Asian-Aust. J. Anim. Sci.
Vol. 21, No. 01 : 66 - 74
January 2008
www.ajas.info

Effects of Supplementation of Mixed Cassava (*Manihot esculenta*) and Legume (*Phaseolus calcaratus*) Fodder on the Rumen Degradability and Performance of Growing Cattle

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ABSTRACT : Two experiments were conducted to assess the effect of replacing a conventional concentrate with mixed cassava (*Manihot esculenta*) foliage and legume (*Phaseolus calcaratus*) foliage. In Exp. 1, three rumen fistulated crossbred cows were used for *in sacco* rumen degradability studies. *In vitro* gas production was also studied. In Exp. 2, 11 crossbred F2 heifers (Red Sindhi×Holstein Friesian) with initial live weight of 129±6 kg and six months of age were allocated in a Completely Randomized Design (CRD) to evaluate a mixture (ratio 3:1) of cassava and legume foliage (CA-LE feed) as a protein source compared to a traditional concentrate feed (Control) in diets based on fresh elephant grass (*Pennisetum purpureum*) and urea treated rice straw *ad libitum*. The Control feed was replaced by the CA-LE feed at the levels of 0% (Control), 40% (CA-LE40), and 60% (CA-LE60) based on dry matter (DM). The *in sacco* degradation of CA-LE feed was higher than Control feed ($p<0.05$). After 48 h incubation the degradation of CA-LE feed and Control feed was 73% vs. 58% of DM and 83% vs. 65% of CP, respectively. The gas production in CA-LE feed was also significantly higher than in the Control feed during the first 12 h of incubation. The results of the performance study (Exp. 2) showed that the level of CA-LE feed in the concentrate did not have any effect on total dry matter intake ($p>0.05$) but live weight gains (LWG) in CA-LE40 and CA-LE60 were significantly higher (551 and 609 g/d, respectively) than in Control group (281 g/d). The intake of CP was higher ($p<0.05$) for the treatments CA-LE40 and CA-LE60 (556 and 590 g/d, respectively) compared to that of Control (458 g/d), while there was no significant difference in ME intake. The feed conversion ratio was 16.8, 9.0 and 7.9 kg DM/kg LWG in Control, CA-LE40 and CA-LE60, respectively. The feed cost in CA-LE40 and CA-LE60 corresponded to 43% and 35%, respectively, of the feed cost of Control feed. The best results were found when CA-LE feed replaced 60% of DM in a Control feed and considerably decreased feed cost. It is concluded that feeding cassava foliage in combination with *Phaseolus calcaratus* legume as a protein supplement could be a potentially valuable strategy which leads to reduced feed costs and a more sustainable system in smallholder dairy production in Vietnam. (**Key Words :** Heifer Calves, Cassava Foliage, Legume Foliage, Rumen Degradability, Growth Rate, Economic Return)

INTRODUCTION

In Vietnam traditional diets for calves after weaning consist mainly of grasses and concentrate. However, due to the high cost of concentrate and scarcity in the dry season, calves will often not get enough supplements to meet their requirement for adequate growth rate. Most native forages are known to have low digestibility and low crude protein content, especially during the dry season (Göhl, 1994). Sebastian and Esther (2002) reported that if the level of crude protein in the forages is not more than seven percent, it will result in a low intake and consequently reduced growth rate or even loss in live weight. Young growing animals have a high requirement for amino acids, glucose and long chain fatty acids (Leng, 1986). Osuji et al. (1993) suggested supplementing the diet in order to ensure adequate amounts of glucose and glycogenic compounds to obtain high ruminant productivity from low quality tropical forage. Thus, it is necessary to supply enough nutrients after weaning for calves on poor basal diets. After weaning the starter ration should contain 14-16% crude protein on a dry matter basis and have moderate energy content (Guyer, 1983). If weaned at six months of age the live weight of a calf is about 120 kg, depending on breed and expected

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Received August 17, 2006; Accepted April 8, 2007

Table 1. Ingredient composition of control and experimental feeds (as % of DM)

Item	Control feed	CA-LE feed
Maize meal (%)	40	-
Rice bran (%)	35	
Green bean husk (%)	25	
Dry cassava foliage (%)	-	75
Dry legume foliage (%)	-	25

Control feed: a typical traditional feed used by farmers for young animals. CA-LE: Experimental feed consisting of the cassava and legume foliage hay in a ratio of 3:1 (DM basis).

mature weight.

The role of cassava foliage as well as the potential of legumes foliage as protein supplement to low quality diets has been reported by Wanapat (2001) and Preston (2001). According to Thang et al (2005) the "Nho Nhe" (*Phaseolus calcaratus Roxb*.) is a leguminous plant that can grow well in the uplands of Vietnam, and that can be inter-cropped with cassava. The study showed that the highest accumulated dry matter (DM) yield (8.84 tons DM/ha) and CP yield (1.98 tons/ha) was found at one row of cassava intercropped with two rows of legume and 45 days cutting interval. No published study has been found where a mixture of cassava foliage and *Phaseolus calaratus* Roxb. foliage has been investigated as feed for growing cattle. The value of these sources as supplements is partly dependent on their capacity to provide essential nutrients to the microbial population of the rumen. They may also directly provide additional energy and protein to meet the host's requirement.

The hypothesis behind this study is that replacing a part of the conventional concentrate with mixed cassava and legume foliage will positively influence rumen degradability and improve the performance of growing cattle.

The aims of the study were: (1) To estimate the feeding value of a mixture of cassava and legume foliage compared to conventional concentrate for cattle by using *in sacco* and *in vitro* gas production methods, and (2) To evaluate the effects of substituting different proportions of a conventional concentrate with cassava/legume foliage on feed intake and performance of calves after weaning.

MATERIALS AND METHODS

Location

The experiments were conducted at BaVi Cattle and Forage Research Center at Sontay, Hatay province in Northern Vietnam. The center is located in the buffer zone between the mountainous area and the delta at E105°25 longitude and N21°06 latitude, and is 220 m above sea level. The climate is tropical monsoon with an average annual rainfall of 1,859 mm and the mean temperature ranges from 24 to 30°C. The study was carried out from October to December, 2004.

Experimental animals

In Exp. 1 three rumen fistulated cows (Red Sindhi× Holstein Friesian, 250-300 kg live weight) were used.

In Exp. 2 eleven crossbred F2 heifers (25% Red Sindhi and 75% Holstein Friesian) at six months of age with an average live weight of 123-135 kg were used for the performance study, which included a 15 days adaptation period and 60 days experimental period. The animals were selected from three farms and had the same age, breed and live weight, and were in good health. They were then randomly allocated to the three treatments. The animals were individually identified by numbered ear tags and housed in individual pens. Before the adaptation period, all the experimental animals were de-wormed and vaccinated. During the fifteen-day adaptation period, feeds were offered individually to the animals following the planned treatment. The animals were weighed at the end of the adaptation period when the feed intake was stable.

Experimental feed preparation

The mixture of cassava and legume foliage was produced from cassava and legumes, which were collected at five harvesting times after planting, from 15th March to 15th December, 2004. In each 45 day interval, the materials of legume and cassava foliage were harvested separately. All the harvested materials were chopped into 3-5 cm lengths by hand and sun-dried immediately for two days to reach a moisture content of less than 12%. The foliage hay was packed in plastic bags. Before the adaptation period the separate cassava and legume foliages were sun dried for a second time and then ground by a milling machine with two mm sieve. The experimental feed (CA-LE feed) was made by mixing the ingredients in the proportion 3:1 of cassava foliage: legume foliage on DM basis.

Traditional concentrate feed (Control feed) was mixed every fifteen days, and consisted of 40% maize meal, 35% rice bran, and 25% green bean husks. The formula of the feeds is shown in Table 1.

The dried rice straw was treated with 4% urea on a dry weight basis. The urea solution (four kg urea plus 0.5 kg of salt dissolved in 80 litres water) was sprinkled onto 100 kg of dried rice straw that was spread out on a plastic sheet placed on the ground. The urea treated rice straw was then stored in an airtight plastic bag for three weeks before feeding.

The re-growth of elephant grass (*Pennisetum purpureum*) at an age of 45 days was harvested daily in the morning. It was chopped into 10-15 cm length before feeding.

Table 2. Chemical composition of feeds used in the experiment (mean and SD)

Item	Elephant grass	Urea treated rice straw	Control feed	CA-LE feed
N	4	4	4	4
DM (g kg^{-1})	183.9 (3.66)	665.9 (20.1)	894.7 (0.83)	924.0 (0.70)
Composition of DM (g/kg)				
OM	872.8 (7.95)	792.7 (13.94)	927.4 (0.62)	901.0 (0.33)
CP	88.0 (4.40)	95.3 (3.76)	103.9 (0.46)	200.5 (0.60)
EE	37.2 (1.30)	11.2 (0.73)	33.9 (0.62)	30.3 (0.46)
Calcium	5.3 (0.09)	3.1 (0.05)	6.5 (0.33)	23.3 (0.73)
Phosphorus	2.9 (0.46)	1.8 (0.05)	3.1 (0.16)	3.9 (0.10)
Tannin	-	-	-	59.7 (1.20)
Calculated by gas production after 24 h				
OMD	47.23 (3.07)	35.12 (2.46)	52.48 (1.05)	57.29 (1.70)
ME	7.05 (0.47)	5.18 (0.38)	7.83 (0.16)	8.45 (0.26)

Tannin = total tannins; OMD = Organic matter digestibility; ME = Metabolisable energy (MJ/kg DM).

Experimental design and treatments

The Exp. 2 was carried out as a Completely Randomized Design (CRD) with three treatments. The daily rations for the animals in each treatment consisted of a basal ration of eight kg chopped fresh elephant grass, urea treated rice straw fed *ad libitum* (15 percent surplus), and the concentrate supplement supplied as follows: Control group was fed 2.24 kg Control feed, CA-LE40 group 1.34 kg Control feed and 0.9 kg CA-LE feed, and CA-LE60 group 0.9 kg Control feed and 1.34 kg CA-LE feed, on DM basis. Thus in group CA-LE40 and CA-LE60 40% and 60%, respectively, of Control feed was substituted by the CA-LE feed. The levels were designed to supply equal amounts DM of supplements in diets for all experimental animals. The experimental period lasted for 60 days.

Feeding regime

The feeds were offered twice per day, in the morning (07.30 h) and afternoon (16.30 h). At each feeding occasion, the concentrate was supplied first to the animal, and then elephant grass was given. Finally, the animals were given urea treated rice straw. The chemical composition and nutritive value of feeds used is detailed in Table 2. The animals had always free access to water.

Measurements

Feed intake : The intakes of supplement, elephant grass and urea treated rice straw were measured daily, based on the amount of offered and refused feeds recorded in the morning of the next day. The total feed intake was calculated as the sum of component feed intakes. The feeds were sampled each fifteen days for chemical analysis.

Live weight : After the adaptation period the animals were weighed at 06.00 h before feeding on two consecutive days, and at 15 day intervals.

Chemical analysis : Samples of elephant grass, urea treated rice straw, Control feed and CA-LE feed were dried in a forced air oven (45°C) for 48 h before analysis of dry matter (DM), organic matter (OM) and crude protein (Kjeldahl method N×6.25) by the AOAC (1990) procedures. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined by the methods of Van Soest and Robinson (1985). Total condensed tannin was determined by the butanol-HCl method (Terrill et al., 1992).

In sacco DM and CP degradation : DM degradation was determined by incubating about five g of dry sample of CA-LE feed and Control feed in nylon bags in three rumen fistulated cattle according to the method of Orskov et al. (1980). The degradation was determined at 4, 8, 12, 24 and 48 h of incubation. The mean of three results for each time were used when calculating the rate of degradation. The diet of the animals was similar to the substrates being tested. In the time procedure of withdrawal of bags from rumen, the samples bags were immediately placed in bucket of cold water to prevent further fermentation and to wash off the feed particles adhering to the outside of the bags. All the bags were washed under running cold water in the laboratory until the water became clear. Then the bags were dried to constant weight at 65°C before recording the weight of bags plus incubated samples.

The course of degradation of the feed was described by fitting DM loss values to the exponential equation of Orskov and McDonald (1979): $P = a+b(1-e^{-ct})$. The degradation characteristics of the samples are defined as: A = washing loss (representing the soluble fraction of the feed); B = (a+b)-A (representing the insoluble but fermentable materials); c = the rate of degradation of B (Orskov et al., 1980).

In vitro gas production : The CA-LE feed and Control feed samples were incubated *in vitro* with rumen fluid in calibrated glass syringes as described by Menke and Steingass (1988), modified by Makkar et al. (1995). The procedure was followed by weighing 200 mg substrate into each numbered syringe placing them in an incubator at 39°C. The blanks, i.e. rumen fluid/artificial saliva mixture on its own, were included at the beginning, in the middle of the set, and at the end. Samples were done in triplicate. The buffer was adjusted to pH 7.0-7.3. The rumen fluid was collected and pooled from three animals, and filtered through three layers of gauze. The rumen liquid was poured into the artificial saliva with ratio of 2:1 of artificial saliva and rumen fluid and mixed by magnetic stirrer during the whole process. Thirty ml solution was added to each syringe using a dispenser. The volume of a syringe was 100 ml. The syringe was filled, the clip opened and the syringe's plunger gently pushed so that all the air was removed. The gas volume of CA-LE feed and Control feed samples was recorded at 3, 6, 8, 12, 24 and 48 h after incubation.

The results of gas volume reading (means of triplicates) at different times of incubation were fitted to the exponential equation of the form: $P = a+b(1-e^{-ct})$ (Orskov and McDonald, 1979), where P represents gas production at t time, (a+b) the potential gas production, c the rate of gas production and a, b and c are constants in the exponential equation.

Metabolisable energy (ME) values of edible biomass of plants were calculated based on gas production data at 24 h of incubation according to the equation: ME (MJ/kg DM) = $2.20+0.1357\times Gv+0.0057\times CP+0.0002859\times CP^2$ (Menke and Steingass (1988) (Gv: net gas production in ml from 200 mg DM after 24 h of incubation).

Economic return : The cost residue over control is a measure of what the farmer gets in higher benefit by decreasing the feed cost, and was calculated based on the feed cost kg^{-1} live weight gain of treatments (CA-LE40 and CA-LE60) compared to the value of Control. The value was also expressed as a percentage of feed cost as compared to Control. The costs of feeds in this study shown in Table 8 are based on local market prices. The cost of CA-LE feed is based on a previous study by Thang et al. (2005).

Statistical analysis

The data were analyzed as a Completely Randomized design (CRD) using the general linear model and pair-wise comparison in Minitab software version 13.31, following the statistical model below:

$$Yi = \mu+\alpha i+\varepsilon i$$

Where: μ = the general mean
αi = the i^{th} treatment
ε = the ε^{th} error term

RESULTS

Chemical composition of diet ingredients

The CP contents of the Control feed and CA-LE feed were 103.9 g/kg and 200.5 g/kg on DM basis, respectively. The content of condensed tannin in CA-LE feed was 57.9 g/kg DM. Digestible organic matter (OMD %) and metabolisable energy (MJ/kg DM) contents were 52.48 and 57.29, and 7.83 and 8.45 in the Control feed and CA-LE feed, respectively.

Table 3. *In sacco* degradation of dry matter (DM) and crude protein (CP) of the experimental (CA-LE) and control feeds

Treatment	Time of incubation (h)				
	4	8	12	24	48
Dry matter (%)					
Control feed	33.75^b	35.72^b	43.06^b	52.47^b	58.13^b
CA-LE feed	37.34^a	39.75^a	60.08^a	70.24^a	72.92^a
SEM	0.35	0.30	0.74	1.63	0.36
p-value	0.002	0.001	0.000	0.002	0.000
Crude protein (%)					
Control feed	25.36^b	28.37^b	39.96^b	55.25^b	64.81^b
CA-LE feed	34.56^a	38.64^a	57.50^a	75.86^a	83.11^a
SEM	0.37	0.36	0.78	1.52	0.32
p-value	0.000	0.000	0.000	0.001	0.000

$^{a, b}$ Means within columns with different superscripts differ significantly ($p<0.05$).

Table 4. Washing loss (A), water-insoluble degradability (B), potential degradability (A+B), rate constant (c) and lag phase (L) of the experimental (CA-LE) and control feeds

Treatment	A (%)	B (%)	A+B (%)	c	Lag time (fraction/h)	ED
Control feed	16.76	43.90^b	60.70^b	0.067^b	0.00^b	44.47^b
CA-LE feed	26.60	48.33^a	74.93^a	0.093^a	2.07^a	54.97^a
SEM	0.00	0.59	0.59	0.003	0.10	0.22
p-value		0.006	0.000	0.005	0.000	0.000

ED = Effective degradability.
$^{a, b}$ Means within columns with different superscripts differ significantly ($p<0.05$).

Table 5. Gas production during incubation of the experimental and control feeds (ml)

Treatment	Time of incubation (h)					
	3	6	8	12	24	48
Control feed	3.00^b	6.33^b	8.80^b	15.97^b	34.27	50.60^a
CA-LE feed	7.67^a	14.50^a	18.40^a	25.00^a	34.43	38.70^b
SEM	0.12	0.55	0.44	0.43	0.72	1.24
p-value	0.000	0.000	0.000	0.000	0.878	0.002

a, b Means within columns with different superscripts differ significantly (p<0.05).

Table 6. Initial gas production (A), gas production during incubation (B), fitted asymptote gas production (A+B), rate constant (c) and lag phase (L) of experimental and control feeds

Treatment	A (%)	B (%)	A+B (%)	c	Lag time (fraction/h)
Control feed	6.00	59.53^a	65.53^a	0.033^b	5.93^a
CA-LE feed	6.00	32.83^b	38.38^b	0.101^a	3.33^b
SEM		1.92	1.92	0.003	0.14
p-value		0.001	0.000	0.000	0.000

a, b Means within columns with different superscripts differ significantly (p<0.05).

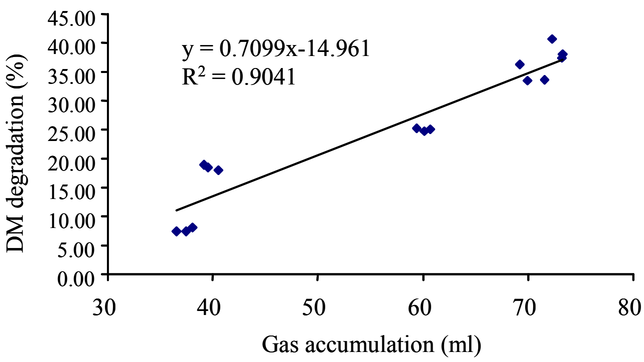

Figure 1. Regression between DM *in sacco* degradation and *in vitro* gas production of experimental feed.

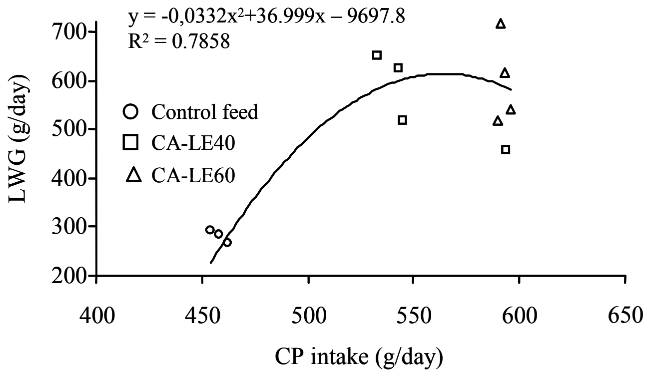

Figure 2. Regression between CP intake and live weight gain in experimental animals.

In sacco degradation of DM and CP of CA-LE feed and Control feed

Results of DM and CP analyses and some characteristics of *in sacco* degradation of CA-LE feed and Control feed are presented in Table 3 and 4. The disappearance of the DM and CP of CA-LE feed was significantly higher than of Control feed after 4, 8, 12, 24 and 48 h incubation in the rumen (p<0.05). More than 72% DM and 83% CP of CA-LE feed had disappeared compared to 58% DM and 65% CP of the Control feed after 48 h incubation. Compared to Control feed, in the CA-LE feed the degradability of DM after 24 h and 48 h incubation increased by 33.8% and 25.4%, respectively.

Significantly higher values of washing loss (A), insoluble but fermentable fraction (B), the rate constant (c) and effective degradability (ED) were also seen in CA-LE feed than in the Control feed.

In vitro gas production of CA-LE feed and Control feed

Gas production of CA-LE feed and Control feed during incubation is shown in Table 5. Significantly higher gas volume was found in CA-LE feed after 3, 6, 8 and 12 h of incubation compared to the values of Control feed. No difference in gas production was found between the feeds after 24 h incubation but it was significantly lower in CA-LE feed than in the Control feed at 48 h incubation. In accordance with the *in sacco* DM degradation, the increase in gas production was significantly higher during the first 12 h of incubation. The gas production study also showed that CA-LE feed had significantly higher values of degradation rate constant (c) and lower lag phase (L) than Control feed (Table 6). The regression of DM degradability and the gas production yield at 4, 8, 12, 24 and 48 h incubation showed that there was a high correlation between *in sacco* DM lost and gas accumulation (R^2 = 0.90; Figure 1).

Feed intake and live weight gain

The data on feed intake of the three diets is shown in Table 7. There were no significant differences in total DM feed intake and estimated ME intake between treatments (p>0.05), while the intake of CP was significantly higher for the treatments CA-LE40 and CA-LE60 (556 and 590 g/d, respectively) compared to Control (458 g/d). However, one of the four heifers in CA-LE40 consumed significantly

Table 7. Effect of the replacement rate of control feed with experiment feeds (mixed cassava and legume) on daily feed intake

Item	Control	CA-LE40	CA-LE60	SEM	p
DMI of grasses (kg)	1.19^a	1.18^a	1.14^a	0.02	0.23
DMI of UTRS (kg)	1.28^a	1.40^a	1.35^a	0.08	0.66
DMI of concentrate (kg)	2.23^a	2.24^a	2.23^a	0.00	0.17
DMI of whole diet (kg)	4.70^a	4.82^a	4.72^a	0.09	0.63
Tannin intake (g)	0.00^c	53.5^b	80.2^a	0.10	0.000
Total DMI (g/kg $W^{0.75}$)	118^a	111^a	115^a	5.50	0.698
Roughage DMI (g/kg $W^{0.75}$)	62	62	59	3.62	0.790
Total DMI (% BW)	3.45^a	3.15^a	3.35^a	0.20	0.602
Total CPI (g)	458^b	556^a	590^a	8.28	0.000
Total CPI (g/kg $W^{0.75}$)	11.5^b	12.8^{ab}	14.4^a	0.59	0.044
Total ME intake (MJ ME)	32.5^a	33.6^a	33.3^a	0.46	0.296

Control feed: a typical traditional feed used by farmers for young animals.
CA-LE40: replacement of control by 40% (on DM) mixed cassava and legume.
CA-LE60: replacement of control by 60% (on DM) mixed cassava and legume.
UTRS: urea treated rice straw with 4% urea.
DMI: dry matter intake; CPI: crude protein intake.
[a, b] Means within rows with different superscripts are significantly different (p<0.05).

Table 8. Effect of replacement rate of control feed with experimental feeds (mixed cassava and legume) on live weight gain and feed cost

Item	Control	CA-LE40	CA-LE60	SEM	p
Initial weight (kg)	128.7	130.0	130.8	6.38	0.975
Final weight (kg)	145.5	163.0	167.4	7.89	0.238
LWG (g/d)	281^b	551^a	609^a	38.51	0.003
FCR (DM/kg LWG)	16.8^a	9.0^b	7.9^b	0.69	0.000
FCR (CP/kg LWG)	1.6^a	1.0^b	1.0^b	0.08	0.003
Feed cost (VND/d)	$11,028^a$	$9,235^b$	$8,287^c$	65.00	0.000
VND kg^{-1} LWG	$39,254^a$	$16,758^b$	$13,607^b$	1,040	0.000
Cost residue over control	0	$22,496^a$	$25,646^a$	1,337	0.101
Economic return (%)	-	42.7	34.7		

Control feed: a typical traditional feed used by farmers for young animals.
CA-LE40: replacement of control by 40% (on DM) mixed cassava and legume.
CA-LE60: replacement of control by 60% (on DM) mixed cassava and legume.
LWG: live weight gain; FCR: feed conversion ratio.
[a,, b, c] Means within rows with different superscripts are significantly different (p<0.05).
Price of elephant grass: 450 VND/kg; price of traditional concentrate: 2,705 VND/kg; price of urea treated rice straw: 350 VND/kg; price of CA-LE feed: 850 VND/kg.
Currency exchange: 1 USD = 15,750 VND.

more UTRS than the other heifers, which resulted in higher CP intake than the other heifers in CA-LE40 treatment, and the same CP intake as the heifers in CA-LE60 (see Figure 2). As expected the consumption of condensed tannins increased with the level of CA-LE feed.

Table 8 shows the effect of different replacement levels with CA-LE feed on live weight gain (LWG) and feed cost. For treatment CA-LE40 and CA-LE60, daily LWG was significantly higher than on the Control (p<0.05). The values of LWG were 281, 551 and 609 g/d in Control, CA-LE40 and CA-LE60, respectively. The difference in LWG between the two CA-LE feed levels was not significant. Replacement with CA-LE feed had a positive influence on feed conversion ratio (FCR) of DM and CP compared to Control. Higher levels of replacement with CA-LE60 did not significantly improve FCR value compared to CA-LE40 (p>0.05). There was a close correlation between CP intake and live weight gain (R^2 = 0.78; Figure 2).

No animal health problems were observed among the heifers during the experiment.

The feed costs per kg LWG were significantly lower for CA-LE40 and CA-LE60 compared to Control, but there was no significant difference between CA-LE40 and CA-LE60. The feed cost in CA-LE40 and CA-LE60 corresponded to 42.7% and 34.7%, respectively, of the feed cost in Control.

DISCUSSION

The nitrogen availability in the rumen improves microbial growth, ensures a high proteolytic population in the rumen, and also allows an accumulation of the cellulolytic bacteria (Orskov, 1992; Tessema and Baars, 2004). Wanapat et al. (1997) and Promkot and Wanapat (2003) have concluded that the nutritive value of proteinrich supplements to a certain extent improves rumen degradability. Synchronizing the rate of degradation of energy and the release of nitrogen from the diet can also improve protein synthesis and feed utilization (Chumpawadee et al., 2006). In the present study, the higher value for DM and CP degradability of CA-LE feed compared to the Control feed could be due to the structure and solubility characteristics of protein and carbohydrates in the CA-LE feed, which facilitate easier attack by microorganisms in the rumen. This is in agreement with prior results reported by Wanapat et al. (1997) and Khang and Wiktorsson (2000), who reported a degradability of cassava leaf meal of 60-79% after 72 h rumen incubation. The observed results in the present study were 73% in CA-LE and 58% in the Control feed after 48 h incubation. The DM degradability in rumen of three tropical forage legumes *Cassia rotundifolia, Lablab purpureus* and *Macroptilium atropurpureum* varied between 47 and 63% after 48 h incubation, depending on the stage of maturity (Mupangwa et al., 2003). Another study in tropical Africa showed that the DM degradability of Leucaena and Gliricidia was higher (68%) after 48 h incubation (Smith et al., 1991), which is comparable to the results in this study. The positive interaction of cassava and legume foliage seems to be due to the high CP content and the fragility of cell walls, which resulted in a high degradation rate during the first time period of incubation in the rumen.

The CP content of 201 g/kg DM in CA-LE feed was the same as of pure cassava foliage reported by Van and Ledin (2001), but lower than the 249 g/kg DM reported by Wanapat et al. (1997) and higher than the 189 g/kg DM reported by Dung et al. (2003). The content of CP in the CA-LE feed included both cassava foliage and legume foliage, which was kept constant at the ratio 3:1, based on the amount of total dry biomass production from cassava foliage and legume foliage. In a separate study (Thang et al., 2005) the CP content in cassava foliage and legume foliage was 175 g/kg DM and 250 g/kg DM, respectively. The theoretical calculated CP content in the present study based on the ratio 3:1 of cassava foliage and legume foliage of 194 g/kg DM was similar to the value for the mixed CA-LE feed used in the study. The total tannin of CA-LE feed (5.9% of DM) was similar to the value of cassava foliage previously reported by Ravindran and Rajaguru (1988), but higher than the 3.05% of DM reported by Wanapat et al. (2000); 3.26% of DM by Netpana et al. (2001), and 2.3% DM by Dung et al. (2003). The tannins are generally found in higher concentrations in mature cassava leaf (Ravindran and Rajaguru, 1988; Wanapat, 2001).

There was no significant effect on total DM intake with increasing level of CA-LE feed. Similar results were reported by Queiroz et al. (1998), who found no significant differences in dry matter intake of urea treated corn stover with or without supplementation of cassava hay. Krailas and Wanapat (2003) also concluded that supplementation of cassava hay, solely or in combination with Stylo hay, did not increase total DM and forage intake. However, Khang and Wiktorsson (2000) showed that urea treated rice straw intakes increased with increasing levels of cassava leaf meal supplementation. The differences in results are probably due to the fact that, in the present study, the total tannin intake increased with increasing level of replacement with CA-LE feed. Kumar and Dmello (1995) and Man and Wiktorsson (2001) concluded that the depression in intake could be due to the low palatability of tannin-containing plants when fed to animals. Krailas and Wanapat (2003) showed that condensed tannins in a basal diet of Stylo 184 and cassava hay reduced the feed intake.

According to Leng (1986), supplementation of a good source of roughage like cassava hay can possibly increase the ratio of protein to energy, and hence could increase productivity in ruminants. It has been reported by Topps (1997) that the most economic way to improve energy intake and performance of animals fed crop residues, is to supplement them with good quality forages, including legumes. The rate of LWG found in the present study agrees well with Combellas et al. (1996) and Seijas et al. (1994), who reported live weight gains of 600-650 g/d obtained by animals grazing on *Gliricidia* legume. Similarly, Khang and Wiktorsson (2006) showed that there was a significant increase in daily LWG when heifers were fed a basal diet of urea treated rice straw with pelleted cassava foliage supplements, compared to a control diet without supplement. Devendra (1995) has demonstrated that tropical tree legumes can supply a portion of the dietary protein for ruminants, but the level of substitution will depend upon the productive status of the animal and type of legume. Krailas and Wanapat (2003) concluded that the replacement of 33% of concentrate with hay made from cassava and Stylo 184 did not change milk yield but increased the milk protein percentage of crossbred dairy cows. However, in the present study there was still a trend effect at the level of 60% replacement of the Control feed with CA-LE feed (Table 7). By replacing part of the Control feed with CA-LE feed the daily total CP intake increased by 100 g and 130 g in CA-LE40 and CA-LE60, respectively. The CP content per kg DM in CA-LE60 was equivalent to the lowest protein level in a study by Lohakare et al. (2006) with low, standard and high protein supply to crossbred *bos indicus×bos taurus* male calves. All the treatments resulted in similar calf performance, and the higher protein supply did not improve the growth.

To what extent the improved growth rate in the present study depended on the amount and higher degradability of

CP, or was a combined effect with the increased amount of condensed tannins in the ration cannot be explained. Condensed tannins are known to bind with the dietary proteins during mastication and protect them from microbial attack in the rumen, making them available for digestion and utilization in the abomasum and small intestine (Preston and Leng, 1987; Norton, 1999). That can be a positive factor for nitrogen utilization if there is a surplus of easily degradable protein and of N in the rumen. According to Makkar (2000), condensed tannins can improve rumen microbial protein synthesis. Under the present conditions, the protein from CA-LE feed not only provided readily available fermentable nitrogen, amino acids and peptides for microbial growth in the rumen but also supplied valuable amino acids for absorption in the lower gut, leading to improvement of the performance of animal.

The replacement of concentrate with CA-LE feed had a positive influence on feed conversion ratio (FCR) of DM and CP of the heifers, which substantially reduced the feed cost. The best results were obtained when CA-LE feed replaced 60% of DM in a conventional concentrate. The heifers not only showed a stable total DM intake, and increased live weight gain, to an optimal level for growing heifers of the present crossbred, but the replacement of concentrate with CA-LE feed also considerably improved FCR and reduced feed cost.

It can be concluded that replacing a conventional concentrate with a mixture of cassava and *Phaseolus calcaratus* legume as a supplemental protein source in the ration for growing heifers resulted in improved rumen environment, increased growth rate, reduced feed cost per kg live weight gain, and gave a higher economic return.

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