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Investigation of the influence of some parameters on biogas yield

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ABSTRACT

The effects of alkalinity/acidity, addition of copper and zinc, and seeding material on biogas generation using freshly voided cow dung as feedstock were investigated. Experimental set-up for seven digesters, labeled A to F, were carried out in the laboratory with varying measurements of slurry in the digesters, varying pH values for three digesters, some with seeding materials while others with addition of metals –copper and zinc separately. The study was carried out for an hydraulic retention time of 32 days during which volumes of gas generated from all digesters range from 1022cm^3 to 1723cm^3 with the highest gas produced from digester with the rice husk and banana peels. The results showed best yields with cow dung seeded with rice husk and banana peels, while addition of metals and an alkaline slurry solution of pH = 7 had an improving effect on biogas production.

Introduction

The importance of energy in national development cannot be over-emphasized. Energy is needed in virtually all facets of human existence. The significance of energy in the provision of goods and services and in the elevation of the standard of living of mankind, and the role it plays in industries for sustainability of production is a well known fact [1,2].

Fossil fuel provides the bulk of the world's primary source of energy. Since they are non-renewable natural resources with little to conserve the earth's supply, supplies of fossil fuel (especially oil and gas) may soon get completely depleted[3]. Also, the rising cost of petroleum and allied products most especially in Sub-Saharan Africa has triggered a need to develop an alternative source of energy. In Nigeria, majority of the population are rural dwellers without access to gas or electricity, and therefore, depend on firewood for cooking and

lighting. This, unfortunately, has contributed immensely to rapid rate of deforestation and desert encroachment[3]. This has led, in the past few decades, to research, investment and usage of renewable energy. Biogas technology is one of the easiest forms of renewable energy that can be established in local communities to ameliorate the problems of the rural dwellers and preserve the environment.

Anaerobic bio-degeneration of cellulosic materials is a biological-engineering process[4] in which a methane rich gas or biogas is produced. Raw biogas contains about 55-65% methane (CH_4), 30-45% carbon dioxide (CO_2), traces of hydrogen sulphide (H_2S) and fractions of water vapors[5]. Biogas, in its pure state, is colourless, odourless, tasteless, and non toxic. 1m^3 of biogas is equivalent of 3.6kg of firewood; 1.5kg of charcoal; and 0.6litres of kerosene. It can also be utilized in modern waste management facilities and as a form of fertilizer[6].

Biogas is produced from various forms of waste and many researches have been conducted in Nigeria to test the suitability or otherwise of some of the common wastes. For example, Adeyemo and Adeyanju[7], used cassava peel seeded with Obeche wood to produce biogas in a laboratory investigation and reported that obeche wood exhibited good medium characteristics in accelerating biogas yield. Adeyanju,[8], used pig waste and cassava peels seeded with wood-ash for biogas generation. He recorded an appreciable success in biogas production ranging from 83-2345cm^3 for a period of 45 days. Ezekoye and Okeke[2], used spent grains and rice husk for biogas production and reported that the maximum volume of biogas obtained from the wastes was 159litres on the 47th day. Also Ezekoye[5], experimented and produced biogas from cow dung and spent grains and recommended that spent grains/cow dung should be used for biogas production with cow dung being used to seed spent grains for faster production. In 2007, Ilori, M.O[3] produced biogas from banana and plantain peels for an hydraulic retention time of 35 days. He reported that 8,800cm^3 and 2,409cm^3 of biogas were produced from banana and plantain peels feedstock Biogas is produced from various forms of waste and many researches have been conducted in Nigeria to test the suitability or otherwise of some of the common wastes. For example, Adeyemo and Adeyanju[7], used cassava peel seeded with Obeche wood to produce biogas in a laboratory investigation and reported that obeche wood exhibited good medium characteristics in accelerating biogas yield. Adeyanju,[8], used pig waste and cassava peels seeded with wood-ash for biogas generation. He recorded an appreciable success in biogas production ranging from 83-2345cm^3 for a period of 45 days. Ezekoye and Okeke[2], used spent grains and rice husk for biogas production and reported that the maximum volume of biogas obtained from the wastes was 159litres on the 47th day. Also Ezekoye[5], experimented and produced biogas from cow dung and spent grains and recommended that spent grains/cow dung should be used for biogas production with cow dung being used to seed spent grains for faster production. In 2007, Ilori, M.O[3] produced biogas from banana and plantain peels for an hydraulic retention time of 35 days. He reported that 8,800cm^3 and 2,409cm^3 of biogas were produced from banana and plantain peels feedstock respectively. Eze, J.I and Uzodima, E.O[9] generated biogas from poultry wastes and reported that poultry wastes generated very high quantity of biogas within a Hydraulic Retention Time of 14 days.

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The use Cow dung seeded with Rice husk, and Banana peels for the production of biogas as well as the effects of concentration of rice husk and banana peels, metals such as Copper and Zinc, and alkaline/acidic medium on biogas production were investigated for optimum yield of biogas.

Materials and Methods.

The materials used for this experiment were cow dung, banana peels and rice husk. Freshly voided cow dung was collected from the main abattoir in Ado-Ekiti and was transferred to the laboratory in clean cellophane bags. Banana peels were collected from the Irona fruit market. They were screened from any foreign object and sun dried. The sun-dried banana peels were later grinded using mortar and pestle. Rice husk were collected from a rice mill in Ilupeju Ekiti, screened of any foreign object and transported to the laboratory.

Setting up the digesters

Seven (7) digester bottles were set up in the thermofluid/energy laboratory of the University of Ado Ekiti, Nigeria. The digesters

Were labeled A to G. The seven digesters were divided into three groups 1, 2 and 3 to test the effects of acidity/alkalinity, addition of metals, and effects of seeding cow dung with banana peels and rice husk respectively.

Group 1, which is for the investigation of the effect of acidity/alkalinity on biogas production, consists of three digesters A, B and C. Digester A is made up of 400g of cow dung mixed with 400cm^3 of water. The slurry has a pH value of 7.0. Digesters B and C, though consist of the same quantity of cow dung and water just like digester A, were however made acidic (pH=2) and alkaline (pH=10) respectively. Group 2, which consists of digesters D and E, is to investigate the effect of addition of metals in the generation of biogas. Both digesters D and E consist of 400g of cow dung and 400cm^3 of water. While digester D contains 40g of copper, digester E contains 40g of Zinc. Group 3, which consists of digesters F and G, is for the investigation of the effect of seeding cow dung with banana peels and rice husk. Digester F contains 200g cow dung, 160g rice husk, and 40g of banana peels dissolved in 400cm^3 of water while Digester G contains 200g cow dung, 40g rice husk, and 160g of banana peels dissolved in 400cm^3 of water as shown in Table I.

However, the digesters were made airtight using rubber corks overlaid with a tube filled through the hole, the tube was passed into a measuring cylinder inverted over acidified water in a plastic bowl. The cylinder was used as a measuring scale as well as gas collector. The acidified water was prepared by adding 0.05ml H_2SO_4 to 18.4g of water in theratio 1: 368. This solution was used to prevent the dissolution of the gas released into the water. The digesters were corked to generate an anaerobic condition. The set up was observed for a Hydraulic Retention Time (HRT) of32days and the quantity of biogas produced measured daily.

The laboratory set-up is as shown in figure I while figures II and III show the pictorial set-up.

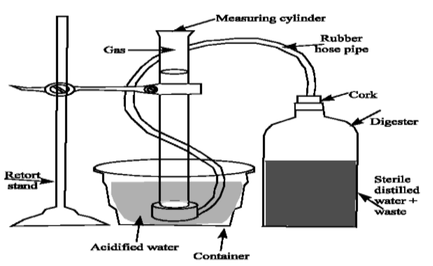

Figure I. Experimental set-up.

Figure II: Picture of one of the digesters

Figure III: Picture of cross section of the digesters.

In the course of the experiment, the ambient temperature was 35^{o}C. The slurry in the digester was mixed and stirred periodically to:

1. prevent the settling of the bacteria at the digester base and maintaining firm contact between bacteria and manure properly.
2. prevent surface scum formation of the slurry in the digester.
3. facilitate the release of biogas.

Laboratory preparation of acidified water

Percentage purity of H_2SO_4= 98%

Density of H_2SO_4= 1.84g/cm^3

Molecular weight or molar mass of H_2SO_4= 98.07g

Concentration of H_2SO_4 =

$$\frac{\%\ \text{Purity of } H_2SO_4 \times \text{Density of } H_2SO_4}{\text{Molar mass of } H_2SO_4}$$

$$= \frac{0.98 \times 1.84}{98.07} \times \frac{1000}{1}$$

= 18.39g/cm^3

To determine the volume of H_2SO_4 in mole required as the acidified water to prevent the dissolution of the gas released, the relation below is used.

$$V_1 C_1 = V_2 C_2$$

Where

V_1 = unknown volume of H_2SO_4

V_2 = volume of water required i.e 25,000 cm^3

C_1 = concentration of H_2SO_4 already estimated i.e C_1 = 18.39g/cm^3

C_2 = concentration of H_2SO_4 required

C_2 = 0.05g/cm^3

Rearranging the formulae above

$V_1 = V_2C_2/ C_1$

$$V_1 = \frac{25000\text{cm}^3 \times 0.05\ \text{g/cm}^3}{18.39\ \text{g/cm}^3}$$

V_1 = 67.97cm^3

The volume of Tetra-Oxo-Sulphate IV acid required to prepare the acidified water is 69.97cm^3.

The ratio of acid to water used was 67.94cm^3: 25000cm^3 = 1: 368

Results and discussions

The amount of biogas generation was read and recorded daily and the results are as tabulated below.

Table II: Table showing the rate of daily biogas generation for the three groups of digesters for 32days

Table I: Table showing the constituents of the digesters.

	A	**B**	**C**	**D**	**E**	**F**	**G**
Cowdung (g)	200	200	200	200	200	200	200
Rice husk (g)						160	40
Banana peels (g)						40	160
Copper (g)				40			
Zinc(g)					40		
pH	7.0	2.0	10.0				

Table II: Table showing the rate of daily biogas generation for the three groups of digesters for 32days

Day	**Group 1 digesters**			**Group 2 digesters**		**Group 3 digesters**	
	Neutral	**Acidic**	**Alkaline**	**Copper**	**Zinc**	**Rice hush dominant**	**Banana peels dominant**
	A (cm^3)	**B (cm^3)**	**C (cm^3)**	**D (cm^3)**	**E (cm^3)**	**F (cm^3)**	**G (cm^3)**
1	0	0	0	0	0	0	0
2	4	3	1	2	10	3	3
3	14	8	1	13	14	26	14
4	12	7	0	17	14	18	12
5	33	22	1	24	22	11	6
6	35	8	1	4	15	15	10
7	80	75	62	80	55	40	76
8	40	35	46	50	60	190	130
9	30	25	56	80	72	100	180
10	50	45	60	40	50	80	140
11	44	12	40	30	34	62	170
12	50	38	38	40	45	74	115
13	40	40	30	30	20	100	92
14	52	60	40	45	40	140	85
15	11	30	14	35	30	64	10
16	55	5	6	30	40	46	15
17	30	15	13	15	32	70	25
18	40	20	30	25	37	87	38
19	60	50	60	55	42	64	56
20	30	43	55	50	48	53	45
21	40	34	45	46	54	15	10
22	50	40	40	40	40	30	35
23	25	18	15	10	18	10	15
24	34	34	15	20	22	8	40
25	60	30	11	25	36	70	70
26	60	35	9	15	14	70	60
27	65	38	40	50	55	65	45
28	67	50	38	30	40	43	34
29	50	48	50	55	55	40	55
30	45	40	43	48	48	55	50
31	33	43	48	43	43	38	38
32	30	40	35	30	30	32	28
Total	1308	1022	1054	1145	1133	1723	1696

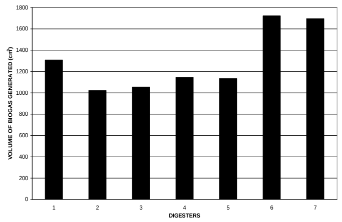

FIGURE 4: BAR CHART SHOWING VOLUME OF BIOGAS GENERATED (cm^3) FOR THE DIGESTERS.

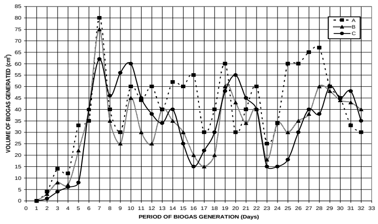

FIGURE 5: THE GRAPH OF VOLUME OF BIOGAS GENERATED (cm^3) AGAINST PERIOD OF BIOGAS GENERATION (Days) FOR GROUP 1 DIGESTERS.

From the three digesters in group 1, digester A generated the highest volume of biogas of 1308cm^3 over the period of retention followed by digesters C and B in that order with 1054cm^3 and 1022cm^3 respectively, as shown in figure IV. The highest volume of biogas for all the digesters in group 1 was generated in day 7 with 80cm^3, 75cm^3 and 62cm^3 for digesters A, B and C respectively as shown in figure V. This result showed that the optimum pH for biogas production is 7.0. Biogas generation will reduce with a reduction in pH value because the pH of the digester is a function of the concentration of volatile fatty acids produced, bicarbonate alkalinity of the system, and the amount of carbon dioxide

Produced. A lower pH which translates to an acidic solution will decrease methanogenic activity and cause a decline in biogas generation. This confirms the works of Chawla, O. P[10] and Mahanta, P[11] that for increased gas yield, a pH between 7.0 and 8.2 is optimum.

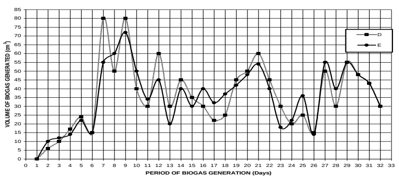

FIGURE 6: THE GRAPH OF VOLUME OF BIOGAS GENERATED (cm^3) AGAINST THE PERIOD OF GENERATION (Days) FOR GROUP 2 DIGESTERS.

Group 2 digesters, which consist of digesters D and E, are for the investigation of the effect of addition of metals on biogas generation. The two metals added are Copper of mass 40g and Zinc of mass 40g for digesters D and E. The total volume of biogas produced is 1145cm^3 and 1133cm^3 for digesters D and E respectively as shown in figure IV. The highest volume of biogas produced for a single day was 80cm^3 for the total period of hydraulic retention time of 32 days for digester D and 72cm^3 for digester E. Figure VI showed that from the 29th day, biogas generation are the same for both digester D and E. It was discovered that biogas generation is influenced by the addition of metals this is attributed this to the increased methanogenic population in the digesters though is more pronounced in copper than in zinc[12].

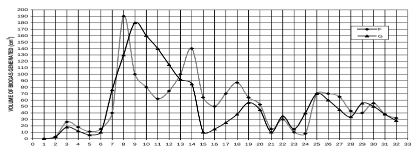

FIGURE 7:THE GRAPH FOR THE VOLUME OF BIOGAS GENERATED (cm^3) AGAINST THE PERIOD OF GENERATION (Days) FOR GROUP 3 DIGESTERS.

Group 3 digesters investigated the effects of seeding cow dung with banana peel and rice husk. From figure IV, it was shown that the total volume of biogas produced is 1723cm^3 and 1696cm^3 for digesters F and G respectively. Also, from figure VII, it was clear that the highest volume of biogas of 190cm^3 were generated on the eighth day for digester F while digester G generated the highest volume of biogas of 180cm^3 on the ninth day. Table 2 also showed that digester F which contained 200g cow dung, 160g rice husk, and 40g of banana peels dissolved in 400cm^3 of water was better than digester G which contained 200g cow dung, 40g rice husk, and 160g of banana peels dissolved in 400cm^3 of water. An increase in biogas generation in digesters F and G is attributable to the fact that banana peel and rice husk are largely made up of pectic materials, soft and decomposed easily.

Table II and Figures I-VII showed that the best result can be obtained when cow dung is seeded with varied amount of banana peels and rice husk. The seeding factor supersedes the effects of addition of metals and the effects alkalinity/acidity. Therefore to get the best result, it is better to seed cow dung with banana peels and rice husk.

Conclusion

Based on the parameter investigated in this experiment i.e addition of metals, acidity/alkalinity, and seeding materials, the single factor that has most influence on biogas yield is the effect of seeding material. In order to get the best production from wastes, it is better to seed one waste material with the other. Therefore from this experiment, it can be concluded that using cow dung as feedstock, biogas yield can be increased with addition of copper, maintaining a pH of between 7.0 – 8.2 and seeding the feedstock with rice husk.

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