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Full Length Research Paper

Development of Anaerobic Digester for the Production of Biogas using Poultry and Cattle Dung: A Case Study of Federal University of Technology Minna Cattle & Poultry Pen

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Abstract
The amount of waste generated in developing countries such as Nigeria has steadily increased over the last decade. This is due to rapid population increase and lack of effective waste management strategy. This study focus on comparative study of biogas production from poultry waste and cattle dung in different proportion was conducted under the same operating conditions. For the experimental design, different mix regimes were adopted for the three digesters employed. In this case, for digester A, 225g of poultry waste and 75g of cattle were mixed with 150ml of water, 150g of poultry waste and 150g of cattle dung were accordingly mixed with 150ml of water for digester B, while for digester C, 75g of poultry waste and 225g of cattle dung were added with the same 150ml of water. Results obtained show that biogas production started on the 2nd day, and reached its apex on the 6th day for digester A, production reached its peak on the 6th day in digester B, while for digester C, it started on the 3rd day and attained maximum on 6th day. The average gas production from the ratio of 75%:25%, 50%:50% and 25%:75% of poultry and cattle dung respectively was 3.84ml, 3.55ml, and 3.19ml. Based on the results, waste can be practically and efficiently managed through conversion into biogas. This shows that waste can be turned into wealth which can serve as a source of income generation for the society.

Key words: *Biogas, Digester, Energy, Fossils, Methane, Waste*

Introduction

The rapid increase in world population has given birth to the developments of industrial and commercial agriculture that require large quantities of energy, and large quantities of wastes that can hardly be disposed off with environmental negative impacts and costs. In addition to that, the limited sources and quantities of non renewable energy (oil, natural gas, and fossil coal) with their negative impacts on our health and environment, necessitates the search for new and renewable sources for energy with least negative impacts.

Energy is generally classified as either renewable or non-renewable. Renewable energy is energy generated from natural resources and can be replenished within a short period of time. Some sources renewable energy include biomass, water (hydro-power), geothermal, wind, and solar. Non-renewable energy. While non renewable energy is taken from finite sources that will eventually dwindle and thus become too expensive or too environmentally damaging to retrieve. Examples of renewable energy include fossil fuels, natural energy fuels for fission mined as uranium ore, and propane gas used for manufacturing and heating. The problems of availability and depletion of non-renewable sources, among others, promote use of renewable sources of energy as guaranteed sources especially in rural communities where materials for generation are abundant (Rai, 1989). Moreover, the dependence on fossil fuels as primary energy source has led to global climate change, environmental degredation and human health problems. It is clearly evident that applied research has the potential to develop more efficient technologies; take advantage of renewable resources, minimise waste and optimize recycling of existing resources (Earth Trends, 2005).

Biogas is a by-product of wastes and has prove to be an efficient way of waste management. Various countries of the world has experimented on converting waste into biogas using digesters. The emergence of biogas from sugarcane by-products has made significant contribution to its availability in rural Brazil (Sayigh, 1992). In Philippines, the Department of Environment and Natural Resources has been promoting biogas production as a means of waste management and pollution control in large pig farms especially those already equipped with waste lagoon. Unlike India, cattle farms are few in the Philippines where there are many pig and poultry farms (FAO, 1996). In Africa, trials have been conducted to produce biogas in different countries. The rapid population growth in rural areas of these countries continue to increase concern over environmental issues. Nigeria has been reported to be losing nearly 14,000 hectares of tropical forest per annum due to wood burning in form of charcoal (FAO, 1996). Exploitation of animal dung for production of biogas in Nigeria is in its infancy. The pioneer biogas plants are 10m^3 biogas plant constructed in 1995 by the Sokoto Energy Research Centre (SERC) in Zaria, and the 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). Generally, it is now recognized that biogas/biomass projects can be more than a means of handling manure or sewage sludge,

disposing of unwanted straw, incinerating municipal solid waste, treating industrial effluents or utilizing residues from sawmills. Purposeful grown biogas offers possibilty of generating electricity or liquid fluids for domestic uses such as cooking gas.
Biogas refers to methane *gas* produced by the biological breakdown (anaerobic digestion) of organic matter in the absence of oxygen. It originates from biogenic materials and is a type of biofuel (IFIC, 1985). Biogas is primarily used for cooking and lighting. However, biogas can also be used for runnig stationary engines such as pumps, fans and blowers, elevators and conveyors, heat pumps and airconditioners. Biogas can be used to run diesel engine. Mixture of biogas and diesel oil can reduce the consumption of diesel oil by about 80% and the engine can run faster by 43% of extra power with this mixture. Similarly, with some modifications, biogas can be used on diesel and spark ignition engines (Crow, 2006). Absorption-type refrigeration machines operating on ammonia and water equipped for automation thermo-siphon circulation can be fuelled with biogas (IFIC, 1985). Other areas where biogas can be used include incubators, water heating, space heating and gas turbines, although information on the later is limited (Wikipedia, 2011). It is evident that no single source of energy would be capable of replacing fossil oil completely which has diverse applications. On the other hand, dependence on fossil oil would have to be reduced at a faster pace so as to stretch its use for longer period and in critical sectors till some appropriate alternative energy sources preferably renewable ones are made available. Methane gas and more popularly known as bio-gas is one such alternate sources of energy which has been identified as a useful hydro-carbon with combustible qualities as that of other hydrocarbons. Though, its calorific value is not high as some products of fossil oil and other energy sources, it can meet some needs of households and farms.

With increase in world population and rise in living standards, the demand for energy is steadily increasing. Global environmental issues, especially global warming, exhaustion of fossil resources and uprising in fossil producing areas pose serious problems for energy generation, consumption and sustenance. Environmentally-friendly technology and a shift to non-fossil energy resources such as natural energy and biomass are inevitable. In the light of the above, the idea of generating energy from agricultural by-products has become a neccesity, at least to complement existing energy sources. Production of biogas will no doubt increase energy in Nigeria at an appreciable level and may reduce energy cost. Also biogas can be produced in rural areas for the rural people, who are often subjected to price and supply fluctuations of conventional fuels and fertilizers, at an affordable price since the raw materials for biogas production are in abundance in the rural areas. Environmental hazards from animal and human wastes will be controlled if these wastes can be converted into biogas. Deforestration will also be reduced if peolple do not rely solely on firewood for cooking. The system can also create employment opportunities for rural communities. These and other benefits that can be derived from the production and utilization of biogas; the issues highlighted underscore the relevance of any study in this regard.

There are reports of successful methane production units in several parts of the world, and many farmers wonder if such small scale methane production units can be installed at their farms to convert waste into wealth (Lewis, 1983). The first digestion plant to generate biogas was built at a Leper Asylum Colony in Bombay (now Mumbai), India in 1859. India as a country with many biogas reactors installed today, has a quite long history of biogas development. Many countries subsequently become aware of biogas technology by the middle of twentieth century. However, real interest in biogas aroused in 1970's with the onset of energy crisis which drew general attention to the depletion of fossil fuel energy resources and the need to develop renewable sources of energy, such as biogas. The importance of biogas as an efficient, non-pollution energy (or renewable source) is now well recognized.

Biogas is produced from organic wastes with the help of anaerobic bacteria. Thus, the microbial conversion of organic matter to methane which is the basic component of biogas has become attractive as a method of waste treatment and resource recovery (Crow, 2006).

The conversion of waste to biogas can be achieved in two major ways namely; uncontrolled anaerobic digestion (Wetlands, ponds, and Landfills) and Controlled anaerobic digestion by use of Sewage treatment plants, and Organic treatment plants/digesters.
Anaerobic digestion process occurs in three stages:

1. Hydrolysis – this process occurs when complex organic materials are broken down into their constituent parts including fatty acids, amino acids and simple sugar;
2. Acidogenesis – in this stage, acid-producing bacteria called acid-formers convert the immediates (produced in hydrolsis) into acetic acid, hydrogen and carbon dioxide. It is called acid formers stage;
3. Methanogenesis – is the final stage in which methane (analogous to natural gas) is formed by the methane-formers along with carbon dioxide and water (Charlie, 2002).

Separate as they are, these stages of anaerobic digestion can occur simultaneously within a single digester vessel. They are strongly dependent on one another and when things are not working well, they can cause mutual inhibition. For this reason, amongest others, it is critical that the content of the digester are agitated or mixed as they would stratify if left alone. Anaerobic process depends largely on methane-formers because they are more environmentally sensitive than acid-formers. Methane bacteria are strict anaerobes and cannot tolerate oxygen in their environment. They are best at temperature of about 35°C. They are equally sensitive to pH and slow in growing than the acid formers. The optimum pH requirement for their survival ranges between 6.8 – 7.4 (Bouallagui et.al., 2005). The speed of this process is mainly influenced by the composition of the feedstock. The digestion times differ from close to infinity (lignin degradation), several weeks (celluloses), a few days (hemicelluloses, fat, protein) to only a few hours (low molecular sugars, volatile fatty acids, alcohols). Therefore, woody biomass is not suitable for

biogas production due to its high lignin content. Gas is expected to start discharge to the collector after 14 days and steadily progressed (Volkmann 2004). Emission of the biogas dwindles, depending on the type of substrate being used, after the fifth week due to the declining amount of carbon in the substrates. Biogas is odourless, colourless and lighter than air (FAO, 1996).
The objective of this research work is therfore to generate biogas from poultry and cattle dung using a suitably designed digesters.

Experimental Procedure

The experimental procedures adopted for this study are as outlined below.

Feeding Methods

Depending on the design of the digester and gas production requirements', feed methods of all biodigesters may either be in batch or continouos system. The batch-type digester operation consists of loading the digester with organic materials (substrates) and allowing it to digest. The retention time depends on the temperature, type of organic material used as well as some other factors. However, the ideal retention time is between 15 to 30 days (Adrian, 2007). Once digestion is complete, the effluent is removed and the process is repeated. The major disadvantage of the batch system is that gas production cease between the loading period and the time gas formation starts.

Continouos digesters are also called continous-batch digester, on the other hand, allows continouos or regular feeding of organic materials into one of the digesters to ensure constant gas production. Thus, the system has more than one digester. This system is sustainable for large-scale gas production for industrial purposes or in a household where gas production is needed constantly. Retention time can be upto 60 days depending on the type of substrate and the operating temperature (Sassie, 1988). According to Arthur (2004), retention time can be determined as:

$$HRT = \frac{Vd}{Fr} \quad (1)$$

where : $HTR =$ Hydraulic Retention Time (days), $Vd =$ Digester Volume, m³, $Fr =$ Daily Feed Rate (m³/day)
The major disadvantage of these digesters is that the cost of maintenance is usually higher than that of the batch system.

Fermentation Slurry

All organic materials consists of; organic solids, Inorganic solids, and Water. The inorganic materials (minerals and metals) are usually materials which are not affected by the digestion process. Adding water or urine gives the substrate fluid properties (slurry). This is important for the operation of the biogas plant. It is easier for the methane bacteria to come into contact with feed material which is still fresh when the slurry is liquid. This accelerates the digestion process. Regular stirring thus speeds up the gas production process. The rule of thumb for diluting the dung (and/or other manure) is 2.5 part of water for every one part of relatively dry waste or one part of water for every one part of fresh manure (Mattocks, 1994). At the initial take-off, two-third of the digester should be filled with the slurry (Kumar, 1989).

Sludge

Although the gas produced from a biodigester is the main target of most biogas plants, sludge (otherwise called effluent) makes up a very important by-product of the biosystem. It consists of mainly undigested organic and inorganic materials and water (Veziroglu, 1991). Effluent is a valuable manure source because of its richness in humus and nitrogen (Kumar, 1989). The effluent can be used as manure in three ways:

1. Directly diluted with water, it is the most beneficial way since it can mix well with the soil,
2. By composting with other vegetative matter, or
3. By drying for later use.

Beside being used for soil enrichment, other uses of the sludge includes: Substitute for bedding materials, Potetial substitute for cattle feed, Feed for aquaculture and fish farming, Used as pesticides on plants, Control weed seeds and pathogens, Reduce air pollution since odour is reduced, and Serves as good soil conditioner (Gupta,2006).

Water is a principal component of manure and sludge, and facilitates the ability to transport the solid substance (SS) as a fluid. However, not only does the water content dilute the potential bioenergy content of the slurry, it also may impact anaerobic digester design and operation, by increasing the digester volume due to hydraulic retention time (HRT) limitations. When considering biogas production from a slurry, the volume of slurry (VS) content of the material is as important as the TS content, since it represents the fraction of the solid material that may be transformed into biogas. Although the VS content is an indicator of potential methane production, the specific methane yield on a VS basis is not a constant, in contrast to the specific methane yield on a COD basis which is precisely 0.35 m^3/kg COD destroyed. This is due to the composition of the VS of the waste which includes both readily degradable organic compounds including lipids, proteins, and carbohydrates, as well as more refractory organics which may include lignocellulosic materials, complex lipopolysacharides, structural proteins (keratin) and other refractory organics.

Loading Rate

The loading rate of a biodigester is related to the residence time of the slurry, that is, how many days the slurry stays in the digester. Undiluted slurry is heavier and gets to the bottom of the digester while it rises to the top as it digestes (Pharaoh, 1996).

Loading rates varies form 0.7 – 5.0kg/m³.day for different substrates. Navickas (2007) determines the organic loading rates of a family size digester for certain substrates at wet basis as follows; Cattle dung (2.5 to 3.5kg/m³.day), Pig manure (3.0 to 3.5kg/m³.day), and Poultry manure (2.0 to 3.0kg/m³.day)

The specific loading rates can be determined, according to Arthur (2004), as follows:

$$Vs = \frac{Mm}{Vd} \quad (2)$$

where: Vs = Specific loading rate, kg/m³, $Mm =$ Mass of manure, kg/day, $Vd =$ Digester volume, m³

According to Torsten and Andreas (2002), loading rates of a biodigester depends on factors such as size of the digester, operating system (whether batch or continous), energy requirement, type of influent used and retention time.

To maintain a uniform gas production and minimise the possiblity of upsetting the balance between the two bacterial processes in the digester, the loading rate should be maintained as uniformily as possible (Lapp Schulte, 1995). When loading rate is too high, it inhibits gas production, but it is possible to gradually increase loading rate once the microbal population is properly established.

Operating Temperature

Operating temperature is another factor influencing biogas efficiency. Biogas technology is feasible in principle under all climatic conditions (Green, 2005). However, the cost of gas production increases with lower average temperature. In this case, either a heating system has to be installed or lager digesters are built in order to increase retention time. Heating system and insullation can provide optimal digestion temperature even in cold climates, but investment cost and gas consumption for heating may reduce the economic viability of the system.

A digester can operate on different temperature ranges depending on the stage of digestion. Illic and Mitelic (2006) determine different ranges temperature ranges for different stages of digestion: Psychophiles (below 20°C), Mesophiles (20 to 45°C), and Thermophiles (45 to 65°C).

Psychophilles are operating temperatures which take place below 20^{o}C. Bacterial that grow best in freezing temperatures; - 10^{o}C to 20^{o}C. Psychophilles are obligate with respect to cold and cannot grow above 20^{o}C. Psychophilic archaea is the primary microorganisms. A Digester operating at psychophilic range takes more retention period to produce the same amount of gas that higher temperature i.e thermophilic will produce.

Mesophiles are operating temperatures which takes place optimally around 37°-41°C or at ambient temperatures between 20°-45°C with mesophiles - mesophilic archaea as the primary microorganism. Thermophilic which takes place optimally around 50°-52° at elevated temperatures up to 65°C where thermophiles - thermophilic archaea is the primary microorganisms. Organic materials degrade more rapidly at higher temperatures because the full range of bacteria are not at work. Thus, a digester operating at a higher temperature can be expected to produce greater quantities of gas. Though operating temperature is critical, stabilizing and keeping the temperature stabilized are even more important. A variation (plus or minus 1°C) in a day may force methane-producing organisms into period of dormancy. Mean temperature is, therefore, important as its change can affect the performance of the biogas plant adversely. These organisms consume acids, and without them, acid will accumulate and the pH will fall, impeding the effectiveness of the whole system. Illic and Mitelic (2006), determined the ideal temperature for methane production to be between 35 to 38°C. The disavantage of an elevated temperature digester is that minor changes in system conditions can off-set digester efficiency or productivity (Mattocks, 1994).

Gas Handling and Storage

Unless biogas produced is immediately used, it should be collected and stored in some form of gas holder or tank. Storage systems are, therefore, employed to smooth out variations in gas production, gas quality and gas consumption. The storage component also acts as a buffer, allowing down stream equipment to operate at a constant pressure. The basic reasons for gas storage therefore, are: **(1)** Storage for later on-site usage, and **(2)** Storage before and/after transpotation to off-site points (Sathianathan, 1999).

Gas storage tank can either be part of the digester, forming a roof floating on top of the slurry, or a separate structure connected to the digester with valves and pipes. The tank can be made of steel or blast polythene (Brown, 2004). Steel tanks may be ordinary or pressurised where higher pressures are required. Generally, when storing biogas, the following factors are taken into consderation, namely: Safety, Storage volume, Pressure of the gas, and Location of the storage facilty.

One of the major problems associated with gas handling is the amount of water vapour contained in the gas (Davis, 2007). Speacial care is taken when installing gas pipes such that provision for removal of water vapour will be easy. Compression of bigoas reduces storage requirements.

Materials and Methods

Materials

Components of a biogas plant

A small scale biogas plant was developed in the laboratoy and the major components of the plant were; the digester, slurry mixing tank, mixer or stirrer, measuring cylinder and hose.

Slurry Mixing Tank

A slurry mixing tank was developed. A conical flask was used as the digester tank. It's made of glass and with height of 20cm. A 5/16mm hose was used to allow the passage of the gas produced to the water tank. A length of 5cm hose was used to connect the digester and water tank. Finally, the digester was rested on a laboratory table and placed close to the window because of sunlight. The schematic view of the digester and other attachments are as shown in plates 3.1 to 3.6. For effective mixing, a mixer is required which sometimes refered to as stirrer, is the device that ensures a thorough mixture of the slurry by agitation for effective gas formation and release. A magnetic stirrer was used which agitates the digester by vibration. In addition, a conical flask of 500ml with a height of 16.5cm was used as water tank and 100ml measuring cylinder as water collector. It is a pre-mixing chamber where different components of the raw materials for the gas production (water and manure) are being mixed to form a uniform mixture of the slurry that will be fed into the digester. A 500ml cylinder was used for the construction of this component. It is made of glass, with height of 12.5cm and diameter 9.7cm. The component of the biogas plant where the sludge accumulates after coming out of the digester is called the sludge or manure storage tank. It is an integral part of the plant as no biogas plant is complete without it (Dennis amd Madison, 2001).

Digester

The digester is an enclosed cylindrical flask where the mixture of poultry manure and water (otherwise called slurrry) decomposes to produce gas due to bacterial activity. For this study, the digester employed contained the following characteristic namely: Inlet – through which the slurry is being introduced in form of liquid slurry, Outlet – where the produced gases pass through, Mixer – a magnetic stirrer that agitates and provides proper mixture of the slurry for effective gas formation, Water storage tank- About 500ml volume of water was filled in the tank, Water collector – measuring cylinder used to collects water displaced by the gas.

Materials for Biogas Production

For this study, the materials used for biogas production or generation include the followings, namely: Poultry waste and Cattle dung.

The poultry waste and cattle dung were chosen because of the following reason; Avalaibility of the materials, Methane yield of the feedstock and Nearness of the feedstock

Poultry manure refers to the mixture of excreated chicken manure and other materials that must be removed from the floor of the poultry housing. These materials include the excreation, bedding materials, feather from the birds, and wasted feed. Its production occurs as a result of the normal daily processes of the poultry industry, Martin et al. (1983).

The poultry waste for this study was obtained from A. Firdous farm, km 10 new airport road off zungeru Minna, Niger State while the cattle dung was obtained from futminna cattle pen.

Digester Set Up Materials

The materials used for the construction of the biogas plant are as shown in Table 1

Table 1: Construction Materials

S/N	Part Name	Material	Specifications	Quantity
1	Digester	Conical flask	500ml	3
2	Slurry mixing tank	Measuring cylinder	400ml	3
4	Test tube	Glass	Ø1 cm	1
5	Mixer	Magnetic stirrer	Gallenkamp	1
6	Cork	Rubber hose	Ø 30cm	3
7	Measuring cylinder	Glass	100ml	3
8	Pipes	Rubber hose	Ø5/16mm Ø3/8mm	2

Similarly, other relevant equipments used in the course of the study are as listed in Figures 1-6

Figure 1: Electronic scale Ohaus adventurer (Arc120)

Figure 2 Magnetc stirrer Gallenkamp

Figure 3: 500ml cylinder for mixing the slurry

Figure 4: Unrisen slurry in the digester

Figure 5: Poultry where waste was collected

Figure 6: Risen slurry in the digester

Measurement of Biogas Yield

The quantity of biogas produced from a digester was measured using the water displacement method. Two containers were used, the first was connected via an airtight tube into the digester. The biogas produced moved under the digester pressure through the tube into a water- filled container. The water- filled container has a tube that led from its interior to the second container (measuring cylinder) to receive displaced water. This tube was again air tight around the water filled- container with its inner end well below water within the water filled container. The volume of the gas entering into the container was equal to the volume of water displaced through the tube leading out into the measuring cylinder to receive displaced water (Itodo 2010). The water displaced was periodically collected from 12 noon of the starting day to the 12 noon, the following day (24hrs) and was measured using a measuring cylinder. The volume of biogas produced in a given time was equal to the volume of water displaced within the period. The set- up is as illustrated in figure 4 and 6.

Methods

The methods employed for this study can be concisely stated as follows:
The batch system was used because all the three digesters were loaded at the same time; this approach is seemingly cheaper.
The use of animal dung, poultry droppings and cattle dung in different propotion was used for this study. Digester A (Cattle dung 25% of 300g, Poultry waste 75% of 300g), Digester B (Cattle dung 50% of 300g, Poultry waste 50% of 300g), while Digester C has (Cattle dung 75% of 300g, Poultry waste 25% of 300g).
Biogas is easy to extract when digester is above the ground than when its dugged the ground, digester will also be easy to maintain when above the ground. Thus, the digester was positioned above the ground.
The operations were kept at room temperature.

Mixture rate of feedstock

Poultry droppings and cattle dung were used as feedstock. 300g of dung and 150ml of water was mixed together in the ratio of 1:0.5 and fed into the digester using batch method.

Methodology

Methodology of this study is to properly mix cattle dung and poultry waste (feedstock) in three different proportion. Analysis of these proportions were fully explained below:
Digester volume = 500ml
Volume of slurry = 450ml
Headspace = 50ml

Slurry means weight of manure + water in ratio of 1:0.5 for (cattle and poultry dung) and water respectively.
i.e 300g of poultry and cattle dung + 150ml of water.

Digester A	*Digester B*	*Digester C*
Cattle dung 25%	Cattle dung 50%	Cattledung 75%
Poultry waste 75%	Poultry waste 50%	Poultrywaste 25%

Digester A
Cattle dung 25% of 300g = (0.25 x300) = 75g
Poultry 75% of 300g = 300 – 75 = 225g
Digester B
Cattle dung 50% of 300g = (50 x 300)/100 = 150g
Poultry 50% of 300g = 150g
Digester C
Cattle dung 75% of 300g = (0.75 x 300) = 225g
Poultry waste 25% of 300g = 300 -225 = 75g.

Results and Discussion

Results

The performance of the conical flask as digester plant was very satisfactory. The problem of rusting or corrosion which typically affects the production of biogas was solved through the use of non corroding materials. The digesters were charged with cattle dung and poultry waste in different proportions, i.e 25%, 75%, 50%, 50% and 75%, 25% of waste respectively. About 450ml of slurry was fed into the digesters in the of ratio 1:0.5. The mean quantity of biogas produced daily from cattle dung and poultry waste in diferent proportions over a period of 7 days for the three digesters was as tabulated in Table 2.

Table 2: Mean of gas produced in three digesters (ml)

DAYS	MEAN A (ml)	MEAN B (ml)	MEAN C (ml)
1	0.00	0.00	0.00
2	1.48	1.20	0.78
3	2.36	2.00	1.61
4	4.68	4.25	4.00
5	5.52	5.20	6.72
6	7.49	5.00	4.69
7	5.33	7.21	4.50

Table 3: Average yield of the three digester (ml/ day)

Digester	Total Volume (ml)	Average Yield (ml/day)
A1	26.80	3.83
A2	26.94	3.85
A3	26.83	3.83
B1	25.00	3.57
B2	24.98	3.57
B3	24.62	3.52
C1	22.30	3.18
C2	22.29	3.18
C3	22.30	3.18

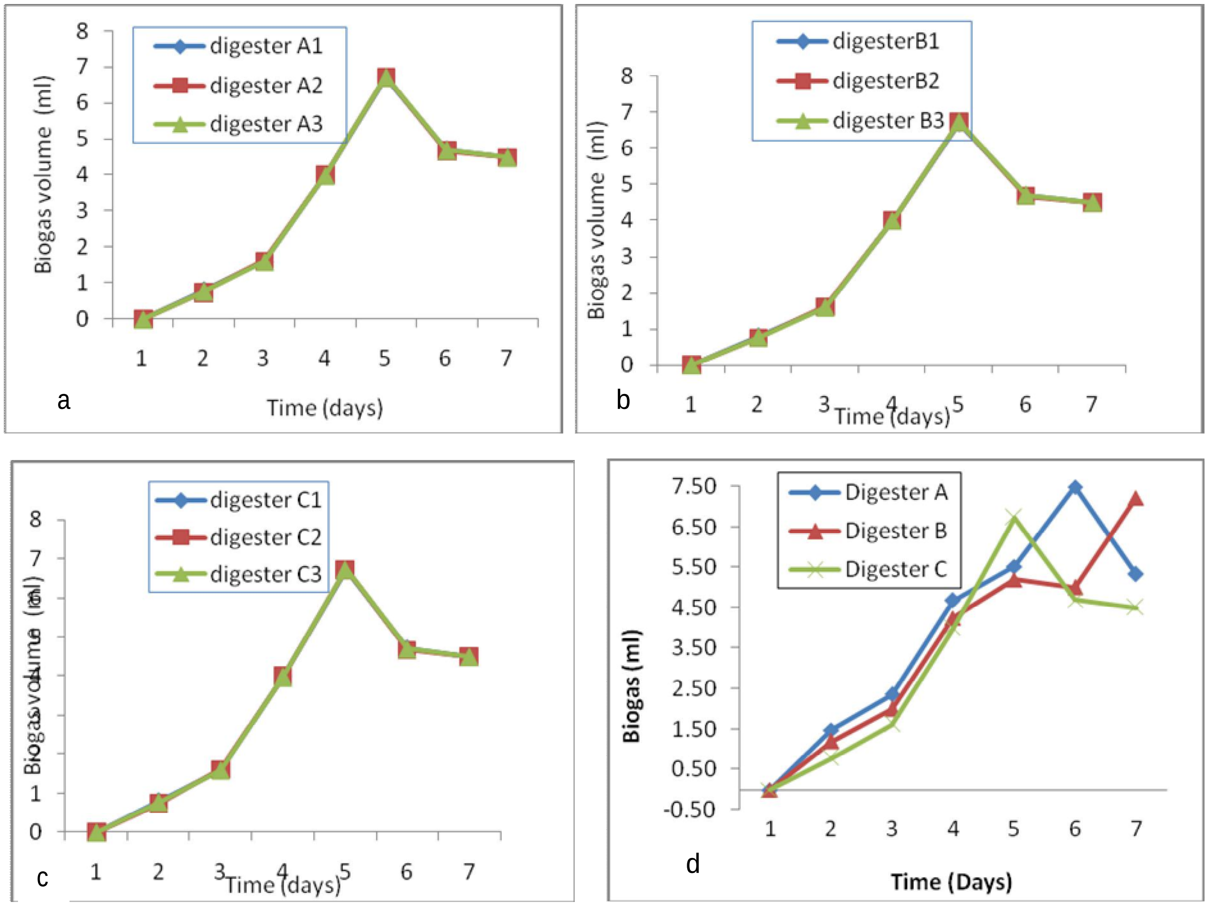

Figure7a-7d: Multiple graph showing biogas production of biogas for the three digesters

Discussion of Results

A cursory look at the figure 7a-7d reveals the following:

1. Digester A recorded the highest biogas production of about 7.49ml compared to the other two digesters on the sixth day of the experiment. The Biogas production from this Digester A was also seen to have increased progressively from day one through day six and declined sharply on the seventh day.This scenerio connotes the attainment of optimium production point per day.
2. Digester B increase steadily from day one through day five and dropped relatively on the sixth day but then went up sharply on the seventh day to about 7.21ml. Based on this, it can be said that optimality in Biogas was not attained in this case as there was evidence from the graph to suggest further production.
3. Digester C rose progressively from 0.00ml from the start of the experiment to about 6.72ml in day 5 and then decreased following the two remaining days of the experiment. Optimality could be said to be attained in the fifth day since it recorded the highest mean biogas within the time frame so far allowed as far as digester C is concerned.
4. Generally speaking, it could be said that biogas production increases from the start of the experiment as the day's increases and reaches an optimum value in a given time and may decrease in a later time/day.

From the gas production analysis, the total volume of biogas was maximum in digester A (Poultry= 75%, Cow dung= 25%) produced 26.86ml, followed by digester B (Poultry= 50%, Cow dung= 50%) which produced total biogas of 24.86ml and digester C(Poultry= 25%,Cow dung=75%) producing least biogas of 22.30ml. This may be due to higher nitrogen content in poultry droppings as compared to other feedstocks. The higher biogas production from poultry droppings could also be attributed to the available nutrient in the droppings. The higher biogas production from poultry droppings could also be attributed to the available nutrient in the droppings. Providing adequate mixing facilities can reduce the scum formation during anaerobic digestion. Biogas production from poultry manure of large farms is an ecologically and economically effective technology. Greater percentage of carbon oxygen demand (COD) reduction can take place with larger biogas volume produced for every proportion of degraded organic matter. Referring to fig 1.1-1.3 above, biogas production started in all the three digesters on the 2nd day after loading. The figure 1.1-1.3 also showed that the total biogas production from each of the digester and suggests that digester A produced the

highest quantity of biogas (26.68ml) in 7days, while digester C produced the least (22.30ml). The figure also revealed thatbiogas yield from the digester over the retention period. There was no gas production in 1st day in all the digesters. This may be due to the fact that the waste has not been fully decomposed. It can be seen that biogas production stated on 2nd day and increased gradually on subsequent days then suddenly attained maximum value on the 6th days for digester A and reduced on the 7th day . Production reached its peak on the 7th in digester B, while production dropped drastically in digester C after attaining maximum on the 5th day. Average biogas production from digester A, B and C were 3.84ml/day, 3.55ml/day and 3.19ml/day respectively.
An analysis of variance and test of significance (Table 2 and 3) was carried out to test whether there are differences in the biogas production or in the digester.This is to establish if any of the three designs may have been appropriate for the experiment.

To surmise, the cumulative biogas yield from 450g (1:0.5 waste to water ratio) slurry of poultry and cattle dung digested over a period of 7days days at room temperature was found to be 26.86ml, 24.86ml and 22.30ml. Mixing or shaking the digester is very important as it prevents scum formation within the digester. Based on the analysis,the main disadvantage of poultry manure is that it produces a proportion of hydrogen sulphide, which even when present in only small proportions, corrodes metal fittings (Ojolo etal., 2007). When it burns in air it oxidises to sulphur-dioxide. Cow dung produces almost no hydrogen-sulphide but needs larger quantities than poultry to produce the same amount of gas. From the results, it is evident that the wastes generated from domestic and agricultural activities could be converted into useful products (methane and manure) with the help of anaerobic digestion technology.

Effect of Time on Biogas Production

Table 4 is the result of the investigation on the effect of Time and Digester on Biogas production the experiment using two way analysis of variance. The analysis revealed that both Types of Digester and days of experiment were significant at 99% confidence level. The hypothesis of equal mean treatment effect of Digester and Days of experiment is therefore rejected. These may imply the followings:

1. The three digesters were formulated using different composition of cow and poultry waste. These digesters proved to be statistically different from each other as suggested by the Table 4. Further investigation using Duncan multiple range test showed that Digester A produced the highest mean biogas of approximately 4.50ml; this value is significantly higher than that produced from the two other Digesters (B and C, see Table 5).

Table 4: Two Way Analysis of Variance

Source	Sum of Squares	df	Mean Square	F	Sig.
Day	191.367	5	38.273	1.246E4	0.001*
Digester	5.226	2	2.613	850.595	0.001*
Day * Digester	26.672	10	2.667	868.165	0.001*
Error	0.111	36	0.003		
Total	223.376	53			

Table 5: Duncan Multiple Range Test for Digesters

Digester	N	Subset
Digester C	18	3.1913a
Digester B	18	3.5521b
Digester A	18	3.8422c

Table 6: Duncan Multiple Range Test for Days

Day	N	Subset
Day Two	9	1.1522a
Day Three	9	1.9900b
Day Four	9	4.3111c
Day Seven	9	5.6789d
Day Six	9	5.7289d
Day Five	9	5.8122e

Table 7: Estimated marginal means for Days x Digester

				95% Confidence Interval	
Day	Digester	Mean	Std. Error	Lower Bound	Upper Bound
Day Two	Digester A	1.480	0.032	1.415	1.545
	Digester B	1.200	0.032	1.135	1.265
	Digester C	0.777	0.032	0.712	0.842
Day Three	Digester A	2.357	0.032	2.292	2.422
	Digester B	2.007	0.032	1.942	2.072
	Digester C	1.607	0.032	1.542	1.672
Day Four	Digester A	4.683	0.032	4.618	4.748
	Digester B	4.250	0.032	4.185	4.315
	Digester C	4.000	0.032	3.935	4.065
Day Five	Digester A	5.517	0.032	5.452	5.582
	Digester B	5.200	0.032	5.135	5.265
	Digester C	6.720	0.032	6.655	6.785
Day Six	Digester A	7.493	0.032	7.428	7.558
	Digester B	5.000	0.032	4.935	5.065
	Digester C	4.693	0.032	4.628	4.758
Day Seven	Digester A	5.327	0.032	5.262	5.392
	Digester B	7.210	0.032	7.145	7.275
	Digester C	4.500	0.032	4.435	4.565

2. Table 6 shows that the days of the experiment do not record the same mean values of biogas production in millilitre. This assertion was confirmed using Duncan multiple range test as seen in Table . This table indicates that irrespective of Digester, day five generally recorded the highest mean value of biogas which is significantly higher than that recorded from day six and day seven. Days six and seven produced relatively the same quantity of biogas but were statistically higher compared to the yield from days four, three and two, respectively.

The result of the estimated marginal means test presented in Table 7 revealed that Digester A produced higher mean values of biogas in all the days of the experiment except day seven. On the other hand, digester B was also seen to perform more than Digester C in terms of biogas production per day.

Conclusion and Recommendations

Conclusions

Anaerobic digestion of biomass offer two important benefits, environmentally safe waste management and disposal, as well as energy generation. The growing use of anaerobic digestion technology as a method to dispose off livestock manure has greatly reduced its environmental impacts. This work revealed the amount of gas that could be gotten from poultry and cattle dung at different proportions. The average gas production from the mixed ratio of 25%:75%, 50%:50% and 75%:25% of cattle dung and poultry wastes were 3.84ml, 3.55ml, and 3.19ml respectively. From the foregoing, it could be seen that digester A which contained 75% of poultry, 25 % of cattle dung has the highest mean value (3.84ml). The higher value in digester A could be related to higher percentage of poultry ration contained in the mixture compared to digester C which has the least percentage of poultry. The three digesters A, B, and C were set up at the same time, loaded at the same rate and subjected to the same experimental condition. Despite all these conditions, digester A performance was very satisfactory because it produced the highest volume (3.84ml) of gas compared to digester B (3.55ml) and the least, the digester C (3.19ml). Generally, these results suggest that waste can be managed through conversion into biogas, i.e. turning waste into wealth which can serve as source of income generation for impoverished society like Nigeria.

Recommendations

1. More attention should be given to animal dung as feedstock for anaerobic digestion plants.
2. Production of biogas from dung is not a dream anymore but a reality, other researchers should focus on using the gas for generation of electricity.
3. If the biogas produced is going to be used to run engines, it has to be cleaned because it contains impurities that can damage engines.
4. Gorvenment agencies should take an active part in biogas project as it is done in other countries like India, Nepal, and philipinne e.t.c.
5. Checking for toxic gases like hydrogen sulphide and ammonia with gas detection equipment should be carried out before entering an empty digester.

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