DESIGN AND FABRICATION OF MINI BIODIGESTER FOR BIOGAS PRODUCTION USING RICE HUSK AND BREWER SPENT GRAIN AS FEED STOCK

***Ugwuodo, C.B[1]., Anike, E. N[1]., Odoh, E.E[2]., Nwachukwu, H.K[1]., Ukah, S.O[1]. and Ogbeide, S. E.[3]**

[1]Chemical Engineering Department, Michael Okpara University of Agriculture Umudike, Umuahia, Abia State.
[2]Project Development Institute, (PRODA), Emene, Enugu, Enugu State.
[3]Chemical Engineering Department, University of Benin, Benin, Edo State. samuelogbeide@uniben.edu.ng

*(+234) 8037156199; Fax: (123); E-mail: chijioke_ugwuodo@yahoo.com

ABSTRACT

Biogas is a mixture of gaseous component generated from the decoposition of organic matter in the absence of oxygen. It consists of methane, carbondioxide, hydrogen and traces level of other gases which include carbon monoxide, hydrogen sulphide etc.Agricultural wastes are abundantly available and serve as one of the potential carbon sources for the production of biogas after biochemical conversion. This study focuses on digester design, fabrication and its utilizationin in the digestion of brewer spent grain and rice husk mixed with algae water. Three biogas digesters (A, B, C) with capacities 32 litres, 30 litres and 32 litres respectively were designed and fabricated. The substrate (Rice Husk and Brewery Spent Grain) was first pre-treated for 21 days using Lake salt (Trona or Soduim carbonate or soda ash) locally known as "Akanwu" which aided to break down the lignin and cellulose in the feed. The substrate was mixed in the ratio 1:1 with algae water to substrate ratio 3:1 was used. The algae served as an inoculum to introduce micro organisms into the digester. The digester was stirred twice daily to avoid scum formation in the digester and allow for easy escape of the gas produced. The retention time used for this experiment was 47 days except for Digester C which was for 8 days. During this period the temperature readings for Digester A and B was taken in order to determine variation and its effect on production rate. The gas produced was measured using water displacement method, and at the end of the experiment the gas generated was further taken to the laboratory for analysis. The result obtained from the laboratory analysis showed that Digester A produced the highest methane content of 73.95% followed by the Digester B with 68.92% content and Digester C had the least methane content of 65.95 %. Digester A had the highest cumulative biogas yield of 37.77 litres over its PVC counterpart Digester B which had 22.66 litres within the retention period. Result of this study showed that Digester A (Metallic Digester) was more efficient in biogas generation, which can be said to have resulted from its ability to retain heat and prevent air entrance or leakage.

Keywords: Biogas, Brewer Spent-grain, Digester, Proximate analysis, Rice Husk.

1. INTRODUCTION

The overall efficiency of processes desingned to convert lignocellulosic biomass to biogas lies on determinig the compositions of such material. Lignocellulosic biomass consists of cellulose, hemicelluloses and lignin which are bonded together by covalent bonding ,various intermolecular bridges, and vander waals forces forming a complex structure, making it resistant to enzymatic hydrolysis and insoluble in water (Sullivan, 1997). Lignoclluloses continue to be investigated as a source of energy production because of their high availabilty. Energy accessibility is the catalyst for economic growth, development and poverty alleviation, and it determines the level of social development (Kennedy *et al.,*2008). There may be no solution to the energy crises in Nigeria and other developing countries except we develop an indigenous technology suitable and convenient to our peculiar circumstances especially, with respect to technological know-how, raw material availability, human and economic resources applicable by rural dwellers (Asikong *et al.,* 2013).

Fast-growing population growth causes increase in energy demand and decrease in environment quality. Although Nigeria is one of the oil and gas producing countries, decrease in oil reserves and revocation of oil subsidy has increased oil price and decreased environmental quality due to excessive utilization of fossil energy. Utilization of alternative renewable and environmental friendly energy resources, therefore is required. Renewable energy has remained one of the best alternative ways for sustainable energy development especially for the rural and suburban areas. It was established that the hydrogen gas in the long run is the alternative energy carrier, providing an environmentally friendly and sustainable production. However, when considering the short-run term, biogas is one of a renewable energy that can be used as an energy source to substitute fossil fuels. It is a readily available energy resource that significantly reduces green-house gas emission compared to emission of landfill gas to the atmosphere.

Biogas is a renewable substitute for fossil fuels which is made from non-toxic biodegradable renewable sources such as animal wastes, agricultural wastes, crops, domestic wastes and industrial wastes. Biogas is produced by anaerobic digestion which is an engineered biochemical process that mineralizes organic substrates to methane and carbon dioxide through a series of reactions mediated by a consortium of micro-organism under anaerobic condition.

The technology of biogas production is not new. The development and construction of biogas digester started in the 1920s and has spread to several developing countries such as India, Taiwan etc. In these countries, biogas technology has supplemented a large proportion of energy requirements of the rural majority. In India for example biogas generating plants using cow manure have been in operation for years. In Taiwan more than 7,500 methane generating devices utilizing pig manure have been in construction. The technology of biogas production is therefore advantageous in that it can be used to provide energy for households and rural communities without tampering with fuel wood and also tackling the challenges faced by effective solid waste management.

Several designs of biogas digesters have been developed over the years, including the two basic digesters, the dome and the floating drum (Rajendra *et al*., 2012). The former is typically built underground in the shape of a dome and the latter is built with an iron floating drum on top of the digester (Rajendra *et al*., 2012). In the dome digester, organic waste is added through an inlet into a large dome typically 2-10 m^3 in size. In floating drum biogas digesters, the biogas is stored in a drum floating on the organic waste being digested. Both digesters are commonly being used in households in the rural areas of developing countries (*Bruun et al., 2013*). Currently, in many developing countries like China, India and Africa almost all household digesters are using animal manure as organic load for the production of methane gas. However, manure is not always available especially in urban areas (Yousf *et al.,* 2011). Having a clear and comprehensive understanding of the relation between the costs involved in constructing a biogas digester, the size of the digester as well as the volume of methane gas produced, can help determine if any value will be obtained from using it (Amigun and Blottnitz, 2007).

The purpose of this research is to design, compare and evaluate the performance of a metallic and plastic digesters. This will be achieved through the design of a bio-digester, generation of gas using spent grain, rice husk and algae water as feedstock. This choice is informed due to the work done by others where high yield is achieved by blending any two of the above substrates (Ezekoye *et al.,* 2006, Ezekoye *et al.,* 2014 and Uzodinma *et al.,* 2007) and characterizing the gas production using an automatic digital gas analyser.

2. MATERIALS AND METHODS

2.1. Material Procurement

Brewery spent grain used for this study was collected from Nigerian Breweries Plc located at Aba, Abia State, Nigeria. The powdered rice husk was procured from a rice mill at Bende, an agricultural centre in Abia State of Nigeria. The Algae water was collected from the environment of Michael Okpara University of Agriculture Umudike, Abia State, Nigeria.

2.2. Preatreatment of Feedstock

Lignocellulosic materials are resistant to hydrolysis due to their structure and composition. Alkali addition causes swelling of lignocelluloses (Kong *et al.,* 1992) and partial lignin solubilisation. Therefore, alkali treatment was carried out by adding lake salt or Soduim carbonate (Locally known as Akanwu) to the solution of Brewery Spent grain and Rice husk in separate buckets for 21 days. Figure 1 shows the lignocelleulosic biomass before and after digestion.

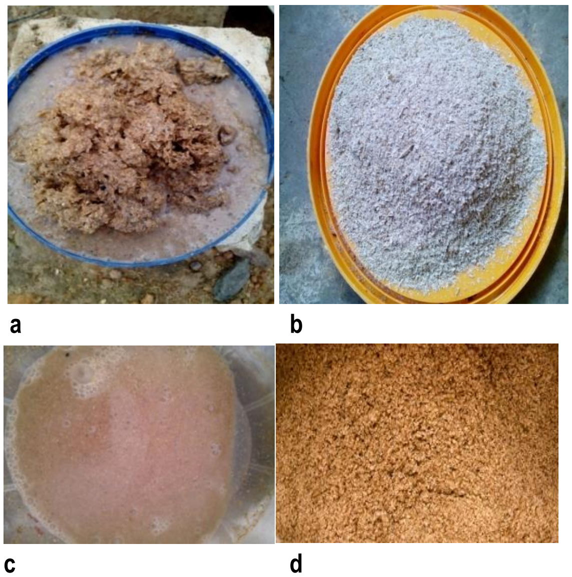


Figure 1. Biomass(raw waste) before and after digestion. Mixed spent grain,rice husk with algae water before digestion (a); Raw rice Husk (b); Digested Slurry (c); Raw brewer spent grain

2.3. Physiochemical Analysis of the Feedstock

In order to ascertain the potential of the substrate for anaerobic digestion, certain analysis on the raw waste biomass were carried out to determine some parameters. The most important analysis carried out were proximate analysis to determine the moisture content(MC), fat, ash(mineral), fixed carbon (FC), nitrogen and fibre. These provided the information on the nutrient content and usability of the raw waste. The analysis were also carried out after the digestion process. Table 1 shows the proximate analysis of the raw waste before and after digestion.

2.4 Experimental Setup

In charging of the digesters, certain factors were considered before feeding the digester with the waste. They include:

a. Digester Size: The amount of waste and the quantity of water that should be fed inside the digester should be such that 75% of the digester will be occupied by the waste and water while the remaining 25% will be reserved for the gas that will be produced.
b. Type of operation: it was convenient to carry out batch operation considering the size of the digester.

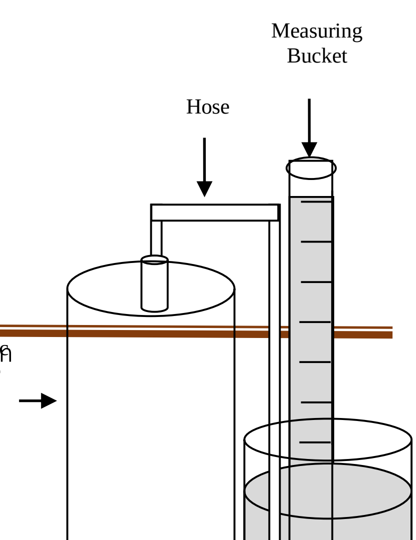
The experimental work was carried out in three digesters. The inlet of the digester was covered tightly to ensure the anaerobic condition was maintained. One end of the rubber hose was connected to the digester gas outlet located at the top of the digester and the other end of the rubber hose was connected to a bucket where the volume of the gas was calculated using water displacement method. The digester capacities are 32 kg, 30 kg and 30 kg for Digester A, Digester B and Digester C respectively. The ratio of waste to water was 1:3, while the ratio of the rice husk to spent grain was 1:1. since 75% of the digester was occupied by waste and water that means that the waste and water ratios are;
Digester A (32 kg) – 18 L of water: 6 kg of waste (3kg of rice husk: 3 kg of spent grain)
Digester B (30 kg) - 16.9 L of water: 5.6 kg of waste (2.8kg of rice husk: 2.8 kg of spent grain)
Digester C (30 kg) - 16.9 L of water: 5.6 kg of waste (2.8 kg of rice husk: 2.8 kg of spent grain)

2.5 Experimental Procedure

Six (6) kg of wastes consisting of brewer spent grain and rice husk which was earlier soaked in water for 21 days was placed in digester A as well as 18 litres of the water containing algae. Digester B and Digester C contained the same composition which is 5.6 kg of wastes and 16.9 litres of the algae water.

The wastes submerged in water were properly mixed to give homogenous slurry. The presence of water in the wastes helped to dissolve the solids in the wastes, thereby creating favorable environment for micro-organisms to feed on the nutrients in the wastes.

The digesters were covered properly to keep the environment anaerobic. Samples of the wastes were collected for proximate analysis. Figures 1 and 2 shows the schematic and real view of anaerobic digester.



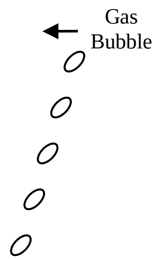


Figure 2. Schematic diagram of the setup for Anaerobic digestion

Figure 3. Rear view of the setup for the anaerobic digestion

The digester was stirred two times using stirrer provided by hand agitation to avoid scum formation in the digester. The experiment was on for 47 days and readings taken for this retention period. This excluded Digester C which was carried out for a short retention period of 10 days with no daily readings. The experiment was conducted at ambient temperature without any form of temperature regulation. The temperature and pH were measured twice daily.

The temperatures were taken with the aid of a mercury-in-glass thermometer, while the pH readings were taken with a pocket pH metre. Volume measurements of biogas produced was done by water displacement. The biogas measurement unit consists of a 9 litres transparent bucket and a big bowl, all connected in series to the digester headspace. Pressure in the digester tends to displace a given volume of the gas produced. The readings were taken twice daily around 9:00 am and 3:00 pm of the day. This was done in order to determine the temperature changes during the day and also the effect of sunlight on the digester. Observations showed that, the body of the digesters received so much heat, especially around 3:00 pm as a result of reduced relative humidity in the air, and this could be related to the black paint used to coat the outside body of the digester.

The experiment lasted for 47 days behind Elctrical Engineering block, Michael Okpara University of Agriculture Umudike, Abia state.

3.0. DESIGN AND FABRICATION

3.1. Design Considerations

Location of the site is selected which has large exposure of sunlight and away from animal attacks. Some other design parameters considered are:

Input parameters

i. Water availability.
ii. Daily availability of raw materials.
iii. Financial inputs.
iv. Climate of the region and its geographical location.

Output parameter:

i. End use energy requirement(kWh) and useful power requirements(kW) of thermal and material energy
ii. Requirement of biogas or methane (in energy units or m^3 per day)

Design parameter

i. Optimum temperature range
ii. Retention period.
iii. C/N ratio of feed.
iv. PH of slurry.
v. Feed of water ratio (V_f/V_w).
vi. Percent of total solid in feed (Ts %).
vii. Gas yield (m^3/m^3 of digester/day).
viii. Ultimate gas yield (m^3/m^3 of digester/total retention time).

3.2 Design of Digester "A" (Metallic)

The metallic digester design was made according to information available in the literature. The digester component includes: the fermentation chamber (Vf), the gas storage chamber (Vgs), the gas collecting chamber (Vc), the influent (Vi), and the effluent chambers (Ve). The components are shown diagrammatically in figure 4. The fermentation chamber is the chamber where the slurry charged in the digester is stored. The gas storage chamber is the upper frustum section of the digester; the gas collecting chamber is the chamber through which the stored gas exits from the digester. The influent chamber is the channel through which the digester is charged, while the digested slurry is discharged from the effluent chamber. The digester is a vertical cylindrical tank constructed with a metal with an inlet pipe for the introduction of substrate and an outlet pipe to collect the digested substrate. A stirrer is incorporated inside the digester to break scum on the substrate and create uniform temperature profile in the digester. The calculation was made for all the components described in this section.

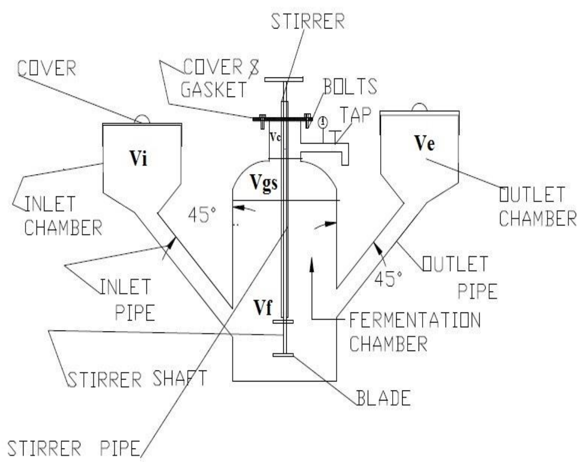


Figure 4. Parts of metallic biodigester

Height of the digester cylinder (Hd): The height of the digester main body was calculated assuming a 24 litres volume fermentation cylinder(Vf), and a digester dimater of 30cm was considered. Table 1 shows the calculated values for digesters A, B and C.

$$\text{Hd} = \frac{4\text{Vf}}{\pi \text{D}^2} \qquad (1)$$

Volume of influent chamber (Vi): The volume of the influent chamber was calculated using the relation.

$$\text{Vi} = \pi r^2 h \qquad (2)$$

Volume of the effluent chamber (Ve): The volume of effluent chamber was also calculated as;

$$\text{Ve} = \pi r^2 h \qquad (3)$$

Volume of the gas chamber (Vc): The gas chamber serves as a temporary storage of the biogas evolved. Since the inlet and outlet of the valves were closed , the gas will be forced to compressed. To calculate volume of a frustum body, let "h'' be the height of the cone that was removed to form the frustum as shown in figure 5.

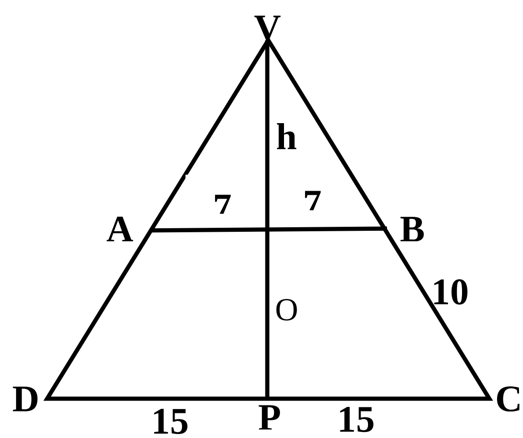


Figure 5 . Shape of a Cone

Let H be the height of the entire cone which the frustum forms a part. Then, H has the relation as;

$$\text{H} = 10 + h \qquad (4)$$

From Figure 5 , triangle VOB and VPC are similar as

$\frac{VO}{VP} = \frac{OB}{PC}$ (5)

Volume of the small cone (VAB)

$= \frac{1}{3}\pi r^2 h$ (6)

Volume of the large cone (VDC)

$= \frac{1}{3}\pi r^2 h$

Volume of frustum = Volume of large cone (VDC) –Volume of small cone (VAB)

Volume of gas collecting chamber i.e. top cylinder

(Vc) $= \pi r^2 h$ (7)

Total Volume of digester is $Vt = Vf + Vi + Ve + Vgs + Vc$ (8)

1.3. Design of Digester "B And C" Plastic Cans

Two identical biogas digester B and C designed for long and short retention time respectively, were made of plastic materials. Digester B and C takes the shape of a non-rectangular perfect tank with an inlet pipe for the introduction of substrate.

a **b**

Figure 6. Plastic can digesters: Digester B (a); Digester C(b)

The fermentation chamber is the chamber where the slurry charged in the digester is stored, The gas storage chamber is the upper section of the digester ; the gas collecting chamber is the chamber through which the stored gas exits from the digester. The influent chamber is the channel through which the digester is charged, while daily sampling of the digester was achieved through the sample chamber. Digester B and C was set up in a vertical and horizontal forms, respctively as shown in Figure 6. No stirrer was incorporated inside the digester in other to reduce the posibility of air entering the digester, based on the natuer of the material. Uniformity was achieved by hand agitation of the body of the digester, as this aided to break the scum on the substrate and create uniform temperature profile in the reactor. The following are the dimensions and calculation for the two biodigesters:

Lenght of Digester(Ld) = 30cm
Width of Digester (Wd) = 24cm
Height of Digester (Hd) = 42cm
Volume of the cubiod
= Ld × Wd × Hd (9)

The total volume of Digester (Vt) = Ld × Wd × Hd

Volume of fermentation chamber (Vf) = $3/4$ × Vt

Volume of gas collection chamber = $V_t - V_f$

Table 1: Dimensions of Digester A,B and C

	Calculated Values (Litres)	
Component	Digester A	Digester B and C
V_i	0.622	-
V_e	0.622	-
V_{gs}	5.00	-
V_c	1.463	7.5
V_f	24.00	22.50
V_t	32.00	30.00

4. RESULTS AND DISCUSSION

4.1. PHYSIOCHEMICAL PROPERTIES OF WASTE

Table 2 shows the physiochemical composition of the substrate (Rice husk and Spent grain) indicating all parameters determined from the analysis of the substrate.

It shows that the raw materials (wastes) contained suitable nutrients needed for anaerobic digestion. The analysis of slurry before and after digestion showed marked differences in the concentration of various elements. Rice husk and Spent grain have high carbon content as shown in Table 2, which indicates that both contain cellulose, hemicelluloses, pectin, lignin and plant wax. The nitrogen concentration increased after digestion as can be seen also in Table 2. This is because the complex molecules have been broken down to smaller units thereby making the elements more available for utilization. The large cellulose molecules are broken down to glucose and the protein molecule to amino acids. The lipids are also broken down to lattice acids ethanoic acids, etc. This implies that the sludge from the three waste could serve as better fertilizers (NPK) after digestion.

Table 2: Physical and Chemical compositions of Substrate before and after Digestion

Parameters	Feed Composition Before Dgestion (kg)		Digester A After Digestion	Digester B After Digestion	Digester C After Digestion
	Spent Grain	Rice Husk	(%)	(%)	(%)
Dry matter	74.46	88.65	73.78	85.02	46.8
Moisture	25.54	11.35	26.22	14.98	53.20
Ash	4.80	21.80	13.57	11.25	7.13
Crude Protein	16.00	5.00	4.56	3.84	6.32
Nitrogen Free Extract	29.70	14.76	20.7	38.83	9.85
pH	6.2	6.2	5.3	5.2	-
Carbon	47.16	30.1	385	36.2	41.62
Nitrogen	1.81	1.13	4.78	4.22	2.36
Crude Fibre	17.70	38.55	30.4	26.15	16.95

During the experiment, green algae were added to the feed as a seed inoculum. Normal biogas production is impossible without sufficient quantity of required microbes. It is these microbes that perform the function of anaerobic degradation of organic substances to yield methane. Inocula of different sources contain different colonies of biogas microbes.

The experimental study was carried out within ambient temperature range of 24 °C to 42 °C. Biogas production commenced from digester A and B within 24 hours after charging.

Untreated rice husk takes about 3 to 4 months before flammable biogas production commences (Uzodinma *et al.,* 2007). This can be attributed to the fact that the hydrolysis of rice husk and spent grain is very slow as a result of the hard structure of the plant and it has been reported that plant materials especially crop residues are more difficult to digest than animal manure because of presence of lignin. Consequently, hydrolysis of cellulosic materials can be a major rate determining factor in anaerobic digestion.

The data presentation and evaluation of the batch reactors for each samples was computed and analyzed using MS Excel-sheet.

Figures 7 and 8 show the plot of the biogas production for digesters A and B with respect to retention time. As earlier stated no biogas readings were taken for Digester C and the biogas production was very slow at the beginning of the process. In the first few days of observation, biogas production was very low or indeed do not form yet due to lag phase of microbial growth (Gupta, *et al.,* 2009; Rabah, *et al.,* 2010). A careful observation shows that the total gas produced by the metallic digester (digester A) is more than that produced by the plastic digester. A number of factors can be said to account for this variance. The temperature retention ability of the metallic digester is more than that of the plastic container (Persson,1979), reported that the optimum temperature range for biogas production is 35 °C , while extremely high and low temperatures affect microbial activity hence resulting in low gas yield. The average temperature chart Figure 12 shows an average of 34.4 °C for digester A and 33.9 °C for digester B both within the mesophilic temperature range while the average ambient temperature is 30.9 °C. The metallic digester has the ability to absorb and retain heat faster than the plastic made digester hence providing a better environment for microbial activity.

During the course of this study, it was observed that the metallic digester unlike the plastic made digester produced more volume of gas to the storage vessel without the help of a compressor. The other digesters made of plastic seemed to expand as the gas yield increases. Hence, economically, the metallic digester is more acceptable than its plastic digester counterpart.

Both materials used for digester fabrication, experienced a common challenge; which is rain. Rain affected the yield as it reduced the temperature of the digesters to an unbearable range of 25 – 29 ^{0}C, hence little or no production at these periods. At other periods, this affected the digesters in another mode. It was observed that a drop in temperature caused by the downpour led to a reduction in pressure in the digesters hence no gas was obtained from the digesters at this condition. The pickup in activity of the digesters at higher retention time can be said to be as a result of more microbial activity in the digester caused by the presence of the algae which acted as an inoculum.

From Figure 10, it could be seen that the Digester A had the highest biogas yield of 37.7 litres. This could be due the fact that Digester A material of construction is a metal making it more receptive to heat compared to Digester B which was made of plastic. The poor performance of Digester B over Digester A could also have resulted from the limitation which we encountered during setup. It was also observed that digester B failed to be efficient in gas production for about 16 days. This could be due to expansion of the plastic that resulted poor pressure build up within the digester, It is generally known that enough pressure must be built in the digester before the gas could escape through the exit pipe of the digester. Digester A started gas production within 24 hours of digestion, could be attributed to the effect of alkaline hydrolysis and seeding of the substrate (Abdullahi*, et al.,* 2011). The performance of the metallic bio digester plant was very satisfactory. Figure 13 illustrates the regression temperature between the slurry and ambient temperature. For rice husk, spent grain and Algae from pond substitute the values of x = 37.0 ^oC for maximum ambient temperature and x =26.5 ^oC of the minimum ambient temperature on the prediction equation Y=1.2523x – 4.2385. The predicted maximum and minimum slurry temperatures were 46.3^{o}C and 29.0 ^{o}C. The equation R^2=0.6604 shows the coefficient of determination which explains proportion of two variables. For example, in Rice husk, spent grain and Algae, R^2 = 0.6604, it means that the relationship between the maximum and minimum temperatures of ambient and slurry temperatures was 66.04%. Figure 14 illustrates the regression temperature between the slurry and ambient temperature for digester A. For Rice husk, spent grain and Algae from pond substitute the values of x = 37.0 ^{o}C for maximum ambient temperature and x =26.5^{o}C of the minimum ambient temperature on the prediction equation Y=0.9187x + 5.4153. The predicted maximum and minimum slurry temperatures were 39.4^{o}C and 29.8 ^{o}C. The equation R^2=0.4319 shows the coefficient of determination which explains proportion of two variables. For example, in Rice husk, spent grain and Algae in digester B, R^2 = 0.4319, it means that the relationship between the maximum and minimum temperatures of ambient and slurry temperatures was 43.19%. This analysis carried out on the two digesters 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 15 show that the starting pH for digester A was 6.2 while the final is given as 5.3. The least pH of 4.9 was recorded on the thirteenth day after which it picked up. From Fig 15, an initial pH of 5.6 was recorded for Digester B. This dropped steadily to about 4.8, maintained there for some time before steadily picking up to a pH of 5.2 on the 47th day.

The pH data obtained showed an initial fall to a more acidic level before assuming stable values toward neutrality but remained within the acidic throughout the fermentation period thus accounting for the scarce population of methanogens as well as reduced gas production. This inhibits or even stops the digestion or fermentation process (Sarno, 2008). The initial drop in pH is important since activities of aerobes and facultative aerobes are essential to produce relevant acidic metabolites, which are acted on by methanogenic bacteria to produce methane. Methanogenic bacteria are very sensitive to pH and occur best within a pH range of about 6 and 7.8 (Sarno, 2008; Gungor *et al*, 2005).

Table 3 : Biogas Composition

Digester Type	**CH_4 and Others (%)**	**CO_2 (%)**	**CO (%)**	**H_2S (%)**
Digester A	73.95	24.00	0.046	2.004
Digester B	68.92	29.00	0.081	1.999

Digester C	65.95	32.00	0.053	1.997

Table 3 displays the results of the biogas collcted and analysed with digital gas analyzer. Biogas consists mainly of methane (50-80%), CO_2 (20-50%) and traces of hydrogen sulphide (H_2S), carbon (II) oxide (CO), hydrogen (H_2) and nitrogen (N_2). The relative percentages of these gases in biogas depend on the type of waste and the management of the digestion process (Seed, 2003).

The high value of CO_2 recorded for Digester C can be attributed to the retention time of 8 days observed. The retention time was chosen as such so as to determine the amount of H_2 and CO_2 that will be recorded. Previous work done in this area suggest that very little amount of CH_4 will be produced with more of H_2 since there will be little methanogens in the media at such retention times of about 7 – 10 days during which H_2 production is maximum (Osuagwu *et al.,* 2014).

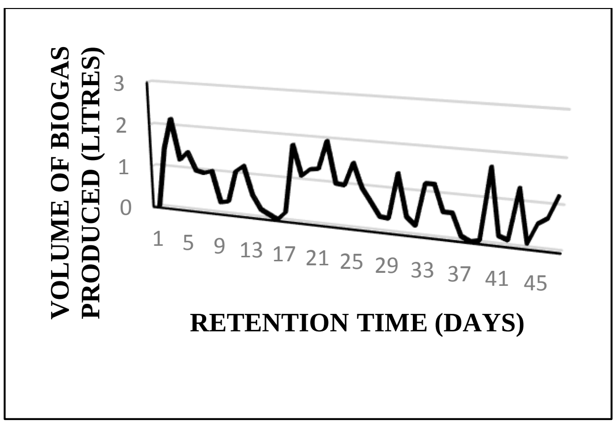


Figure 7. Daily volume of biogas production for Digester A

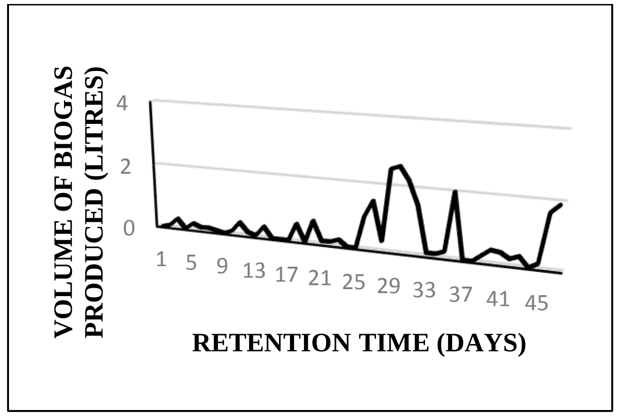


Figure 8. Daily volume of biogas production for Digester B

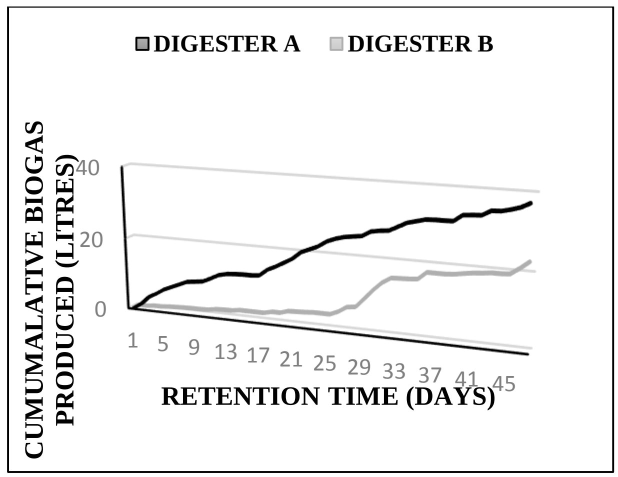


Figure 9. Cumulative biogas production for Digester A and B

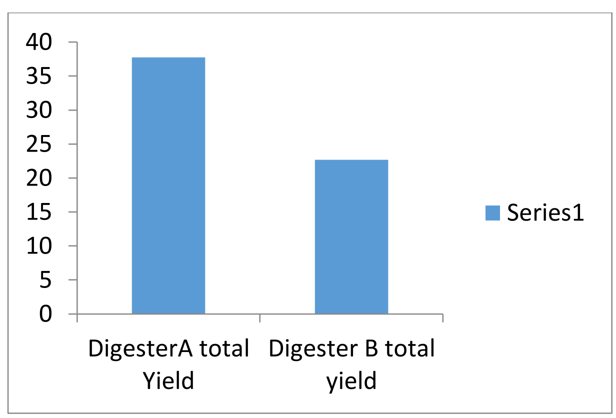


Figure 10. Total Gas Yield for Digester A and B

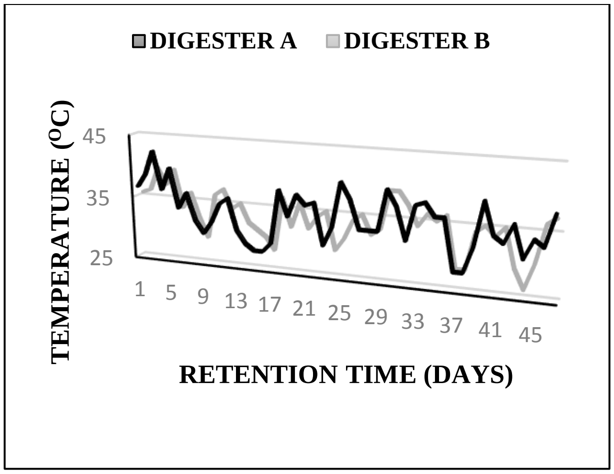


Figure 11. Slurry Temperature for Digester A and B

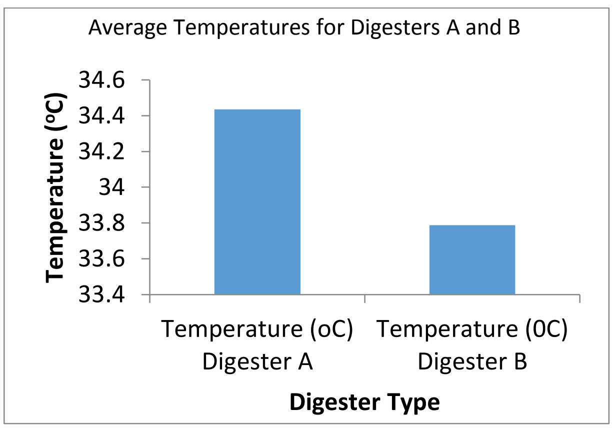


Figure 12. Average Temperature for Digester A and B

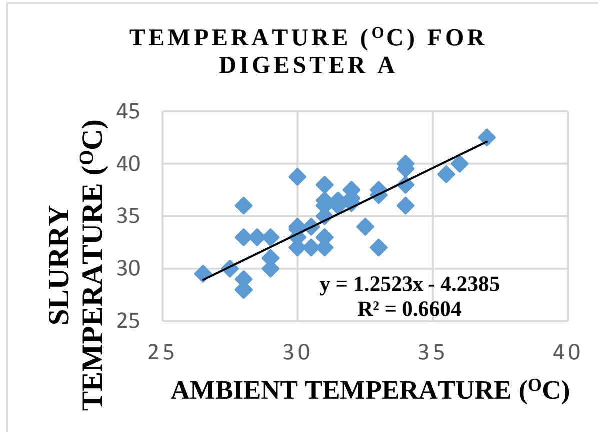


Figure 13. Slurry versus Ambient Temperature for Digester A

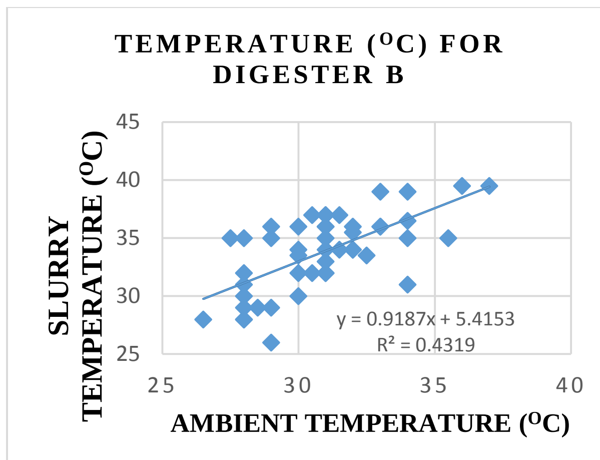


Figure 14. Slurry versus Ambient Temperature for Digester B

The method of non-acclimatization was adopted in this case where about 2 kg of rice husk and spent grain sludge was heated at about 80^{o}C for 15 minutes before being mixed with about 6 kg of fresh rice husk and spent grain (ratio of 1:1). The setup was allowed to run for about 8 days before the gas produced was analysed for its composition. The inability of the gas analyser in this case to detect H_2 gas was a limitation as the quantity of H_2 produced could not be detected. The high amount of CO_2 produced in this case is of great significance to prove the work of Osuagwu *et al*. (2014) and to show that little amount of CH_4 is produced under the conditions at which this work was carried out.

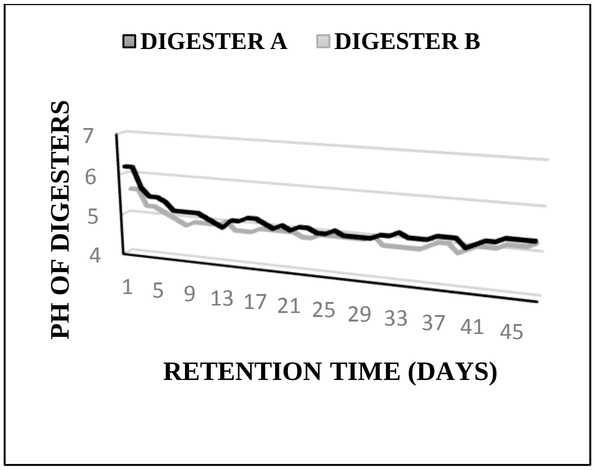


Figure 15. PH changes for Digester A and B

5. CONCLUSION

From this study, it has been reasonably shown that rice husk and spent grain is a good source of biogas. It was established that the volume of biogas produced by feedstock can be greatly increased by adding algae and that pre-treatment of the feedstock with Lake salt (Trona or Sodium carbonate) to hydrolyze the feed aided to increase the rate of digestion. The lake salt also provided a cheap source of alkali and improved gas yield.

It was also reported that metallic digester is a better material of construction for biogas digester than plastic materials. In this regard,the temperature retention ability of the metallic digester is far better than plastic digesters. This was clearly shown in the results obtained during the experiment. Result of post digestion proximate analysis shows clearly that the sludge from digestion of rice husk, spent grain with algae is a good source of manure. The development of the biotechnology and bio-derivable energy from agricultural residues if effectively harnessed will help alleviate the energy problems of developing countries such as Nigeria and also help in environmental sanitation and sustainability. The underlying principle guarding this technology is strictly based on the correct manipulation of the digester's environment so as to avert digester failure and enhance higher gas yield paying strict attention to the pH and temperature of the system.

A comparative study of the production of biogas from the different digesters was carried out. At the end of the retention period, Digester A had the highest methane yield, while Digester C produced the least methane, due to its short retention time.

The digested slurry was found to have an increased nitrogen content, showing that it would serve as a good fertilizer. From the study, the following conclusions can be made;

i. Biogas can be produced by microbial digestion of organic material in the absence of air.

ii. Addition of algae as an inoculum is very helpful in accelerating biogas production.

iii. Pre-treatment of feedstock with lake salt aids to break down lignin and cellulose composition of the feed.

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