

Development of a Batch-type Biogas Digester using a Combination of Cow Dung, Swine Dung and Poultry Dropping

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ABSTRACT

The overdependence on crude oil in African countries warrants the need for alternative sources of energy. A 56litres capacity biogas digester was designed, fabricated and evaluated. Investigations were made into the production of biogas from the mixture of cow dung, swine dung and poultry dropping. Standard equations and models were used in the design of the components of the manually operated digester. The digester temperature, ambient temperature and pH were monitored during the experiment. The proximate analysis showed that volatile solid, total solid and moisture content for the mixed substrates at the initial stage were: 64.7%, 83.5% and 13.5 % respectively. Similarly, at the digestion stage, the volatile solid, total solid and moisture content were: 54.1%, 22.6% and 74.4% respectively. Advancement of decomposition leads to gradual increasing pH value from 7.2 to 7.4, which indicates the stability of organic matter. The moisture content on wet basis was initially 13.5%. This value later increased to 74.4%. On the average, 15kg of mixed substrates with 25 litres of impure water produced biogas within 25 days of digestion. The gas produced from mixed substrates became flammable with blue flame after 16 days of production, indicating that the ratio of methane gas generated with the three mixtures of fresh animal waste was higher than other gases produced.

Keywords: Biogas, renewable energy, cow dungs, swine dungs, poultry droppings, slurry, anaerobic decomposition

INTRODUCTION

The rising cost of petroleum products is a serious problem facing most developing countries of the world including Nigeria. The extent of increase in industrialization and population has resulted in excessive energy demands from both rural and urban dwellers, raising the need for exploration of other natural sources of energy [1]. Hence, conversion of agricultural wastes into biogas could be a leeway to solving some of these energy problems [2, 3]. However, due to epileptic electricity supply in Nigeria which has greatly reduce daily income and lead to abnormal hike in foreign currency on daily market stock, it is therefore important that Nigerians should embrace an alternative way by which electricity and cooking gas can be generated [4, 5]. It is also important to be more conscious of environmental sanitization, as indiscriminate disposal of waste results in health issues and environmental disasters. The concept of waste management involving the collection of generated waste into modified tanks for

recycling purpose to produce biogas, will be of great advantage to the nation's rising population [6, 7]. Furthermore, in accomplishing the sustainable developmental goal of ensuring access to affordable, reliable, sustainable and modern energy in Nigeria, rural communities with farming as major occupation, lacking access to electricity, can be brought to lime-light through the adoption of biogas system for generation of energy for household usage. International Energy Agency reported in EIA [8] that the electrification rate in Nigeria is 45percent leaving approximately 93 million people in Nigeria without access to electricity and 115 million people in Nigeria relying on traditional biomass and waste as their main sources of energy for domestic uses.

Achieving solutions to probable scarcity of fossil fuels and environmental problems that the world is facing today requires long-term potential actions for sustainable development [9, 10, 11]. The dependence on fuel wood for the domestic energy supply has aggravated deforestation, with annual deforestation rate

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estimated at 3%, which is equivalent to the loss of 410,000 hectares of forested land annually. Indoor air pollution from burning biomass in open fires, usually without chimneys is a major concern, as it results into respiratory diseases and premature deaths [2, 6]. Thus, the need for the utilization of more agricultural wastes as an alternative energy source is apparent. Globally, there has been an increasing call for diversification in oil production and consumption by economist, environmentalist and health practitioners. However, Nigeria's dependence on oil remains unwavering, as it provides 10.04% of the Gross Domestic Product, 92% of foreign exchange earnings, and about 78.5% of budgetary revenues [12]. These petroleum products are not available and affordable to rural community to meet energy needs. Hence, the need for alternative source of energy for domestic use [2, 13]. A possible alternative to fossil fuels is the production of biogas by anaerobic digestion of residues, waste and energy crops. The use of cheap locally sourced materials and its reduction of green gas emissions is of enormous advantage.

Globally, cow manure is used as feedstock for many digesters currently running to produce biogas (methane) for energy recuperation [5, 14]. Although convenient and feasible, it has been recognized that using cow manure alone may not achieve the most efficient production of biogas due to its inherent deficiency of carbon (low carbon/nitrogen ratio). Mid-West Plan Service Publication [15] reported the carbon/nitrogen (C/N) ratio of cow manure as eight (8) with regards to the cow growth stages, this value is relatively low for an anaerobic digester to function efficiently in the utilization of the manure nutrients and maximization of methane yields. Dioha et al. [16] achieved an optimal C/N range of 15.5/1 to 19/1 for cow manure digestion in terms of maximum methane production by adding either urea or glucose to the flask digesters.

Several researchers have conducted several studies on the optimization of biogas yield in Anaerobic digestion as reported by [1, 5, 7, 9, 13, 17, 18]. Similarly, swine manure has a C/N ratio of 6-8[15]. The greatest methane production is achieved when its C/N is adjusted to 25/1 using glucose. Particularly, using urea and/or glucose to change the C/N ratio in digested content cannot be an economically sustainable method to facilitate methane generation from large scale digesters [16, 19].

However, the productivity of anaerobic digestion process can be enhanced by optimizing the substrate C/N ratio. Therefore, it is worth the effort to research alternative additives to accomplish the C/N ratio modification in the digester feedstock. Crop residue such as maize husks and cassava peels are produced in large quantity in Nigeria every year, which, due to its organic nature can be a valuable alternative feedstock for biogas production. The benefit of co-digesting plant material with animal manure can provide buffering capacity and a wide range of nutrients while the added plant materials with high carbon content can improve the C/N ratio of the feedstock, thus potentially improving methane yields [20, 21, 22]. Because of its large unexploited benefits for biogas production, via anaerobic digestion, crop residues certainly deserve research attention for use as a feedstock for co-digesting with cow manure.

Developments in Anaerobic Digestion of Organic Solid Waste

Anaerobic digestion is a microbial process involving the biodegradation of organic matter by association of microorganisms in the absence of oxygen, resulting in the formation of biogas which consists of methane and carbon dioxide, and effluent consisting of the remaining solids and liquids [23]. It occurs naturally in wetlands, marshes and a principal agent in degradation of bio-waste in landfills, it is also present ruminants' digestive tracts [14, 24].

Stages involved in Anaerobic Digestion

Anaerobic Digestion occurs in four stages which include: hydrolysis, acidogenesis, acetogenesis and methanogenesis. The degradation stages are carried out by different consortia of microorganisms, which partly stand in syntrophic interrelation and place different requirements on the environment [23, 25].

Hydrolysis

During anaerobic digestion, hydrolysis is the first step in which long-chain organic molecules are broken down by hydrolytic bacteria into their constituent monomers; complex polymers from organic biomass which are inaccessible to microorganisms are broken down. During this process, hydrolytic bacteria are able to secrete extracellular enzymes (cellulase, xylanase, amylase, protease, lipase) that convert carbohydrates, lipids, and proteins into sugars, long chain fatty acids, and amino acids,

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respectively [26, 27], products of this process are able to diffuse through the cell membranes of acidogenic microorganisms [25]. Generally, hydrolysis is best achieved at an optimum temperature between 30–50°C and an optimum pH of 5–7 [28, 29].

Acidogenesis (Fermentation)

Acidogenic microorganisms absorb the products of hydrolysis through their cell membranes, and then ferment them into volatile fatty acids (VFAs) such as acetate, propionate, and butyrate. Short-chain VFAs (i.e., propionate, butyrate, and valerate) are converted into acetate via the process termed acetogenesis [25]. Acidogenesis is perceived to progress at a quicker rate than all other stages of anaerobic digestion [23]. The degradation of these compounds results in the production of H₂, CO₂, alcohols, organic acids, organic-nitrogen compounds, and organic-sulfur compounds. The most important of the organic acids is acetate since it can be used directly as a substrate by methanogenic bacteria. [29, 30, 31].

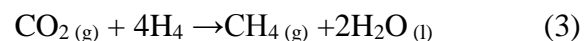
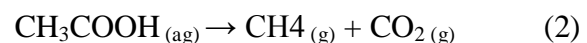
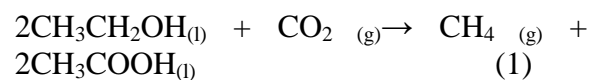
Acetogenesis (Acidification)

During acidogenesis, some of the acetate produced are already rendered into a suitable substrate for acetoclastic methanogenesis [25]. However, other higher VFAs produced are not accessible to the methanogenic microorganisms. Acetogenesis is the process by which these higher VFAs and other intermediates are converted into acetate, with hydrogen also being produced [32]. Acetogenic bacteria break down low molecular weight volatile fatty acids and alcohols into acetate, hydrogen gas and carbon dioxide. Acetate is not only produced through the fermentation of soluble organic compounds but also through acetogenesis [33]. Hydrogen gas is a major product of this process and an excessive partial pressure is proven to be harmful to the acetogenic microorganism [30, 34]. This conversion process can only be thermodynamically favourable if the partial hydrogen pressure is kept low. However, due to the presence of hydrogenotrophic methanogens, there is a rapid consumption of hydrogen, thereby maintaining the hydrogen partial pressures at a favorable level to acetogenesis by creating an exergonic reaction [35].

Methanogenesis (Methane Formation)

This is the final stage of anaerobic digestion, where the methanogenic microorganisms produce methane by consuming all forms of

intermediates compounds found in the system. The methanogenic bacteria convert acetic acid and hydrogen into CO₂ and methane. This microorganism requires a higher temperature and pH than previous stages of anaerobic digestion [24]. Methane is formed around 66% from acetate by means of acetate decarboxylation, preceded by acetoclastic methanogenic bacteria (e.g. Methanosaeta spp and Methanosarcina spp.) and 34% from carbon dioxide reduction by hydrogen, catalyzed by hydrogen-utilizing (hydrogenophilic) methanogenic bacteria [28, 36]. These bacteria are strict anaerobes and require a lower redox potential for growth than most other anaerobic bacteria ([20]). Methanogens tend to have a significantly slower regeneration time than other microorganisms in anaerobic digestion, upwards of 5-16 days [23]. Although, Methanococcus maripaludis, among other hydrogenotrophic species is reported to possess a doubling time of only two hours [31]. Chemical reactions during methanogenesis can be summarized as in (1) and (2) below:



In digester, the termination in the supply of biogas signifies the end methanogenesis, which can take between 25-40 days [19, 29]. The Volatile solid content could then be analyzed to assess the degree of digestion.

Bio-digestion is a complex fermentation process birth by the symbiotic association of different bacterial types. The activities and products of one set of bacteria support the other and vice versa [29]. Practically, fermentation processes involve the metabolic actions of the various bacteria acting in synchronization. A group of microorganisms serve as the substrate for the next resulting into several interdependent, complex sequential and parallel biological reactions [27, 37]. When the acid-producing bacteria use up the oxygen to create light compounds, it creates an anaerobic environment for the methanogens as well as compound of low molecular weight. On the other hand, methane-producing microorganisms use up the intermediates of the acid-producing bacteria from the system thereby eliminating the possibility of creation of toxic conditions for the acid-producing microorganisms.

Conditions for Anaerobic Digestion

Two of the most important factors for proper anaerobic digestion and methane production are temperature and pH, irregularities of these factors result in challenges in digestion, particularly the rates of hydrolysis and methanogenesis. Digester performs well in warmer atmospheres [6, 10], although anaerobic digestion is not absolutely terminated at lower temperature, overall methane production is reduced as methanogenesis is impeded. Selected chemicals such as sodium nitrate, lime, sodium (bi-) carbonate and quick lime can be added slowly to adjust the pH of the system without having adverse effect on the bacteria [31, 38].

The solid concentration, which is the amount of fermentable material of the feed in a unit volume of slurry, affects the rate of digestion as well. Increase in solid content inhibits the mobility of methanogens within the substrate, affecting the biogas yield [29]. Ordinarily, 6-9% solids concentration is best suited for biogas production [13]. The amount of substrate fed per unit volume of digester capacity per day, regarded as the loading rate has an impact on the rate of digestion. Overloading of the digester will result in high gas yield initially which reduces abruptly due to inhibition, which is restraint in the multiplication of methanogenic bacteria as compared to acidogenic bacteria thereby limiting the gas produced.

In addition, in ensuring adequate growth of bacteria in anaerobic digestion, a regular supply of organic substances as a source of carbon and nutrients is important, they also require certain mineral nutrients in addition to nitrogen, Sulphur, carbon, oxygen and hydrogen. These elements are largely found in agricultural residues and wastes [6]. The duration of retaining the slurry in the digester influences the rate of digestion. The average time spent by the input slurry, which is the Hydraulic Retention Time (HRT), if shorten could result in the collapse in the bacterial population while achieving a longer HRT requires larger digester volume [17, 30].

Furthermore, the ratio of carbon to nitrogen in the digester influences the operation of the bacteria. An optimum carbon/nitrogen (C/N) ratio for anaerobic bio-digestion is between 20:1 and 30:1 [16, 19]. In situation of relatively high ratio than the optimum range, methanogenic bacteria will exhaust the nitrogen rapidly

leaving the remaining carbon in the material, thereby reducing the gas production. Conversely, for a relatively low ratio than the optimum range, large amount of ammonia will be formed, thereby raising the pH of the system above 8.5, inhibiting the microbes limiting gas production. Also, the presence of toxic substances such as mineral ions, heavy metals and inhibits the activities of methanogenic bacteria in the digester. However, small quantity of mineral ions (ammonium, Sulphur, sodium, potassium) can activate the growth of bacteria, while large amount of these ions will have a toxic effect [16, 31, 39].

Moreover, continuous stirring of the digester content is vital in ensuring close contact between the microorganisms and substance which ultimately improves the digestion process. Agitation can be achieved by daily feeding of the digester instead of periodicals mixing to create the same effect [1, 4, 7]. All processes in anaerobic digestion does not require oxygen, and they are indeed very sensitive to the presence of oxygen, as the breakdown of organic materials in the presence of oxygen, will produce carbon-dioxide instead of the desired methane gas. Hence, an air-sealed digester is essential for optimum digestion [39]. Additionally, optimal moisture content, of about 90% of the total volume of feedstock is required for the effective performance of bacteria in the digester [19, 20], as metabolic activities involved in the digestion of organic matter requires water. Excess water reduces the rate of production, while in adequate water results in accumulation of acetic acids which inhibits the digestion process [14, 29].

This research is aimed to help our people to reduce the over-dependence on liquefied fossil fuels, with the lowest possible cost. This project will also provide an alternative mean of keeping our environment clean from animal waste. Others include conservation of our natural resources like the forest, natural gas and replenishment of the exploited farm land. The effluent, after gas has been evolved, can be used as manure which is a good source of organic fertilizer for the farmer. The gas produced by biogas is an alternative for energy production and utilization thereby going a long way to conserving our natural gas [26]. It will also serve as a means of managing our environment against unpleasant odour by the evacuation of animal waste or dung that would have resulted into air pollution, which would have impaired

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our breathing. Above all, this project will help to make cooking easy in our individual homes

and reduce excessive exposure to hot radiation cause by firewood.

Table1. Relative biogas generation from various materials

Organic material	Biofuel (L/Kg/ dry matter)
Cow manure	40
Sheep manure	94
Savage sludge	65
Water lettuce	105
<i>Eupatorium odoratum</i>	256
Cassava leaf	55
Water hyacinth (<i>Eichhornia crassipes</i>)	98
Poultry dung	128

Source: [7, 9, 21, 40]

MATERIALS AND METHODS

Materials

The Digester was filled with a mixture of the substrates from the combination of Cow Dung (CD), Poultry droppings (PD), and Swine Droppings (SD). The compositions of the Digesting Materials were collected from abattoir within Akure metropolis and Federal University of Technology Akure (FUTA) agricultural research farm. Each of which was measured in kilograms (5kg) and mixed with impure water to form slurry.

The digester is circular in shaped and consists of the inlet valve, the outlet valve, the fermentation section and the stirrer as shown in Plate 1 below. The stirrer is manually powered for even and easy stirring of the mixture to aid fermentation. Also connected to the top of the digester is a pressure gauge to indicate the

amount of gas produced in the digester. Plate 1 showed the complete system and how the units are interconnected. The biogas plant consists of two major components (the digester tank and the storage tank) which were connected by hose. The digester tank consists of inlet valve at the top, where the substrates were loaded and also locked afterwards to prevent escape of gas and for easy fermentation process to occur. It also has an outlet at the base of the digester where the mixture of effluents and substrate is being released from the tank for further use in crop fertilization. The digester tank also has a pressure gauge at the top, this help to determine the amount of gas produced. The digester tank also has a filter that contains the filtering substance which helps in the purification of the biogas produced. The gas produced is being controlled by set of valves attached to the digester. The gas produced is transported to the burning point by the hose.



Plate1. Biogas Digester

Design Consideration

Biogas digester is a convectional machine that would interact with different waste such as plant and animal waste and also micro-organism in the process of production, with some high

degree of strength, pressure and precision, with consideration for cost and maintainability. Ideally, the materials used for construction should be durable and strong enough to retain its shape under pressure and heat, and must be easy

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to dismantle and couple back during cleaning. The factor like pressure builds up which tends to blast the cylinder was considered and corrosion by using thick mild steel for the construction.

High consideration was given to the strength in designing the biogas unit because of internal forces of the substrate to be used and pressure of the produced. Torsional stress and strain factor were adequately considered. Also, the size was taken into account to ensure the ease of moving the machine from one place to another. The bearing capacity to withstand the internal load of the material and external force of the environmental influence e.g. weather, and corrosion resistance were reviewed. Cost of production of the biogas unit as well as affordability of the unit was also considered during design to encourage adoption of the technology.

Design Analysis

The main objective of the design is for energy production, maximizing the primary variables such as biodegradability of the materials, concentration of the feed, kinetic constants, Retention time, that affects the production of the biogas is important [18]. In designing a bio digester, the total volume of digester, VT, volume of gas storage, Vg, retention period, Rt and the amount and type of organic waste to be digested are majorly considered according to experiment carried out by [7, 6, 41].

Digester Tank Capacity Determination

According to [7] and [9], the Total Volume of the digester, VT is the addition of the Slurry volume, Vs and the storage capacity of the gas, Vg.

$$VT = V_s + V_g \quad (1)$$

The digester was fed once, but the calculation was based on daily feeding with the design criteria of 25 days retention period, 5kg of CD, PD and SD each was fed into digester, with equal volume of water for mixing, waste and water are in 1:1 [7]. 1 kg is equivalent to 1 liter; using 15kg of waste. A total of 15kg is fed for 25days at the rate of 0.6kg/day.

Volume of Slurry, Vs = 15ltrs of waste + 15ltrs of water = 30 litres

Volatile solid loading rate is a measure of the biological conversion of the anaerobic digestion system ([29]). For mixture of animal and kitchen waste, the rate of biogas production is

about 0.5 m³/kg of volatile solid added ([42] et al., 2014). The amount of biogas generated each day (m³/day) will be calculated using equation 2 and 3 below, on the basis of the daily substrate input (volatile solids content) and specific gas yield of the substrate [6, 29, 41], Hence;

$$\text{Daily gas production} = \text{volatile solids content} \times \text{the specific gas yield (solids)} \quad (2)$$

$$= 0.6\text{kg/day} \times 0.50\text{m}^3/\text{kg} = 0.3\text{ltrs/day}$$

$$\text{Total volume of gas after 25days} = 0.3\text{ltrs/day} \times 25\text{days} \quad (3)$$

$$= 7.5 \text{ litres}$$

Using equation 1, the total volume of digester, Vo is given as 37.5 litres. The maximum loading capacity of the digester must not exceed 80% of the total volume of the digester to at least give 20% of the total volume for slurry rise and for biogas as reported by [6]. The total volume VT is, thus, given in Eq. 4:

$$\text{Total volume of Digester, VT} = V_o \times 1.2 \quad (4)$$

$$= 37.5 \times 1.25 = 46.875 \text{ litres}$$

In designing acylindrical digester tank of 48 litres capacity, with height 0.7m. Equation 5 is used below as used by [11], the diameter is given as 0.094m

$$V = \pi r^2 h \quad (5)$$

Shaft Design

In designing the shafts for the machine, considerations were given to the following factors:

Since deflection is typically the design limiting issue, higher strength steel such as low carbon steel was used.

to minimize both deflection and stresses, the shaft length was kept as short as possible and over hangs was also minimized.

Design for the Diameter of Shaft/Stirrer

The diameter of shaft for the stirrer can be determined using the equation below:

$$d^3 = \frac{16}{\pi S_s} \sqrt{(M_t k_t)^2 + (M_b k_b)^2} \quad (3.3)$$

Where, Ss = allowable shear stress of metal with key way = 40 x 10⁶N/m²

mb = maximum bending moment = 25.61Nm

mt = torsion moment = 22.3N

Kb = combined shock and fatigue factor applied to bending moment = 1.5

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K_t = combined shock and fatigue factor applied to torsional moment = 1.0 [4]

Methods

Collection of Substrates

The substrates (materials used for biogas production) are poultry droppings, swine droppings and cow dung waste were collected

locally within the Federal University of Technology, Akure. The substrates were mixed together in the same proportions with water of 15 litres, the individual substrate was weighed to be 5 kilograms each, and these were mixed together and loaded into the digester. Equal volume of water is used in mixing each substrate used (CD, PD and SD) to form slurry.



Plate2. Loading of Biogas Digester with Mixed Substrates

Production of Biogas

The substrate was left in the digester for two weeks for anaerobic digestion; biogas was produced after which it was stirred so that the gas can evolve. The stirring is done by rolling the handle manually for about 5 to 10 minutes. The outlet valve is then opened for collection of gas produced. Gases produced were burnt using gas lit.

Measurement of Parameters of the Digester

The temperature of the digester was maintained within the allowable temperature ranges for optimum gas production being; mesophilic, cycrophilic and thermophilic temperature ranges. Temperature reading was taken twice

daily both in the morning and evening, with a thermocouple placed inside the digester. Digital pH meter was used to measure the pH daily.

RESULTS AND DISCUSSION

The feed stocks were analyzed for temperature, total solid, ash content, volatile solid, pH, moisture content. The total solid, volatile solid and moisture content were determined in accordance with the method provided in section 2540 E of American Public Health Association—Standard Methods as executed by [6].

Analysis of Physicochemical Properties

Table 2 below shows the physicochemical properties of the mixed substrates from

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laboratory analysis. Physicochemical properties of mixed substrate (fresh chicken droppings, cow dung and swine dung) at exact day of digestion and after the experiment are shown. The results of the physicochemical properties of mixed substrates over a period of 25 days shows a decrease in the total solids and volatile solids from 83.50% to 22.60% and 64.70% to 54.10% respectively, which may be due to the utilization of the wastes by the microorganisms. This is in

agreement with the result of [17] and [27], who explained that there is reduction in the total solids and volatile solids reduce as methane yield increases. The retention period for biogas production was twenty-five days. This may be due to the accumulation of acids, exhaustion of nutrient or production of auto-toxic substances by the microbes because this process is a batch culture system.

Table 2. Physicochemical properties of Fresh mixture of Cow Dungs, Swine Dungs and the Poultry Droppings.

Parameters	Fresh Substrates	Digested Substrates
Total solids(%)	83.5	22.6
Moisture content(%)	13.5	74.4
Volatile solids(%)	64.7	54.1
Ash content(%)	34.6	45.6
pH	6.6	7.2
Temperature (°C)	30.3	29.5

It is obvious that the moisture, ash content and pH increased significantly ($p < 0.05$) while the total solids, volatile solids and the temperature reduced significantly ($p < 0.05$) as also observed by Nwankwo et al [11]. Although the total solid content of the waste used were above the optimum range of 7-9% recommended by Nwankwo et al. [11] and Deepanraj, et al. [37] and, in order to avoid overloading the system. However, the digestion process was efficient in removing the total solid.

Effects of Temperature and pH

Figure 2 and Figure 3 shows the variation in pH and temperature of the mixed substrate with respect to the retention time of 25 days respectively. pH reading recorded was within the range of 6.7 – 7.4, with the mean pH at 6.90 ± 0.18 . From the experiment, it was revealed that the acidity in the digester caused the very low yield of biogas in the first 7 days of retention. The result was compared to some other results obtained previously by Musa and Raji [10] from the analysis of biogas from three organic wastes, Ukpabi [30] who produced biogas from cow dung and food waste, Nwanko et al. [11] who generated biogas from kitchen waste and cow dung, and Otun et al.[7] who evaluated the production of biogas from the co-digestion of animal, food and fruit waste. During the early stage of decomposition, the acid-forming bacteria were found to be breaking down the substrate with volatile fatty acids produced. This changed the values of the general acidity for the digesting material with the value of the pH falling below neutral [6, 38].

These changes assisted the microorganisms in the system to perform well which led to increase in the production of the biogas. On the first week, the lower level of the pH recorded by mixed substrates explains the first stage of anaerobic digestion - hydrolysis and acetogenesis.

Acetogenesis involves the conversion of volatile fatty acids present in the substrate into simpler organic acids including acetic acid, propionic acid and ethanol. This acidic intermediate naturally causes a drop in the hydrogen ion concentration of the slurry in the bio-digester which was observed to fall as low as 6.2 after the first two weeks of digestion. As the weeks went by, the organic acids produced during acetogenesis (majorly acetic acid) were acted upon by methanogenic bacteria and hence broken down into methane and carbon dioxide; the major constituents of biogas.

The pH begins to rise as the acetic acid is converted into biogas. It should be noted that pH affects the growth of microbes during anaerobic fermentation/digestion. Otun et al.[7] reported that it is important to maintain the pH of an anaerobic digestion process between 6 – 8, in order not to inhibit the growth of methanogens. It was also observed that the changes in the pH value also resulted in changes in the volume of gas produced, as consistency in the higher range of pH favours the methanogenic bacteria. These bacteria are inhibited in pH greater than 8 or less than 5 as reported by Nwanko et al. [11] and Okewale [40].

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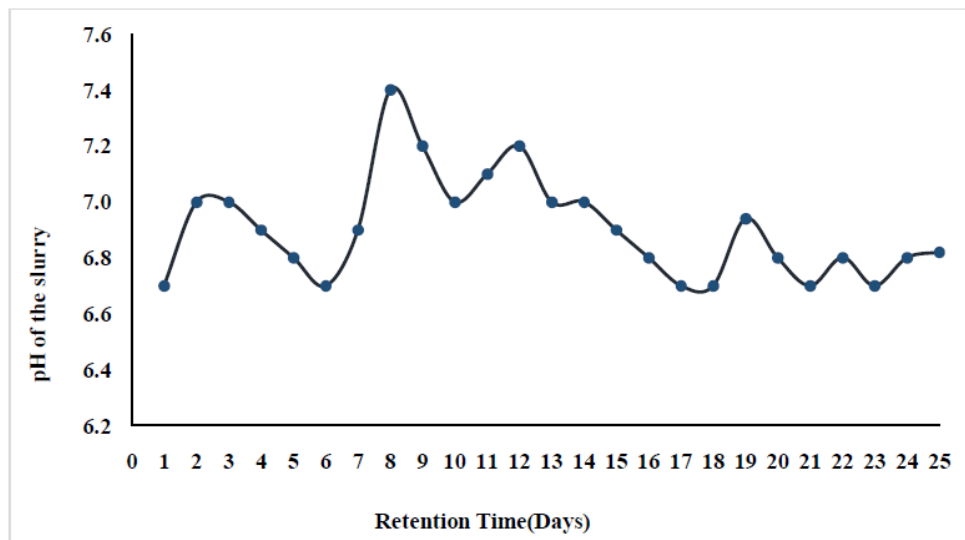


Figure2. Variation of mixed substrates pH with retention time (Days)

Figure 3 shows the slurry temperature trend of the mixed substrates. The ambient temperature varied from 20oC and 32oC with the mean temperature at $29.26 \pm 1.580C$, this fluctuation is as a result of climatic conditions, which in turn affects the slurry at each stage of digestion. The mesophilic (21oC – 38oC) is the temperature range that was identified from the slurry temperature. This is similar to the result observed by Otun et al. [7] and Nwanko et al. [11]. From the results obtained, anaerobic bacteria thrive best at a mesophilic temperature

of about 34oC [27, 40]. Temperature is observed by many biogas researchers as a critical condition for anaerobic digestion, as methanogenic bacteria operate most efficiently at temperatures 30oC – 40oC [37]. The ambient temperature affects the rate of digestion due to the direct contact of the outside walls of the digester and the atmosphere [13, 17]. It was observed that the volume of gas produced increases with increase in temperature and as temperature drops, the rate of biogas production declines agreeing with Gaby [38].

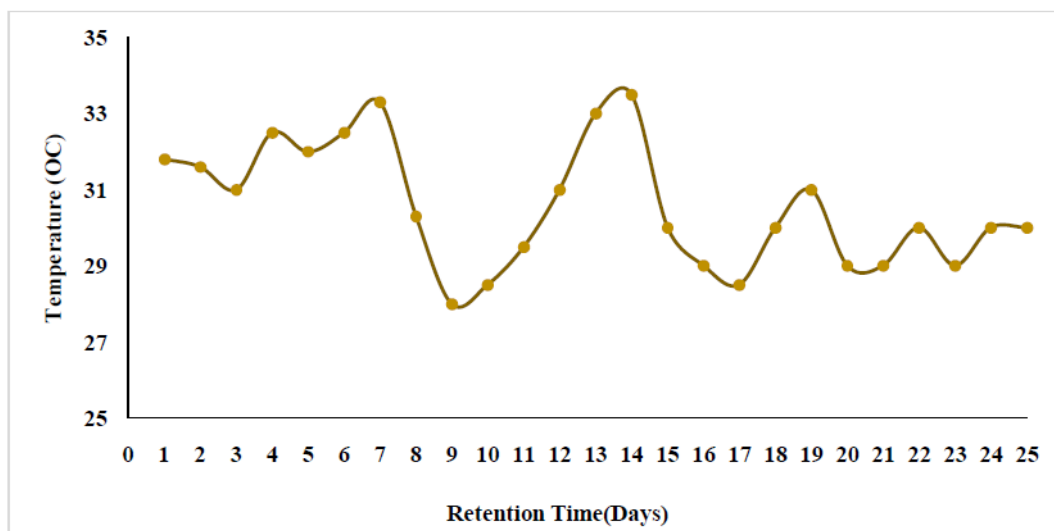


Figure3. Variation of mixed substrate slurry temperature with retention time (Days)

Flammability of the Gas

Biogas is a flammable gas produced when organic materials are fermented under anaerobic condition. It contains mainly methane and carbon (IV) oxide with traces of hydrogen sulphide and water vapour. Biogas burns with a pale blue flame and it has a calorific value of

between 25.9J/m– 30J/m, depending upon the proportions of methane and other constituent gases[11, 6].During the research, an increase in the pressure gauge was observed after a week of retention, indicating an occurrence of biochemical reaction due to microbial activities resulting in the production of biogas. The combustibility of the biogas produced was

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determined out by igniting matches near the gas opener as experimented by [10] and [6]. The result gave a pop sound with flames. The test was repeated after 25 days of digestion. The test proved positive for the gas burnt with a blue flame, producing no soot.

CONCLUSION

The effective implementation of biogas digester for production of biogas from the decomposition of agricultural waste offers a reliable solution for economic development energy and environmental sustainability. A biogas digester consisting of inlet opener, outlet opener, a stirrer handle, spikes and cylindrical chamber was designed, fabricated and evaluated. The result of this research showed that many of the microorganisms associated with the fermentation of cow dung, swine dung and poultry dropping originated from the substrate used and it was established that temperature variation, PH and Concentration of Total solid, are some of the factors that affected the volume yield of biogas production. The biogas yield was dependent on the temperature of the environment where the digester was placed. The pH on the other hand was affected by the Carbon: Nitrogen (C: N) ratio of the mixed substrates. An increase in the amount of gas produced with respect to the retention time of twenty-five (25) days, yielding a reasonable amount of gas. The quantity and quality of biogas produced after the 25th day makes the biomass to be regarded as the best mixture and the best C: N ratio for optimized biogas production. In conclusion, the mixed substrates produced biogas faster than other substrates in mixture when compared to findings from literatures. The cost of production of the digester was N38, 805.75; this is considered a price affordable to the lower and middle class. One of the limitations to the research and adoption of technology is the availability and regular supply of feedstock.

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