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BIOGAS PRODUCTION FROM ORGANIC WASTE

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ABSTRACT

Waste management is a very big challenge in Nigeria today. With increased poultry farming and animal husbandry, a lot of droppings is generated which is presently constituting a nuisance in many neighbourhoods. One simple, effective and low cost method of management, which has not been optimally utilized, is the anaerobic digestion. The main objective of this project is to design and fabricate a simple, low cost and acceptable household biogas plant, which can serve as waste management device and, also as a source of energy for cooking. A 100 litre galvanized plate biodigester was designed, fabricated and used to obtain biogas from these waste. The digester was charged with cow dung slurry, which had the composition: potassium (1.47), phosphorus (4.60), Nitrogen (3.19) and Organic Carbon (68.6). To 300 litres of the feed (dung), an equal volume of water was added and made into 600 litres slurry. An average of $0.3151 m^3$ of methane gas was generated daily - a quantity of gas capable of sustaining cooking for 2.6403 hrs. On the 44th day from the day the first charging began, the process attained stable steady-state with 15 litres of slurry fed into the digester daily and an equal volume of spent sludge discharged. On the average, the gas generated was enough to provide an average of 1hr, 36mins cooking daily.

***Keywords:* Biodigester, Anaerobic Digester, Biogas.**

INTRODUCTION

Pressure on the environment, escalating costs of fossil fuels, and the decreasing availability of non commercial sources, e.g. firewood, in recent years have forced many developing countries to look more closely at renewable energy technologies. One of the best-established technologies available is anaerobic digester, where organic materials, e.g. animal manure, nightsoil, agriculture residues and industrial effluents, are biologically fermented in the absence of oxygen to produce flammable gas consisting predominantly of methane (CH_4) and carbon dioxide (CO_2). The technology is popularly referred to as "biogas" (Stuckey, 1983). Also the growth and concentration of the livestock industry in most countries of the world e.g. the United States of America created opportunities for the proper disposal of the large quantities of manures generated at dairy and poultry farms. The major pollution problems associated with these wastes are surface and groundwater contamination and surface air pollution caused by odours and dust. Energy-deficient age in which we live today demands, that new and renewable sources of energy be fully exploited. Biologically produced energy has been identified as attractive alternative to increasingly scarce fossil-fuel supplies in the world. Unfortunately, biogas technology has not been optimally used on large scale in Nigeria compared with the level obtained from reports in some countries like China, Korea and Philippines. According to Ezeokoye et al (2006) there is need to popularize biogas technology in Nigeria in view of large numbers of brewery and agricultural wastes. In particular, little has been done on waste management and energy generation, using biogas technology. Therefore this work is meant to explore this method of waste management and energy generation. The objective of this project is to design and fabricate a medium size household biogas plant, which will operate on animal waste, household waste and any other decomposable waste as feeds. Biogas technology in the form of two designs, the fixed dome (used in China) and floating dome (used in India) have been used in a number of developing countries for many years. However, very little effort has been made to rationally optimize these designs to reduce the capital cost and increase their volumetric gas yield. This is due primarily to lack of sound technical data, and weak indigenous Research and Development capacity. Also there has been very little attempt to "unpack" new techniques from developed countries (Stuckey, 1983). India launched the National Project for Biogas Development (NPBD) to give a renewed thrust to biomethanation in the country. Department of Non-conventional Energy Sources (DNES) under the ministry of Energy was in September 1982 assigned the task of pursuing the NPBD ((Chenogappa, 1985). The DNES also initiated several measures for the success of NPBD which covered upward revision of the Central Government subsidy for plant construction, availability of more effective post-installation follow-up services, creation of large cadre of trained manpower in the field, and supply of raw materials (The Hindu, 1990, 1991). During the seventh plan 1985-90, it was planned to set up several biogas plants (Economic Times, 1985).

The History of Anaerobic Digester (AD)

In 1808, Sir Humphry Davy determined that methane was present in the gases produced during the AD of cattle manure (Dodson, et al, 1981). The first digestion plant was built at a leper colony in Bombay, India in 1859 (Meynell, 1976). AD reached England in 1895 when biogas was recovered from a "carefully designed" sewage treatment facility and used to fuel street lamps in Exeter. (McCabe and Eckenfelder 1957). The development of microbiology as a science led to research by Buswell (Buswell, and Hatfield, 1936) and others in the 1930s to identify anaerobic bacteria and the conditions that promote methane production. Interest in Biogas as a fuel received attention during the Second World War. French scientists took particular interest in advancing biogas technology in the forties and installed large number of plants in French colonies in Africa. During this period fuel-starved French and Germans used biogas as fuel for vehicles and farm tractors. Following the war, several nations such as England, USA, Canada, Russia, China, India, etc. showed interest in biomethanation but this later waned as a result of cheap fossil fuel that was available for the following three decades. However, series of energy shocks, which rocked the world from 1973 onwards along with concern for environmental protection, revived interest in biomethanation. In view of its potential, large number of community and family-size plants has been set up in recent years in countries like China, India, Philippines and Nepal (Leach, 1987). During the energy crises of the mid- and late 1970s, the search for alternative energy sources led to investigation of small- and medium-scale anaerobic digesters developed in India and China to determine whether these technologies were directly transferable to farms in the United States. Unfortunately, although these technologies were useful in providing fuel for cooking and lighting in developing economies, most are much too small to be useful to most American farmers. For example, the typical small-scale digester daily produced about the same amount of energy as contained in 1 gal of propane (Volunteers in Technical Assistance (1979), Ranier and VITA, 1979). The greater energy requirements of the larger American livestock operations led to the design and installation of several demonstration projects that transferred state-of-the-art sewage treatment plant technology to the farm. (Coppinger et al, 1980).

MATERIALS AND METHODS

The university of Ibadan dairy farm was chosen as the sampling site even though several other sites were visited in Ibadan metropolis. 30kg of the cow dung, was added to an equal weight of water, (ratio of 1:1). The resulting mixture (slurry) was properly mixed together and fed into the digester through the inlet pipe. This was left for several days before the daily addition of 15litres of slurry (7.5kg of cowdung and 7.5kg weighed water) to fill about ¾ of the volume of digester. The digester was agitated once in a day, through the used of inbuilt stirrer. The inlet and the outlet of the digester were made airtight. Attached to the digester was a gas outlet valve through which gas was released into the storage container. The temperature of the environment of the digester was recorded using a thermometer, and the volume of gas produced calculated. The pressure in the system was also monitored using the installed pressure gauge.

Experimental Procedure of Feedstock and Spent Slurry (Effluent)

Both the feedstock and the effluent were analyzed for the percentage of P, K, C and N. The pH of the two samples were also determined. The standard procedures for the analysis of these elements were followed.

Test Running of the Digester

The digester was charged with cow dung slurry, which has a pH of 7. To 300 litres of the feed (dung), equal volume of water was added and made into 600litres slurry. This was followed by proper stirring and removal of inert materials. The resulting mixture was then fed into the digester under anaerobic decomposition. After a period of six days the pressure in the digester rose indicating gas production in the digester. However, the gas so produced did not ignite and when tested contained essentially hydrogen sulfide which was then expelled. Until the fourth week from the day of the first charging, the gas was not combustible. At the end of 4^{th} week, the use of the gas for cooking began and a daily record of the quantity of gas generated and used was recorded. On the 44th day, the process attained stable steady state with 15 litres of feeds (Cow dung) fed into the digester daily and equal volume of spent sludge collected.

Experimental Analysis of the Feedstock and the Spent Slurry (Effluent)

Separate chemical analysis of the feedstock and the plant effluent were carried out using the method earlier described and the results obtained are shown in Tables 1 and 2 below:

Table 1: The Composition of Feedstock

Element	Sample 1	Sample 2	Sample 3	Mean	SD
Nitrogen (N)	3.19	3.42	2.97	3.19	0.18
Phosphorus (P)	4.47	5.01	4.31	4.60	0.30
Potassium (K)	1.42	1.51	1.47	1.47	0.04
Carbon (C)	67.57	69.20	69.03	68.6	0.73

C: N = 68:6/3.19 = 21.50

Table 2: The Composition of Spent Slurry

Element	Sample 1	Sample 2	Sample 3	Mean	SD
Nitrogen (N)	0.87	1.21	0.92	1.00	0.15
Phosphorus (P)	4.38	4.56	4.61	4.52	0.10
Potassium (K)	0.23	0.43	0.35	0.34	0.08
Carbon (C)	3.79	4.16	3 .95	3.97	0.15

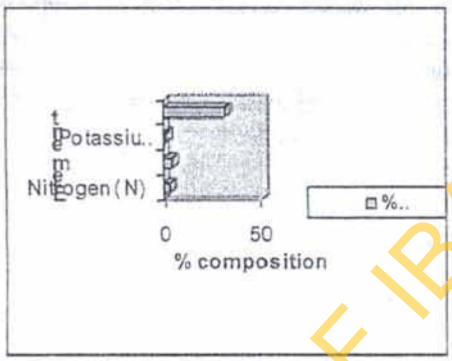

Figure 1: Percentage Composition of various Elements in the Feedstock

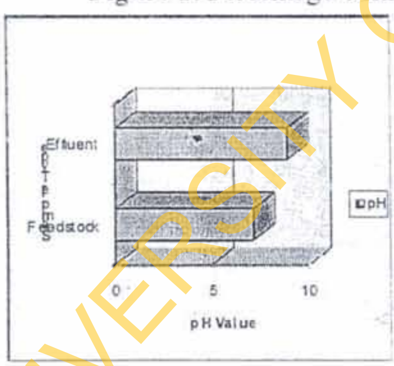

Figure 2: The pH Value of the Feedstock and Spent Slurry

Day	Qty of feed	Tube O^{ce} (m)	Length (m)	Volume (m^3)	Volume (L)	Cooking time (hrs)
1	15	1.20	3.26	0.3735	373.4	2.00
2	15	1.155	3.275	0.3476	347.7	2.50
3	15	1.19	3.295	0.3713	371.1	2.67
4	15	1.023	3.219	0.2680	266.5	2.45
5	15	1.121	3.274	0.3274	327.1	3.38
6	15	1.126	3.285	0.3314	331.2	3.67
7	15	1.132	3.296	0.3361	336.0	3.33
8	15	1.028	3.23	0.2716	270.9	1.73
9	15	1.062	3.29	0.2952	295.3	2.42
10	15	0.995	3.216	0.2533	252.8	2.50
11	15	1.13	3.32	0.3373	327.2	2.80
12	15	1.023	3.225	0.2685	268.6	2.23
Avg.	15	1.0988	3.2654	0.3151	313.98	2.64

Table 3: Daily Gas Generation for a Given Daily Feedstock

Using equation (20)
Gives,

$$V = \frac{(1.0988)^2}{4(3.142)}(3.2654) = 0.3137m^3$$

Table 4: Cumulative Daily Feedstock, Gas Yield and Cooking Time

Days	1	2	3	4	5	6	7	8	9	10	11	12
Feedstocks	15	30	45	60	75	90	105	120	135	150	165	180
Gas generated (m3)	0.3735	0.7211	1.0924	1.3604	1.6878	2.0192	2.3553	2.6269	2.9221	3.1752	3.5127	3.78
Cooking Time (hr)	2.000	4.500	7.1667	9.6167	13.000	16.667	20.000	21.7333	24.1500	26.650	29.450	31.6

Based on the results of Table 4, various charts showing the correlation between different parameters were generated as shown in Figures 3-6 below:

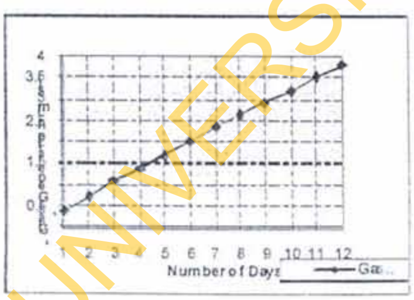

Figure 3: Daily Feed of 15 Litre and Corresponding Cumulative Gas Generation

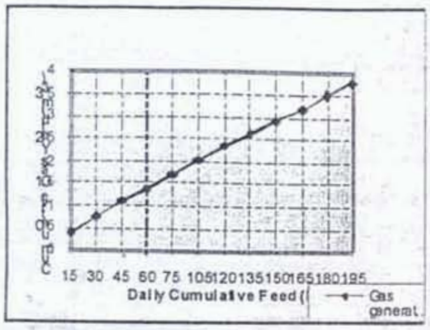

Figure 4: Cumulative Daily Feed and Corresponding Cumulative Gas Yield

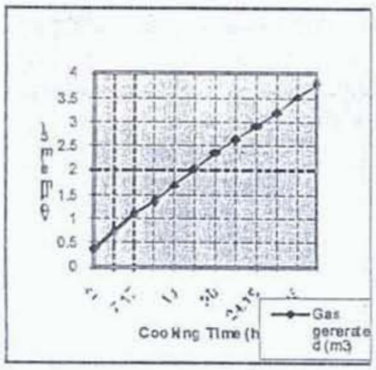

Figure 5: Cumulative Gas Generated and Corresponding Period the Gas can sustain cooking

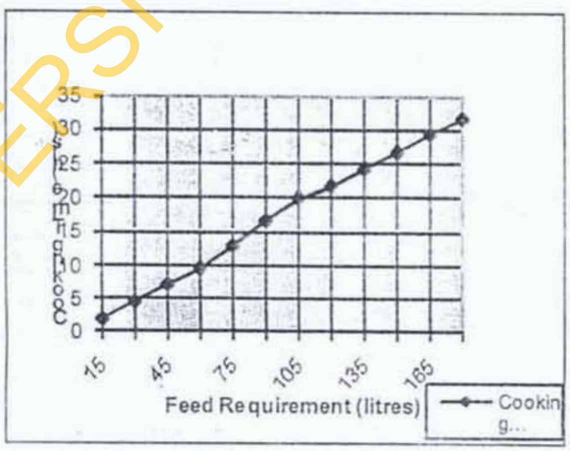

Figure 6: Cumulative Cooking Time and Quantity of Feed Required to generate the Required Biogas

Table 5: Average Weekly Temperature & Change in Pressure

Weeks	1	2	3	4	5	6	7	8	9	10	11
Temp.(0C)	27.2	28.2	27.4	27.8	26.4	26.4	26.75	30.6	27.75	27.5	28.7
Press(bar)	0	0	0.59	1.22	1.00	1.22	1.19	1.22	0.86	0.4	0.66

Table 5 shows the average weekly temperature and pressure change during the fermentation process.

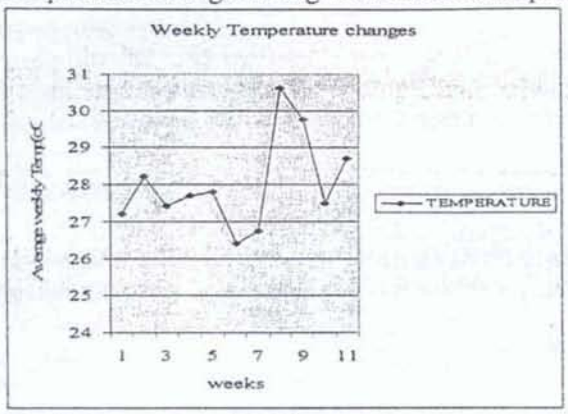

Fig. 7 Average weekly Temperature

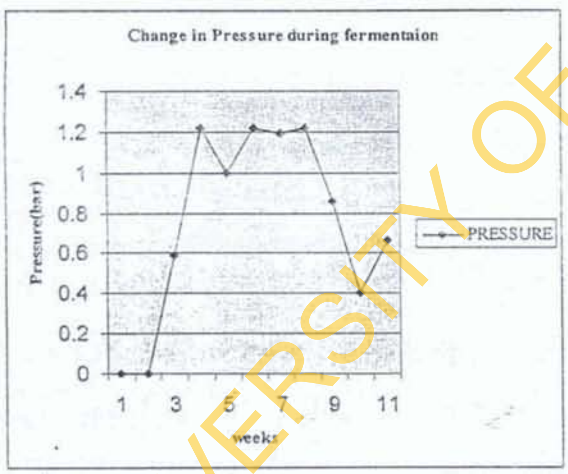

Fig. 8 Average weekly pressure

The above table shows the time spent by family of size ten on cooking for seven days. This was used as a basis to determine the volume of gas that will sustain the family for cooking.

DISCUSSION

Feeding and Gas Yield

From Table 4, it was observed that the digester efficiency is such that each 15litres feed (slurry) produces an average of 0.3151m^3 of biogas which sustains cooking for an average of 2.6403hrs daily. However, the finding shows that the family of ten spent an average of 1hr,.36min on cooking daily. This means, that gas which will last for 1.64hrs is required daily. It therefore follows that with the daily gas yield of 0.3151m3, which can last for 2.6403hrs, an excess gas that will last for about an hour will be available after cooking everyday. Also from Table 5, it can be seen that cumulative feed of 180 litres for 12 days produced 3.7812 m^3 of gas that can sustain cooking for 31.6833 hrs. This gas when stored can sustained the cooking activities of the family for approximately 20days, since their average daily cooking time was 1.64hrs. Figure 6, shows that when the plant is operating steadily (undisturbed) the cumulative gas generation is directly proportional to the cumulative daily feed that is fed into the digester. That implies a positive relationship. This is up to a maximum daily feed of 15 litres. This is also corroborated in figures 4, 5 and 6.

Chemical Analysis of the Feed and Effluent

Chemical analysis of both the input and output of the Biogas plant to ascertain its performance was carried out and the result of the analysis shows (tables 6 and 7) that C, N, P, K and pH for the feed were C (68.6), N (3.19), P (4.60), K (1.47) and C (3.96), N (100), P (4.52), K (0.34) for the effluent respectively. The reduction of 94% of C indicates that the plant is meeting the design expectation of producing biogas (CH_4) and manure of high nutrient value, as depicted by the high percentage of nitrogen in the effluent.

CONCLUSION

Anaerobic digester (AD) has been found to be an effectively wastes management and cheap energy generation device. This is based on the findings from the study of digester that was designed and fabricated. It was observed that this digester is adequate for a family of ten people in terms of energy needs and waste management capacity.

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