The Use of Cassava Chips as an Energy Source for Lactating Dairy Cows Fed with Rice Straw

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ABSTRACT : Thirty-six crossbred (70% Holstein Friesian) cows in mid-lactation were assigned to one of four treatments. The dietary treatments were concentrate based, containing 13.5, 27.0, 40.5 and 54.0% of cassava in concentrate replacing ground maize (16.0% CP). There were curvilinear responses to intake of organic matter, non-structural carbohydrate and metabolisable energy. Cassava and corn fed in a ratio of 50:50 maximised organic matter, metabolisable energy intake; milk yield, milk protein and lactose yield. Milk fat yield was not affected by levels of inclusion. Dietary treatment did not influence ruminal pH, ammonia and volatile fatty acid concentrations or plasma glucose. The low market price for cassava resulted in a lower concentrate feed cost. The optimal level of cassava in a dairy cow diet is suggested as being between 20.0 and 30.0% of cassava in dry matter intake when fed with rice straw. *(Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 8 : 1094-1101)*

Key Words : Cassava, Milk Production, Cows, Feed

INTRODUCTION

Cassava production in tropical areas has a potential for increased use in ruminant livestock nutrition. 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 dairy rations. Cassava chip is such a possible source. Cassava compared to cereal or maize grain has been reported to have a relatively low crude protein, accompanied by a high rate and extent of degradation in the rumen (Conn et al., 1989; Tamminga et al., 1990; Sommart et al., 1991; Aroeira et al., 1996). Cassava has a similar digestibility value to steam-flaked corn, but higher than sorghum grain (Tudor et al., 1985; Zinn and DePeters, 1991; Holzer et al., 1997). It has also been reported that inclusion of cassava to partly replace cereal grains (maize, barley, sorghum) with up to 30 to 40% in diets results in satisfactory animal performance and no negative effects on animal heath in finishing beef cattle (Tudor et al., 1985; Zinn and DePeter, 1991; Wanapat et al., 1996; Holzer et al., 1997). Increased daily weight gains and feed efficiency have also been reported when cassava replaced maize up to 20% in concentrates fed to buffalo calves (Etman et al., 1993b). In addition, cassava successfully replaced maize/barley in studies on milk production in buffaloes (Etman et al., 1993a) and dairy cows fed grass silage or pasture (Brigstoke et al., 1981; Martin et al., 1993). However, the responses to cassava, which is highly degradable in the rumen, have not been extensively studied in lactating cows when fed low-quality diets. Therefore, this study was conducted to evaluate the effects of cassava inclusion in to the diets based on rice straw upon feed intake, rumen fermentation and animal performance of lactating cows.

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MATERIALS AND METHODS

Animals and feeding management

Thirty-six mid-lactation Holstein Friesian crossbred cows were used for the experiment. They were part of the breeding stock herd of the Dairy Promotion Organisation of Thailand (DPOT), Saraburi Province, Thailand. The breed of cow used in this experiment averaged 70.0±12.3% Holstein-Friesian, 20.0±14.2% Danish Red and 16.0±7.2% Native cattle. They were on average 2.0±1.0 number of lactation, 69.0±39.2 days in milk, milk yield pre-experiment 13.3±2.0 kg/day and body weight 383.8±9.9 kg. Four cows were allocated to each of nine experimental groups which were balanced for breed, parity and days in milk. There were nine groups or statistical blocks in the experiment. All cows within each group were randomly allocated to one of the four experimental diets accordingly to a randomised complete block design (RCBD) with nine replications per treatment.

Four iso-nitrogenous concentrate mixes were formulated to contain cassava chip at 13.5, 27.0, 40.5 and 54.0 percent replacing corn grain meal. Crude protein in the concentrate was balanced by using feed grade urea to result in nitrogen content of 16.0% CP. The details of feed formulation and ingredients used are shown in table 1. The feed concentrate was fed at a flat rate of 13.0 kg fresh matter/head/day. Animals were held in individual pens with rubber mats. All cows were fed ad-libitum with water and rice straw (the rice straw was fed at a level of 110% of the previous days intake) as a roughage source. Animals received the concentrate and roughage before morning and afternoon milking at 0430 and 1630 hr for an 80 day collection period following 15 days pre-treatment (Jume-September, 1995). At this time of the year, typical maximum day time temperatures were in the range of 31-34℃ and relative humidities between 75-80%. In practice additional rice straw was provided to some cows to ensure *ad libitum* intake was not restricted. Before the experimental period, the cows were at grass in the pasture and supplemented with commercial concentrate at morning and afternoon milking time. During the preliminary period, cows received a control diet containing 40.5 percent of cassava in the concentrate with rice straw. Feed intake of concentrate and roughage were measured separately and refusals recorded.

Table 1. Composition of concentrate diets used in the experiment (%)

Ingredients	Cassava levels in concentrate, %			
(DM basis)	13.5	27.0	40.5	54.0
Cassava chip	13.5	27.0	40.5	54.0
Corn (ground)	40.5	27.0	13.5	-
Kapok meal	10.8	10.8	10.8	10.8
Rice bran	7.6	7.4	7.0	6.7
Cotton seed meal	16.2	16.2	16.2	16.2
Soybean meal	2.7	2.7	2.7	2.7
Fish meal	2.7	2.7	2.7	2.7
Cane molasses	4.3	4.3	4.3	4.3
Urea	0.5	0.7	1.1	1.3
Limestone	0.3	0.3	0.3	0.3
Sulphur	1.3	1.3	1.3	1.3
Mineral-vitamin mix.	0.8	0.8	0.8	0.8
Total, kg	100	100	100	100

Sample collection and chemical analysis

Rice straw, cassava and concentrate were sampled every two weeks for 2 consecutive days and composited prior to analyses. Composited samples were ground (1 mm screen using Cyclotech Mill, Tecator, Sweden) and then analysed for DM, Ash, NDF, CP and EE content (AOAC, 1980; Goering and Van Soest, 1970; Van Soest et al., 1991). Milk yields were measured daily at morning and afternoon milking from each cow. Composited milk samples were collected every two weeks for 2 consecutive days at pm and am accordingly to yield proportion except when cows were suffering from mastitis infection. Milk samples were analysed for fat, protein, lactose, total solid and solid not fat content by infrared methods using Milko-Scan 33 (Foss Electric, Hillerod, Denmark).

A ruminal sample (200 ml) from each cow was collected in the last week of the experiment at 4 h after feeding by a stomach tube connected with a vacuum pump. Ruminal pH was measured immediately using a portable pH (Orion Research portable meter 200 series, USA). Twenty ml of rumen fluid was acidified with 1 ml 6 N HCl and centrifuged at 2500 rpm for 20 minute. The clear supernatant was transferred to 1 ml microcentrifuge tube (Model 3810, Eppendorf, Hamburg, Germany) and frozen until analysis for rumen ammonia nitrogen and volatile fatty acids concentration using the gas chromatography technique as detailed in Seal et al. (1992).

Urine samples from each cow were collected directly from the animal by the vulva stimulation technique twice a day at 09:00 and 15:00 h for two days before the end of the experiment. A 5 ml sample of urine was acidified with 5 ml 10% H_2SO_4 to maintain pH<2. The samples from each cow were composited a 50:50 basis and frozen for subsequent analyses of urinary purine derivatives using HPLC techniques (Balcells et al., 1992).

Statistical analyses

All data obtained from the experiment were subjected to the General Linear Models procedure of SAS/STAT (SAS, 1990) according to a RCBD using animal breed, parity, and days in milk as blocks. The following models were used for statistical analysis. $Y_{ij} = \mu + Co + Bl_i + T_j + E_{ij}$; Where Y_{ij}=observation in block i, (i=1-9) and treatment j (j=1-4), μ=overall mean, Co =covariant (pre-treatment of milk yield or body weight), Bl_i=block effect (i=1-9), T_j=treatment effect (j=1-4), E_{ij}=residual. Analysis of covariance was used for the parameters of milk yield, feed intake and animal body weight. Type III Sums of Squares, which account for missing values in the data, were used to determine whether treatment effects were significant. Least square means are presented along with predicted differences. Significant treatment differences are shown at $p<0.05$ unless otherwise noted.

RESULTS

Chemical composition of rice straw, cassava and concentrate feed

Table 2 shows the chemical composition of the concentrate, rice straw and cassava used in this experiment. Analysed crude protein contents were slightly higher than formulated values and were 17.5, 16.6, 16.4, 17.4% DM basis, respectively for inclusion levels of 13.5, 27.0, 40.5 and 50.4% of cassava. The calculated ME contents were 12.9, 12.8, 12.6 and 12.5 MJ/kg respectively and the content of NSC ranged from 52.0 to 57.2% DM.

Table 2. Chemical composition of concentrate and feed ingredients

Composition	Cassava levels in concentrate, %				Rice straw	Cassava
	13.5	27.0	40.5	54.0		
DM, %	86.5	87.9	86.3	89.4	93.3	89.3
Ash, % DM	8.1	8.3	8.6	9.1	13.6	8.1
NDF, % DM	26.8	22.4	23.3	21.5	70.5	9.7
CP, % DM	17.5	16.6	16.4	17.4	3.7	2.2
NSC[1], % DM	52.0	57.2	55.8	54.7	9.2	81.2
EE, % DM	2.7	2.2	2.3	2.1	1.5	0.8
ME, MJ/kg[2]	12.9	12.8	12.6	12.5	6.9	12.9
Price, US$/Tonne[3]	227	213	197	181	32	155

[1] NSC = 100 - (Ash+CP+NDF+EE); [2] Calculated values; [3] Based on local market prices in June 1995.

Table 3. Least square means for feed intake of lactating dairy cows fed concentrate containing different proportions of cassava and corn using rice straw as roughage[1]

Intake	Cassava levels in concentrate, %				SE
	13.5	27.0	40.5	54.0	
Rice straw, kg DM/d	2.89^{a}	2.49^{b}	2.93^{a}	2.51^{b}	1.06
Concentrate, kg DM/d	10.72^{a}	11.14^{b}	10.52^{c}	11.11^{b}	0.63
Total intake, kg DM/d	13.61	13.69	13.46	13.67	1.38
Total intake, % BW	3.7	3.6	3.6	3.5	0.34
OM intake, kg DM/d	12.46^{ab}	12.66^{a}	12.27^{b}	12.51^{ab}	1.23
NDF intake, kg DM/d	4.22^{a}	3.82^{b}	3.96^{b}	3.80^{b}	0.79
NSC intake, kg DM/d	5.84^{a}	6.60^{b}	6.14^{c}	6.31^{d}	0.38
CP intake, kg DM/d	1.98^{a}	1.88^{b}	1.83^{c}	2.03^{d}	0.12
ME intake, MJ/d	158^{a}	160^{a}	153^{b}	157^{ab}	12.30
CP intake, % DMI[2]	14.5	13.7	13.6	14.8	-
NDF intake, % DMI[2]	31.0	27.9	29.4	27.8	-
NSC intake, % DMI[2]	42.9	48.2	45.6	46.2	-
Cassava, % DMI[2]	9.9	19.7	30.1	39.5	-

[1] Different superscripts in the same row indicate significant difference between treatment means ($p \leq 0.05$).
[2] Calculated values.

Feed intake

Two cows, both on the 13.5% cassava in the diet treatment, were removed from the experiment because of mastitis infection and a knee problem respectively at the beginning of the experiment. Least square means of feed intakes for the experiment are given in table 3. There was no evidence that dietary treatment affected total feed intake which ranged from 13.46 to 13.67 kg/d. Levels of cassava inclusion affected roughage and concentrate intakes. Calculated NDF intake was depressed by higher cassava inclusion. This reflected roughage intake which was lowest at 27.0 and 50.4% of cassava in feed compound and this was paralleled by an increased total NSC intake with higher levels of cassava. Total NSC and metabolisable energy intake was highest in cows fed 27.0%. In the present study, estimated dietary CP, NDF and NSC ranged from 13.6 to 14.8, 27.9 to 31.0 and 42.9 to 48.2% of total dry matter intake, respectively (table 3).

Characteristics of ruminal fermentation

Dietary treatment had no effect on ruminal pH (table 4). These data suggest that inclusion of cassava up to 54.0% did not alter ruminal pH in this study. The concentration of NH_3-N in ruminal fluid was also not affected by levels of cassava and ranged from 10.57 to 13.42 mg N/100 ml. Concentration of total VFA in the rumen fluid sampled at 4 h post-feeding exhibited a trend to increase ($p>0.05$) with increasing cassava inclusion from 13.5 to 40.5%, but was lowest ($p<0.05$) at 54.0% of cassava in the diet. However, dietary treatment had no effect on either the molar proportions of individual volatile fatty acid nor on the acetic:propionic acid ratio (table 4). In general, these data suggest a similar pattern of rumen fermentation of cassava when compared to corn grain in the diets.

Urinary purine derivative excretion

The concentration of urinary purines from spot

Table 4. Least square means for ruminal fermentation characteristics, concentration of urinary purine derivatives and creatinine of lactating dairy cows fed concentrate containing different proportions of cassava and corn using rice straw as roughage[1]

	Cassava levels in concentrate, %				SE
	13.5	27.0	40.5	54.0	
Ruminal fermentation					
pH	6.49	6.57	6.64	6.66	0.36
NH_3, mg N/100ml	13.42	10.57	11.65	10.9	5.5
Total VFA, mM[1]	63.6[a]	66.4[a]	78.7[a]	56.9[b]	21.5
Acetic acid, %	65.3	65.4	61.9	64.7	5.8
Propionic acid, %	20.2	20.2	23.5	19.5	7.2
Iso-butyric acid, %	0.6	0.6	0.6	0.6	0.1
Butyric acid, %	11.4	11.3	11.2	12.3	2.1
Iso-valeric acid, %	1.4	1.5	1.4	1.7	0.4
Valeric acid, %	1.1	0.9	1.3	1.1	0.3
Urinary purine derivative (PD) and creatinine (C) concentration					
Allantoin, mM	6.7	9.2	7.5	8.3	4.1
Uric acid, mM	0.9	1.1	1.0	1.2	0.5
Creatinine, mM	8.4	9.0	7.6	7.1	3.7
Allantoin/C ratio	0.9	1.0	1.1	1.4	0.5
PD/C ratio	1.03	1.15	1.24	1.61	0.54

[1] Different superscripts in the same row indicate significant difference between treatment means ($p \leq 0.10$).

Table 5. Least square means for milk yield and milk composition and yield of milk components of lactating dairy cows fed concentrate containing different proportions of cassava and corn using rice straw as roughage[1]

	Cassava levels in concentrate, %				SE
	135	270	405	540	
Pre-treatment, kg/d	14.02	14.08	12.56	12.60	2.01
Milk yields					
kg/d	12.66[a]	13.50[b]	12.47[a]	12.02[c]	1.4
3.5% FCM	14.05[a]	13.83[a]	13.64[ab]	13.29[b]	1.7
Fat, %	4.17[a]	3.72[b]	4.18[a]	4.19[a]	4.6
Protein, %	3.39[a]	3.45[b]	3.46[b]	3.51[c]	2.1
Lactose, %	4.90[a]	5.11[b]	4.83[c]	4.67[d]	2.9
Total solids, %	13.17[a]	12.78[b]	13.17[a]	13.08[a]	7.0
Solid not fat, %	8.99[a]	9.08[b]	8.99[a]	8.88[c]	3.1
Fat, kg/d	0.53[a]	0.49[b]	0.50[ab]	0.50[b]	0.08
Protein, kg/d	0.42[a]	0.46[b]	0.42[a]	0.41[a]	0.05

[1] Different superscripts in the same row indicate significant difference between treatment means ($p \leq 0.05$).

samples is shown in table 4. Allantoin concentration was shown to be at a higher concentration than uric acid and ranged from 6.7 to 9.2 mM. Urinary PD/creatinine and allantoin/creatinine ratio values used as an index of ruminal microbial protein synthesis, were slightly increased with increasing level of cassava inclusion raging from 1.03 to 1.61 and 0.9 to 1.4, respectively. Their differences were not statistically significant (table 4).

Milk production

The influence of cassava replacement of corn on lactation performance is shown in table 5. All cows were able to maintain levels of milk yield compared to initial milk yield during the 80 days of experiment. Pre-treatment milk yields were 14.02, 14.08, 12.56, 12.60 kg/d for cows fed 135, 270, 405 and 540 g cassava/kg, respectively. These values indicating that crossbred dairy cows, raised in tropical conditions such as Thailand, produce medium yields during mid-lactation. Yield of milk was greatest from cows fed diets containing 270 g cassava/kg, but decreased ($p<0.05$) when the inclusion level was 540 g cassava/kg in the diet.

In addition, production of 3.5% FCM exhibited a slight decrease as cassava replaced corn in the diets and was lowest ($p<0.05$) at the 54.0% inclusion rate. The inclusion of cassava in the diets of dairy cows fed rice straw based diets also had an effect upon milk composition. Milk protein concentration increased ($p<0.05$), but lactose declined as cassava replaced corn in the diets and lactose concentration was lowest with 540 g cassava/kg inclusion. The lowest SNF occurred when 540 g cassava/kg was fed to cows (table 5) which reflected the decrease in lactose concentration. There was a curvilinear response to the inclusion of cassava in dairy cows diets, suggesting that cassava inclusion improved milk production up to a particular level but increased rate of inclusion higher than 40.5% in the concentrate depressed milk yield in dairy cows fed rice straw based diets. These results suggest that the optimal level of cassava in dairy cow diets is between 200-300 g cassava/kg total DMI.

DISCUSSION

Animals used in this feeding trial did not show any clinical problems associated with the dietary treatments. All cultivars of cassava contain the cyanogenic glucoside which produces HCN toxicity in mammals. These compounds, however, are able to be eliminated during either the chip or pellet drying processing methods. The HCN value of chips/pellets imported in to the EC from Southeast Asia has been reported as ranging between 49.3-79.0 mg HCN/kg cassava (Brigstocke et al., 1981; Stevenson and Graham, 1983). This value has been accepted for imports and has been suggested not to be a problem in the feeding of either ruminant or non-ruminant livestock (Stevenson and Graham, 1983).

The total dry matter intake was similar on all dietary treatments and ranged from 13.46 to 13.69 kg/d. In this experiment, high concentrate intake was achieved due mainly to the extremely low quality rice straw roughage used (table 2). It has been reported that inclusion of cassava replacing barley at a rate of up to 24.0% of total DMI fed with grass silage based diets had no effect on total feed intake and milk performance of dairy cows (Brigstocke et al., 1981). However, the low-quality rice straw used in the current experiment would have had a low rate of passage and digestibility, resulting in a lower total feed intake in contrast to silage based diets. Although, previous reports (Hoover, 1986) have suggested that the reduced pH decreases digestion of fibre. Higher degradation rates can result in a substantial decrease in ruminal pH and fibre digestibility thus reducing feed intake. Grant (1994) has reported that the source of starch influenced the rate of NDF digestion differently at pH 6.8 from 5.5 and led to dramatic differences in the apparent extent of ruminal NDF digestion in *in vitro* studies using corn and sorghum starch. Recently, Lebzien and Engling (1995) have undertaken a comparison of cassava, corn, barley and wheat as sources of starch in non-lactating dairy cow diets. They found that the source of starch had no effect on silage and total feed intake, ruminal pH and total VFA concentration in rumen fluid. Digestibility of crude fibre was also not affected by cassava or corn, but was lower when barley or wheat was included in the diet of cows. In addition, they reported higher flows of starch to the duodenum in animals fed corn starch than when fed cassava. Total tract digestibility of cassava has been reported as ranging from 98.9 to 100 percent of intake (Tudor et al., 1985; Zinn and DePeters, 1991; Lebzien and Engling, 1995).

No difference in rumen fluid pH values was noted among cows fed cassava in this study, indicating no specific effect of the inclusion of cassava (table 4). Zinn and DePeters (1991), Etman et al. (1993a, b) and Lebzien and Engling (1995) have found no effect on ruminal pH when cassava was compared to corn grain with slightly lower ruminal pH values (5.55 to 5.41) than measured in this experiment. This phenomenon may suggest that the coarse fibre from rice straw stimulates rumination, increasing salivation and the control of rumen buffering capacity. Hoover (1986) suggested that fibrolytic microbes and fibre digestion may be inhibited when pH ranged from 5.0 to 5.5, but at pH 6.0 there was a small decrease in fibre digestion. The results from this experiment suggest that 200-250 g rice straw/kg in the diets is adequate to maintain rumen function in dairy cows.

The inclusion of cassava in the diets had no effect on ruminal ammonia concentration in samples taken 4 hour after feeding in this experiment. Ammonia concentration was noted to be within the value of the optimal concentration for rumen microbial growth. The results from this study were similar to those from dairy cows fed a ration containing rapidly or slowly degradable starch (Khorasani et al., 1994). The average ruminal total VFA for each of the four treatments was lower (56.9-78.7 mM) than values reported for diets containing more than 300 g starch/kg (Khorasani et al., 1994). This may reflect the different roughage sources when silage is compared with rice straw. The values were comparable to those from reports in cows fed cassava and corn silage together with grass hay (Sutton et al., 1993). Rate and pattern of fermentation change with the time after feeding, although, no differences in VFA proportions have been reported between cassava and corn or barley (Zinn and DePeter, 1991; Etman et al., 1993a, b; Lebzien and Engling, 1995; Wanapat et al., 1995; Wanapat et al., 1996; Schwarz et al., 1996). These results imply that cassava has no effect on VFA production when included into ruminant diets compared to maize.

Cassava in diets has been reported to result in higher net microbial protein synthesis and microbial efficiency when compared with corn (Zinn and DePeter, 1991; Lebzien and Engling, 1995). In addition, Zinn and DePeter (1991) have also reported higher nitrogen efficiency (NAN/N intake) with cassava compared to steam flaked corn diets. The relationship between microbial protein synthesis and urinary purine derivative excretion has been extensively studied. Several studies have demonstrated that increased urinary purine excretion reflects changes in microbial protein flow to the small intestine (Verbic et al., 1990; Balcells et al., 1991; Vagnoni et al., 1997). Although, it has been found that purine is transfered into milk and saliva contributing a variable proportion of total excretion in lactating animals, (Giesecke et al., 1994; Gonda and Lindberg, 1997; Martin-Orue et al., 1996). It has also been suggested that purine to creatinine ratio in spot samples of urine can be used as an index of urinary purine excretion in intact dairy cows as a non invasive method (Susmel et al., 1994a, b; Gonda et al., 1996; Giesecke et al., 1994; Dewhurst et al., 1996; Vagnoni et al., 1997; Gonda and Lindberg, 1997). Urinary purine concentration and the PD/C ratio were noted to be lower than reported in lactating cows (Gonda and Lindberg, 1997), but were in the range reported by Dewhurst et al. (1996). The lower values reflected smaller amounts of microbial protein synthesis which may reflect different levels of dietary energy and protein intake between the experiments. Keady et al. (1998) has found that concentration of purine derivatives increased with increasing starch intake.

Milk yields and milk protein yield were highest in cows fed 270 g cassava/kg in the concentrate and tended to decrease at higher levels of inclusion. This implies that cassava can replace corn grain in the concentrate mixture to a certain extent. Improvements in milk production occurred with cassava inclusion (270 g cassava/kg in concentrate), a level at which corn was replaced on a 50:50 ratio. The maximum response may be associated with the greatest intake of both ruminal degradable starch and intestinal degradable starch (Nocek and Tamminga, 1991) which would provide higher glucogenic precursors through rumen fermentation and exogenous glucose supply, thus, meeting a demand for glucose for oxidative metabolism by the gastrointestinal tissues, sparing nutrients for metabolism by the peripheral and mammary gland tissues (Nocek and Tamminga, 1991; Balcells et al., 1995). Other researchers (Sutton et al., 1993) have also reported significant milk yield increases, but low milk fat yield and concentration when cows were fed diets containing high levels of starch from cereal and cassava. Research using cassava in dairy cows is limited, however, the potential of replacing cereal grains has been reported and Campero (1994) found similar responses in milk yield and live weight gain with cows supplemented with either cassava or corn grain under grazing conditions. Lopez and Hernandez (1996), have also demonstrated the ability of cassava to replace up to 35 per cent of cereals in concentrate mixtures with no differences in milk yield and composition in Holstein cows grazing pasture in Cuba. In addition, current research (Lopez and Herrera, 1998) has shown the use of cassava forage-tuber mix on top of supplementation to grazing cows resulted in improved milk yield.

The addition of protein may also play an important role in energy and protein efficiency, especially on microbial protein synthesis or metabolisable protein available to the host animal. However, it has been reported that protein from either plant sources (groundnut, soya bean meal) or animal sources (meat and bone meal, fish meal) are no better than NPN (urea, poultry litter) as nitrogen sources in beef and dairy cows diets (Tudor et al., 1985; Brigstocke et al., 1981; Holzer et al., 1997). The lower price of cassava resulted in a lower cost of concentrates with the higher inclusion rate of cassava. These were approximately 50 US$/tonne cheaper when comparing the inclusion of 135 with 540 g cassava/kg (table 2). These prices would suggest a high potential economic response in replacing cereal by cassava in dairy cows concentrate as has been suggested previously (Brigstocke et al., 1981). Currently, world trade of cassava has hit its lowest price from 178, 177 and 103 US$/tonne while barley was 222, 209 and 153 US$/tonne in 1991, 1995 and 1999 (January-February), respectively, as reported by FAOGIEWS (1999).

CONCLUSIONS

Cassava as a source of ruminal degradable starch replacing corn grain has the potential to improve dairy cow performance. In this study the yield of milk was maximal at an inclusion of 270 g cassava/kg in the concentrate, although animal performance tended to decline at higher inclusion levels. In addition, urinary PD/C ratio as an index of ruminal microbial protein synthesis was slightly increased when cassava levels were increased. There was no evidence of any adverse effects on rumen fermentation pattern or animal health. Given the lower cost of cassava compared with corn, there are likely to be economic advantages to higher inclusion rates of cassava in diets. Biologically, there was a curvilinear response to the inclusion, suggesting that the optimal levels of cassava in diary cows diets from this study was between 270 to 405 g cassava/kg in the concentrate or 200-300 g cassava/kg DMI in the total ration when fed with rice straw as the fibre source.

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