Nutritional Evaluation of Energy Feed Sources for Ruminant Using In Vitro Gas Production Technique

Songsak Chumpawadee¹, Kritapon Sommart², Thevin Vongpralub² and Virote Pattarajinda²

ABSTRACT

Five energy feed sources were used to evaluate for nutritive value using the in vitro gas production technique. The rumen mixed microbe inoculums were taken from fistulated Brahman-Thai native crossbred steers. The energy feed source treatments were 1) corn meal, 2) cassava chip, 3) broken rice, 4) rice bran and 5) rice pollard. The treatments were assigned to completely randomize design (four replications). The results indicated that soluble gas fractions (a) (-32.39, -50.98, -34.02, -21.67 and -3.39 mL, respectively), the fermentation of the insoluble fraction (b) (132.39, 150.98, 134.02, 119.09 and 62.66 mL, respectively), rate of gas production (c) (0.12, 0.19, 0.08, 0.11 and 0.06 %/h, respectively) and potential of extent of gas production (a+b) (164.79, 201.97, 168.05, 140.76 and 66.05 mL, respectively) were significantly different (P<0.01) among energy feed sources. The cumulative gas volumes at 24, 48 and 96 h after incubation were significantly different (P<0.01). Cassava chip exhibited the greatest gas production characteristics and gas volume. These results together with its locally available at an inexpensive cost cassava chip was one of the potential energy source for beef and dairy cattle.

Key words: in vitro, gas production, energy feeds, steers

INTRODUCTION

Energy content of ruminant feed sources is an important factor to take into consideration. Energy content should compose roughly seventy percent of feed ration (Chumpawadee, 2002). Cost, chemical composition and digestibility of energy feed source should be fully taken into account when formulate ruminant diet. Recently, the in vitro gas production technique has been proposed in use for determining fermentation kinetics of ruminant feed (Menke et al., 1979; Menke and Steingass, 1988; Blummel and Ørskov, 1993; Theodorou et al., 1994; Tessema and Baars, 2004). Nitipot and Sommart (2003) also used the in vitro gas production technique to evaluate nutritive values of cassava starch industry by-products, energy feed sources and roughages, who found that cassava and cassava starch industry by-products had high potential to be used as a locally novel energy feed source for ruminants.

With respect to energy feeds source in Thailand, limited information is available on the kinetics of degradation. Therefore, the aim of this study was to evaluate nutritive values of energy feed sources for ruminants using the in vitro gas production technique.
MATERIALS AND METHODS

Feedstuffs samples and chemical analysis

Five energy feed sources were collected from various feed mills and organizations (Kantharavichai dairy cooperation, Khonkaen dairy cooperation, Mahasarakham University feed mill, Khon Kaen University feed mill, Chareon Esan commercial feed mill, Songserm Kankaset feed supplier) in the North East of Thailand. All test feed samples (Table 1) were ground to pass through a 1 mm screen for the in vitro gas production technique and chemical analysis. The feedstuff samples were analyzed to determine dry matter (DM), crude protein (CP) and ash content (AOAC, 1990). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were assayed using the method proposed by Van Soest et al. (1991).

Experimental design

The experimental design was completely randomized (four replicates per treatment). The treatments included ground corn, cassava chip, broken rice, rice bran and rice pollard. Strict anaerobic techniques were used in all steps during the rumen fluid transfer and incubation period. Rumen fluid inoculums was removed before the morning feeding under vacuum pressure via the rumen fistula into a 2 liter glass flask and transferred into two pre-warmed 1 liter thermos flasks which were then transported to the laboratory. The medium preparation was as described by Sommart et al. (2000). Mixed rumen fluid inoculums were obtained from two fistulated Brahman-Thai native crossbred steers (weighing about 250±15 kg). The animals were offered rice straw on ad libitum and fed 0.5 % body weight of concentrate (concentrate mixture: 49.80% cassava chip, 17.5% rice bran, 14.60% palm meal, 7.0% soybean meal, 1.40% urea, 0.4% salt, 1.0 % mineral mix and 8.30% sugarcane molasses). The animals were fed twice daily, water and a mineral lick was available ad libitum for 14 days.

The feed sample of approximately 0.5 g on a fresh weight basis was transferred into a 50 mL serum bottle (Sommart et al., 2000). The bottles were pre-warmed in a hot air oven at 39°C for about 1 hour prior to injection of 40 mL of rumen fluid medium (using a 60 mL syringe) to each bottle. The bottles were stoppered with rubber stoppers, crimp sealed and incubated in a hot air oven set at 39°C.

The rate of gas production was measured by reading and recording the amount of gas volume after incubation using a 20 mL glass syringe connected to the incubation bottle with a 23 gauge, 1.5 inch needle. Readings of gas production were recorded from 1 to 96 h (hourly from 1-12 h, every 3 h from 13-24 h, every 6 h from 25-48 h and every 12 h from 49-96 h) after incubation periods. Amount of cumulative gas volume 2, 4, 6, 12, 24, 48, 72 and 96 h after incubations were fitted using the equation $y = a + b [(1-\exp(-ct))]$ (Ørskov and

Table 1  Chemical composition of energy feed sources.

<table>
<thead>
<tr>
<th>Feedstuffs¹</th>
<th>DM(%)</th>
<th>CP</th>
<th>Ash</th>
<th>NDF</th>
<th>ADF</th>
<th>ADL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%DM basis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GC</td>
<td>92.20±0.05</td>
<td>8.53±0.10</td>
<td>1.69±0.02</td>
<td>13.25±0.17</td>
<td>3.63±0.06</td>
<td>0.41±0.03</td>
</tr>
<tr>
<td>CC</td>
<td>93.40±0.39</td>
<td>1.89±0.07</td>
<td>2.01±0.08</td>
<td>6.93±0.68</td>
<td>6.35±0.22</td>
<td>1.87±0.13</td>
</tr>
<tr>
<td>BR</td>
<td>92.06±0.38</td>
<td>7.80±0.15</td>
<td>0.66±0.02</td>
<td>9.28±0.11</td>
<td>0.65±0.08</td>
<td>0.12±0.01</td>
</tr>
<tr>
<td>RB</td>
<td>91.70±0.06</td>
<td>14.26±0.32</td>
<td>6.31±0.07</td>
<td>20.29±0.24</td>
<td>8.12±0.10</td>
<td>2.61±0.008</td>
</tr>
<tr>
<td>RP</td>
<td>90.49±0.02</td>
<td>8.46±0.28</td>
<td>14.08±0.08</td>
<td>61.18±0.30</td>
<td>45.96±1.27</td>
<td>11.91±0.32</td>
</tr>
</tbody>
</table>

Where: DM = dry matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; ADL = acid detergent lignin

¹ GC = ground corn, CC = cassava chip, BR = broken rice, RB = rice bran, RP = rice pollard
McDonald, 1979), where $a$ = the intercept, which ideally reflects the fermentation of the soluble fraction, $b$ = the fermentation of the insoluble fraction, $c$ = rate of gas production, $(a+b)$ = potential extent of gas production, $y$ = gas production at time ‘$t$’.

**Statistical analyses**

All data obtained from the trials were subject to the analysis of variance procedure of statistical analysis system (SAS, 1996) according to a completely randomized design. Means were separated by Duncan New’s Multiple Range Test. The level of significance was determined at $P<0.01$.

**RESULTS AND DISCUSSION**

**Chemical compositions of energy feed sources**

The chemical compositions of energy feed sources are presented in Table 1. Generally, wide variations existed in the chemical composition of the investigated feedstuffs. The crude protein content ranged from 1.89 % for cassava chip to 14.08 % for rice bran meal. Ash content ranged from 0.66 % for broken rice to 14.08 % for rice pollard. Neutral detergent fiber content ranged from 6.93 % for cassava chip to 61.18 % for rice pollard. Acid detergent fiber ranged from 0.65 % for broken rice to 45.98 % for rice pollard. Acid detergent lignin ranged from 0.12 % for broken rice to 11.91 % for rice pollard.

There are many factors that affect chemical composition of energy feed sources such as stage of growth, maturity, species or variety (von Keyserlingk et al., 1996; Agbagla-Dohnani et al., 2001 and Promkot and Wanapat, 2004), drying method, growth environment, (Mupangwa et al., 1997) and soil types (Thu and Preston, 1999). These factors may partially explain differences in chemical composition between this study and the others.

**Gas production characteristics of energy feed source**

Gas production from the fermentation of energy feed sources was measured at 2, 4, 6, 12, 24, 48, 72 and 96 h using *in vitro* gas production technique adapted to describe the kinetics of fermentation based on the modified exponential model $y = a + b \times (1 - \text{Exp}(-ct))$ (Ørskov and McDonald, 1979). The gas production characteristics are presented in Table 2 and Figure 1. The intercept ($a$) was lowest ($P<0.01$) in cassava chip, compared to all other feed sources. However, absolute $a$ ($|a|$) is used to describe ideally reflects the fermentation of the soluble fraction. The absolute $a$ was highest in cassava chip. The findings were similar to those report by Nitipot and Sommart (2003).

The gas volume at asymptote ($b$) described the fermentation of the insoluble fraction. The fermentation of the insoluble fraction of energy feed sources were significantly different ($P<0.01$). The fermentation of insoluble fractions of cassava chip, broken rice, corn meal, rice bran and rice pollard were: 150.98, 134.02, 132.39, 119.09 and 62.66 mL, respectively. The fermentation of the insoluble fraction was highest in cassava chip and lowest in rice pollard. The results suggest that cassava chip has the highest potential for use as ruminant feed when compared to the remaining energy feed sources.

Rates of gas production ($c$) expressed in %/h, ranked from the fastest to the slowest were cassava chip, ground corn, rice bran, broken rice and rice pollard, respectively. The rate of gas production was highest in cassava chip. These results were closely related to reports by Chanjula et al. (2003), who studied the *in sacco* technique. They also found that cassava chip had the highest rate of degradation when compared all other energy feed sources. Additionally, these results were similar to reports by Nitipot and Sommart (2003) who studied the *in vitro* gas production technique. They found that the rate of gas production of cassava chip was higher than that in
corn meal, broken rice and other industrial by-products. Potential extents of gas production \((a+b)\) expressed in mL as ranked from the highest to the lowest were: cassava chip, broken rice, ground corn, rice bran and rice pollard, respectively. These findings were similar to reports by Nitipot and Sommart (2003), which found that cassava chip

Table 2  Gas production characteristics and gas volume of energy feed sources using gas production technique.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Treatment(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GC</td>
</tr>
<tr>
<td>Gas production characteristic(^2)</td>
<td></td>
</tr>
<tr>
<td>(a), mL</td>
<td>-32.39(^c)</td>
</tr>
<tr>
<td>(b), mL</td>
<td>132.39(^b)</td>
</tr>
<tr>
<td>(c), %/h</td>
<td>0.12(^b)</td>
</tr>
<tr>
<td>(a+b), mL</td>
<td>164.79(^b)</td>
</tr>
<tr>
<td>Gas production (mL/0.5g)</td>
<td></td>
</tr>
<tr>
<td>24 h</td>
<td>123.0(^b)</td>
</tr>
<tr>
<td>48 h</td>
<td>159.12(^b)</td>
</tr>
<tr>
<td>96 h</td>
<td>176.87(^b)</td>
</tr>
</tbody>
</table>

\(^{a,b,c,d}\) Means within a row with different superscripts differ at \(P<0.01\)

1  GC = ground corn, CC = cassava chip, BR = broken rice, RB = rice bran and RP = rice pollard
2  \(a\) = the intercept (mL), which ideally reflects the fermentation of the soluble fraction, \(b\) = the fermentation of the insoluble fraction (asymptote) (mL), \(c\) = rate of gas production (%/h), \((a+b)\) = potential extent of gas production (mL)

Figure 1  Cumulative gas volume estimated by \(y = a+b \cdot (1-\text{Exp}(-ct))\) (mL/0.5 gDM Substrate) throughout 96 h. (GC = ground corn, CC = cassava chip, BR = broken rice, RB = rice bran and RP = rice pollard).
had the highest potential gas production. It was possible that cassava chip also had the lowest NDF content. Thus, cassava chip is more easily degradable than other energy feed sources. The present study was in agreement with Sommart et al. (2000) and Nitipot and Sommart (2003) because energy feed source having lower NDF showed higher potential extent of gas production (Table 1 and Table 2).

**Gas volume**

Cumulative gas volumes 24, 48 and 96 h after incubation are shown in Table 2. The results indicated that cumulative gas volumes at 24, 48 and 96 h after incubation were significantly different (P<0.01). The gas volumes ranked from the highest to the lowest were: cassava chip, broken rice, ground corn, rice bran and rice pollard, respectively. Menke et al. (1979) suggested that gas volume 24 h after incubation was in direct relationship with metabolizable energy in feedstuffs. Sommart et al. (2000) suggested that gas volume was a good parameter to predict digestibility, fermentation end-product and microbial protein synthesis of the substrate by rumen microbes in the *in vitro* system. Additionally, *in vitro* dry matter and organic matter digestibility were shown to have high correlation with gas volume (Sommart et al., 2000; Nitipot and Sommart, 2003). Gas volume has also shown to have a close relationship with feed intake (Blummel and Becker, 1997) and growth rate (Blummel and Ørskov, 1993).

**CONCLUSIONS**

Chemical composition and kinetics of gas production were different among the different energy feed sources. The potential extent of gas production, ranked from the highest to the lowest were cassava chip, broken rice, ground corn, rice bran, and rice pollard. Because cassava chip is available locally and inexpensive, it is the best potential energy source for beef and dairy cattle.

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**LITERATURE CITED**


