ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 10, April 2014

Development and Performance Evaluation of Piggery and Water Hyacinth Waste Digester for Biogas Production

B.O. Akinnuli, T.O. Olugbade
Department of Mechanical Engineering, Federal University of Technology, P.M.B.704, Akure, Nigeria

Abstract - Biogas refers to a gas produced by breakdown of organic matter in the absence of oxygen. Organic waste such as dead plant and animal material, animal feces and kitchen waste can be converted into a gaseous fuel called biogas. Usually, getting rid of waste places burden of not only cost on organizations, communities, government among others but also engender several environmental issues. The objective of this study was to design and develop a digester for biogas production, analyze the biogas produced by the mixture of piggery waste and water hyacinth, and finally test the biogas produced to confirm its flammability. In this work, waste material specifically piggery waste and hyacinth was used for the production of biogas in a locally fabricated digester of volume 95.5 liters. The quantity of waste material fed into the digester were 13.8 kg of total solid of piggery waste, 4.6 kg of water hyacinth and 12 liters of water to mix wastes into the slurry. The mixture was done in the ratio of 75% to 25%; piggery waste to water waste respectively. Analysis showed the compositions of the input to the digester as follows; Moisture content of the piggery-waste sample and water hyacinth sample respectively were (85% and 87%), Ash content of both samples were (3% and 2.4%), Nitrogen-content were (0.71% and 6.8%), pH-values were (7.28 and 6.71%), Total solid content were (15% and 13%), Carbon content were (28% and 26.4%), Phosphorus content were (15% and 18.88%) and finally the Potassium content of the two samples were (17.89% and 18.87%). Finally, analysis of the biogas thus produced were studied and compared to previous work. The biogas produced in this work was indeed flammable and at a relatively low cost, thus validating the methodology used in the research for experiment 3. Production of biogas at optimal conditions was recommended as a panacea to solving the prevalent environmental issues caused by waste disposal; and should be embraced not only by government on a large scale but also by individual on smaller scale.

Keywords: **Biogas, digester, moisture content, organic matter, piggery waste, water hyacinth waste.**

I. INTRODUCTION

Biogas is a flammable gas produced by anaerobic fermentation of organic waste materials. Biogas is composed of methane (55 – 70%), carbon-dioxide (30 – 40%) and traces of other gases such as Nitrogen, Carbon-monoxide, water and hydrogen sulphide [5] and [9]. In a fermentation process, an organic matter is an aerobically degraded to carbon-dioxide (CO_2) and methane (CH_4) with only a relatively small yield of microbial cells. The various feedstock substrates for an economically feasible biogas production were identified by [3], [4] and [6]. They include water lettuce, water hyacinth, dung, cassava leaves and processing waste, urban refuse, solid (including industrial) waste, agricultural residues and sewage. An investigation into the operating parameters for the generation of quality biogas from piggery waste was done by [1] and the pig waste feedstock for the determination of the design parameters for biogas digester plants was characterized by [2]. In 2007, [8] produced biogas from banana and plantain peels while [7] utilized poultry, cow and kitchen wastes for biogas production. Similarly, an engineering design and economic evaluation of a family sized plant was carried out at the Technology Planning and Development Unit, Obafemi Awolowo University, Ile-Ife by [14]. In 2008, [10] provided a synthesis of the key issues and analyses concerning the design of a high-performance anaerobic digester. In 2006, [11] designed and constructed a plastic bio-digester and used it to produce biogas from spent grains and rice husk mixed together. They have all worked on piggery waste and other materials for biogas production and its characterization but biogas production from the mixture of piggery and water waste has not been done before. This research work is therefore aimed at developing a biogas digester, producing biogas from the mixture of piggery and water waste and evaluating the biogas produced from the mixture. The production of biogas becomes necessary as a readily available source of energy for domestic use such as cooking, lighting as well as for running small thermal Engines. The conversion of these wastes to gas will in no doubt reduce the pollution of the environment. This study will create or reveal another alternative to source of fuel that is highly economical, friendly to the environment with low cost effort for domestic use.

II. MATERIALS AND METHODS

A. Materials

The materials used for this project are piggery waste, water hyacinth, water, measuring scale, thermometer and digester. Materials used for the digester are mild steel, stirrer, valve and pressure gauge. Samples of piggery wastes, was obtained from an Omo-Olugbade piggery pen at Oke-Afa, Isolo, Lagos State. Samples of water hyacinth were also collected from River Ogun, along Lagos – Ibadan expressway, Isheri, Lagos State. The samples were immediately transported to the laboratory for analysis. The samples of water hyacinth were chopped and milled into fine slurry, also piggery waste into slurry

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 10, April 2014

with water (1: 1w/v). The following analyses were carried out on the slurry samples: determination of moisture, ash, nitrogen, carbon, phosphorus and potassium content as well as pH seal and total solids.

1. Determination of Moisture content

5.0g of each slurry sample was weighed into a pre-weighed aluminium drying dishes. The dish and its contents was then transferred into the oven at a temperature of 105°C and dried for 4 hours. This was then allowed to cool in a dessicator and weighed.

$$Moisture\ content = \frac{weight\ of\ water}{Total\ weight} \times \frac{100}{1} \quad (1)$$

2 .Determination of the Ash Content

5.0g of the samples was weighed into porcelain crucible previously ignited and weighed; igniting the material on a hot plate in the fume cupboard until no fume was seen, charred organic matter. This was later transferred to a muffle furnace (55°C) using a pair and ignited for hours.

This was cooled in desiccators and weighed immediately.

$$Ap = \left(\frac{[C\omega t + A\omega t] - Ce\omega t}{S\omega t}\right) \times 100 \quad (2)$$

Where:

Ap = Percentage of ash

$A\omega\tau$ = Weight of ash in kg

$Ce\omega\tau$ = Weight of empty crucible in kg

$S\omega\tau$ = Weight of sample in kg

3. Determination of the Nitrogen Content of Samples

For this, Kjedahl nitrogen method was used as stated by [5], [12] and [13]. 1gm of each sample was weighed into a digestion flask. Kjedahl catalyst (selenium tablets) was added to the samples. 20ml of concentrated tetraoxosulphate (vi) acid was added to each sample and then fixed in the digestion units (450°C) of the Kjedahl apparatus in a fume cupboard. The digest, pure yellow coloration after cooling changes into a colourless liquid that was transferred into 100ml of 4% boric acid solution was pipette into conical flask, 5 drops of methyl red was added to each flask on indicator.

4. Determination of the pH value of Samples

10 mls of the slurry was separately dispensed into a beaker; and its pH meter (Unican 9450 model). The pH meter was calibrated using standard buffers of pH 4.0 and 7.0.

5. Determination of Total Solids. (T.S)

This was determined by subtracting the percentage moisture from 100. The remainder value is the total solids on the dry matter.

6. Determination of Carbon Content

5g of the sample were separately weighed into a 250 ml Erlenmeyer flask, 35 mls of 72% tetraoxosulphate (vi) acid was added, swirled to dissolve. 10 ml of concentrated trioxonitrate (v) acid was added and allowed to stand for 30 mins. This was follow by gentle boiling for 30 mins and allowed to cool to room temperature. 50ml of 72% tetraoxosulphate (vi) acid was again added followed by 20 ml of concentrated trioxonitrate (v) acid. The residue was filtered, put in a crucible and transferred to a muffle furnace at 800°C for 2 hrs until the carbon content burns off. This was later cooled in a desiccators and re-weighed the percentage carbon was then calculated from the weight of carbon in the crucible as stated by [5].

$$Cper = \left(\frac{A-B}{S\omega t}\right) \times 100 \quad (3)$$

Where:

$Cper = Percentage\ of\ carbon$

A = Weight of sample after digestion in kg

B = Weight of sample after the removal of carbon in kg

$S\omega t = Weight\ of\ sample\ in\ kg$

7. Determination of Phosphorous and Potassium Content of Samples

10g of the sample was separately incinerated to a white ash at 550°C in a muffle furnace for hours, cooled and the ash was washed into 250 ml beaker with 30 ml of concentrated trioxonitrate (v) acid evaporated to dryness on steam bath and the residue further heater for 30 minutes. Thereafter the sample was dissolve in 40 ml Hydrochloric acid (HCl) and digested for 2hrs on a hot plate magnetic stirrer. This was later filtered while hot using Whitman Number 4 filter paper, washed with HCl and the volume made up to 100 ml with distilled water. The minerals (potassium and phosphorous) were then determined using spectrometry method of atomic Absorption spectrophotometer (AAS) (Model Phillip pu 9100X) with a hollow cathode lamp and a fuel rich flame (air acetylene, sample were aspirated and the mean signal responses were recorded at each of the elements respective wavelength.

The concentration of the element was calculated using the equation below:

$$Econ = \frac{Scon \times Sab \times 100}{Stab \times S\omega t} \quad (4)$$

Where:

$Econ = Element\ concentrated\ in\ mg/100g$

$Scon = Standard\ concentrate\ in\ mg/100g$

$Sab = Sample\ absorbance\ in\ mg/100g$

$Stab =$ Standard absorbance

$S\omega t = Weight\ of\ sample\ in\ kg$

III. METHODOLOGY

A. Digestion Procedure

Collection of water hyacinth was done, chopped and milled. Piggery waste was also collected and left open for

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 10, April 2014

three days for fermentation. On the third day, the mixture of the waste was loaded into the digester at temperature 37ºC for digestion with stirring every day. The feed stocks were prepared using three different experiment A, B and C. Experiment A determine the appropriate mixing ratio; 1.2 kg : 1 Litre (fresh piggery waste to water), 1.5 kg : 1 Litre (fresh piggery waste to water). Experiment B increases the carbon content of the feed stock; 2.0 kg of piggery waste + 1.0 kg of water hyacinth, 4.2 kg of piggery waste blended with 1.64 litre water hyacinth. In experiment C, another experiment was performed on one-week old piggery waste using a ratio of 1.4 kg: 1litre (piggery waste to water). The gas produced was later passed through 10% (w/v) potassium hydroxide and 10 grams of an hydroxide and 10 grams of anhydrous calcium chloride to remove carbon dioxide and water vapour respectively. In the above experiments, the following items were monitored: (i) Total solid (AOAC 1980: 125-127, 552-554), (ii) volatile solids (as stated in AOAC 1980 method), (iii) pH: carried out on daily basis, (iv) temperature: taken twice daily (morning and later in the afternoon), (v) gas produced, monitored daily, (vi) gas analysis, done on a weekly basis, (vii) Stirring, done on a daily basis, (viii) quality of gas by simple burning test using a glowing splint.

1. Digester Design

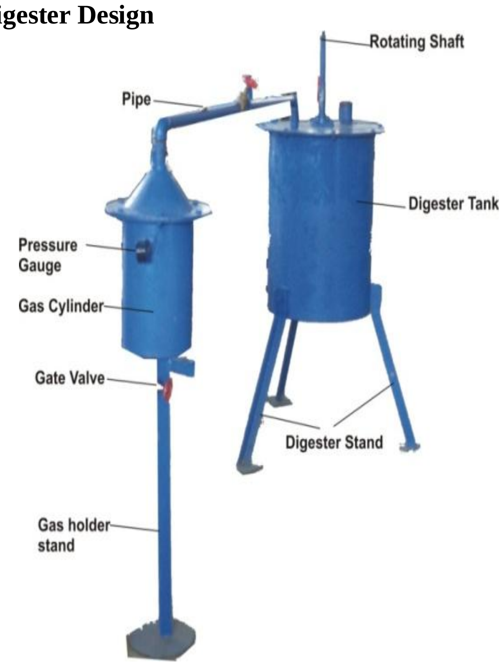

Fig. 1: Developed Digester Assembly

A digester is a tank that processes the organic matter that produces biogas. A digester can be in different forms, shape and sizes, depending on the need of the people using it and the availability of building materials. A domestic digester of prototype biogas with a partition between the digester and gasholder was designed and fabricated for this study. The digester was of mild steel, of 45cm by 60cm with three outlets connection, one for gas and the other for the introduction of slurry sample and taking out digested slurry, these outlets will be closed after in and out of slurry. The Design capacity of the digester is 95500 litres while that of the gas cylinder is 10,650 litters.

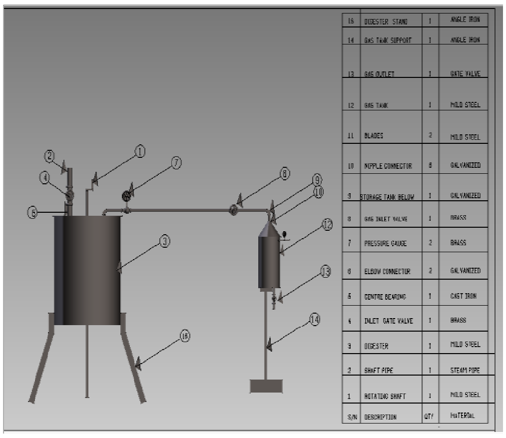

Fig.2: Labelled Drawing of the Digester

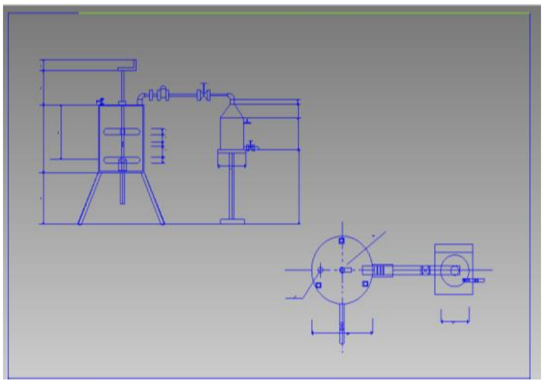

Fig. 3: Detailed Drawing of the Digester

2. Digester Production Cost

Table 1 shows the costing of the materials for the construction of the 10,560cm^3 Portable gasholder and 95,500cm^3 digester. The prices are given in Naira, and are due to change with time.

IV. RESULTS AND DISCUSSION

A. Results

The results obtained showed the moisture content of the samples, ash content of samples, nitrogen content of samples, pH value of samples, carbon content of Samples and mineral analysis of samples. Moisture content of the piggery-waste sample and water hyacinth sample respectively were (85% and 87%), Ash content of both samples were (3% and 2.4%), Nitrogen-content were (0.71% and 6.8%), pH-values were (7.28 and 6.71%), Total solid content were (15% and 13%), Carbon content were (28% and 26.4%), Phosphorus content were (15% and 18.88%) and finally the Potassium content of the two samples were (17.89% and 18.87%). The analysis of results as obtained from experiment A, B and C are shown in the tables below.

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 10, April 2014

Table 1: Materials and Labour for the Construction of a Portable Gas Holder and Digester

S/N	Materials	Quantity/Quality	Total Cost (Naira)
1.	Galvanized Mild steel sheet	3mm	6,000
2.	Road Shaft	30mm	2,000
3.	Plate Plunge	4mm	1,200
4.	Bearing	30mm	2,500
5.	Basting x 60mm	30mm	1,000
6.	Elbow	1	600
7.	Valve	2	1,000
8.	Steel GI Pipe		1,000
9.	Union lock with cover	3	1,500
10.	Pressure gauge	1	4,500
11.	Electrode	1	800
12.	Transportation		3,500
13.	Sheet metal cutting and welding Expenses		5,000
14.	Miscellaneous		5,000
15.	Consultancy		10,000
	Total		45,600

Table 2: Physiochemical assessment and quality of biogas using mixing ratio of 1.2kg: 1.0litre (piggery waste: water)

weeks	Average pH	Average Temp.	Volume of gas produced (m3)	Analysis of biogas CO2:CH4	Quick burning test for gas
1	7.2	30	0	High : Low	Not Burning
2	6.9	38	0.2	High : Low	Not Burning
3	6.3	30.5	0.6	High : Low	Not Burning
4	6.8	28	0.8	High : Low	Not Burning
5	6.5	28	1.4	High : Low	Not Burning
6	6.6	30	1.6	High : Low	Not Burning

Total Solids: 19.76%, Volatile Solid: 5.6%

Biogas from Experiment B

Table 3: Physiochemical assessment and quality of biogas using mixing ratio of 1.5kg: 1.0litre (piggery waste: water)

Week	Average pH	Average Temperature	Volume of gas produced (m3)	Analysis of biogas CO2:CH4	Quick burning test for gas
0	7.0	30		High : Low	Not Burning
1	6.7	32	.6	High : Low	Not Burning
2	6.4	28.5	.4	High : Low	Not Burning
3	6.5	30	.6	High : Low	Not Burning
4	6.5	29	.5	High : Low	Not Burning
5	6.6	30	.5	High : Low	Not Burning

Total Solids: 18.76%, Volatile Solids: 4.2%

Biogas from Experiment C

Table 4: Physiochemical assessment and quality of biogas using mixing ratio of 1.4kg: 1.0litre (piggery waste: water)

Week	Average pH	Average Temperature	Volume of gas produced (m3)	Analysis of biogas CO2 : CH4	Quick burning test for gas
0	6.5	28	0	High: Low	Not Burning
1	6.4	30	.8	Low: High	Good Burning
2	6.5	31.5	.2	Low: High	Good Burning
3	6.7	27	.8	Low: High	Good Burning
4	6.8	28		Low:	Good

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 10, April 2014

			.5	High	Burning
5	6.8	30	.5	Low: High	Good Burning

Total Solids: 14.02%, Volatile Solids: 3.7%

SUMMARY OF RESULT

Table 5: Water Hyacinth

S/N	Parameters	Values
1	Moisture content	87%
2.	Ash content	2.4%
3.	Nitrogen content	0.68%
4.	pH value	6.79%
5.	Total solid content	13.0%
6.	Carbon content	26.4%
7.	Phosphorus content	18.88%
8.	Potassium content	18.87%

Table 6: Piggery Waste

S/N	Parameters	Values
1	Moisture content	85%
2.	Ash content	3.0%
3.	Nitrogen content	0.71%
4.	pH value	7.28%
5.	Total solid content	15.0%
6.	Carbon content	28.0%
7.	Phosphorus content	15.0%
8.	Potassium content	17.89%

V. DISCUSSION

Analysis on the potentials of piggery waste and water hyacinth were investigated as substances for biogas production. The moisture content of piggery waste and the hyacinth was 85% and 87% respectively. Both samples possess adequate moisture content required for the proliferation of anaerobic microorganism and hence proper digestion of the waste fort the release of gas production. The ash content of piggery and water hyacinth was 3.0% and 2.4% respectively. The ash content can be regarded as a measure of the mineral content of a product sample. The high ash content will be utilized by the micro-organisms for growth, and multiplication and hence digestion process for the release of Biogas. The pH of piggery waste and Water hyacinth was 7.28 and 6.79 respectively. The pH value observed for both samples was adequate enough for the activeness of micro-organisms for proper digestion of the waste. A pH value of 6.0-7.2 is necessary for good and rapid digestion of the waste samples. The total solid of piggery waste and water hyacinth was organic materials in which the micro-organisms will feed on as for food for growth and metabolic activities. The total solids could also serve as a surface area for enhanced growth of micro-organism. The carbon content of piggery and water hyacinth was 28% and 26.4% respectively. The Nitrogen content was 0.71% and 0.68% for piggery waste hyacinth respectively. The C:N ratio of piggery waste was 28:0.71 and for waste sample were adequately ideal as substrate for Biogas, for good and adequate digestion of waste sample, a C:N ratio of 30:1 is required. Physiochemical assessment and quality of biogas monitored for the various experiments revealed that the pH was within the range required for biogas production, but good quality biogas was not obtained until experiment 3, as evident from the quick burning test that gave poor result for experiment 1 and 2 as shown in Table 1, Table 2. The biogas produced from experiment 3, in that it has higher percentage of CH_4 gas gave better result. The results of experiment 3, shown in table 3, showed the good quality combustible biogas yield. The retention time was 12 days, and at this stage, the biogas produced was scrubbed by passing it through 10% KOH and 10% calcium chloride

VI. CONCLUSION AND RECOMMENDATION

It can be deduced from the results carried out on the analysis of piggery wastes and water hyacinth that both wastes are very good source for the production of biogas as the Carbon Content is greater than the Nitrogen Content from the analysis carried out. It is pertinent to provide appropriate mixing ratio and other optimal conditions to help ensure that adequate and good quality biogas is engendered. The gas produced in this study was very little due to low temperature. In carrying out this project, it must be ensured that the conditions for the smooth production of biogas are met as stated in the literature review of this project. It is therefore recommended that the process for the production of biogas should be done during summer period (dry season). The piggery waste and other materials which can decompose should be used for the production of biogas, the wastes should not be too solid or watery, it should be in a slurry form and be mixed in the ratio of 1.4kg: 1litre (piggery waste to water).

REFERENCES

[1] F.N. Ajuebor and A.K. Lawal: "An Investigation into the Operating Parameters for the Generation of Quality Biogas from Piggery Waste", FIIRO Journal of Industrial Research and Technology, Vol. 2, No. 1, Pp. 1-4, 2008.

[2] F.N. Ajuebor and A.K. Lawal: "Characteristics of Pig Waste Feedstock for the Determination of the Design Parameters for Biogas Digester Plants", FIIRO Journal of Industrial Research and Technology, Vol. 3, No. 2, Pp. 5-8, 2008.

[3] J.F.K. Akinbami, M.O. Ilori, T.O. Oyebisi, I.O. Akinwuni and O. Adeoti:"Biogas energy use in Nigeria: current status, future prospects and policy implications", Renewable Sustainability Energy, Rev. 5: 97-112, 2001.

[4] R.N. Okagbue: "Fermentation Research in Nigeria", MIRCEN J. 4:169-182, 1988.

[5] H. William: "Official Methods of Analysis of the Association of Official Analytical Chemists", Washington, Publishing Town, P. 437, 1980.

[6] A.O. Ubalua: "Cassava wastes: Treatment options and value addition alternatives", Africa Journal on Biotechnology. 6: 2065-2073, 2008.

[7] S.J. Ojolo, S.A. Oke, O.K. Animasahun and B.K. Adesuyi: "Utilisation of poultry, cow and kitchen wastes for biogas production: A comparative analysis", Iranian Journal on Environmental Health Science Engineering. 4: 223-228, 2007.

[8] M.O. Ilori, A. Adebusoye, A.K. Lawal and O.A. Awotiwon: "Production of biogas from banana and plantain peels". Advance Environmental Biology 1: 33-38, 2007.

[9] S. Fariku and M.I. Kida: "Biomass potentials of Lophira lanceolata fruit as a renewable energy resource", Africa Journal on Biotechnology. 7: 308-310, 2008.

[10] A.H. Igoni, M.J. Ayotamuno, C.L. Eze, S.O.T. Ogaji and S.D. Probert: "Designs of anaerobic digesters for producing biogas from municipal solid-waste", Journal on Applied Energy. 85: 430-438, 2008.

[11] V.A. Ezekoye and C.E. Okeke: "Design, construction, and performance evaluation of plastic biodigester and the storage of biogas", The Pacific Journal on Scientific Technology. 7: 176-184, 2006.

[12] E.I. Atuanya and M. Aigbirior: "Mesophilic biomethanation and treatment of poultry wastewater using a pilot scale UASB reactor", Environment Monitor Assessment. 77: 139-147, 2002.

[13] A.A Adeyanju: "Effect of seeding of wood-ash on biogas production using pig waste and cassava peels", Journal on Engineering and Applied Science. 3:242-245, 2008.

[14] O. Adeoti: "Engineering economy studies of biogas as a renewable energy source at household level in Nigeria". Unpublished MSc thesis in Technology Management, Technology Planning and Development Unit, Faculty of Technology, Obafemi Awolowo University, Ile-Ife, Nigeria, 1998.