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CARBOHYDRATE BASED OPTIMIZATION MODEL DEVELOPMENT FOR BIOGAS PRODUCTION USING TRIPARTITE MIXTURE OF COWDUNG, PIGDUNG AND POULTRY DROPPING

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ABSTRACT

The determination of biogas production for varieties of substrates is pivotal in designing a self sufficient digester for private application and also for the development of large scale digester for marketing purposes. Some digester takes over 30days to generate ignitable gas. These substrates utilised in this work were mixture of cow dung, piggery waste and poultry waste. Substrates A, B, C of three digesters were mixed in proportion of 1:2:3, 2:3:1, and 3:1:2 respectively. Smart sensor gas detector was used to determine the biogas production capacity. The mean percentage of the carbohydrate (CH_2O) for A, B, and C were 21.167, 26.333, and 19.5 respectively. The maximum quantity of gas produced daily was 0.00479m^3 from 0.01125m^3 volume of available space. The methane gas production model developed was a function of pig dung, carbohydrate and the curing days. Gas generated by the digester became ignitable at the 17th day of the curing period. The methane gas produce were collected from day 17 to 31. The carbohydrate content was found to be inversely proportional to the volume of methane gas produced. The pig dung has more of protein than carbohydrate. The lesser the carbohydrates content the more the biogas production at the early days which decreases accordingly as the curing days increases. The model developed is an effective tool for optimum collection planning and strategy storage management that will enhance the economic viability of a Biogas production firm.

KEYWORD: Biogas, Carbohydrate, Developed, Digester, Model, Methane and Tripartite

INTRODUCTION

Biogas refers to a gas produced by breakdown of organic matter in the absence of oxygen. Organic waste such as animal faeces like cow dung, piggery and poultry waste can be converted into a gaseous fuel called biogas (Ocwieja, 2010). 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, poultry waste and cow dung, and finally test the biogas produced to confirm its flammability.

Biogas prevent damaging the earth's ecosystems and maintain a high quality of life for the planet's inhabitants, humans must manage their waste efficiently and safely. Agricultural wastes from animals such as poultry droppings, cow dung, and pig dung usually produce obnoxious odour and environmental problems for the people living around the areas where such wastes are dumped. These animal wastes have been found to consist of exploitable gas and energy which can be obtained by a process called Anaerobic Digestion and the gas produced can be used as a source of energy (Salminen and Rintala, 2002). Biological process of treating solid and liquid organic residues that leads to formation of digest rate and biogas production is called Bio-methanisation or Anaerobic digestion. Biogas can be produced from almost all organic materials that could be decomposed or processed by anaerobic digestion. These include animal dung, sewage, landfills and industrial wastes (Fariku and Kida, 2008). Animal wastes are available close to the point-of-use of the feedstock and economical for biogas production. It is inevitable that with large volume and high density poultry and pig productions, there will be large quantities of poultry wastes and pig wastes, which are rich in methane content, can be used to produce biogas through the process of anaerobic digestion (Igoni *et. al.*, 2008; Okagbue, 1988). Improvement can be done in the efficiency of the biogas production by utilizing the poultry waste along with pig manure by co-digesting them. The main objective of this work was to develop a biogas production model using tripartite mixture; The specific objective are to installed the developed digester in a suitable site, mix the tripartite extract with different ratio at constant water ratio, collect data manually, of temperature, PH, gas volume and quality of gas produced and develop a biogas production model based on the data generated.

HISTORICAL DEVELOPMENT OF ANAEROBIC DIGESTION TECHNOLOGIES

Historical evidence indicates that the anaerobic digestion process is one of the oldest technologies (Monnet, 2003). Very old sources indicate that using wastewater and so-called renewable resources for the energy supply is not new, but were already known before the birth of Christ (Deublein and Steinhauser, 2008). The first allusion to animal manure comes from Humphrey Davy, who reported early in nineteenth century the presence of this combustible gas in fermenting farmyard manure.

Davy is known for the invention of the miner's safety lamp (Maramba, 1978). However, the industrialization of anaerobic digestion began in 1859 with the first digestion plant in Bombay. By 1895, biogas was recovered from a sewage treatment facility and used to fuel street lamps in Exeter, England (Monnet, 2003). Research led by Buswell (Monnet, 2003) and others in the 1930s identified anaerobic bacteria and the conditions that promote methane production. As the understanding of the anaerobic digestion process and its benefits improved, more sophisticated equipments and operational techniques emerged. The result was the use of closed tank, heating and mixing systems to optimize anaerobic digestion.

China is one of the countries in the world where the use of biogas started at a very early stage (Ahmadu, 2009). In 1920, Luo Guorui built a biogas digester called "Chinese Guorui Natural Gas store", which was the first hydraulic digester in China, (Ahmadu, 2009). This marked the beginning of rural biogas systems development in China (Fulford, 2011). In 1978, 7 million plants were built, but only 3 million were working. In 2009, about 17 million biogas plants which mainly use underground masonry plants of size 4 to 10 m^3 but less than 50% success was recorded (Fulford, 2011).

In India, Mumbai system gas was used in lights in 1897 while the gas was used in an engine in 1907. In 1951, the KVIC national programme developed floating drum design plants for individual farmers of volume 7 to 35 m^3 with cattle dung as feed stock (Fulford, 2011). More so, in 1961, PRAD (state sector) involved adapted Chinese dome design as "Janata" plant (4 to 10 m^3). In 1981, AFPRO (NGO sector) involved adapted Chinese dome design as Deenbhandu plant (2 to 8 m^3). As at 2009, 12 million plants built with less than 60% success rate. In 2005, ARTI won Ashden Award for a floating drum design made from HDPE water tanks designed for urban families of volume 1 to 2 m^3 with food wastes as feed stock.

In 1975, Nepal school of demonstration anchored a Government programme term Development and Consulting Services (Aid programme) sponsor by Agricultural Development Bank for Biogas research development. In 1976 the Gobar Gas Company was set up to continue the programme as commercial operation. Pilot programme of 95 plants which used KVIC design with metal gas drums were set up. In Indonesia, fixed dome type biogas plants of $18m^3$ capacity with biogas purification plant have been constructed across communities. Efforts are on to develop the technology to the level of gas bottling and electricity generation (Karan 2012: Widodo and Hendriadi, 2005).

The use of petrol, kerosene firewood and other sources of energy have been found to be not only bad for the environment but it has detrimental health effects. Health problems due to smoke inhalation cause 1.6 million deaths per year, 28% of deaths due to indoor air pollution occur in many countries like Nigeria, these effects also account for 20% of fatalities in children fewer than 5 years of age. To alleviate some of these unsustainable and dangerous practices, the installation of a biogas settler with a latrine feed has been proposed. The system will collect waste from human and animal waste and convert it to energy and fertilizer. Ever since the beginning of mankind man has depended so much on the use of heat, energy this form of energy is widely used in various area and ramification of mankind, this include industrial application, environmental, household application amongst others (Baba and Nasir, 2012).

During the past two decades, developing countries and particularly Nigeria has witnessed increased level of waste generation due to population explosion, increased agricultural activities, and the growth of industries. Consequently, there is intense scrutiny of possible alternative of solid waste utilization through biogas production using organic residues, which includes poultry droppings, cattle dung, and kitchen wastes. Governments and industries are constantly on the lookout for technologies that will allow for more efficient and cost-effective waste treatment (Guruswamy *et al*., 2003; Alvarez *et al*., 2006). One technology that can successfully treat the organic fraction of wastes is anaerobic digestion (Verma, 2002). It has the advantages of producing energy, yielding high quality fertilizer and also preventing transmission of disease (Koberle, 1995). Anaerobic digestion is the controlled degradation of organic waste in the absence of oxygen and the presence of anaerobic microorganisms. The digestion process is carried out using an airtight reactor tank and other equipment used for waste pre-treatment and gas retrieval. The process generates a product called “biogas” that is primarily composed of methane (which can be used for cooking), carbon dioxide (which can be used for fire extinguishers), and compost products suitable as soil conditioners on farmlands (Ojolo and Bamgboye, 2005). The final effluent can be used as fertilizer on farmlands and sometimes as animal food additives. Harnessed biogas can either be processed and sold directly or used to generate energy, which can then be sold. Anaerobic digestion also produces savings by avoiding costs of synthetic fertilizers, soil conditioners and energy from other sources.

Exploitation of animal dung for production of biogas in Nigeria is in its infancy. The pioneer biogas plants are a $10m^3$ biogas plant constructed in 1995 by the Sokoto Energy Research Centre (SERC) in Zaria and an $18m^3$ biogas plant constructed in 1996 at Ojokoro Ifelodun piggery farm, Lagos by the Federal Institute of Industrial Research Oshodi (FIIRO) Lagos (Zuru *et al*., 1998; Ajuebor and Lawal, 2008). Approximately 70% of Nigeria's 120 million people live in areas where no formal waste management systems are in place. A recent study assessed Nigeria's biogas potentials (minimum value) from solid waste and livestock excrements. It revealed that in 1999, Nigeria's biogas potential represents a total of $1.382\times109\ m^3$ of biogas/year or an annual equivalent of 4.81 million barrels of crude oil. This work is a comparative study on the quantity and energy production of five different types of municipal wastes. It is a test for optimization of an anaerobic digestion process, which depends on the waste producing the highest quantity of biogas (Akinbami *et. al*., 2001). 12.7 mm plastic flexible connectors were utilized such that the fabricated gas collecting apparatus had a tap, which was used to run-off and measure water displaced by the collected gas. The gas was collected by water displacement method. This was carried out by measuring and recording the quantity of water displaced daily using a 100 ml measuring cylinder. The experimental set-up was as reported by Ojolo *et. al*., (2007).

Sagagi, (2009) presented results of the study on biogas production from fruits and vegetables waste materials and their effect on plants when used as fertilizer (Using digested and undigested sludge). It has been observed that the highest weekly individual production rate is recorded for the cow dung (control) slurry with average production of $1554\ cm^3$, followed by pineapple waste which had $965\ cm^3$ of biogas, then by orange waste which had $612cm^3$ of biogas, lastly, pumpkin and spinach wastes had $373\ cm^3$ and $269\ cm^3$ respectively. The results obtained shows that difference in the production of biogas to a large extent depends on the nature of the substrate. All the substrates used appeared to be good materials for biogas production and their spent slurries can be used as a source of plant nutrients (Ilori *et. al.*, 2007; Kamoru *et. al.*, 2014).

Sravanthi, (2011) assesses diffusion of one of the earliest renewable energy technologies initiated in India, which is domestic Biogas Plants (BPs). In his paper they examine the trends and patterns of the diffusion of biogas plants over time across states. Basically this project treats the need for the generation of heat energy for household, the use of heat energy in the household cannot be overemphasized, and mankind in the quest for useful energy has been applying so many method in generating the needed energy for the household consumption, for instance, the burning of wood, which often generate heat and emit a lot of carbon which often result to various health hazard.

However this was improved by the inception of technology in which natural gas gotten out from the fractional distillation of crude oil and the use of electricity generated energy in the household. In a simpler context, this method has been considered and seen be of many disadvantages, which includes: high capital cost for setting up (e.g. the natural cost), bad odour generation, emission of various chemical compound, which are harmful to the user (E.g. wood burning), high cost of maintenance (E.g. natural gas) and high skill in handling (electric heater and natural gas). Therefore this led to the generation of the biogas (gas generated from living organism) using the remains and waste in the house in which the needed energy is generated. But it is also a health risk. The spread of disease is increased during the raining season when these deposits are washed into water sources that in turn become contaminated (Raven, 2011; Thyagarajan *et. al.*, 2013). Several digesters have been developed to produce biogas, the challenge has been the effectiveness of it performance and detection of the gas composition. Some digester takes over 30days to generate ignitable gas. The ignitable gases are ethane, butane, propane, and gasoline. Through the performance evaluations of developed digesters an optimization model can be formulated to determined varieties of substrates biogas production capacity.

MATERIALS AND METHOD

An open area was selected for installation of the biogas digester where the effect of the sun ray is optimal. This is due to the pivotal effect of temperature in the production of the biogas as seen in several literatures. The experiment facilities were located in the School of Engineering, the Federal Polytechnic Ado-Ekiti. The digester was positioned on a concrete foundation to maximize atmospheric factor interaction. The position gave room to accommodate the sun effect from the lowest altitude at the East and from the lowest altitude at the West.

The data collected during experimentation includes, ph value using a Pen Type ph digital meter as produced by EN and SKU company**,** made in Vientiane,, temperature data collected using thermometer as produced by CDN The Time & Temperature Company, made in Portland and quality of gas produced was tested with the use of Smart Sensor Multi Gas Monitor A58900 by Intell Instrument produce in China.

The method of generating the data involves rationalizing the extract mixed. The extract was mixed with ratio 1:2:3, 3:1:2, and 2:3:1 for cow dung, piggery and poultry waste respectively. This done against quantitative output based on the result as derive from the pressure gauge, gas collector cylinder, weight variation and the volume of gas generated for curing days of 7, 21, 35 days. The process was also considered based on qualitative output, which is related to the data collected from the gas detector as applied for different curing days. The material used in the production of biogas are as follows; the digester tank: this was the storage tank in which the mixed substrate was poured, it was constructed with mild steel material with variation in height sizes, Regulator with pressure gauge: This is another material used in the construction of biogas which is use to measure the amount of force of a gas exerted in an area, which was produced by Rock view company in Nigeria. It was mounted on the top of the gas connector so as to regulate the quality of gas flowing out through the gas connector. Gas pipe is another material in which the gas passes through from the digester to the gas cylinder. Digital scaling device: This is a device in which the substrates are weighed. Other materials are; External threaded bolt, Hose connector, Tape, Clips, Gas connector, Animal dung (Cow dung, Piggery, Poultry waste).

Components

- INLET: It is a ù3 inch diameter PVC pipe having half meter in length, which is fixed at an angle that allows the feedstock to move into the digester. A pipe reducer having an inner diameter of 8cm and outer diameter of 6 inch is used as funnel.
- OUTLET: Through which the slurry after the digestion is moved out. It is made by a 3 inch diameter PVC pipe. It is placed at an angle that allows the slurry come out from the digester and reach in the outlet chamber.

- DIGESTER BODY: This is the place where the anaerobic digestion takes place. The feedstock is mixed well and fed through the inlet will reach the digester body and after the digestion process slurry goes outside through the outlet or effluent chamber.
- GAS HOLDER: The biogas formed after the anaerobic digestion is collected on the top of the plant, called gas holder. As the gas formation starts the gas holder will expand or inflate and if pressure reduces the gas holder deflate, since the digester is a flexible biogas digester.
- Gas Outlet The biogas which is present in the gas holder is taken using the gas outlet, which is a gas valve connected with a reducer. The gas valve is opened when it is to be used. Here a gas valve is made of brass.

Design calculation

Following the records accessed from various scholarly performed works on biogas production, the design calculation was carried out thus; FAO (1988); Filani and Ejiko, (2018) assumed daily biogas energy need of 1.5 to 2.0 m^3 for a household of six people while Ejiko *et. al*., (2012) reported that 0.8 to 1.0 m^3 of biogas per day would be sufficient to supply the energy needs of a family of 5 - 6 people to cook 3 times daily. The differences in these assessments can be due to variations in the quality of the biogas (that is the CH_4 concentration), which is affected by the composition of the feed entering the digester. It has been reported that daily energy requirement for cooking is estimated to be 0.34 to 0.42 m^3 of biogas per person; 1.7 to 2.1 $m^3$for five people (Singh and Sooch, 2004). The digester to be designed and constructed is to serve 100% of the energy needed for a household of 6 people per day, the capacity of the digester can be calculated thus with daily energy requirement for cooking for an individual is estimated to be 0.34 to 0.42m^3/day, then, for a household of six people, it becomes 2.04 to 2.52 m^3 / day, as estimated by Singh and Sooch, (2004); Forhad, (2013), Therefore the capacity of digester that would be constructed should be able to produce biogas of up to 2.00 to 2.52 m^3/ day.

The mixture of animal and kitchen waste rate of biogas production is about 0.5 m^3/kg of volatile solid as given by (Ejiko *et. al*., 2019).

$$\text{Volatile solid per day} = \frac{\text{Amount of gas generated each day}}{\text{specific gas yield of the substrate}} \quad (1)$$

$$\frac{2.52}{0.5} = 5.40\text{kg volatile solid /day}$$

Then with 5.40 kg volatile solid/day, the volume of digester containing waste could be calculated. But the normal range of volatile solid loading is in the range of 1 - 4kg vs /m^3/day and the optimal loading rate for animal and kitchen waste is about 2.0 kg vs/m^3/day (Eze, 2000; Malaťák and Dlabaja, 2011). Then with the volatile solid loading of 2.0 kg vs /m^3/day and volatile solid added of5.4 kg/day;

$$\text{Volume of digester containing waste} = \frac{\text{volatile solid per day (kg/day)}}{\text{volatile solids loading}\left(\frac{\text{kgvs}}{m^3}/\text{day}\right)} \qquad (2)$$

$$\text{The volume of digester containing waste} = \frac{5.4\text{kg/day}}{2\text{kgvs}/(\text{m}^3/\text{day})} = 2.7\ \text{m}^3$$

From the above equation it follows that, the volume of the digester that could bear the required waste is 2.7m^3.

Volatile solid loading rate is a measure of the biological conversion of the anaerobic digestion system. Feeding the system above its sustainable volatile solid loading rate, results in low biogas yield due to accumulation of inhibitory substances in the digester slurry (fatty acid) (Ejiko *et. al.*, 2019). Under such circumstances, the feeding rate of the system must be reduced.

The amount of biogas generated each day (m^3/day) will be calculated on the basis of the daily substrate input (volatile solids content) and specific gas yield of the substrate (Sasse, 1988), such that;

Daily gas production = V.S.C × S.G.Y (3)

Where, V.S.C = volatile solid content and

S.G.Y= specific gas yield

volatile solids content = 5.4 kg / day

Specific gas yield = 0.50 m^3 / kg

Daily gas production = 5.4 kg / day × 0.50 m^3 /kg

= 2.70 m^3 / day ≈ 2.70 m^3/ day

The maximum loading capacity of an ideal digester should not exceed 90% of the digester volume (Eze, 2000). If 2.70 m^3 is 75% of the volume of the digester containing waste required for 2.40 m^3 daily biogas production, then the entire volume (that is, 100%) is given as 75% = 2.70m^3

$$100\% = \frac{100 \times 2.70}{75} = 3.60\text{m}^3$$

Therefore, the entire digester volume is of 3.60 m^3 with a diameter of 0.56m and height of 1.22m.

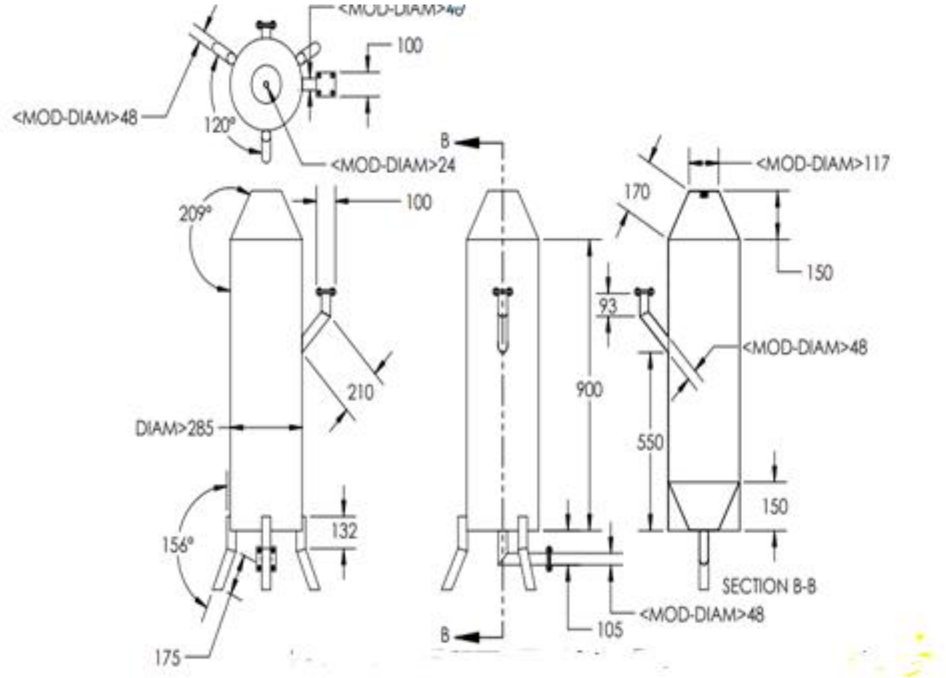


Fig 1: Working Diagram of Biogas Digester.

Plant capacity

For the purpose of this project, the drum type biogas plant was preferred. The digester volume was estimated using equation 4 as given by Okeke and Okeke, (2005).

$V_d = \pi r^2 h_d$ (4)

where, V_d=digester volume,

h_d=height of the digester,

r=radius of the digester.

$h_d = 1.0\, m, V_d = ?$, and r = 0.1425m

$V_d = \frac{22}{7} \times 0.1425^2 \times 1$

V_d= 0.0638 m^3

$V_f = \pi r^2 h_f$ (5)

Where

V_f= volume of the fluid in the digester,

r = radius of the digester,

h_f= height of slurry in the digester.

where, $h_f = 0.824m$, r = 0.1425m.

$V_f = \frac{22}{7} \times 0.1425^2 \times 0.824$

$V_f = 0.05255m^3$

Volume of gas space in the digester = $V_d - V_f$

Volume of gas space= 0.0638−0.05255

= $0.01125m^3$

Stress exerted in the cylinder

There are stresses exerted in the biogas cylinder, these are generated from the constituents (gas and the biomas) these stresses are estimated below.

Circumferential stress, according to Okeke (2005) for a closed vessel

Circumferential stress= $\frac{pd}{2t}$ (6)

where, σ -is the yield stress of the plastic chamber, p is the safe pressure the chamber can withstand. r -is the radius of the chamber (top and bottom will be considered), t -is the thickness of the digester and d is the diameter of the digester.

Force= Mass×acceleration due to gravity. (7)

F=230kg×9.81m/s^2 =2.26KN

Area=2×3.142×0.1425×1.0+ 2×3.142× 0.1425^2 =1.023m^2

To determine the pressure that the gas chamber can accommodate using the equation below as given by Okeke, (2005)

Pressure=$\frac{Force}{Area} = \frac{2256.3}{1.023} = 2.205\ KN/m^2$ (8)

Circumferential stress$\sigma = \frac{2205 \times 0.56}{2 \times 0.002}$ = 308.8KN/m^2

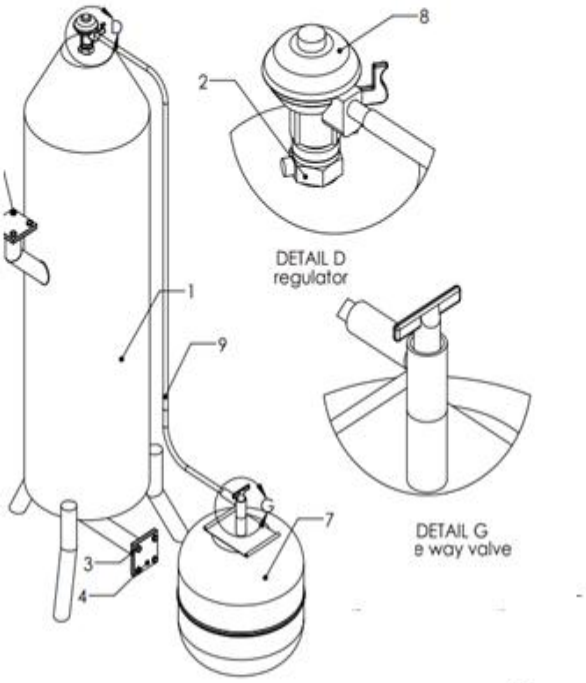
In order to ensure proper safety and to avoid strain hardening as it will later change the structure to be brittle, a factor of safety of 2 can be taken, hence, Sing and Sooch, (2004) estimated that:

Safe pressure $P_s = \frac{\text{Yield pressure}}{\text{Factor of safety}} = P_S = \frac{2205}{2}$ = 1102.5N/m^2 (9)

Maximum Allowable Stress

The maximum allowable stress can be calculated from the formula; $S_s = 0.27Ys$, as given by Eze, (2000). Y_S is the ultimate yield stress for steel.

$$S_s = 0.27Ys = 0.27 \times 240 = 64.8MPa \quad (10)$$



ITEM NO.	PART NUMBER	QTY.
1	cylinder	1
2	B18.2.4.2M - Hex nut, Style 2, M24 x 3 --D-S	1
3	gassget	2
4	cover plate	2
5	B18.2.3.2M - Formed hex screw, M10 x 1.5 x 20 --20WS	8
6	B18.2.4.5M - Hex jam nut, M10 x 1.5, with 16mm WAF --D-N	8
7	storage cylinder	1
8	regulator	1
9	hose	1

Fig.2: Biogas Digester.

Collection of the substrate

Fresh samples of poultry waste, pig manure and cow dung used for the study were obtained in a large clean plastic container, in which Poultry waste (manure) was obtained from Regional Poultry Farm, Pig manure was obtained from the pig farm and cow dung from cow farm at Federal Polytechnic Ado Ekiti Farm.

Experimental procedure

In order to find the optimal biogas production, a small scale testing of the sample in which cow dung, poultry waste and pig manure at different mixing ratios was tested. Three identical biogas digesters of capacity 15 litres were made and used for the study. 15 litres capacity PVC-barrel will act as the digester unit. PVC pipes were used for feeding the substrate waste (inlet), outlet for the slurry, tire tube connected acted as gas storage. Barrels were painted in black in order to prevent the entry of light thus preventing the algae growth. Since algae produces oxygen, microbes inside the digester will respire aerobically, thus the production of biogas stops. Also black colour will maintain the temperature needed for the gas production.

The experimental study was conducted in three digesters at different mixing ratios of cow dung, poultry waste and pig dung. The substrate should be mixed in the ratio 1:2:3, 3:1:2, 2:3:1 for cow dung, piggery and poultry waste respectively in which the Performance was analyzed for 35 days. About 3kg from each waste was weighed and then mixed thoroughly with about 15 litres of water for optimum gas production. This was then loaded to about 3/4 of the digester volume. The reactor inlet openings were tightly sealed to exclude oxygen. The reactor tanks containing substrates of cow dung, poultry droppings and piggery wastes were labelled as reactors 1, 2 and 3, respectively. The tanks were subjected to periodic shaking to ensure thorough mixing of the digester content while maintaining intimate contact between the microorganisms and substrate and to enhance complete digestion of substrate. The volume of biogas yield was measured and recorded on a daily basis. The experiment was monitored for 35days and was repeated for three consecutive times for each substrate. During this period, daily ambient temperature varied from 27ºC to 32ºC.

Experiment 1 for Digester A

- 1.4m of digester was filled with 30kg of substrate (cow dung, piggery and poultry waste) in the ratio 1:2:3.
- 5kg of cow dung, 10kg of piggery and 15kg of poultry waste mixed with 20 litres of water.

Experiment 2 for Digester B

- 1.4m of digester was filled with 30kg of substrate (cow dung, piggery, and poultry waste) in the ratio 2:3:1.
- 15kg of cow dung, 5kg 0f piggery and 10kg of poultry waste mixed with 15 litres of water.

Experiment 3 for Digester C

- 1.4m of digester filled with 30kg of substrate (cow dung, piggery and poultry waste) in the ratio 3:1:2.
- 10kg of cow dung, 15 kg of piggery and 5kg of poultry waste mixed with 12 litres of water.

Daily measurement of biogas production, methane percentage and temperature were calculated for each experiment. The optimum biogas production was taken for the large scale experimental design. The complete burn off time of the maximum production among the three was used for calculation.

RESULTS AND DISCUSSION

Results

A house hold scale anaerobic digester were designed and fabricated for the digestion of the three substrates in this study. The experimental results obtained during the monitoring period in the study were analysed using statistical methods. They are presented in tables, histogram and discussed as follows. In the second day of mixing the substrates, that is, cow dung, poultry and piggery waste, mixed in the ratio of 1:2:3, 2:3:1, and 3:1:2 for A, B, C respectively which were loaded in different digester of the same capacity (height, volume and diameter). An evidence of gas bubbles in the digester showed an indication through leakage at the top of the digester of the mixed substrates C (cow dung, poultry and piggery waste). This leakage was blocked with the use of male and female 4minutes mixed with sand to thicken the bubble region of the digester. Temperature readings for substrates A, B and C were observed for morning, afternoon and evening periods during the curing days. The afternoon section has the highest temperature, this is due to the high radiation of the sunlight at mid day while the temperature of each of the curing days tend to reduce at nights due to absent of sunlight, which actually made the environment to be cool and the coolness affects the temperature of each of the loaded digester. An average of 35o C was estimated as the noon temperature for the 31 curing days.

Quality of Gas Produced In Different Mixing Ratio for Each Substrates

The qualities of gases produce in the substrates are show in Fig. 3, 4 and 5.

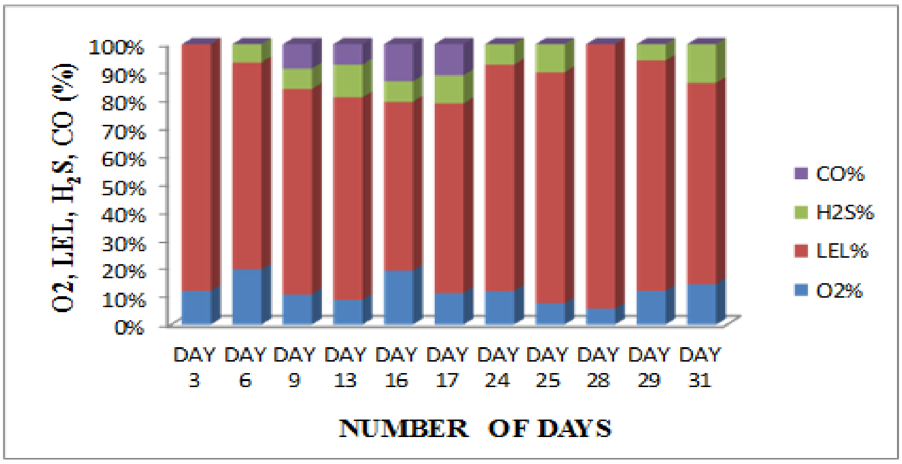


Fig 3: Quality of Gases Produce in Substrates A.

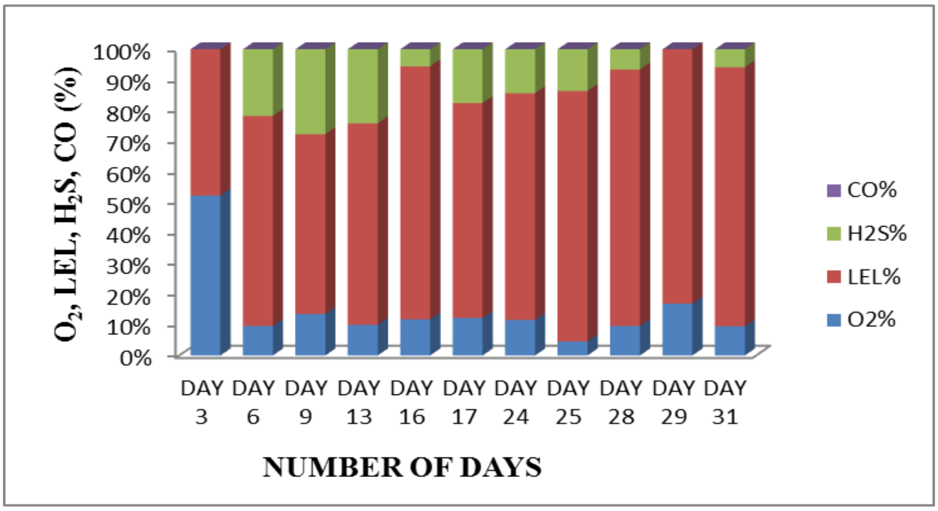


Fig. 4: Quality of gases produced in substrates B.

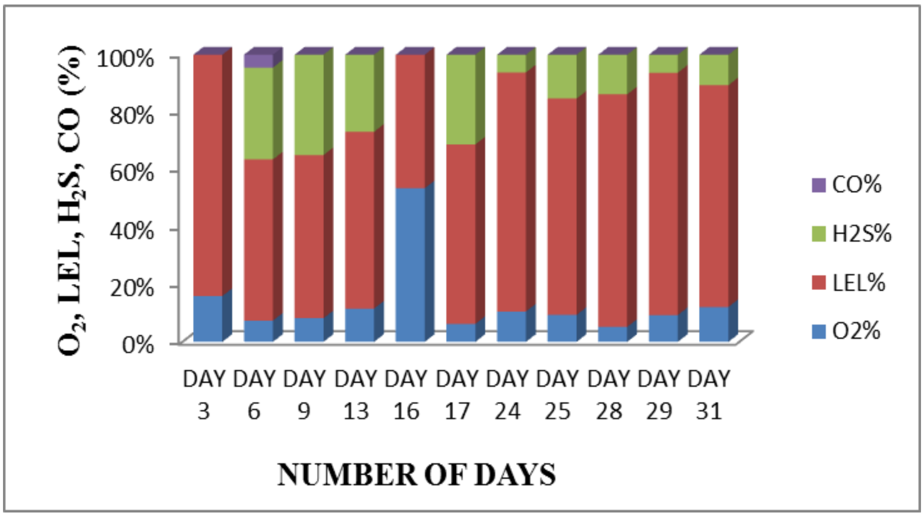


Fig. 5: Quality of gases produced in substrates C.

Figures 3, 4 and 5 show that H_2S (Hydrogen sulphide) was absents in all of the substrates on the third day. The observation as reflected in Fig. 3 shows that O_2 (oxygen) was 13.4% and the Lower Explosion Limit (LEL) was 98%, also from Fig. 4, O_2 (oxygen) was 17.5% and the Lower Explosion Limit (LEL) was 16% and from Fig. 5, O_2 was 14.% with a Lower Explosion Limit (LEL) of 78%. In the sixth days, there was an evidence of H_2S (Hydrogen sulphide) in each digester as presented in fig.3, 4 and 5 which was 26%, 31% and 57% respectively, after which there was an evidence of CO (carbon monoxide) which was 8% in only Fig. 5.

PROXIMATE ANALYSES

Experimental Procedure of the Proximate Analysis.

- **Determination of percentage ash content**

2.0 g of the sample was weighed into a pre-weighed crucible and burnt over a Bunsen burner flame until there was no more smoke. The sample was then placed in the muffle furnace at 600^{o}C until it turned grey-white. This was cooled in a dissector and weighed to a constant weight. The following expression was used to calculate ash content (William, 1980).

- **Determination of percentage oil/lipid content**

2.0 g of the sample was weighed into a filter paper and wrapped; the filter paper was placed inside the inner part of the Soxhlet extractor. The apparatus was then fitted to a round bottom flask, which contained 200 ml of hexane solvent. It was then attached to a reflux condenser. The set-up was clamped and heated in a water bath such that extraction is considered completed by the extracting solution becoming clear. The solvent was distilled off in the distillation set. The oil was then poured into a bottle and left for 5 days for the remaining solvent to evaporate. The oil was then weighed and the percentage oil content determined using the following expression (Ukpai and Nnabuchi, 2012).

- **Percentage moisture content**

2g of the sample was weighed into pre-weighed crucible. The crucible and the content were weighed again. This was then put in the oven at 105^{o}C for 3 hrs after which it was removed, cooled and weighed until a constant weight was obtained. The following expression was used to calculate the moisture content (Ubala, 2008).

- **Determination of percentage protein**

2 g of the sample was transferred to a Kjeldahl digestion flask and 8 g of the catalyst (96% anhydrous Na_2SO_4, 3.5% $CuSO_4 \cdot 5H_2O$, 0.5% Selenium dioxide) were added. 20 mL of conc. H_2SO_4 were added in an inclined position and shaken occasionally 11 times for 2hrs. The liquid formed was cooled and washed into the distill flask with distilled water. 50 ml of boric acid (2%) solution and screened methyl red indicator were added to the receiving flask. The distillation apparatus was collected with the delivery tube deeping below the boric acid solution. The diluted digest was made alkaline by the addition of 50% NaOH solution. About 50 ml of the distillate were collected and titrated with 0.1 M H_2SO4. A blank was also titrated under the same condition.

- **Determination of crude fiber**

About 2g fat free sample was taken into a fiber flask and 100ml of 0.255M H_2SO_4 was added. Then the moisture was hated under reflux with heating mantle for one hour. The hot moisture was filtered through a fiber sieve cloth. The difference obtained was thrown off and the residue was returned to the flask to which 100ml of 0.313m NaOH was added and heated under reflux for another one hour. The mixture was filtered through a fiber sieve cloth and 10ml of acetone was added to dissolve any organic constituent. The residue was wasted with 50ml of hot water twice on the sieve cloth before it was finally transferred in the pre-weighed crucible. The crucible with residue was even dried at 105^oC over night to drive off mixture. The oven dried crucible with crucible containing the residue was cooled in a desiccators and later weighed (W_1) for ashing at 550^oC for 4hours.

The crucible containing white and grey ash (free of carbonaceous material) was cooled in desiccators and weighed to obtain W_2. The % of crude fiber was calculated as follows.
Fiber (%)= [(W_1-W_2)/ weight of sample] x 100).

- **Determination of carbohydrates**

The carbohydrate value is the difference between 100 and the sum of all other values (protein, fiber, ash, fats, and moisture contents) present in the work.

Actual volume of the digester= 0.045m^3

Digester Oxygen Value 20.8-11.94 =8.86

1/4 of actual volume => 1/4 x 0.045= 0.01125m^3

Quantity of gas = 8.86/20.8 x 0.01125 = 0.00479m^3

The decision criteria utilize in this study implies that the oxygen is indirectly proportional to the gas produce. The quality of gases produce with reference to the applied decision is 0.00479m^3 from a volume of 0.01125m^3 gas production space. This implies that the digester produces 42% of the biogas on daily bases.

In comparison to some published work whose digester produces ignitable gases at 31days, the developed digesters produces burning gas at 17days, this implies that the anaerobic digestion is twice quicker.

Table 1: Ignitable Methane Gas Production Data Day 17 to 31

Cow	Poultry	Pig	Days	CH_2O	Protein	Methan m^3
1	2	3	17	31.17	9.2	0.00126
1	2	3	24	31.17	9.2	0.00101
1	2	3	25	31.17	9.2	0.00126
1	2	3	28	31.17	9.2	0
1	2	3	29	31.17	9.2	0.000756
1	2	3	31	31.17	9.2	0.00126
2	3	1	17	26.33	7.8	0.0029
2	3	1	24	26.33	7.8	0.00164
2	3	1	25	26.33	7.8	0.00164
2	3	1	28	26.33	7.8	0.000882
2	3	1	29	26.33	7.8	0
2	3	1	31	26.33	7.8	0.000756
3	1	2	17	19.5	8	0.00479
3	1	2	24	19.5	8	0.000756
3	1	2	25	19.5	8	0.001765
3	1	2	28	19.5	8	0.001765
3	1	2	29	19.5	8	0.000882
3	1	2	31	19.5	8	0.001387

Table 2: Quantity of Methane Gas Produced for ANOVA Analysis.

Cow	Poul	Pig	Days	CH_2O	Protein	Q m^3
1	2	3	17	31.17	9.2	0.00126
1	2	3	24	31.17	9.2	0.00101
2	3	1	25	26.33	7.8	0.00164
2	3	1	28	26.33	7.8	0.000882
3	1	2	29	19.5	8	0.000882
3	1	2	31	19.5	8	0.001387

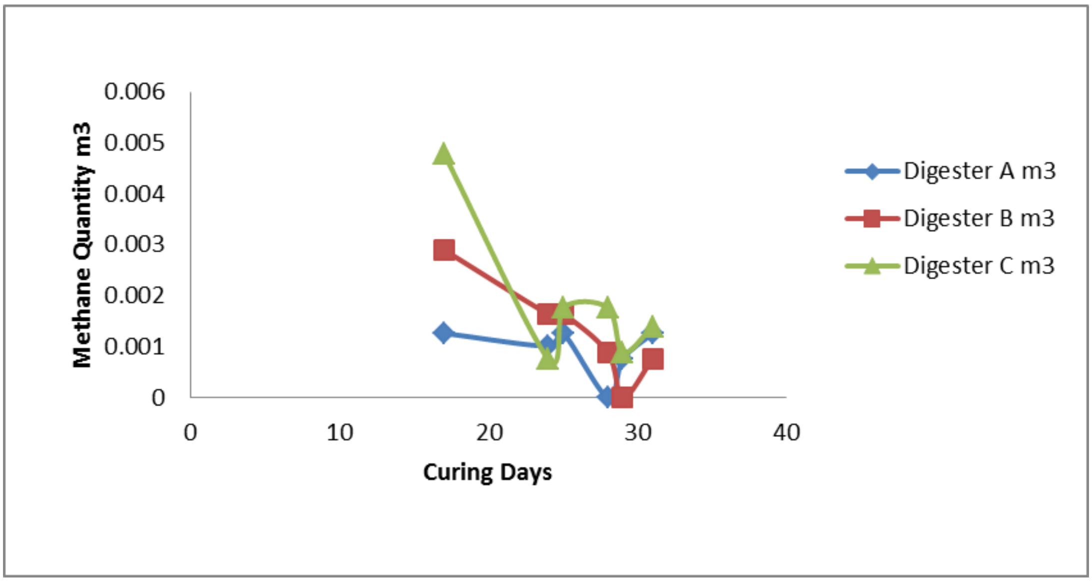


Fig 6: Ignitable Methane Gas Production Data Day 17 to 31.

SUMMARY OUTPUT	
Regression Statistics	
Multiple R	0.757684194
R Square	0.574085337
Adjusted R Square	0.268532195
Standard Error	0.000780466
Observations	18

ANOVA

	df	SS	MS	F	Significance F
Regression	6	1.14945E-05	1.9157E-06	6.2901448	0.004443392
Residual	14	8.52778E-06	6.0913E-07		
Total	20	2.00223E-05			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.007425268	0.001446858	5.13199352	0.0001525	0.004322065	0.01052847
X Variable 1	0	0	65535	#NUM!	0	0
X Variable 2	0	0	65535	#NUM!	0	0
X Variable 3	1.39903E-05	0.000247353	0.05655986	0.9556951	-0.00051653	0.00054451
X Variable 4	-0.000152886	4.05745E-05	-3.7680212	0.002078	-0.000239909	-6.586E-05
X Variable 5	-8.4018E-05	4.21874E-05	-1.9915449	0.0663014	-0.000174501	6.4649E-06
X Variable 6	0	0	65535	#NUM!	0	0

Methane Quant. (m^3) = 0.00001399Pi + 0.0001529D – 0.00008402Ch + 0.0074253 (11)

MODEL RESULTS DISCUSSION

The methane gas production model as given in equation 11 implies that the gas generated by the digester became ignitable at the 17th day of the curing period. The trend of the methane gas produce tends to decline from day 17 to 31. This is likely due to the inability to stir the residue within the digester, thereby minimising the interaction of the chemical constituent. The quantity of methane gas produce is linearly related to pig dung volume, curing days and carbohydrate content. The piggery waste and curing days are positively related to the quantity of the methane gas generated. The carbohydrate content was found to be inversely proportional to the volume of methane gas produced. The piggery waste has more of protein than carbohydrate. The lesser the carbohydrates content the more the biogas production at the early days which decreases accordingly as the curing days increases.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The results of evaluation of optimum biogas production showed that the best mixing ratio of the extract will be mixed in ratio 1:2:3, 3:1:2, and 2:3:1 for cow dung, piggery and poultry waste for A, B, C respectively. The results of this study clearly showed that biogas can be produced from mixture of cow dung and poultry and piggery waste through fermentation. The result also reveals the applicability of the locally made bio-digesters as a biogas production model. The remaining slurry in the bio-digester after biogas production was also found to be enriched compost which can be used to improve agricultural soil nutrient and productivity. The biogas generated from animal wastes (cow dung, poultry droppings and pig dung) produces an energy resource that can be purified and stored in gas cylinders and used efficiently for direct heat conversion. The process also creates an excellent residue that retains the fertilizer value of the original waste products. The increasing cost of conventional fuel in urban areas necessitates the exploration of other energy sources. The gas generated within the digester comprises of oxygen, Carbon monoxide, Hydrogen sulphide with their Lower Explosion Limit (LEL). This experiment shows the tremendous potential for the generation of biogas which is available from livestock wastes. Specifically, the following are noticeable from the experiment. For substrate A, mixed in ratios 1:2:3 cow dung: poultry: piggery waste was the first to combust compared to the other two substrate B (2:3:1) and substrate C (3:1:2). It was also observed that substrate C produced more biogas than those of substrate A and B. The model developed is an effective tool for optimum collection planning and strategy storage management that will enhance the economic viability of a Biogas production firm.

Recommendations

The model developed will go a long way to establish a viable, economical and strategy production of biogas that will alleviate the inability of meeting client demand. Secondly, the production of biogas digester should be cheap, reliable and easy to construct to make it sustainable as such will lead to the exploitation its technological benefit to the rural population. The rural community should be sensitized in harnessing biogas as a means of powering a supplementary electrification program.

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