

Ruminal Degradability of Tropical Feeds and Their Potential Use in Ruminant Diets

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ABSTRACT : The objective of this study was to determine the degradability of cassava chip (CC), cassava waste (CW), yellow sweet potato (YP), white sweet potato (WP), purple sweet potato (PP), corn meal (CM), and rice bran (RB) using *in situ* technique. Two ruminally fistulated steers with an average weight of 303 ± 10 kg were used to determine *in situ* degradabilities of DM and OM. Seven feed sources were weighted in nylon bags (38 μ m pore size) and incubated ruminally for 1, 2, 4, 6, 8, 12, 24, and 48 h. The results showed that asymptote (a+b) and effective degradability (ED) of DM of energy sources ranked from the highest to the lowest: CC, YP, WP, PP, RB, CW, and CM (99.3, 92.5; 97.6, 87.9; 97.5, 87.9; 97.2, 87.8; 87.5, 63.6; 78.6, 63.0 and 81.7; 59.3, respectively) and for OM asymptote (a+b) and effective degradability (ED) were similar to those of degradation of DM (99.4, 93.4; 98.8, 89.8; 98.5, 89.4; 98.4, 88.1; 92.4, 65.8; 85.1, 66.9 and 83.6, 63.3, respectively). It was concluded that disappearance characteristic of CC was the highest and it may potentially facilitate the achievement of optimal ruminal availability of energy: protein especially with NPN for microbial protein synthesis. (*Asian-Aust. J. Anim. Sci.* 2003, Vol 16, No. 2 : 211-216)

Key Words : Ruminal Degradability, Tropical Energy Sources, Ruminants, Nylon Bag, Microbial Protein Synthesis

INTRODUCTION

Optimal rumen ecology is an essential for improving fermentation end-products for ruminants use, as reported by Wanapat (2000) that ruminal volatile fatty acids and $\text{NH}_3\text{-N}$ in ruminants in the tropics fed on low-quality roughages especially rice straw were imbalance. Strategic supplementation for both carbohydrate and protein particularly non-protein nitrogen (NPN) needs to be undertaken. Carbohydrates (CHO) are the major source of energy for rumen microorganisms and the single largest component (60-70%) of a dairy cow's diet. Both structural and non-structural carbohydrate sources are essential to rumen fermentation in providing volatile fatty acid (VFAs) and carbon skeleton the synthesis of the amino acid required for coupling microbial protein synthesis (Wanapat et al., 1995).

Many reports have been published on the digestion of starch in ruminants (Cone et al., 1989; Herrera-Saldana et al., 1990; Nocek and Tamminga, 1991; Huntington, 1997; Yu et al., 1998; Nozière and Michalet-Doreau, 2000; Sommart et al., 2000). Starch in cereal grain is almost completely digested in the whole digestive tract, however the rate and extent of ruminal fermentation vary widely and its digestion depended on type of grain and degree of processing. The site of starch digestion has implications for the nature and amount of nutrients delivered to the animal

(Nozière and Michalet-Doreau, 2000). However, the close relationship with digestible dry matter intake, organic matter and growth rate of ruminants need to be observed (Ørskov et al., 1988) and nylon bag degradation values justifies this method to be used as a relevant tool to evaluate the changes occurring in the ruminal breakdown of energy sources.

Limited information has been available on characteristics of DM and OM degradation in the rumen of feed sources locally used for livestock in the tropics with special reference to Thailand, namely cassava chip, cassava waste, yellow sweet potato, white sweet potato, purple sweet potato, corn meal, and rice bran. The digestion of these feed sources may assist in nitrogen supplementation that will optimize the synchronization of carbohydrate degradation and nitrogen availability. Information and combination of energy and protein sources with similar ruminal degradation, and thus a more efficient use of energy and protein in ruminant diets. The objective of this study was to determine DM and OM disappearance of tropical feeds of seven sources locally available in Thailand on fermentation characteristics using *in situ* technique.

MATERIALS AND METHODS

Animals and diets

Two ruminally fistulated crossbred beef steers (303 ± 10 kg BW) were used as replicates to determine *in situ* DM and OM degradabilities of the seven feed sources (cassava chip, cassava waste, yellow sweet potato, white sweet potato, purple sweet potato, corn meal and rice bran). All samples were ground to pass a 1 mm screen and stored for further chemical analysis and degradability study. Steers

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were housed in individual pen and fed ad libitum a diet consisting of 50% urea-treated rice straw and 50% concentrate feed (on DM basis) (Table 1). The diets were offered in two equal meals at 07:00 and 15:00 h. Animals had free access to water and trace mineralized salt.

Ruminal disappearance study

Bags were made of dacron cloth (7×14 cm) with and approximate pore size of 38 µm (Ørskov and McDonald, 1979). Approximately 6.0 g of feed sources were weighed into a previously dried (60°C) and tared bag. Bags were tied to a weighed chain and placed in the ventral rumen sac of steers approximately 2 h after the morning feeding. All feeds were incubated simultaneously in both steers using duplicates bags per feed at each time point and a blank bag containing no sample for each removal time. Bags for each feed were removed after 1, 2, 3, 4, 6, 8, 12, 24 and 48 h of incubation. Immediately after removal from the rumen, bags were washed with cold tap water until rinsed the water was clear. Bags were dried for 72 h at 60°C in a forced air oven. The bags were weighed and residues were removed and then analyzed for DM, and OM. All bags feed samples were collected for their corresponding blank. The 0 h incubation samples were washed and dried in similar condition. The bags were weighed and tested according to the procedure described by Ørskov and McDonald (1979). Samples of rumen fluid were taken through the ruminal canulae at 1, 2, 3, 4, 6, 8, 12, 24 and 48 h of incubation, during each time and pH and temperature were measured immediately using a portable pH and temperature meter (Orion Research portable meter 200 series, USA).

Chemical composition analysis

The samples were analyzed for DM, ash, OM, and Kjeldahl-N according to AOAC (1990). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined using the method of Goering and Van Soest (1970).

Table 1. Ingredients and chemical composition of the diet consumed by ruminally fistulated crossbred beef steers used for the *in situ* trials (% of DM basis)

Ingredient	% DM basis
Cassava chip	72.7
Rice bran meal	22.8
Urea	2.5
Minerals and vitamins ¹	1.0
Salt	1.0
Estimated values (total diet)	
DM, %	88.7
CP, %	12.0
TDN, %	75.4

¹ Mixed minerals and vitamins.

CP=Crude protein, TDN=Total digestible nutrient.

Data analysis

Data for ruminal disappearance characteristics of DM and OM were fitted to the exponential equation following the procedure described by Ørskov and McDonald (1979) and using the NEWAY program (Chen, 1996).

$$P = a + b(1 - e^{-ct})$$

Where,

P=disappearance rate at time t (%),

a=the intercept of the degradation curve at time zero (%),

b=the fraction of DM and OM which will be degraded when given sufficient time for digestion in the rumen (%).

c=a rate constant of disappearance of fraction b (h⁻¹), and

t=time of incubation (h).

The effective degradability (ED) of DM and OM were, therefore, calculated using the following equation.

$$ED = a + b \{c / (c + k)\}$$

Where k assuming the rate of particulate outflow from the rumen, k, is 0.05 h⁻¹ by equation of Ørskov and McDonald (1979).

Analysis of variance (ANOVA) for a randomized complete block design (RCBD) (Steel and Torries, 1980) was performed on the data in the same incubation time as a separate set following the ANOVA procedure of SAS (1998).

$$\text{Model} = Y_{ij} = \mu + \delta_j + \tau_j + \epsilon_{ij}$$

Where Y_{ij} = observation in block of each time, μ = overall mean, δ_j = block effect (time), and τ_j = feed sources, ϵ_{ij} = residual.

RESULTS AND DISCUSSION

The chemical composition of the seven feed sources is given in the Table 2. With the exception of rice bran, all the seven feeds had similar dry matter (DM), organic matter (OM), crude protein (CP), ash, neutral detergent fiber (NDF) and acid detergent fiber (ADF). The rice bran contained the highest CP, ash, NDF and ADF (13.3, 8.0, 35.1 and 20.3%, respectively) and CW had higher NDF (32.4%) but similar ADF to those of the other feeds.

Ruminal DM and OM disappearances of seven feeds are shown in Figures 1 and 2, respectively. Ruminal DM and OM disappearances increased with rumen incubation time for all feed sources (0 to 48 h). CC had the greatest values at all times and the lowest DM and OM disappearances

Table 2. Chemical composition of energy sources used for *in situ* trials (DM basis)

Items	DM ¹	Ash	OM	CP	NDF	ADF
	%			%DM		
CC ²	88.6	5.1	94.9	2.0	11.3	5.0
YP	90.6	3.5	96.5	3.8	14.5	5.4
WP	96.3	3.8	96.2	2.6	15.7	4.6
PP	94.6	3.8	96.2	3.4	14.9	5.7
RB	88.4	8.0	92.0	13.3	35.1	20.3
CW	92.6	5.5	94.5	3.4	32.4	7.2
CM	88.3	1.7	98.3	7.8	10.4	4.4

¹ DM=dry matter, CP=crude protein, OM=organic matter, NDF=neutral detergent fiber, ADF=acid detergent fiber.

² CC=cassava chip; YP=yellow sweet potato; WP=white sweet potato; PP=purple sweet potato; RB=rice bran; CW=cassava waste; CM=corn meal.

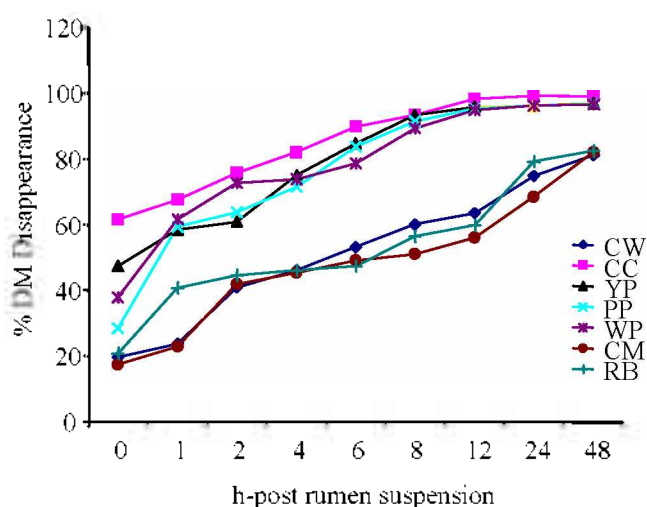


Figure 1. *In situ* DM disappearances of seven energy sources (CC=cassava chip; YP=yellow sweet potato; WP=white sweet potato; PP=purple sweet potato; RB=rice bran; CW=cassava waste; CM=corn meal) at various h-post rumen suspension.

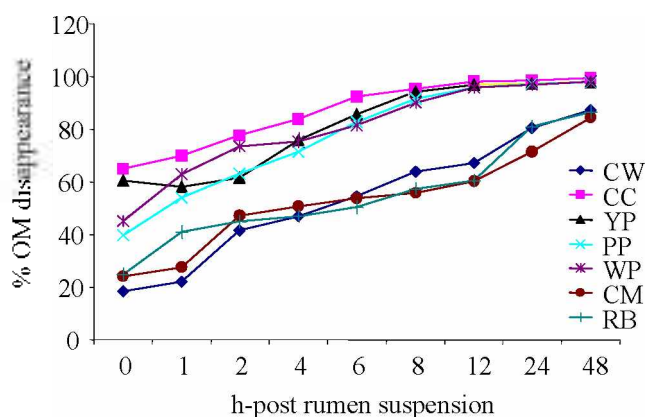


Figure 2. *In situ* OM disappearance of seven energy sources (CC=cassava chip; YP=yellow sweet potato; WP=white sweet potato; PP=purple sweet potato; RB=rice bran; CW=cassava waste; CM=corn meal) at various h-post rumen suspension.

were found with CW, CM and RB. Amount of DM and OM disappearance characteristics ranked from the highest to the lowest of degradation rate (c) as follows: CC, YP, PP, WP, CW, CM and RB, respectively. 0 h to 48 h of DM and OM degradation rate (C) of CC (23 and 26% h⁻¹) were significantly higher ($p < 0.05$) compared with all feed sources, especially CW, RB and CM, respectively. While YP, WP and PP were degraded to a similar extent, but significantly higher ($p < 0.05$) than CW, RB and CM. However, after exposure to the rumen for 8 to 48 h DM and OM disappearance of CC, YP, WP and PP were not different ($p > 0.05$). But DM and OM disappearance were higher ($p < 0.05$) than CW, RB and CM, respectively.

DM and OM disappearance characteristics of feed sources could be divided into two groups. CC, YP, WP and PP which were rapidly degraded and CW, RB and CM was generally intermediate among those of energy sources. CW and RB had greater DM and OM degradability than CM up to 24 h; but by 48 h, CW, RB and CM were degraded to a similar extent.

The degradable fraction (a) and also degradation rate constant (c) of DM and OM were highest ($p < 0.05$) on CC (61.5, 0.23; 65.0, 0.26, respectively) as compared to all feed sources. Similarly, the potential degradation (a+b) (99.3 and 99.4%) (Table 3) was higher for CC ($p < 0.05$) than for other feed sources.

The effective degradability of DM and OM at outflow rate of 0.05/h of CC (92.5 and 93.4%, respectively) were higher than all feed sources. As OM only difference of DM in each content and is expected that result would be similar for both parameter. These data were in accordance with reports by Cone et al. (1990); Nocek and Tamminga, (1991); Cone et al. (1997) who used *in vitro* and gas techniques, while Sommart et al. (1991) used in sacco technique in cattle and buffalo.

The differences could be attributed to starch difference and was greatly dependent upon sources, chemical composition and extent of processing (Cone et al., 1989; Owens et al., 1986; Nocek and Tamminga, 1991; Huntington, 1997). Moreover, The differences in rate and extent digestion have been attributed to lower of amylose content in cassava when compared with cereal grains (Cone and Wolters, 1990), probably reflecting the physicochemical characteristics of its energy and protein matrix to slow degradation of starch in oats, barley corn and wheat, respectively (Cone and Wolters, 1990; Rickard et al., 1991). As expected, starch in corn was slowly degraded. Rooney and Pflugfelder (1986) explained that the low digestibility of corn starch was result of the protein matrix associated with starch granules, the type and proportion of protein bodies found in the endosperm, and the proportion of comeous endosperm that must be disrupted for release of starch. Furthermore, these structural differences also are the

Table 3. Dry matter (DM) and organic matter (OM) disappearance in the rumen of CC, YP, WP, PP, RB, CW and CM at various incubation times in crossbred beef steers

Items	CC ¹⁾	YP	WP	PP	RB	CW	CM	CV, %
DM disappearance, %								
a	61.5 ^a	47.4 ^b	37.7 ^c	28.5 ^d	20.7 ^e	19.7 ^e	17.4 ^f	2.8
b	37.8 ^e	50.2 ^d	59.5 ^c	69.0 ^a	66.8 ^b	58.9 ^c	64.3 ^b	2.0
c	0.23 ^a	0.21 ^b	0.16 ^c	0.20 ^b	0.05 ^e	0.13 ^d	0.06 ^e	10.4
a+b	99.3 ^a	97.6 ^{ab}	97.5 ^{ab}	97.2 ^b	87.5 ^c	78.6 ^e	81.7 ^d	0.9
²⁾ Effective degradability, %	92.5 ^a	87.9 ^b	87.9 ^b	87.8 ^b	63.6 ^c	63.0 ^c	59.3 ^d	1.6
OM disappearance, %								
a	65.0 ^a	60.4 ^b	45.3 ^c	39.8 ^d	25.0 ^e	18.4 ^f	24.1 ^e	2.3
b	34.4 ^e	38.4 ^b	53.1 ^c	58.7 ^b	67.4 ^a	66.6 ^a	59.5 ^b	1.6
c	0.26 ^a	0.24 ^a	0.18 ^b	0.22 ^a	0.05 ^d	0.13 ^c	0.07 ^d	12.6
a+b	99.4 ^a	98.8 ^a	98.5 ^a	98.4 ^a	92.4 ^b	85.1 ^c	83.6 ^d	1.0
²⁾ Effective degradability, %	93.4 ^a	89.8 ^b	89.4 ^b	88.1 ^c	65.8 ^d	66.9 ^d	63.3 ^e	0.7

^{a-f} Within rows not sharing a common superscripts are significantly different ($p < 0.05$).

SEM=Standard error of the mean.

¹⁾ CC=cassava chip; YP=yellow sweet potato; WP=white sweet potato; PP=purple sweet potato; RB=rice bran; CW=cassava waste; CM=corn meal.

²⁾ Effective degradability in the rumen (assuming rate of passage of $0.05/h^{-1}$).

basis for reported differences in *in vitro* or *in vivo* digestion among feed sources, particularly starch granules which is embedded in a protein-rich matrix (Huntington, 1997). Subsequently, differences in animal performance could be attributable by grain species or varieties (Kotarski et al., 1992; Wester et al., 1992). Rate and extent of starch digestion in the rumen determined by intricate interrelations among several factors, including origin of energy, pore size of *in situ* bags, grinding, sample size, diet composition, amount of feed consumed per unit time, mechanical alterations (grain processing, chewing), chemical alterations (degree of hydration, gelatinization), diet of animals, and degree of adaptation of ruminal microbiota to the diet. Feed sources in this study were ground to pass a 1 mm screen in a wiley mill, and this small particle size may also explain the relatively high *in situ* degradabilities.

The amount of DM and OM degraded by 12 h *in situ* for CC, YP, WP and PP was greater than 95% of total, suggesting that most of the DM and OM in this energy was available to ruminal microbes. At 12 h, less than 65% of DM and OM in RB, CW and CM had been degraded. Assuming normal outflow rate for particulate matter from the rumen (Ørskov, 1982), it may be concluded that considerable DM and OM from feed sources (RB, CW and CM) would escape rumen degradation and be available for intestinal digestion. In our experiment, however, disappearance from nylon bag did not reveal effects on the total tract disappearance and the intestinal digestibility of feeds. These may differ among feed sources and the possibility of an overprotection effect will be further investigated in studies of intestinal digestibility using a mobile bag technique (De Boer et al., 1987).

The average ruminal pH and temperature were 6.65 and 38.8°C, respectively. No difference in rumen fluid pH and temperature values were noted among steers (Table 4).

Table 4. Ruminal pH and temperature (°C) in crossbred beef steers

h post feeding	Temperature means±SD	pH means±SD
0	38.5±0.7	6.95±0.5
1	39.0±0.0	6.98±0.5
2	39.0±0.0	6.40±0.4
3	38.5±0.7	6.59±0.1
4	38.5±0.7	6.50±0.3
6	40.0±0.0	6.54±0.1
8	39.0±0.0	6.33±0.4
12	39.0±0.0	6.50±0.1
24	38.5±0.7	6.75±0.1
48	38.0±0.0	6.93±0.1
Mean±SD	38.8±0.5	6.65±0.2

Ruminal pH ranged from 6.49 to 6.66 which has been reported as optimal for microbial digestion of fiber (Hoover, 1986; Firkins, 1996).

These data would potentially be used in synchronizing with degradation of NPN in the rumen to improve their feeding values for ruminants. As shown in Table 5, using effective OM degradability (%) with potential use of urea, cassava chip could be used with higher level of urea and the higher level in the concentrate the more urea could be used.

CONCLUSIONS AND RECOMMENDATIONS

The results of this study demonstrate that the ruminal disappearance characteristics of seven feeds differed among feeds and cassava chip had the greatest values at all time. Amount of DM and OM disappearance characteristics ranked from the highest to the lowest of degradation rate (c) as follows: cassava chip, yellow sweet potato, purple sweet potato, white sweet potato, cassava waste, corn meal and rice bran, respectively.

These values could potentially be used in synchronizing

Table 5. Potential use of tropical feed sources with non-protein nitrogen (NPN) especially urea (30 gN/kg DOMR ratio) (Preston and Leng, 1987)

Items	Effective OM degradability in rumen, %	Various level of energy sources replacement (%): gN/kg DOMR ¹			
		25	50	75	100
CC ²	93.4	1.45	2.90	4.35	5.80
YP	89.8	1.42	2.83	4.25	5.67
WP	89.4	1.41	2.81	4.22	5.63
PP	88.1	1.39	2.78	4.15	5.55
CW	66.9	1.04	2.07	3.10	4.14
RB	65.8	1.02	2.04	3.05	4.08
CM	63.3	0.99	1.98	2.97	3.97

¹ DOMR=organic matter digestible in the rumen (30 gN/kg DOMR) (Preston and Leng, 1987). Method to calculate gN/kgDOMR.

Equation=(N×0.46×1,000)/(I×ED×%OMI).

Where I=quantity of ingredient (kg). ED=effective degradability (%). N=quantity of urea (kg). OMI=organic matter of ingredient (%).

² CC=cassava chip; YP=yellow sweet potato; WP=white sweet potato; PP=purple sweet potato; RB=rice bran; CW=cassava waste; CM=corn meal.

with degradation of NPN in the rumen, using effective degradability (ED, %) of organic matter for optimal ruminal availability of energy: protein especially with NPN (urea) in ruminant feeding for possible increasing microbial protein synthesis. As could be seen, cassava chip could be used efficiently with high level of urea as compared to other feed sources. Furthermore, diet formulation using these values *in vivo* feeding trials would offer more useful information.

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