International Journal of
Dairy Science

ISSN 1811-9743

Academic
Journals Inc.

www.academicjournals.com

International Journal of Dairy Science 2 (3): 217-225, 2007
ISSN 1811-9743

Evaluation of the Banana (*Musa paradisiaca*) Plant By-product's Fermentation Characteristics to Asses Their Fodder Potential

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Abstract: Banana by-products viz., stem, pseudostem and leaves were evaluated in three sequential runs measured at 8, 12, 24, 48 and 72 h using Hoheneim gas production test on rumen fermentation pattern. The exponential equation of gas produced by Stem is Y = -6.68+56.71 (1-EXP$^{(-0.0153\ t-l)}$) Lag time: 8.2 h, RSD1.09, pseudostem is Y = -11.14+69.27 (1-EXP$^{(-0.0209\ t-l)}$) Lag time: 8.4 h, RSD1.86 and leaves is Y = -3.79+44.58 (1-EXP$^{(-0.0259\ t-l)}$) Lag time 3.4 h, RSD1.40. The acetate propionate ratio was observed to be relatively higher in leaves than stem and pseudostem. The apparent and true dry matter degradability of the stem was significantly ($p<0.05$) lower than pseudostem and leaves. Pseudostem and leaves were able to generate microbial production at significantly ($p<0.05$) higher level than stem at 24 and 36 h of incubation, while stem could support significantly ($p<0.05$) better than pseudostem and leaves later than 48 h of incubation. Inverse relationship existed between ^{Y}ATP and incubation period. Pseudostem had the lowest partition factor compared to stem and leaves. The values range from 2.24 to 4.99. The half time ($T^{1}/_{2}$) was 45.46 h for stem, 33.03 h for pseudostem and 26.8 h for leaves. The microbial biomass production, energetic efficiency of Volatile fatty acids and ^{Y}ATP was significantly ($p<0.05$) highest in leaves when compared to stem and pseudostem at $T^{1}/_{2}$ of c. Hence among by-products evaluated for their fodder potential to cattle, banana leaves rank first with low partition factor, high ^{Y}ATP and high microbial biomass followed by pseudostem and banana stem.

Key words: Banana, by products, stem, leaves, pseudostem, fermentation

INTRODUCTION

Animal agriculture is one of the most important components of global agriculture. However, a major constraint of livestock rearing in tropical countries is chronic feed shortage. Tapping the available fodder resources is one of the options to bridge the gap. Crop residues are the best resources to be explored in this context; as such attempts do not require additional cultivable land. However, very few of fodder have been screened for their use in animal feed. Many more are yet to be evaluated before being used as animal feed. Banana by-products are one among them.

Banana (*Musa paradisiaca*) is a traditional plant cultivated widely for its fruits. After harvesting of the fruit, the various other parts of the plant (by products) are not effectively utilised. It has been estimated that a residual biomass (pseudostem and leaves) of 13 to 20 tones dry matter/hectare/year is available. Gupta *et al*. (2001) suggested that feeding of whole banana plants (stem and leaves) will meet the maintenance requirement of cattle. Hembade and Patel (2004) concluded that banana leaves can be incorporated in the diet of kids. However, at present they are thrown out as waste on roadsides, or allowed to rot away in the fields or some times burnt in the field.

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In order to throw light on the efficacy of banana by products to serve as a potential source of roughage to ruminants, a study was undertaken to evaluate the various by-products of banana as a source of feed to ruminants through studying the effect of banana plant by products on rumen fermentation pattern.

MATERIALS AND METHODS

The by-products viz., stem, pseudostem and leaves from various banana growing areas in Tamil Nadu state at India were collected as follows:

- Banana stem sample was collected from the portion immediately above the rhizome. Banana pseudostem was collected from the ground level to the (1 feet below) portion of the petiole and banana leaves were collected with mid rib excluding petiole.
  The samples were chopped, dried and ground to pass one mm sieve and stored in airtight container.

Evaluation of Fermentation Characteristics of Banana By-Products

In vitro Gas Production

The banana by-products were evaluated using Hoheneim gas production test as per the procedure of Menke and Steingass (1988) to evaluate their fermentation characteristics.

In vitro Gas Production Studies

The rumen liquor was obtained from three Jersey crossbred cattle maintained on grazing alone to ensure that cellulolysis was optimum. All the laboratory handling of rumen fluid was carried out under continuous flushing with CO_2.

Accurately weighed 500 mg samples and 40 mL rumen buffer volume was taken per 100 mL glass syringe for incubation as described by Blummel and Becker (1997) to minimize the analytical error in gravimetric determinations of apparent and truly degraded substances. The syringe nozzle was fastened with butyl rubber cap designed to fit airtight.

Three blanks containing rumen buffer alone were included for each incubation period. The syringes were rotated at one rotation per minute as described by Menke *et al.* (1979).

Measurements

The syringes were incubated in duplicate in three sequential runs. Gas production was recorded at 8, 12, 24, 48 and 72 h. Piston of the syringes was reset to 10 mL mark by releasing the gas production whenever it reached the level of 60 mL mark. The release of gas was done by withdrawing the gas with the help of another syringe by piercing through the butyl rubber cap of the 100 mL syringe with 23G needle. This step prevents the atmospheric air equilibrating the fermented gas in the process of releasing the excess gas. Net gas volume at each incubation hour was calculated by subtracting the mean gas volume of blank from mean gas volume of syringe with sample.

Characteristic of Gas Production

The results of gas volume at various time intervals were fitted to exponential equation (Blummel and Orskov, 1993) and modified for lag phase as suggested by Krishnamoorthy *et al.* (1991).
The Eq. is:

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

Where,

P = Gas production
t = Time
a+b = Potential gas production
c = Rate of gas production

a, b and c are constant in exponential equation.

With lag phase: $P = a+b\ (1 - e^{-c(t-l)})$

Where l = initial lag for on set of fermentation.

Chemical Analysis

At the end of each incubation hours, the whole contents of the syringes was transferred into 45 mL capped centrifuge tubes. Residues were centrifuged in an ultracentrifuge (HIMAC, model SCR 20BA, Hitachi) at 20,000 g for 30 min at 4°C. 2.5 mL of supernatant was collected for VFA and added into glass tubes, which already contained 0.5 mL metaphosphoric acid (25%).

Volatile Fatty Acids Estimation

Total and individual short chain fatty acids concentrations were measured by gas chromatograph method as per the procedure of Chase (1990). Netel make of gas chromatograph model omega QC was used in this study. The internal standard used in analysis was 2 ethyl butyric acid.

Column Conditions/Requirements

Stainless steel column of 6 inches × 2 mm internal diameter packed with 10 percent SP 1200/1 percent phosphoric acid and on 30/100 chromosorb W(AW), was used in the present study of separating C_2 to C_5 volatile fatty acids in the sample. Column temperature was maintained at 130°C, inlet temperature and detector temperature were maintained at 170 and 210°C, respectively. The flow of carrier nitrogen was kept at 40 mL min^{-1}. The flame ionization detector was used. The concentrations of volatile fatty acids were calibrated from the standards.

Stoichiometry Derivations

The following stoichiometrical derivations were considered in this study.

- Calculation of CO_2 and CH_4 produced from VFA (Wolin, 1960):
  CO_2 (moles) = a/2+p/4+1.5 x b
  CH_4 (moles) = a+2b – CO_2
  Where a = acetate, b = butyrate and p = propionate.
  In *in vitro* gas production, additionally 1 mmol of SCFA produces one mmol of CO_2
  Volumes (v) were calculated as
  V = mmol × gas constant × temperature k/pressure (p)
- The relationship between SCFA production and ATP production (Blummel *et al*., 1997a)
  1 mmol acetate = 2 mmol ATP
  1 mmol propionate = 3 mmol ATP
  1 mmol butyrate = 3 mmol ATP
  1 mmol CH_4 = 1 mmol ATP
- $\text{A/P ratio} = \frac{\text{Acetate}}{\text{Propionate}}$
- Energy efficiency of VFA = 0.622 A+1.092 P+1.56 B/A+P+2B (where A, P and B represent acetic, propionic and butyric acids (Mol percent) (Orskov *et al*., 1968).

In vitro Degradability Studies

The degradability studies on banana by-products were studied at 24, 36, 48 and 72 h.

Apparent Digestibility

The apparent digestibility was determined as per Blummel *et al.* (1997b).

Analysis of _in vitro_ True Degradability

In vitro true degradabilities were determined by refluxing the pellet contained in the centrifuge tubes to separate the microbial mass from the undegraded substrate. To achieve this, the pellet was transferred from the tubes into 600 mL spoutless beakers and the centrifuge tubes were thoroughly washed with about 70 mL neutral detergent solution and reflexed for one hour (Van Soest and Robertson, 1985) which was added to the beakers. True degradability was calculated as the weight of substrate incubated minus the weight of the residue after NDS treatment.

Partition Factor

Partition factor was calculated using the following formula (Blummel *et al.*, 1994; Blummel *et al.*, 1997a).

$$\text{Partition factor (PF) mg mL}^{-1} = \frac{\textit{In vitro}\text{ truly degraded substrate}}{\text{Volume of gas produced}}$$

Microbial Biomass

The microbial biomass was calculated from the equation quoted by Blummel *et al.* (1997a). Microbial biomass = Substrate truly degraded-Substrate apparently degraded.

Efficiency of Microbial Production

The efficiency of microbial production was calculated using the following formula:

$$\text{Efficiency of microbial production} = \frac{\text{Microbial biomass}}{\text{Substrate truly degraded}}$$

^{Y}ATP

^{Y}ATP was calculated using the following formula:

$$^{Y}\text{ATP} = \frac{\text{Efficiency of microbial production}}{\text{ATP produced}}$$

RESULTS

Evaluation of Degradation Characteristics and Rumen Fermentation Pattern of Banana By-products by _in vitro_ Studies

The cumulative gas produced (mL) for 500 mg incubation of substrate viz., banana stem, banana pseudostem and banana leaves for various hours of incubation is furnished in Table 1. The description of the gas produced is furnished through exponential equation as follows:

Stem: $Y = -6.68+56.71\ (1-EXP^{(-0.0153\ t-1)})$ Lag time: 8.2 h, RSD 1.09,
Pseudostem: $Y = -11.14+69.27\ (1-EXP^{(-0.0209\ t-1)})$ Lag time: 8.4 h, RSD 1.86,
Leaves: $Y = -3.79+44.58\ (1-EXP^{(-0.0259\ t-1)})$ Lag time: 3.4 h, RSD 1.40,

Table 1: Effect of banana by-products (500 mg) on various *in vitro* parameters and stoichiometric derivations at various hours of incubation (Mean±SE)

By products	Cumulative gas produced (mL/500 mg)	Acetate	Butyrate	Propionate	CO_2:CH^4	ATP produced (mmol L^{-1})
		(mmol L^{-1})				
8 h						
Stem	0.77±0.07^a	21.82±1.69^b	1.60±0.14^a	1.04±0.64	1.18±0.10^a	*
P stem	1.00±0.04^a	20.07±1.28^b	1.04±0.16^a	1.03±0.82	1.15±0.09^a	*
Leaves	3.58±0.11^b	17.77±1.66^a	2.52±0.19^b	1.05±0.67	1.30±0.14^b	*
12 h						
Stem	2.01±0.14^a	23.68±1.48^b	2.30±0.26^b	2.36±0.28	1.28±0.09^a	*
P stem	2.75±0.18^a	23.80±1.27^b	1.54±0.18^a	2.23±0.17	1.21±0.08^a	*
Leaves	8.11±1.01^b	18.19±1.39^a	2.79±0.22^b	1.23±0.18	1.33±0.10^b	*
24 h						
Stem	9.95±1.03^a	24.90±1.12	2.82±0.42^a	2.59±0.51^a	1.31±0.12^a	2.61±0.21
P stem	14.83±1.54^b	22.49±1.25	2.91±0.70^a	2.97±0.26^a	1.36±0.08^a	2.62±0.19
Leaves	16.83±2.01^b	23.50±1.10	5.23±0.42^b	1.70±0.51^a	1.43±0.14^b	2.68±0.14
36 h						
Stem	17.22±2.04^a	34.21±1.91	7.77±0.53^b	5.13±0.38^b	1.52±0.10^b	2.69±0.19
P stem	27.50±2.64^b	31.91±4.08	5.60±0.81^b	5.62±0.97^a	1.48±0.90^b	2.66±0.19
Leaves	23.22±2.51^b	33.50±1.61	5.23±0.71^a	2.70±0.21^a	1.35±0.13^a	2.64±0.15
48 h						
Stem	23.90±3.08^a	78.54±9.20^b	14.13±2.01^b	12.21±1.79^b	1.46±0.12^b	2.66±0.11
P stem	32.50±3.54^b	80.99±4.62^b	10.94±0.47^b	18.89±1.09^b	1.49±0.15^b	2.64±0.21
Leaves	27.91±3.61^b	40.90±2.37^a	6.51±0.39^a	3.46±0.28^a	1.36±0.18^a	2.64±0.20
72 h						
Stem	30.66±3.01^a	83.78±4.23^b	17.05±0.98^b	13.29±0.89^b	1.50±0.14^b	2.67±0.20
P stem	42.50±3.41^c	104.89±5.18^c	18.43±0.94^b	25.71±1.44^c	1.56±0.12^b	2.66±0.23
Leaves	33.87±3.24^b	53.54±2.69^a	7.84±0.53^a	4.63±0.53^a	1.34±0.09^a	2.63±0.24

By products	Apparent digestibility DM (%)	True digestibility DM (%)	Microbial biomass production (%)	Efficiency of microbial production	^{Y}ATP	Partition factor
8 h						
Stem	*	*	*	*	*	*
P stem	*	*	*	*	*	*
Leaves	*	*	*	*	*	*
12 h						
Stem	*	*	*	*	*	*
P stem	*	*	*	*	*	*
Leaves	*	*	*	*	*	*
24 h						
Stem	3.54±0.58^a	4.45±0.59^a	0.91±0.05^a	20.45±1.24^a	0.34±0.02^a	2.24±0.12^a
P stem	4.08±0.74^a	7.81±0.68^b	3.73±0.22^b	47.76±2.34^b	1.41±0.07^b	2.63±0.13^a
Leaves	7.13±0.94^b	12.71±1.01^c	5.58±0.35^c	43.90±2.11^b	2.07±0.61^c	3.47±0.62^b
36 h						
Stem	14.89±1.07^a	16.52±1.11^a	1.63±0.09^a	9.87±0.84^a	0.60±0.03^a	4.8±0.23^b
P stem	18.24±1.15^b	22.43±1.06^b	4.19±0.53^b	18.68±1.06^b	1.57±0.01^b	4.08±0.51^a
Leaves	18.81±0.94^b	22.13±1.21^b	3.32±0.19^b	15.0±1.31^b	1.25±0.02^b	4.97±0.24^b
48 h						
Stem	20.02±2.16^a	23.18±1.21^a	3.16±0.21	13.63±1.15^b	1.18±0.31	4.85±0.89^b
P stem	24.02±1.67^b	26.78±1.76^b	2.76±0.17	10.31±1.05^a	1.04±0.04	4.12±0.20^a
Leaves	24.16±1.94^b	26.94±1.67^b	2.78±0.18	10.32±1.15^a	1.05±0.03	4.99±0.31^b
72 h						
Stem	22.82±1.85^a	26.46±2.41^a	3.64±0.22^b	13.76±1.24^b	1.35±0.03^b	4.32±0.19^b
P stem	28.42±1.94^b	30.43±2.67^b	2.01±0.12^{ab}	6.61±0.57^b	0.75±0.04^a	3.58±0.22^a
Leaves	29.71±1.99^b	31.38±2.78^b	1.67±0.08^a	5.32±0.49^b	0.63±0.04^a	4.55±0.20^b

Mean of six measurements; Means bearing different superscript within column at concerned incubation hour differ significantly ($p<0.05$), *Not estimated as it is inappropriate

The cumulative gas volumes from incubation of 500 mg of banana by-products ranged from 30.66 to 42.5 mL. The rates © of gas production ranged from 1.5 to 2.6% per hour.

Studies on End Products and Their Stoichiometric Derivations

The mean effect of banana stem, banana pseudostem and banana leaves on *in vitro* synthesis of mean short chain fatty acids (mmol L^{-1}), CO_2 to CH_4 ratio, ATP produced (mmol L^{-1}), percent apparent and true degradabilities, microbial biomass production, efficiency of microbial production, ^{Y}ATP production and partition factors (mg/mL) at various h of incubation are presented in the Table 1.

The molar proportion of VFA across incubation period and across banana by-product studies ranged form 84 to 89% acetate, 1 to 5% propionate and 5 to 14% butyrate. The banana by-products were relatively acetogenic. Among the short chain fatty acids, acetate production in banana leaves was consistently lower than stem and pseudostem ($p<0.05$) for most of the incubation periods studied. The butyrate production in stem and pseudostem increased steeply from 2.82 and 2.91 mmol L^{-1} at 24 h to 17.05 and 18.43 mmol L^{-1} at 72 h, respectively. The corresponding yield (5.23 to 7.84 mmol L^{-1}) differed significantly ($p<0.05$) from leaves. The propionate production in leaves was significantly ($p<0.05$) lower than stem and pseudostem from 24 to 72 h of incubation.

The acetate propionate ratio was observed to be relatively higher and consistent at 16.82 to 11.54 for 8 to 72 h in leaves than stem and pseudostem. whereas stem and pseudostem showed wide variations ranging from the ratio of about 20.0 at 8 h of incubation to the ratio of about 6.0 at 72 h of incubation.

The CO_2 to CH_4 ratio remained similar for all the three substrates. The ATP production (mmol L^{-1}) for the three substrates revealed a spurt at 24 h of incubation for pseudostem and leaves whereas stem recorded gradual elevation from 8 to 36 h.

The apparent as well as the true dry matter degradability of the three substrates at 36, 48 and 72 h of incubation revealed a significantly ($p<0.05$) lower degradability for stem, compared to pseudostem and leaves. However, at 24 h of incubation, the three substrates had significantly ($p<0.05$) different true digestibilities of 4.45, 7.81 and 12.71 for stem, pseudostem and leaves respectively. Consequently, the microbial yield also showed similar significant difference at 24 h incubation period. The microbial biomass production at 36 h showed a different pattern with stem being significantly ($p<0.05$) lower than pseudostem and leaves and no significant difference was observed at 48 h incubation, whereas at 72 h of incubation, stem had maximum microbial production followed by pseudostem and significantly ($p<0.05$) lowest in leaves.

The ^{Y}ATP calculated based on the efficiency of microbial production per unit of ATP produced revealed an inverse relationship between ^{Y}ATP and incubation period. The partition factor derived from the substrate truly degraded per mL of gas produced indicated pseudostem had the lowest partition factor when compared to stem and leaves. The values range from 2.24 to 4.99.

Table 2: Effect of banana by-products on the ratios of Acetate and Propionate, CO_2 to CH_4, energetic efficiency, apparent, true digestibility, partition function, ATP production, microbial biomass production, efficacy of microbial production and ^{Y}ATP produced at half time (hours of c during incubation (Mean±SE per 500 mg of each substrate)

Parameters	Stem 48 h	Pseudostem 36 h	Leaves 24 h
A:P	13.81±0.98^{b}	5.67±0.52^{a}	6.43±0.49^{a}
CO_2:CH_4	1.46±0.12^{b}	1.48±0.90^{b}	1.43±0.14^{a}
Energetic efficiency	32.54±2.45^{a}	43.09±3.51^{b}	104.88±5.68^{c}
Partition factor (mg mL^{-1})	4.85±0.89^{b}	4.08±0.51^{a}	3.47±0.62^{a}
ATP production (mmol L^{-1})	2.66±0.11	2.66±0.19	2.68±0.14
Microbial biomass production (%)	3.96±0.21^{a}	4.19±0.53^{b}	5.58±0.35^{c}
Efficiency of microbial production	16.50±1.15^{a}	18.70±1.06^{a}	43.90±2.11^{b}
^{Y}ATP	1.487±0.31^{b}	1.574±0.61^{b}	2.077±0.56^{b}

Numerical before the substrate denote the half time (h) of c during incubation; Mean of six measurements; Means bearing different superscript within row differ significantly ($p<0.05$)

Keeping in view of Blummel and Lebzien (2001) suggestion to evaluate diets at diet specific time (half time) instead of uniform time interval, the generated data in this study was compared according to their half time of c.

The half time (T½) was found to be 45.46 h for stem, 33.03 h for pseudostem and 26.8 h for leaves. Therefore, the data generated at 48 h for stem, 36 h for pseudostem and 24 h for leaves were compiled for relative values viz., ratio/efficiencies and presented in Table 2. The relative values were given more weightage for the purpose of comparison. Stem had significantly ($p<0.05$) highest acetate to propionate ratio, lowest energetic efficiency of VFA than pseudostem and leaves. The energetic efficiency was significantly ($p<0.05$) highest in leaves and CO_2:CH_4 ratio was lowest in leaves. Similarly the microbial biomass production, energetic efficiency of VFA and ^{Y}ATP was significantly ($p<0.05$) highest in leaves when compared to stem and pseudostem at T½ of c.

DISCUSSION

Evaluation of Degradation Characteristics and Rumen Fermentation Pattern of Banana By-Products by *in vitro* Studies

The initiation of gas production varied with substrate, banana leaves at 3.4 h banana stem at 8.2 h and pseudostem at 8.4 h. Even though, leaves produced gas at 3.4 h itself, subsequent measurement of gas at 48 and 72 h revealed lower cumulative gas production than banana pseudostem but higher than banana stem. However, the cumulative gas production in leaves was significantly ($p<0.05$) lower than pseudostem and significantly ($p<0.05$) higher than banana stem at 72 h of incubation.

The observed cumulative gas production measurements were in agreement with Brenda Keir *et al.* (1997) and Ly *et al.* (1997) for banana leaves. The description of gas production for banana leaves through $Y = A+B (1 - e^{-ct-l})$ also in close agreement with those described by Ly *et al.* (1997). However, literature reviewed did not provide information on the gas production values for banana stem and banana pseudostem.

The proximate principles and fibre fractions of the substrates viz., banana stem, banana pseudostem and banana leaves (Amarnath, 2002) do not explain the different course of the gas production by the three substrates, except for banana stem having lower organic matter resulting in delayed onset as well as lower gas production. However, mathematical modelling predicts higher potential gas production in stem than leaves.

Spurt in ATP production (mmol L^{-1}) at 24 h of incubation for pseudostem and leaves may probably indicate the optimal incubation duration required for the concerned substrate to express its nutrient delivery to the host.

The *in vitro* apparent dry matter digestibility values for stem (20.02%) at 48 h incubation obtained in this study found to be lower than the IVDMD value observed by various authors (Geoffroy *et al*., 1978; Pieltain *et al*., 1999). Similarly the *in vitro* apparent dry matter degradability values (24.02%) of pseudostem at 48 h also found to be lower than the values reported by various authors (Viswanathan *et al*., 1989; Pieltain *et al*., 1999).

The dry matter apparent digestibility value (24.16%) of leaves at 48 h of incubation period in this study found to be lower than the values 61.7% as reported by Shem *et al.* (1995). The *in vitro* apparent digestibility results obtained in this study were lower than the *in vivo* results of degradability of pseudostem (Viswanathan *et al*., 1989) and leaves (Shem *et al*., 1995). The true dry matter digestibility for banana stem observed in the study was in dis-agreement with Goeffroy *et al*. (1978) who reported IVDMD for banana stem as 78-82% and with Pieltain *et al.* (1999) with the value of 68.4% IVOMD. Similarly, the IVDMD and IVOMD values reported by various authors (Viswanathan *et al*., 1989; Pieltain *et al*., 1999) were higher than the values obtained in this study for pseudostem as well as for leaves reported by Pezo and Fanola (1980).

The only agreement with the reported values was Pieltain *et al.* (1999) who reported that IVOMD for banana leaves were as 35.2%. The *in vivo* digestibility figures reported for stem (Pieltain *et al.*, 1999), for pseudostem (Ffoulkes and Preston, 1978) and leaves (Reddy and Reddy, 1991; Shem *et al.*, 1995) were all higher than the corresponding values obtained in this study. Variety difference could only be the possible reason between reported and observed values.

The efficiency of microbial production based on the microbial production for truly degradable substrate indicated the pseudostem and leaves were able to generate microbial production at significantly ($p<0.05$) higher level than stem at 24 and 36 h of incubation. The stem was able to support microbial production significantly ($p<0.05$) better than pseudostem and leaves later than 48 h of incubation.

Banana leaves had significantly ($p<0.05$) highest microbial biomass production, energetic efficiency of VFA and ^{Y}ATP compared to stem and pseudostem at T½ of c. Since T½ of c is the right period to judge the relative merit of the various resources, among the three banana by-products evaluated for their fodder potential to cattle, banana leaves rank first with low partition factor, high ^{Y}ATP and high microbial biomass followed by pseudostem and banana stem in that order.

ACKNOWLEDGMENT

The authors gratefully acknowledge the Tamil Nadu Veterinary and Animal Sciences University authorities for the facilities rendered in conducting this study as a part of M.V.Sc Thesis.

REFERENCES

Amarnath, R., 2002. *In vitro* studies to evaluate the various by-products of banana plant as a source of feed to ruminants. Thesis submitted to Tamil Nadu Veterinary and Animal Sciences University, MVC, Chennai-7.

Blummel, M. and E.R. Orskov, 1993. Comparison of *in vitro* gas production and nylon bag degradability of roughages in predicting feed intake in cattle. Anim. Feed. Sci. Technol., 40: 109-119.

Blummel, M., H. Steingass and K. Becker, 1994. The partitioning of *in vitro* fermentation products and its bearing of voluntary feed intake. Proc. Soc. Nutr. Phys., 3: 123 Absrt.

Blummel, M. and K. Becker, 1997. The degradability characteristics of fifty four roughages and roighge neutral detergent fibre as described by *in vitro* gas production and their relationship to voluntary feed intake. Br. J. Nutr., 77: 757-768.

Blummel, M., H.P.S. Makkar and K. Becker, 1997a. *In vitro* gas production: A technique revisited. J. Anim. Physiol. Anim. Nutr., 77: 24-34.

Blummel, M., H.P.S. Makkar, G. Chisanga, J. Mtimuni and K. Becker, 1997b. The production of dry matter intake of temperature and tropical roughages from *in vitro* digestibility/gas production of African roughage in relation to ruminant live weight gain. Anim. Feed Sci. Technol., 69: 131-141.

Blummel, M. and P. Lebzien, 2001. Predicting ruminal microbial efficiencies of dairy rations by *in vitro* techniques. Livestock. Prod. Sci., 68: 107-117.

Chase, L.E., 1990. Analysis of fatty acids by packed column gas chromatography. G.C., Bulletin 856, Division of Rohand Has, Suppalco, pp: 1-12.

Ffoulkes, D. and T.R. Preston, 1978. The Banana plant as cattle feed: Digestibility and voluntary intake of different proportions of leaf and pseudostem. Trop. Anim. Prod., 3: 114-117.

Geoffroy, F., V. Fabert, E. Calif, G. Saminadin and H. Varo, 1978. Potential of banana leaves and stems as forage 1. Availability and nutritive value. Nouv. Agron. Antilles. Guyane, 4: 4.

Gupta, R.S., B.R. Devalia, G.R. Patel, J.B. Nayak and M.B. Pande, 2001. Nutritional evaluation of whole banana plant in cattle. Ind. J. Anim. Nutr., 18: 383-384.

Hembade, A.S. and P.M. Patel, 2004. Green banana leaves in the ration of kids. Ind. J. Anim. Nutr., 21: 5-7.

Keir, B., N. Van Jai, T.R. Preston and E.R. Orskov, 1997. Nutritive value of leaves for tropical trees and shrubs:1. *In vitro* gas production and *in sacco* rumen degradability. Livestock Res. Rural Development, 9: 31-34.

Krishnamoorthy, U., H. Soller, H. Steingass and K.H. Menke, 1991. A comparitive study on rumen fermentation of energy supplements *in vitro*. J. Anim. Physiol. Anim. Nutr., 65: 28-35.

Ly, J., Nguyen Van Lai, Lylian Rodriguez and T.R. Preston, 1997. *In vitro* gas production and washing losses of tropical crop residues for ruminants and pigs. Livestock Res. Rural Development, Vol. 9. www.cipav.org.co/lrrd/lrrd9/4/ly941.htm.

Menke, H., L. Raab, A. Salewski, H. Steigass, D. Fritz and W. Schneider, 1979. The estimation of digestibility and metabolizable energy content of ruminant feeding stuffs from the gas production when there are incubated with rumen liquor *in vitro*. J. Agric. Sci., 93: 217-222.

Menke, K.H. and H. Steingass, 1998. Estimation of the energetic feed value obtained from chemical analysis and *in vtro* gas production using. Rumen Fluid. Anim. Res. Dev., 28: 7-55.

Orskov, E.R., W.P. Flatt and P.W. Moe, 1968. Fermentation balance approach to estimate extent of fermentation and efficient of VFA fermentations in ruminants. J. Dairy Sci., 51: 1429-1435.

Pezo, D. and A. Fanola, 1980. Chemical composition and *in vitro* digestibility of pseudostem and leaves of banana. Trop. Anim. Prod., 5: 81.

Pieltain, M.C., J.I.R. Castanon, M.R. Ventjura and M.R. Flores, 1999. The nutritive value of banana (*Musa acuminata* L.) by products for maintaining goats. Anim. Sci., 69: 213-216.

Reddy, G.V.N. and M.R. Reddy, 1991. Utilisation of banana plant (*Musa paradiosica* L.) as feed for crossbred cattle. Ind. J. Anim. Nutr., 8: 23-26.

Shem, M.N., E.R. Orskov and A.E. Kimambo, 1995. Prediction of voluntary dry matter intake, digestible dry matter intake and growth rate of cattle from the degradation characteristics of tropical foods. Anim. Sci., 60: 65-74.

Van Soest, P.J. and R.L. Robertson, 1985. A laboratory manual for animal science 612. Ithaca, Ny: Cornell University.

Viswanathan, K., R. Kadirvel and D. Chandrasekaran, 1989. Nutritive value of banana stalk (*Musa cavendishi*) as a feed for sheep. Anim. Feed. Sci. Technol., 22: 93-113.

Wolin, M.J., 1960. A theoretical rumen fermentation balance. J. Dairy Sci., 43: 1452-1459.