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Comparative Study of Biogas Production with different Dilution Ratios of Straw and Water

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Abstract - Excessive utilization of fossil fuel as a primary source of energy brings about several crisis. Therefore, an alternative source of renewable energy, preferably biogas, production via anaerobic digestion technology has become the best solution for these energy issues. Comparing the volume of biogas produced during the digestion of the two substrates of digestion. The volume of biogas produced is always a function of the residence time of digestion and the concentration of organic matter in the experiment. In this study, rice straw was used as the raw materials and mixed with 20% cow dung starter in batch type anaerobic digestion. Among the four different dilution ratios of straw and water (1:0.5, 1:1, 1:1.5 and 1:2 v/v), 1:1 ratio was the optimum for bio-gas production within 20 days period. The addition of nutrient, ammonium molybdate (0.01%, 0.02%, 0.03% and 0.04% w/v) to the anaerobic digester of optimum ratio of rice straw and water were studied and 0.02% w/v was observed to be the best for biogas production. The compositions of gases in biogas without nutrient were observed as 9.8% H2S, 20.2% CO2, 7.5% O2 and 62.5% CH4 and with (0.02% w/v) nutrient were observed as 0.1% H2S, 28.3% CO2, 1.8% O2 and 69.8% CH4. This nutrient addition method was improved the volume of biogas as well as the percentage of me-thane gas.

Indexed Terms: Biogas; rice straw; water; dilution ratios; methane gas

I. INTRODUCTION

Biogas is an environmentally friendly fuel which is part of nature's own cycle. It consists of a mixture of methane and carbon dioxide which are produced naturally when organic materials such as animal, agricultural, domestic, and industrial wastes decompose under anaerobic conditions (wellinger, 2000).

Worldwide biogas is used to provide energy for cooking, lighting, and even running internal combustion engines. The combustible portion of the biogas is methane. The rest of the gas is carbon dioxide, with small amounts of nitrogen, oxygen, hydrogen, water, hydrogen sulphide and trace elements. The percentage of methane to carbon dioxide varies depending on the feedstock and the completeness of the process (World Energy Council, 1994).

The biogas produced contains usually 50-65% methane, 35-50% carbon dioxide (World Energy Council, 1994). However the proportions of methane and carbon dioxide keep on varying with the duration and extent of bio methanation over retention time. In order to determine the thermal capacity of the biogas, it is important to know when and how much methane is produced at a given time. It is also important to determine the composition of the other gases in order to keep track of the quality of the gas as well as assessing its greenhouse effects.

II. MATERIALS AND METHODS

A. Raw Materials for Biogas Production

Rice straw was used as the raw material for biogas production. It was collected from the farms near Mandalay Technological University (MTU), located in Patheingyi Township, upper Myanmar. It was piled up in a well ventilated room. The starter (cow dung) for the anaerobic digestion was also collected from the farms near MTU.

Table 1. Chemical composition of straw sample

Chemical component	Content (%)
Carbohydrate	32.33- 35.69
Amylose	24.81- 30.26

Protein	5.87- 6.68
Albuminoids	3.70
Fats	1.42
Lignin	14-22
Ash	12.82
Carbon	42.96
Nitrogen	0.63
C/N ratio	68

This study was aimed to develop the best yield of biogas from the optimum dilution ratio of the typical raw material, rice straw; to observe the effect of a nutrient (ammonium molybdate) addition to anaerobic digester; and to measure the purity of biogas by using Orsat gas analyzer.

B. Chemicals and Solvents

Ammonium molybdate, $(NH_4)_6Mo_7O_{24}$, $4H_2O$, from (BELL COMPANY, U.S.A) was used to increase the biogas production rate. Pellets potassium hydroxide (JUNSEI CHEMICAL Co.Ltd., JAPAN) was used for the absorption of carbon dioxide in the analysis of biogas. Pyrogallol (BDH, ENGLAND) was used to determine the composition of oxygen in the biogas mixture. 95% methyl alcohol (BDH, ENGLAND) was utilized to absorb the methane gas in the Orset meter for the percentage of methane in the biogas. 95% reagent grade (sp.gr 1.84) concentrated sulphuric acid, H_2SO_4 (BDH, ENGLAND) and 98% copper (II) sulphate,CuSO4 (BDH, ENGLAND) were used as hydrogen sulphide absorbent acidified solution in the Orset meter.

C. Equipments for Analysis of Biogas

An Orset meter (Cabinet model No.39-289 Burell Corporation, PGH.PA) with 100 mL glass materials was served as a platform for this experiment.

D. Equipment for Process Running

Lab scale digester (20 Liter, Plastic bottle), Gas holder (1 Liter, Glass), Circulation oven (230V, 30 Watt, 80 Hz, MRK Inc., JAPAN), Pipes (0.5 cm Φ and 0.4 cm Φ, Plastic), U-tube (0.5 cm, Glass), Thistle funnel (10 cm Φ, Glass) were used for process running.

III. ANALYSIS OF RAW MATERIALS (RICE STRAW)

A. Principle of Method

Moisture content of straw may be determined

i. By drying in an oven
ii. By distillation with an immiscible solvent
iii. By chemical and physical methods

The first method consists in measuring the weight lost by straw due to the evaporation of water. Drying methods are generally used as they give accurate results.

B. Apparatus Requirements

i. Porcelain crucible with lid
ii. Electric oven
iii. Desiccator

C. Procedure

Accurately weighed straw sample(ca.1g) was transferred to a lid covered porcelain crucible which had previously been ignited to constant weight. The porcelain crucible with its contents was heated in an oven at 105°C (378 K) for about two hours. During the heating, the crucible was kept slightly uncovered. After heating, the crucible was removed from the oven, and cooled in a desiccator.

Heating, cooling and weighing were repeated at hourly intervals until the loss in weigh between successive weighing did not exceed 0.5 mg.

The results of total solid and moisture contents are recorded in Table 1.

Table 2. Total Solid and Moisture Contents of Rice Straw

sample	total solid content %	Moisture content
1	83.04	16.96
2	84.00	16.00

3	94.22	15.78
Average	87.09	16.25

IV. PREPARATION OF RICE STRAW FOR ANAEROBICDIGESTION

A. Pretreatment of Straw Sample with Lime Solution

Pretreatment of raw materials for biogas production can be carried out by two reactions. They are chemical and enzyme reactions. In this research paper, biogas production was studied from rice straw which has too much lignin. So it needs to break down lignin with lime treatment. Lime treatment is suitable for rural areas, because it is cheap and easy to obtain and control.

Firstly, raw sample was cut in to small pieces 0.5 cm. The chopped straw sample was suspended in lime solution (pH=10) in the bucket. Suspended raw materials were stirred dalily. The raw materials were soaked for five days before the experimental time.

B. Anaerobic Digestion of Straw Sample with Different Dilution Ratios

To study the effect of dilution ratio on biogas production, in this research two digesters, with straw sample and water with the 4 different dilution ratios are described in Table 2.

Table 3. Preparation of Slurry with Four Different Dilution Ratios

Digester No.	Dilution ratio (vol %)	Straw Sample (v/v)L	Water (v/v)L	Starter (v/v)L
1	1:01	5.6	5.6	2.8
2	01:01.5	4.5	6.7	2.8
3	01:00.5	7.5	3.7	2.8
4	1:02	3.7	7.5	2.8

C. Biogas Production of Straw Sample with Ammonium Molybdate(Nutrient) Using Optimum Dilution Ratio

For the study of the effect of ammonium molybdate on microbial degradation, two sets of experiment were set up. In the first set, 2.8 liter of starter was placed in a 20 liter digester along with the optimum dilution ratio of (1:1). And then (0.02%)(w/v)(2.16g) of ammonium molybdate was added. Biogas production was measured hourly by simple water displacement technique. The percentage of CH_4 content was observed by constant pressure volumetric analysis using an Orsat apparatus. During the experiments the temperature was observed as the room temperature. The pH of the slurry was recorded directly by pH paper.

Similarly, (0.03%) (w/v)(3.24 g) of ammonium molybdate was placed in another digester as the above procedure. And then biogas production with another two amounts of ammonium molybdate (0.01%)(w/v)(1.08g) were made as the above procedure. Preparation of slurry with four different amounts of ammonium molybdate are described in Table 3.

Table 4. Preparation of slurry with Four Different Amounts of Ammonium Molybdate

Digester No.	Dilution ratio (vol %)	Straw Sample (v/v)L	Water (v/v)L	Starter (v/v)L	Ammonium Molybdate	
					%(w/v)	g
1	1:01	5.6	5.6	2.8	0.01	1.08
2	1:01.5	4.5	6.7	2.8	0.02	2.16
3	1:00.5	7.5	3.7	2.8	0.03	3.24
4	1:02	3.7	7.5	2.8	0.04	4.32

V. EXPERIMENTAL SET UP FOR LAB-SCALE DIGESTER

The prepared straw samples were placed in each 20L digester and capped tightly with rubber stopper which had two holes for adding lime and the biogas outlet. Then, the adapter was joined with the open end U tube by a plastic pipe.

The open-end U tube was entered the inverted measuring cylinder which was on the bee-hive shelf in the water bowl. Another open-end U tube coming out from the measuring cylinder was joined to the Orset meter by using an adapter. All the junctions were sealed with grease to ensure that there was no leakage within the system.

VI. ANALYSIS OF BIOGAS COMPOSITION

A. Apparatus

Orset-type gas analysis apparatus consisting of the absorption pipettes for H_2S, CO_2, O_2, CH_4, and water jacketed gas burette with leveling bottle was used for analysis of biogas composition.

B. Preparation of Absorbents

i. Concentrated sulphuric acid (2 cm^3) was added to 100 cm^3 of 10% copper (II) sulphate solution. This solution was used for H_2S Absorption.

ii. 100 cm^3of33% Potassium hydroxide solution was prepared and this solution was used for CO_2 Absorption.

iii. III. Pyrogallol (20 g) was dissolved in 500 cm^3 of potassium hydroxide solution and this solution was used for O_2 Absorption.

iv. 95% methyl alcohol was used for CH_4 Absorption.

C. Procedure for biogas Analysis

Four gas absorption pipettes were connected to the gas burette in series according to the priority order as shown in Table 5.

Table 5. The Priority Order of Absorption of the Gases

Constitu-ents	Absorbent	Priority Order
H_2S	Acidic copper (II) sulphate solution	1
CO_2	33% potassium hydroxide solution	2
O_2	Alkaline pyrogallol solution	3
CH_4	Methyl alcohol	4

VII. RESULTS AND DISCUSSION

A. Effect of Water on Anaerobic Digestion

The amount of water is an important factor for anaerobic digestion. With too much water, the rate of gas production per unit volume in the pit will fall, preventing optimum use of pit. If the water content is too low, acetic acid will accumulate inhibition the fermentation process and hence a rather thick scum will form on the surface.

Table 6. Analysis Data for Four Different Dilution Ratios of Slurry

Dilution ratio (by vol;)	Gas production rate (cm^3/hr)	% Gas composition (by Vol;)			
		H_2S	CO_2	O_2	CH_4
1:0.5	137.9	12.3	29.6	10.5	47.6
1:1	143.6	9.8	20.2	7.5	62.5
1:1.5	121.2	4.3	25.7	14.9	55.1
1:2	1	10.5	31.3	7.5	50.7

Table 7. Analysis Data for Four Different Amounts ofAmmonium Molybdate in Slurry

Dilution ratio (by vol;)	Avg. Gas production rate(cm3/hr)	% Gas composition (by Vol;)			
		H_2S	CO_2	O_2	CH_4
1:0.5	76.1	5.3	31.7	1.3	61.7
1:1	164.2	9.80.1	28.3	1.8	69.8
1:1.5	1464.8	4.32.6	24.6	5.2	67.6
1:2	97.6	10.55.1	28.4	6.4	60.1

Table 8. Comparison of Biogas Composition between Experimental Result (0.02%)

Biogas composition	% Gas composition (by Vol;)	
	Biogas from this Analysis	literature
1:0.5	0.1%	0.1%

1:1	28.3%	27-43%
1:1.5	1.8%	0.5-1%
1:2	69.8%	54-70%

The v/v % H2S,CO2, O2 and CH4 obtained from biggas analysis are shown in Table 8. It was found that composition of H_2S,CO_2, and CH_4 lies between the theoretical ranges except O_2 amount present is little high.

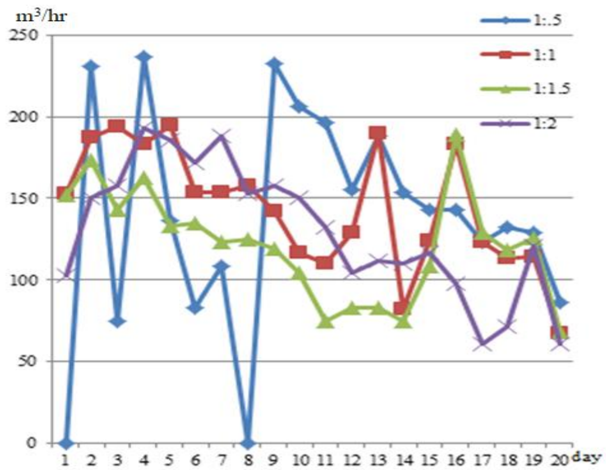

Fig. 1.Daily Gas production rate for four different dilution ratio of Slurry

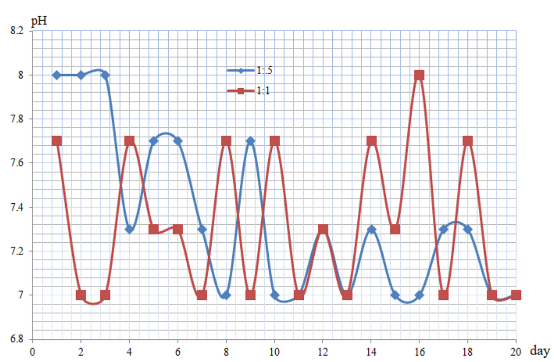

Fig.2.Daily pH for straw and Water (1:0.5 and 1:1)

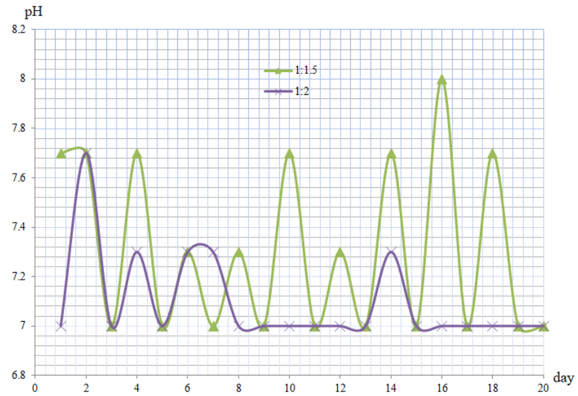

Fig.3.Daily pH for Straw and Water (1:1.5 and 1:2)

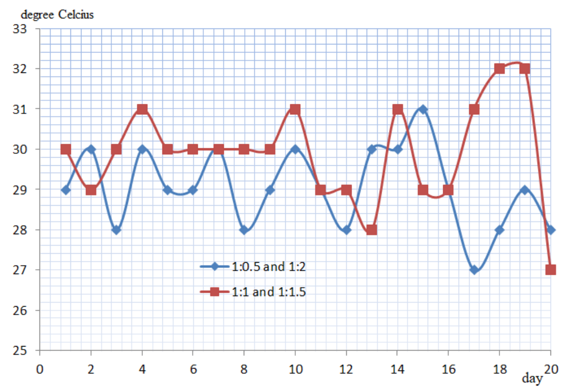

Fig.4. Daily Room Temperature for Four Different Dilution Ratios of Slurry(1:0.5,1:1,1:1.5 and 1:2)

Therefore the experiments were carried out to observe the optimum production of biogas from four different dilution ratios of straw and water (1:0.5, 1:1, 1:1.5 and 1:2 v/v) within 20 days periods. Each experiment is mixed with 20% cow dung starter and recorded gas production rate. In early stage, fewer biogas come out from the 20L digesters. When the enough aging time of straw pieces for anaerobic digestion was reached, the biogas evolved daily faster and faster. 1:1 dilution ratios of straw and water gave the best result as shown in Table 4.

The daily gas production rates for four different dilution ratios of slurry (1:0.5, 1:1, 1:1.5 and 1:2 v/v) are as shown in Figure 1. We observed that the optimum dilution ratio (1:1) gave the maximum average gas production rate (143.6 cm^3/hr). The pH range was 7-8 and the temperature range was 27-32℃ for that optimum dilution ratio.

day

VIII. CONCLUSIONS

In this biogas production process, rice straw was used as the raw materials and mixed with 20% cow dung starter in batch type anaerobic digestion. Among the four different dilution ratios of straw and water, 1:1 (v/v) ratio was the optimum for biogas production rate (143.6 cm^3/hr) within 20 days period. The addition of various concentration of nutrient, ammonium molybdate to optimum ratio of the anaerobic digester of straw and water were studied and 0.02% w/v was observed the best for biogas production and the gas rate was (174.2cm^3/hr). The nutrient addition method was improved the volume of biogas as well as the percentage of methane gas. This research work would be helpful in future studies on the continuous two-stage bio methanation or methanogenesis process.

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