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Characterization of Biogas Produced from Rice Husks and Algae using a Metal Fixed-Dome Biodigester

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Strictly as per the compliance and regulations of :

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I. Introduction

About one third of the world's population have little or no access to modern energy services. Majority of these people are living in poverty. The acute symptoms of this poverty, as well as its chronic causes, are critically linked in many ways to today's patterns of energy production and use. Renewable energy resources (biogas) are available and replenishable. Biogas is formed solely through the activity of bacteria. Bacteria have a temperature range in which they are most productive in term of production rates, growth rates and substrate degradation performance. Several groups of bacteria involved in anaerobic digestion have different temperature optimum. This results in two main temperature ranges at which digestion usually can be performed optimally and most economically. These ranges are 30-45.00 °C called the mesophilic range and 45-70 °C called the thermophilic range (BTG, 2003; Ezeonu *et al*., 2005).

Biogas is made up of methane, carbon dioxide, nitrogen, hydrogen sulphide, ammonia and water vapour. The percentage composition of these gases varies depending on the substrates and the optimum conditions of biogas production (Jenangi, 2002, Philip and Itodo, 2002). Temperature and nutrient addition (Seeding) were one of the most important factors that affect biogas production. The rate of bacteriological methane production increases with digester temperature, retention time and with the percentage of total solid/volatile solid in the slurry (Werner *et al*., 1987, Dioha et al., 2006, Kalia and Singh, 1996). This is because temperature and addition of inocula affects the enzymatic activities of the microorganisms (anaerobic) responsible for the conversion of organic materials into biogas (Kepler, 2006, Maurya *et al*., 1994).

To guarantee optimum biogas production, it is very important to mix various raw materials in accordance with carbon to nitrogen (C/N) ratio requirements of the fermentation. The C/N ratio reflects the relative proportions of these two elements in the digester. Carbon (in form of carbohydrates) and nitrogen (as protein, nitrates, ammonia, etc) are the chief nutrients for anaerobic bacteria. There are two major differences between the digested and undigested products. More volatile nitrogen is contained in anaerobically digested manure and nutrients are more uniformly distributed in anaerobically digested manure. The temperature of mesophilic fermentation is preferred worldwide because: it is easy to maintain the digester at this temperature. Mesophilic bacteria are more stable than thermophilic bacteria. They produced high quality sludge (Chawla, 1969; Bardiya and Gaur, 1997).

In addition to the production of biogas as a form of energy, the use of plant waste as raw materials for biogas production is also a plus for sanitation technology. In this study plant waste (Rice husk and Algae) has been used as raw material for biogas production. The biogas produced was stored under pressure in cylinders using compressor for domestic uses.This paper aim at producing combustible biogas from biomass (rice husk and algae), to study rate of production of biogas, to study biodegradation of rice husk and algae and to investigate the effect of fermentation temperature on the production rate of biogas from organic waste.

II. Materials and Methods

a) *Materials*

The rice husks and algae collected from community were used for the experiment. The digester

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used was fixed-dome type. The basic parts of the digester are shown and labelled in the schematic diagram in figure 2 below.

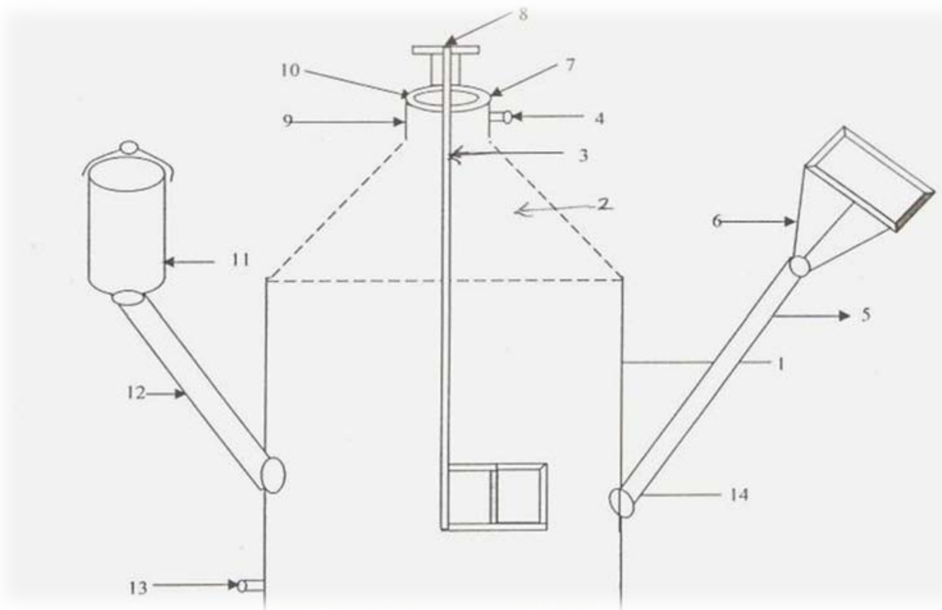

Figure 1 : Schematic Diagram of the biogas digester

Part no. = part name:

1 = Fermentation unit,
2 = gas storage unit,
3 = stirrer shaft,
4 = gas outlet pipe,
5 = slurry inlet pipe,
6 = funnel-like mouth,
7 = bolts hole,
8 = stirrer handle,
9 = short metal neck,
10 = metal rim/ring,
11 = cylindrical outlet mouth,
12 = slurry pipe,
13 = Nipple and socket,
14 = shaft blade

III. Methods

a) Apparatus used and testing of Digester

Figure 2 : Fixed-dome biogas digester (NCERD UNN)

The figure above is the photograph of the fixed-dome biogas digester used for digestion of rice husk. The rice husk and algae were treated in anaerobic sequencing batch reactor or digester whose capacity was 0.971 m^3 and operated at 29.00 °C as their maximum ambient temperature and 35.45 °C as their maximum slurry temperature.

The digester was tested for leakage and its ability to absorb radiant energy (heat). Leakage arising from any part of the digester will inhibit microbial activities of methanogenes. The microbes responsible for anaerobic digestion of organic waste to produce mahtane are adversely affected by the presence of oxygen.

Biogas digestion is a microbial process and therefore requires the maintenance of suitable growth condition for biogas-producing bacteria. These operating parameters like nutrient, an optimum temperature, pH and other environmental factors are vital for the activities of living bacteria. Only when these conditions are met will the normal bacterial activity and subsequent gas production is assured (Yadvika, 2004; Song *et al*., 2004).

In order to maintain an optimum mesophilic temperature range, i.e. temperature within the range of 30°C to 40°C, the walls (inside and outside) of the digester were painted with a dull black colour paint to enhance the absorption of heat for proper metabolic activities of methane-producing micro- organisms.

b) Experimental Procedure for Rice Husk and Algae

The digestion of waste was undertaken by a metal fixed-dome type of anaerobic digester. The fixed-dome digester was accessed using rice husk and algae from a sewage pond. The rice husk and the algae water were mixed in the ratio of 1:6. Hence 5kg of rice husk and 30kg of algae water were mixed together thereby summing up to 35kg of content of the digester. After charging of digester, daily ambient and slurry temperatures were recorded as well as daily volume of gas yielded for a about 75days retention time (RT) .See table 1.

Using the built-in stirrer, the slurry was stirred regularly to distribute and maintain uniformity of temperature and thus, the thickening and caking of scum was prevented. Stirring did not only distribute temperature, it also ensured even distribution of bacteria and at the same time improved surface contact of the waste with the anaerobic bacteria, thereby speeding up biochemical reaction of fermentation.

The volume of the daily gas produced was measured by method of downward displacement of water using a graduated twenty-litre jerry can under atmospheric pressure. The combustibility of the gas produced was checked severally until the gas became combustible.

Table 1 : Days of flammability and total biogas produced.

Waste	Flammable time (day)	Retention time (Days)	Total biogas produced (L)	Temp.(°C)	Mixing Ratio
Rice husk/Algae	45	75	156.25	29.00-35.45	1:6

IV. Results

a) Proximate Analysis

Some samples of the waste were taken to Department of Crop Science laboratory, University of Nigeria Nsukka for proximate analysis on the waste during the course of the research at Exhibition Centre of National Centre for Energy Research Development. About 0.04kg of the waste was collected and analyzed in the laboratory for determination of concentration of various components of the slurry before and after digestion (see table 2).

In the present study the C/N ratio of 6:1was notice at the initial stage which decreases with the passage of substrate decomposition. The result corroborated with the study of Philip and Itodo (Philip and Itodo, 2002).

In the experimental sets, initial pH value of substrate was found to be 6.4.As the decomposition preceded, the pH value gradually increased up to 8.0, while the final value was recorded as 7.1, indicating the stability of organic matter. Earlier studies have indicated that pH range of 5.5-9.0 was suitable for microbial decomposition of organic materials, while the compositing process was most effective at pH values between 6.5 and 8.0 (Kalia and Singh,1996; Philip and Itodo, 2002).

Table 2 : Proximate Analysis before and after digestion

Parameters	Rice Husk/Algae	
	Before digestion Quantity (%)	After digestion Quantity (%)
Ash	3.50	0.14
Carbohydrate	17.38	8.17
Carbon	12.64	1.2..37
Fats	2.00	1.82
Fibre	2.43	Trace
Moisture	72.50	80.36
Nitrogen	2.19	9.63
Ph	6.40 (not in %)	7.10 (not in %)
Phosphorus	7.75ppm	6.483ppm
Volatile Solid	6.30mg/l	2.82mg/l
Total Solid	8.00mg/l	4.32mg/l

b) Flammability of the gas

Three days after charging of the digester, biochemical reaction due to microbial activities gave rise to production of biogas observed from rise in water level at the outlet of the digester resulting from downward displacement due to the pressure built inside the digester by the biogas. Several combustibility tests were run using a special burner designed for biogas combustion. The first test was run 10days after production of gas began and the test proved negative. This test was repeated at intervals of about 7times until positive result was obtained on the 45th day. The gas burnt with a blue fame, producing no soothes.

c) Measurement of Volume of Biogas Produced

The gas produced was measured under atmospheric pressure using the method of downward displacement of water contained in an inverted calibrated transparent 20 litre jerry can. The calibration of the can was expressed in litres. This jerry can was inverted in wide plastic basin with the free end of the hose connected to the digester passing through the brim of the can. The volume of the biogas was determined by measuring the volume of water displaced by the gas as the tap on the digester was turned on. Daily volume of the gas was recorded. For the period of about 62 days an appreciable production of gas was recorded, a total volume of approximately 156.25 litres of gas, an average of 2.52 litres per day (Arnell and Vallin, 2007; Wikipedia for free encyclopedia,2011; Yadvika, 2004).

Table 3 : Percentage of the component of biogas from Rice husk/Algae wastes using Orsat Apparatus

Waste	Carbon dioxide (CO_2) (%)	Hydrogen sulphide H_2S (%)	Carbon monoxide (CO) (%)	Methane and other components
Rice husk/Algae	30.7	2.1	9.9	52.3

V. Discussion

It has been noted in the literature that temperature and retention time are among the parameters that influence anaerobic fermentation of organic matter. From figure 3, it can be observed that from retention time (RT) interval between 4 days and 34 days, the rate of production of biogas was almost constant. Between about 38 days and 55 days, the rate of generation of the gas was increased. Within this time interval, the gas was tested and it became flammable. Also, figure 3 shows daily variation of volume of gas with retention time. The maximum daily gas produced was recorded during fermentation, it was about 6.50 litres.

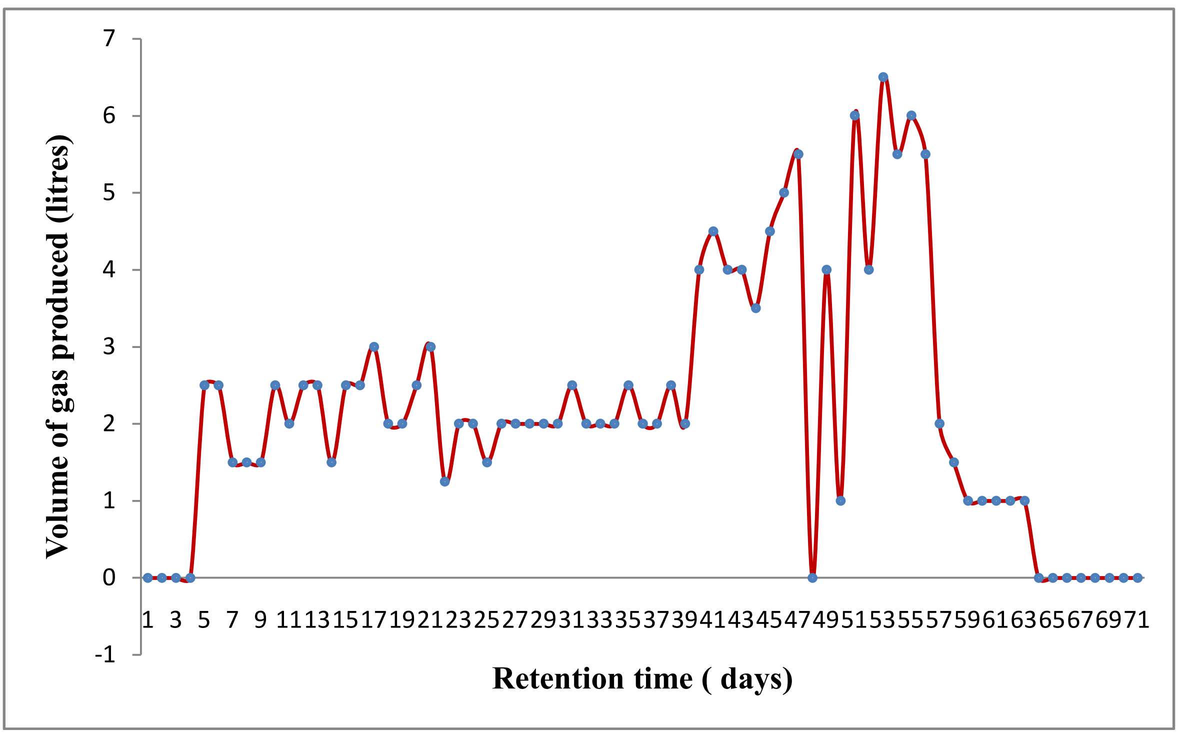

Figure 3 : Daily volume of gas produced

Figures 4 and 5 also show variation of ambient temperature and slurry temperature with retention time respectively.

From the study (see table 1), the slurry average temperature was measured to be about 33.45ºC. This temperature was within the mesophillic temperature range. On the other hand, the ambient has an average of about 29.00ºC. Also figure 4 gives the distribution relationship between slurry and ambient temperature which shows that the increase in slurry temperature was proportional to the ambient temperature.

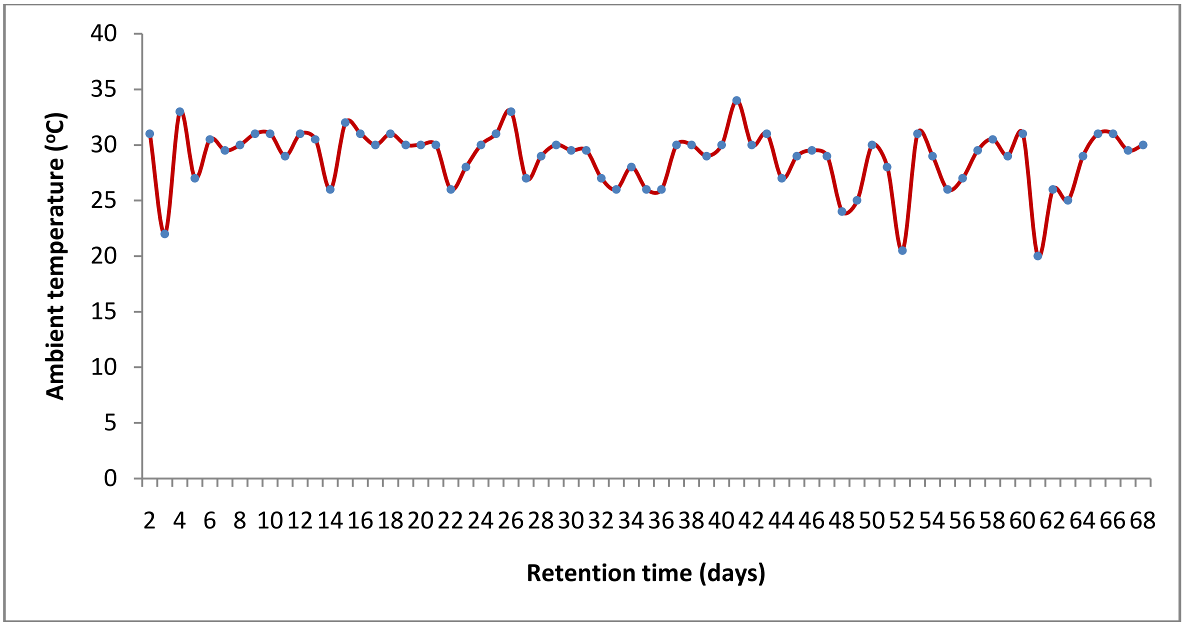

Figure 4 : Daily change in ambient temperature during fermentation

Figure 5 : Daily changes in slurry temperature during fermentation

Results obtained from the study have indicated inoculum age influence in cumulative gas and average daily gas production. Seeding the digester with algae collected from sewage pond as an inoculum generated a total biogas of 156.25 litres within a retention time of 75 days. The average daily gas produced was calculated to be 2.52 litres .Percentage analysis of the component of biogas produced from Rich husk/Algae wastes was done using Orsat Apparatus (see table 3). Table 2 shows the Proximate Analysis of Rice husk/ Algae before and after digestion.

The percentage the methane component of biogas produced was 52.3% .The mean weekly temperature was found to be in the range of (29.00–33.45^{0}C) which was high mesophilic range of temperature. Figure 6 show graph of cumulative volume of biogas produced for 75 days.

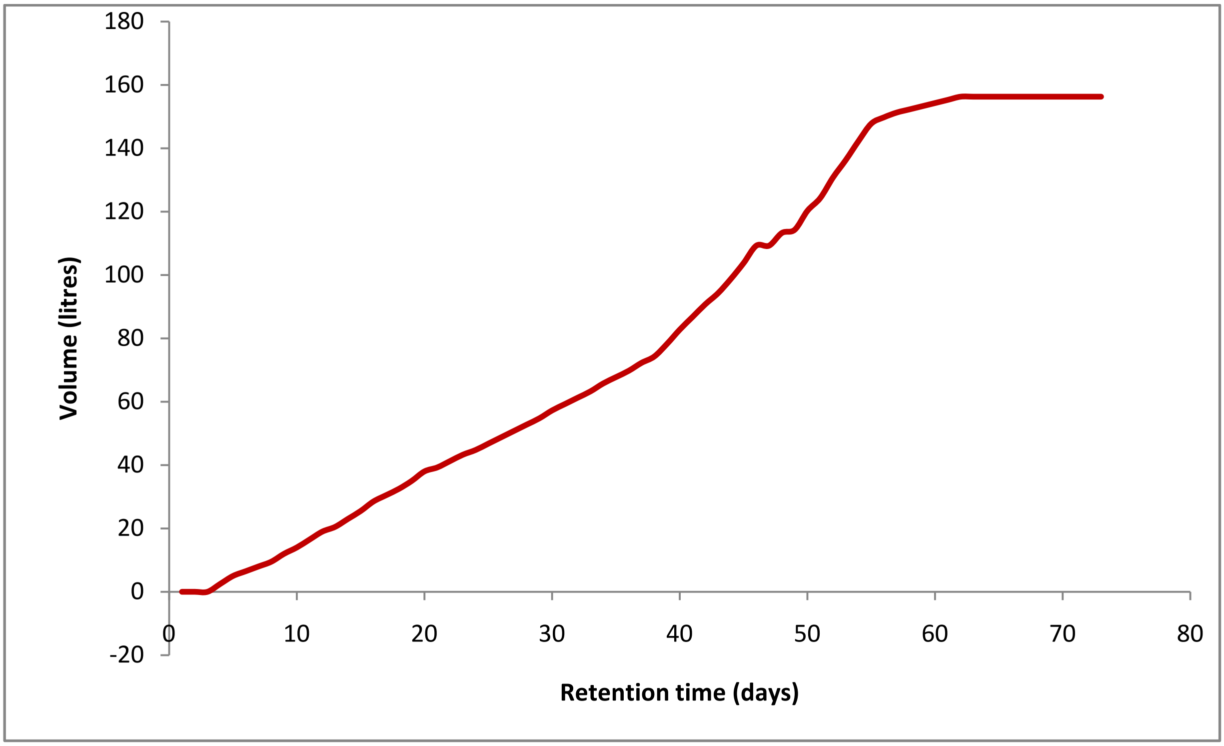

Figure 6 : Variation of cumulative volume of biogas against retention time

The two temperatures fall within the mesophilic range. Figure 7 illustrates the regression temperature between the slurry and ambient temperature. For Rice husk and Algae from seawage pond substitute the values of x = 33.0°C for maximum ambient temperature and x =22.0°C of the minimum ambient temperature on the prediction equation Y=0.62x +15.24. The predicted maximum and minimum slurry temperatures were 40.00° and 26.00°C. The equation R^2=0.313 shows the coefficient of determination which explains proportion of two variables. For example in Rice husk and Algae from seawage R^2 = 0.313, it means that the relationship between the maximum and minimum temperatures of ambient and slurry temperatures was 31.3%. The co-efficient of correlation was deduced from the coefficient of determination R^2, for the waste, it was 0.559. The correlation coefficient between slurry temperature and ambient temperature was r =0.56. This was used to support the claim that the increase in the ambient temperature could be attributed to the increase in slurry temperature (Philip and Itodo, 2002; Goodger, 1980).

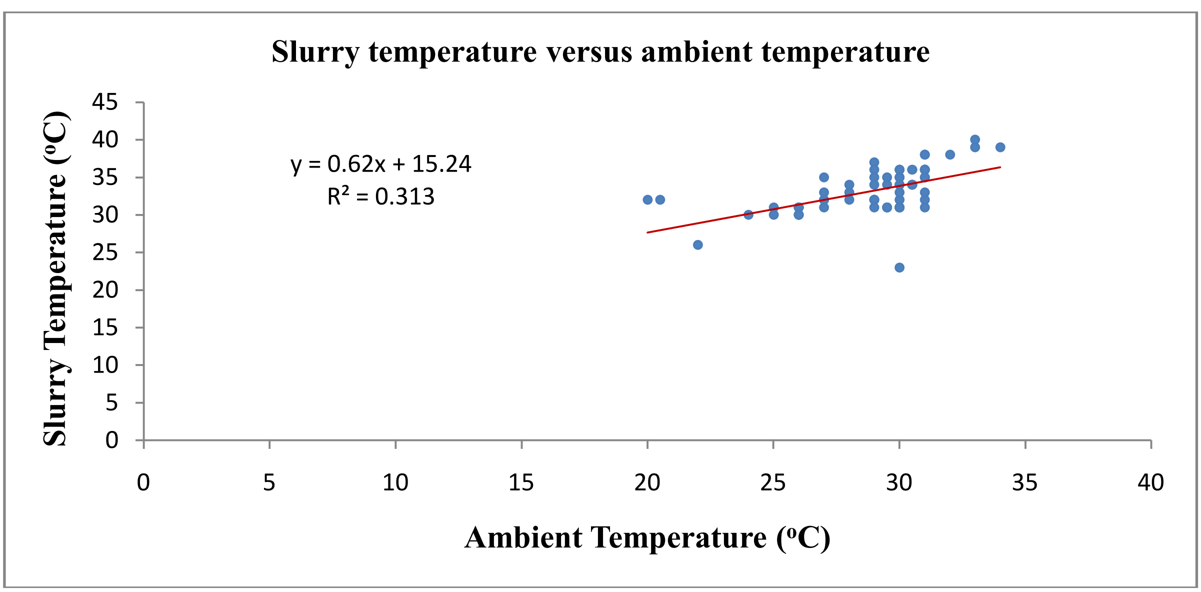

Figure 7 : Slurry temperature versus ambient temperature

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Table 2 shows the Proximate Analysis of Rice husk/Algae before and after digestion

VI. Environmental Benefits and Applications of Biogas

Biogas system designed to process animal and human excreta are expected to contribute to a cleaner and healthy environment in the following ways: elimination of smoke reduces the incidence of lung and eye diseases, especially among village inhabitants; improved rural sanitation due to systematic collection and processing of animal dung and human excreta. This also leads to reduction in water-borne diseases caused by lack of sanitation; and aids to prevent deforestation and consequently soil erosion, flood and climatic effect.

Also, well-functioning biogas systems can yield a whole range of benefits for their users, the society and the environment in general through: production of energy (heat, light, electricity); transformation of organic waste into high quality biofertilizer; improvement of hygienic conditions through reduction of pathogens, worm eggs and flies; and reduction of workload, mainly for women, in firewood collection and cooking.

Environmental advantages through protection of soil, water, air and woody vegetation: micro-economical benefits through energy and fertilizer substitution, additional income sources and increasing yields of animal husbandry and agriculture; and macro-economical benefits through decentralized energy generation, import substitution and environmental protection.

VII. Conclusion

The result of this research has shown that many of the microorganisms associated with the fermentation of rice husk and algae from sewage pond originated from the inoculum and substrate used. Also since the population of the microbes in the digester was increased by addition of the inoculum, there was fierce competition for the limited substrate, and the intensity of this competition depends on the net population of the microbes in the digester. This is the determinant factor for the retention time of the substrate as well as the quantity of the biogas produced. The addition of inoculum to rice husk was found to enhance gas production. It was also found to be influential especially in specific gas production, cumulative gas production and percentage degradation of solid particles. An inoculum of between two to three weeks of age could be used as a seeding agent for starting up biogas digesters.

VIII. Recommendation

Algae from seawage pond are recommended as the best seeding material so far. Also a 1:6 ratio (feedstock to water) is therefore recommended for optimal digestion of Rice husk and Algae from seawage pond. To encourage the use of biogas requires an awareness of the potential users of the process.

IX. Acknowledgement

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