[1] T_1 = Level of CC 0%, T_2 = Level of CC 25%, T_3 = Level of CC 50%, T_4 = Level of CC 75%, T_5 = Level of CC 100%.
[a-b] Within rows not sharing a common superscripts are significantly different ($p<0.05$).
SEM = Standard error of the mean (n = 10).

growth of protozoa was greatly enhanced by starch and without starch in the ration, protozoa density was low and the rates of digestion were reduced. Moreover, if the ration is based on grain, protozoa engulfment of starch grains can modulate pH and protect the animal from acidosis (Russell and Hespell, 1981; McAllister et al., 1993). In the present study, protozoal numbers tended to be higher in goats fed high levels of cassava chip (inclusion 75-100% CC). More soluble carbohydrate would probably provide a better niche for protozoal growth.

Nitrogen utilization

Whole body N data are presented in Table 6. Total N intake in this study in terms of N-roughage and total N intake were similar ($p>0.05$) between control diet and cassava inclusion in diets, except for treatment 5 N-concentrate intake was lower ($p<0.05$) for goats fed cassava in replacing corn 100% CC in diets. This trend may be related to the lower DMI and CP digestibility of goats fed diets containing 100% CC compared with other treatments. Likewise, total excretion of fecal and urinary N were not significantly different, except for treatment 5 in which the goats have tended to slightly lower fecal and urinary N. This pattern of fecal and urine excretion is indicative of the extremely low N intake for goats fed diets containing 100% CC and the extremely high intake for other treatments. This could be explained by the fact that excess ruminal NH_3-N is absorbed and excreted in the urine in the form of urea (Nolan, 1993).

The amount of N absorption and retention were similar among treatments, except for treatment 5 which tended to be slightly lower for goats fed diets containing 100% CC. It is now well established that nitrogen retention depends on the intake of nitrogen, amount of fermentable carbohydrate of the diet (Sarwar et al., 2003). In this regard, however the positive N balance observed in this study indicates the positive influence of different cassava replacement of corn in the diets with FEG based feeding of goats. Although the differences in the quantity and routes of N excretion with consequent influences on N retention could reflect treatment feed differences in N metabolism, in which N retention is considered as the most common index of the protein nutrition status of ruminants (Owens and Zinn, 1988).

CONCLUSIONS

Cassava was a good source of ruminal degradable starch in replacing corn grain and has the potential to improve goat performance. Based on this experiment, it could be concluded that the optimal inclusion of cassava in replacing corn is suggested to be between 25-75% of CC (12.5-37.50 kg) in concentrate. There was no evidence of any adverse effects on feed intake, digestibility, rumen fermentation patterns, blood metabolites, rumen microbes and nitrogen balance or animal health when fed with fresh elephant grass. Based on this data, it would be desirable to conduct further research on the use of cassava chips in practical rations for small ruminants feeding systems as well as using this approach for on-farm research to explore more relevant findings.

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