Quantitative Analysis of The Effect of Organic Additive (*Cymbopogon Citratus*) on the Production of Biogas

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Abstract- This study is a quantitative analysis of the effect of organic additives (Cymbopogon citratus) on the production of biogas. The substrates (cow dung, poultry droppings) was mixed in ratio 1:1 while addition of additive to substrates was maintained in ratio 1:4. Also, the water to substrate ratio was 1:1.4 to result in a total slurry content of 6 litres. At the end of the first 7 days of the experiment, a total of 357.4ml of biogas had been collected at an average of 51.06ml per day. At the end of another round of 7 days, 346.9ml of biogas was realized with an average of 50.7ml per day. One end of the hose was connected to the digester gas outlet located at the top of the digester and the other end of the hose (rubber) was connected to a graduated flask for gas collection and measurement. At the end of the study, it was observed that Cymbopogon citratus is not a good additive for the production of biogas. The yield (biogas) was reduced on the addition of the additive to the substrate for the production of biogas. The reason for this inhibition is due to the relatively undigested state of the additives compared to the substrates.

Indexed Terms- Organic Additive, Substrate, Biogas, Digester, Poultry droppings and Cow dung

I. INTRODUCTION

In Nigeria, kerosene is one of the most commonly used fuels for lighting and cooking. The demand for this fuel is overwhelming, yet it remains scarce and the price is ridiculously high. As a result of this, larger percentage of the populace seeks solutions to their energy needs from other sources which in most cases are detrimental to the environment. For instance, there was a 5.5% increase in the dependence on wood fuel for cooking between 2007 and 2008 (1). More so, 79.6% of the households depend on wood fuel for their cooking while kerosene, coal, gas and electricity came behind with percentages of 18.51%, 1.1%, 0.6% and 0.2% respectively (1).

Over the years, so many researchers have worked on biogas production from various biodegradable materials. It is therefore necessary to research on methods to make the production process faster by enhancing the rate of digestion through addition of additives. Also, the excessive waste generated from various farms across the country if not properly handled can cause adverse environmental and health issues. Cow dungs and chicken droppings are such wastes if channelled towards biogas production instead of the current habit of using them for landfills or as fertilizer without pre-treatment can help in environmental clean-up.

Environmental pollution is a major problem in the world today; it affects humans, animals and other forms of living organisms including plants. This pollution is mostly as a result of man activities, either in the process of producing his food, shelter, transportation, or the quest to improve his economy. (2), stated that economic growth and heavy consumption of natural resources are responsible for global warming, acid rain and destruction of the ozone layer.

Energy is an essential tool for development. Africa and other developing countries are faced with energy challenge. Less than 10% of the population of 21 Sub-Sahara African countries have access to electricity (3). These countries however produce tremendous amount of waste which if channelled towards energy production can meet the energy need of the region. In Nigeria for instance, aside from the large amount of waste and manure generation, (4)submitted that, the country is endowed with huge resources of conventional energy resources (hydrocarbons) and reasonable amount of renewable energy resources (hydro, wind, solar and biomass).

Despite all these abundant energy resources, Nigerian Bureau of Statistics (NBS) revealed that, Nigeria as at

2006 had a total of about 28,900,492 households. 79.6% of these households still depend on wood fuel for cooking as at 2008. In some Northern states like Adamawa, Nasarawa, Zamfara, and Sokoto, there is over 90% dependency on fuel wood (1).

Over dependency on fossil fuel in most part of the urban area is also a major problem which often results in the accumulation of carbon dioxide in the atmosphere. As human development continues to increase and fossil fuels continue to be depleted, it is undeniable that sustainable alternative energy sources must replace fossil fuels in order for society to maintain its quality of life.

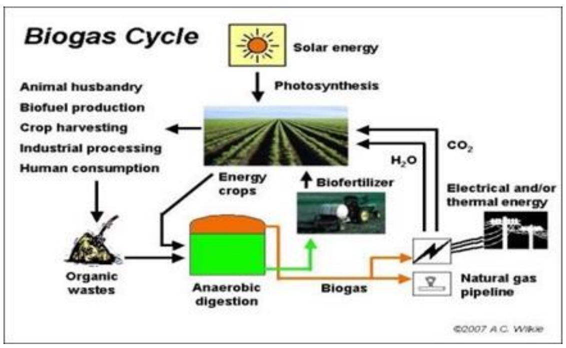

Figure 1: biogas from organic waste (Igboro, 2011)

Energy crisis is a major challenge combating most parts of the World today. For instance; employment, security, climate change, food production or increasing incomes, access to energy for all is essential. Part of the United Nations Sustainable Development Goal is to harness the potential of other sources of energy other than fossil fuel which is clean and sustainable. Sustainable energy is an opportunity to transform lives, economies and the planet. At the UN conference held in France, December 2015 on climate action, the following were revealed;

i. One in five people still lacks access to modern electricity
ii. Three billion people rely on wood coal, charcoal or wood fuel for cooking
iii. Energy is the dominant contributor to climate change, accounting for around 60 percent of total global greenhouse gas emissions
iv. Reducing the carbon intensity of energy is a key objective in long term climate goals.

There is a great deal of environmental pressure in many parts of the world to ascertain how livestock and poultry waste can best be handled. These wastes like cow dungs and poultry droppings in the absence of appropriate disposal methods can cause adverse environmental and health problems such as pathogen contamination, greenhouse gases, air borne ammonia and odour. Anaerobic digestion has been considered as waste to energy technology, and is widely used in the treatment of different organic wastes, for example, organic fraction of municipal solid waste, sewage, sludge, food waste, animal manure among others. Anaerobic treatment comprises of decomposition of organic materials in the absence of oxygen resulting in the production of methane, carbon dioxide, ammonia and traces of other gases.

Biogas refers to a mixture of different gasses produced by the breakdown of organic matter in the absence of oxygen. Agricultural waste, sewage, food waste, municipal waste, plant material and manure are some of the raw materials used to produce biogas. Biogas can be produced by anaerobic digestion with anaerobic bacteria, which digest materials inside a closed system, or fermentation of biodegradable materials. Biogas is primarily methane (CH_4) and carbon dioxide (CO_2) and may have small amount of hydrogen sulphide (H_2S) and traces of other gasses. The gasses methane, hydrogen, and carbon monoxide can be combusted or oxidized with oxygen. This energy released allows biogas to be used as a fuel for heating or in some cases are used to generate electricity.

Typical compositions of biogas are; Methane (CH_4) 50 – 75%, Carbon Dioxide (CO_2) 25 – 50%, Nitrogen (N_2) 0 – 10%, Hydrogen (H_2) 0 – 1%, Hydrogen Sulphide (H_2S) 0 – 3%. Environmental air quality has been largely affected as a result of petroleum-based fuels. The detrimental consequences of the fossil-based fuels and the depleting supplies of crude oil products have prompted and triggered the search for renewable alternative energy.

Biofuel should meet peculiar criteria such as providing net energy gain, positive favourable environmental effect and benefits, be economically cost effective and competitive. It is important to note that in biogas production, the substrates which are basically waste from municipalities helps in environmental clean-up, it produces lower CO_2 emissions compared to fossil fuels. The sources of anaerobic digestion can be classified as either industrial waste and waste water, sewage sludge, farm waste, municipal solid waste, or green waste (5).

Over the years, a lot of research has been made to produce gas from various bio-degradable materials. In this study, the effect of catalyst on biogas production using cow dung and chicken droppings with grass was assessed. The effectiveness of SSP (Single Super Phosphate) and ash to accelerate the rate of digestion to produce biogas in batch operation was also determined.

II. LITERATURE REVIEW

Historical Development of Anaerobic Digestion Technologies

Historical evidence indicates that the anaerobic digestion process is one of the oldest technologies (6). Very old sources indicate that using waste water and so-called renewable resources for the energy supply is not new, but were already known before the birth of Christ (7). The first allusion to animal manure comes from Humphrey Davy, who reported early in the nineteenth century the presence of this combustible gas in fermenting farmyard manure. Davy is known for the invention of the miner's safety lamp (8). 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 (6). Research led by Buswell (6) 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 equipment and operational techniques emerged. The result was the use of closed tank, heating and mixing systems to optimize anaerobic digestion.

In Africa, efforts are being made to reduce excessive use of wood fuel and biogas technology is being adopted all over the continent. In Rwanda for instance, Kigali Institute of Science and Technology has built sewage systems for overcrowded prisons (10,000 people) using underground masonry plants with 100 m3 volume, linked to make 1,400 m3. This development saved 50% of wood for cooking (9).

In 2006, Biogas Technology West Africa Ltd won the Ashden Award by building sewage systems for hospitals, schools, colleges, etc using underground masonry dome systems of 60 to 160 m^3 volume. The water recovered was used to flush the toilets while gas was collected and used for cooking (9).

In Nigeria, research into biogas technology and its practical application is on-going, though, has not really received the deserved attention. The Sokoto Energy Research Centre, UsmanDanfodio University, Sokoto, has carried out a number of pilot projects on construction of household size digesters. In addition to this the centre has constructed biogas digester plants of 20m3 capacity at these locations: NAPRI-Zaria, Zaria prisons, Kiri-kiri Prisons in Lagos, May flower School-Ikene, Ogun State, Ojokoro-Lagos and Maiduguri (3).

There is a new African initiative to increase the number of biogas plants that was launched in 2007. (10)stated that the goal of this initiative is to provide 2 million households by 2020 with biogas digesters. However, the number of biogas plants currently in Africa is unknown with most units installed in Tanzania (around 4,000) (11). It has also been estimated that only 60% of these plants have remained in operation (12). (11) opined that the following are some of the reasons responsible for failure or unsatisfactory performance of these biogas systems;

i. Planning stage errors
ii. Community interest.
iii. Construction faults.
iv. Routine maintenance failure.
v. Misconception of benefits of the system.
vi. Lack of training for new owners on the system, and
vii. Budgeting errors.

- Biogas Composition

Biogas is the mixture of gas produced by methanogenic bacteria while acting upon bio-degradable materials in an anaerobic condition. This gas is primarily composed of 50 to 70% methane (CH_4) and 30 to 40% carbon dioxide (CO_2), with smaller amounts of hydrogen sulphide (H_2S) and ammonia (NH_3). Trace amounts of hydrogen (H_2), nitrogen (N_2), carbon monoxide (CO), saturated or halogenated carbohydrates and oxygen (O_2) are occasionally present in the biogas. Usually, the mixed gas is saturated with water vapour and may contain dust particles (13). Methane is virtually odourless and colourless. It burns with a smokeless clear blue flame and is non-toxic.

However, the main constituents of biogas are CH_4 and CO_2 gases. Biogas burns very well when the CH_4 content is more than 50%. Therefore, biogas can be used as a substitute for kerosene, charcoal, and firewood for cooking and lighting. This saves time and money and above all it conserves the natural resources such as cutting trees to get firewood (14).

The composition of biogas is different from that of natural gas but it is quite similar to landfill gas which often contains significant amounts of halogenated compounds and occasionally oxygen content when too much air is sucked during the collection on the landfill. The calorific value is 36.14 MJ/m^3 for natural gas and 21.48 MJ/m^3 for biogas (15). The methane content and hence the calorific value is higher with longer digestion process. The methane content falls to as little as 50% if retention time is short.

The first gas from a newly filled biogas plant contains too little methane. The gas formed in the first three to five days must therefore be discharged unused. The methane content depends on the digestion temperature. Low digestion temperatures give high methane content, but less gas is then produced (16). The methane content also depends on the feed material. Some typical values of methane content for different feed materials (in %) are; Cattle manure 65, Poultry manure 60, Pig manure 52, Farmyard manure 55, Straw 59, Grass 70, Leaves 58, Kitchen waste 50, Algae 63, and Water hyacinths 60 respectively (17). Biogas is somewhat lighter than air and has an ignition temperature of approximately 700°C (diesel oil 350°C; petrol and propane about 500°C). The temperature of the flame is 870°C (17).

- Advantages and Disadvantages of Biogas

Advantages

- Renewable Source of Energy: Biogas is considered to be a renewable source of energy. Since it is often produced from organic materials that form sewage and waste products, the only time it will be depleted is when we stop producing waste.
- Non-Polluting: It is also considered to be non-polluting in nature. The production of biogas does not require oxygen, which means resources are conserved by not using any further fuel.
- Reduces Landfills: It also uses up waste material found in landfills, dump sites and even farms across the country, allowing for decreased soil and water pollution.
- Cheaper Technology: Application for biogas is increasing as the technology to utilize it gets better. It can be used to produce electricity and for the purpose of heating as well. Production can be carried out through many small plants or one large plant.
- Jobs Creation: Large number of jobs can be created through biogas technologies, especially in the rural areas.
- Little Capital Investment: Biogas is relatively easy to set up and require little capital investment on a small-scale basis. Farms can easily produce sufficient gas for its use from wastes generate by livestock, poultry and or crops.
- Reduces Greenhouse Effect: It also reduces the greenhouse effect by utilizing the gases being produced in landfills as forms of energy. It recycles most forms of biodegradable waste and works on simple forms of technology.

Disadvantages

- Contains Impurities: Biogas contains a number of impurities even after refining process have been put in place. When compressed for use as fuel, these can become corrosive to the metal part of an engine.
- Not Attractive on Large Scale: The process of using biogas on large scale is not economically viable and is difficult to enhance the efficiency of biogas systems.
- Little Technology Advancement: Little new technology has been introduced for streaming the

process and making it more cost effective. As a result, large scale industrial biogas production is still not on the energy map. Although it could solve the energy issues being faced by countries all over the world, very few investors are willing to put in the start-up capital.
- Unstable: It is also somewhat unstable, making it prone to explosions if the methane comes in contact with oxygen and become flammable in nature.

Uses of Biogas

Like any other fuel, biogas can be used for household and industrial purposes; the main prerequisite being the availability of especially designed biogas burners or modified consumers appliances (5).Uses of biogas according to (5), are;

- Cooking: Cooking is by far the most important use of biogas in the developing world. Biogas burners or stoves for domestic cooking work satisfactorily under a water pressure of 75 to 85 mm. The stoves may be single or double varying in capacity from 0.22 to 1.10 m3 gas consumption per hour.
- Lighting: Biogas can be used for lighting in non-electrified rural areas. Special types of gauze mantle lamps consuming 0.07 to 0.14 m3 of gas per hour are used for household lighting.
- Refrigeration: Biogas can be used for absorption type refrigerating machines operating on ammonia and water, and equipped with automatic thermo-siphon. Since biogas is the only refrigerator's external source of heat, the burner itself has to be modified. Refrigerators that are run with kerosene flame could be adapted to run on biogas.
- Biogas-fuelled engines: Biogas can be used to operate four stroke diesel and spark ignition engines. Biogas engines are generally suitable for powering vehicles like tractors and light duty trucks as has been successfully experimented in China. When biogas is used to fuel such engines, it may be necessary to reduce the hydrogen sulphide content if it is more than 2 percent. Using biogas to fuel vehicles is not so much of an attractive proposition as it would require carrying huge gas tanks on the vehicle. One of the uses of biogas, which has wide application in Nepal, is to fuel engines to run irrigation pumps. A dual-fuel engine is available in India, which will run on a mixture of biogas and diesel (80% biogas and 20% diesel).
- Electricity generation: Generating electricity is a much more efficient use of biogas than using it for gas light. From energy utilization point of view, it is more economical to use biogas to generate electricity for lighting. In this process, the gas consumption is about 0.75 m3 per kW hour with which 25 40-watt lamps can be lighted for one hour, whereas the same volume of biogas can serve only seven lamps for one hour (18).
- Small internal combustion engines with generator can be used to produce electricity in the rural areas with clustered dwellings. Bio-digesters can be used to treat municipal waste and generate electricity (18). One of the options to utilize biogas is to produce electricity using a gas engine or gas turbine.

Other benefits of biogas include;

- Improvement of hygienic conditions through reduction of pathogens, worm eggs and flies;
- Environmental advantages through protection of soil, water, air and woody vegetation;
- Reduction of workload, mainly for women, in firewood collection and cooking.
- Micro-economic benefits through energy and fertilizer substitution, additional income sources and increasing yields of animal husbandry and agriculture;
- Macro-economic benefits through decentralized energy generation and import substitution.

Thus, biogas technology can substantially contribute to conservation and development, if the concrete conditions are favourable (14).

- Effects of Biogas System

Biogas technology if properly harnessed will greatly impact positively on the socio-economic life of rural dwellers, aside the fact that is a source of clean energy. The use of energy and manure can lead to better environment, health, and other socio-economic gains (19) (14). Biogas technology is best suited to convert the organic waste from agriculture, livestock, industries, municipalities and other human activities into energy and manure (5).

- Digestate

Anaerobic digestion can be seen as a method to treat the organic wastes but, in order to extract the maximum recovery value from these wastes, the digester should have a useful purpose and benefit should be derived from its production (6). Anaerobic digestion draws up carbon, hydrogen and oxygen from the feedstock. Meanwhile, essential plant nutrients (nitrogen (N), phosphorus (P) and potassium (K)) remain largely in the digestate. Its main advantage is that it has a high nutrient content. The availability of nutrients is higher in digestate than in untreated organic waste. For instance, digestate has 25% more accessible NH_4-N (inorganic nitrogen) and a higher pH value than untreated liquid manure (6). More so, it reduces the odour nuisance by about 80%.

(20)noted that the quality and composition of the dewatered solid depend on the feedstock and the digestion process. Additionally, even if digestion were allowed to proceed for long time periods, a maximum of only about 70% of the total organics are available for degradation.

(6)noted that the dewatering separates the digestate into two fractions: the fibre and the liquor. He further stated that, because the fibre is bulky and contains a low level of plant nutrients, it can be used as a soil conditioner and as low-grade fertilizer. In addition, further processing of the fibre such as through composting can produce a good quality compost.

The liquor (liquid effluent) on the other hand contains a large proportion of nutrients and can be used as a fertilizer. The high-water content of the liquor facilitates its application through conventional irrigation methods. Furthermore, consideration has to be given to the application time so that nitrogen which is readily available after digestion is taken by the crop and not leached into soil and subsequently groundwater. Nonetheless, it has advantages over raw manure applications, as the ammonia uptake by plants is higher than for organic nitrogen (6).

The use of fibre and liquor from anaerobic digestion has led to improved fertilizer utilization and therefore less chemical consumption in cropping systems. In other to obtain high quality product, with a higher value, the digestate, can be processed into compost. It would ensure a complete breakdown of the organic components as well as fixing the mineral nitrogen onto humus-like fraction which would reduce nitrogen loss. As an additive to composting process, it provides a good source of nitrogen for speeding up the process. At same time, it enriches the compost in phosphorus and micro nutrients like magnesium (Mg) and iron (Fe). The water content of the digestate is also interesting for moisture management in the composting process (6).

According to (20), the safety of the digestate, measured by the concentration of pathogens present, is of great concern to end users. Pathogen destruction can be guaranteed at thermophilic temperatures with a high SRT (solid retention time). A sufficient degree of pathogen destruction can also occur at mesophilic temperatures and at lower SRT. In general, the lower the SRT, the more biologically active the solid will be. If solid digestion has occurred for at least 15 days, most of the organics would have been degraded and the resulting solid is stable.

Techniques for Enhancing Biogas Production

Different methods used to enhance biogas production can be classified into the following categories:

i. Use of additives
ii. Recycling of slurry and slurry filtrate
iii. Variation in operational parameters like temperature, retention time and particle size of the substrate
iv. Use of fixed film/ bio filters.

- Use of additives

Some attempts have been made in the past to increase gas production by stimulating the microbial activities using various biological and chemical additives under different operating condition. These additives are either organic or inorganic.

- Organic Additives

Additives under this category includes; different plants, weeds, crop residues, microbial cultures, among others, (Mata-Alvarez *et al.,* 2003) which are available naturally in the surroundings. As such, generally these are of less significance in terms of their use in the habitat, however if used as additives in biogas plant could improve its performance significantly. The suitability of an additive is expected to be strongly dependent on the type of substrate.

Powdered leaves of some plants and legumes (like *Gulmohar, Leucaena leucocephala, Acacia auriculiformis, Dalbergia sissoo and Eucalyptus tereticonis*) have been found to stimulate biogas production between 18% and 40% (20). Increase in biogas production due to certain additives appears to be due to adsorption of the substrate on the surface of the additives. According to (20), this can lead to high-localized substrate concentration and a more favourable environment for growth of microbes. The additives also help to maintain favourable conditions for rapid gas production in the reactor, such as pH, inhibition/promotion of acetogenesis and methanogenesis for the best yield. Alkali treated (1% NaOH for 7 days) plant residues (lantana, wheat straw, apple leaf litter and peach leaf litter) when used as a supplement to cattle dung resulted in almost twofold increase in biogas and CH4 production.

(21) opined that partially decomposed ageratum produced 43% and *Euphorbia tirucalli* produced 14% more gas as compared to pure cattle dung. They further found that the addition of the tomato-plant wastes to the rabbit wastes in proportion higher than 40% improved the methane production. Crop residues like maize stalks, rice straw, cotton stalks, wheat straw and water hyacinth each enriched with partially digested cattle dung enhanced gas production in the range of 10– 80% (22).

(23) observed improvement in biomethanation of mango processing wastes by several folds by the addition of extracts of seeds of nirmali, common bean, black gram, guar and guar gum at the rate of 1500ppm. Mixture of *Pistia stratiotes* and cow dung (1:1) gave a biogas yield of 0.62 m3/day (CH4 ¼76.8%, HRT¼15 days). Sharma (2002), observed an increase of 40–80% in biogas production on addition of 1% onion storage waste (OSW) to cattle dung in a 400-l floating drum biogas reactor.

- Inorganic Additives

Several inorganic additives that improve gas production have also been reported. (24) claimed that higher concentration of bacteria could be retained in the digester by the addition of metal cations since cations increase the density of the bacteria, which are capable of aggregating by themselves. (24) found that the plant with a higher content of heavy metals (Cr, Cu, Ni and Zn) had a higher CH_4 yield than the control. The addition of iron salts at various concentrations [FeSO4 (50 ml, FeCl3 (70 ml)] have been found to enhance gas production rate (RaO and Nickel ions (2.5 and 5 ppm) enhanced biogas up to 54% due to the activity of Ni-dependent metalloenzymes involved in biogas production (25). Single super phosphate (SSP) used in digesting rice straw in batch fermenters yielded 8-11% increase of biogas (26).

III. MATERIALS

The following materials (equipment, glassware) were used in this study;

i. Shovel: used to pack the waste material into sacks
ii. Sacks: used to convey the cow dung and chicken droppings to the site
iii. Protective gloves: worn to protect the hands from contamination
iv. Nose mask: used to prevent inhalation of particulates and odour.
v. Pestle and Mortar: used to pound the waste
vi. Stirrer (wooden stick): to stir the mixture of waste and water to form slurry.
vii. Spring Balance: used to measure weight of samples before mixing in the various digesters
viii. Gallenhamph Weight balance, Mettler P160: used to measure weight of catalyst
ix. Plastic bucket used to fetch water
x. Boiling ring (heater) for heating the water before mixing
xi. Thermometers: was used to obtain daily temperature of the digester as well as the ambient temperatures.

While the feed materials that were used includes;

i. Cow dung from Abattoir located along EKSU Road, Ado-Ekiti
ii. Chicken droppings
iii. *Cymbopogon citratus* (Lemon grass known as koriko oba in Yoruba)


Figure 2. feed materials

- Material Selection

Selection of all the materials was based on the following;

1. Cost-effectiveness
2. Availability and
3. Durability.

- Materials for Digester Construction

The material used was aluminium. It was selected to meet the following requirements:

i. Good tensile strength, ductile and ease of rolling by machine to the required design geometry (malleability).
ii. Water/gas tightness: Water tightness in order to prevent seepage and the resultant threat to soil and ground water quality. Gas tightness to ensure proper containment of the entire biogas yield and prevent air from entering into the digester.
iii. High resistance to corrosion
iv. Relatively cheap
v. Provides reflective surface thereby minimizing heat build-up inside the gas holder and within the water seal
vi. Provides gas tightness to store biogas

- The process

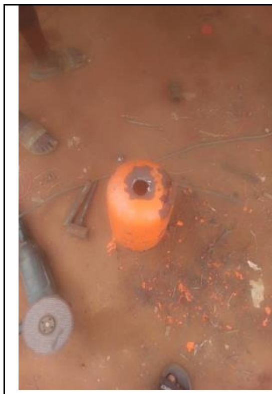
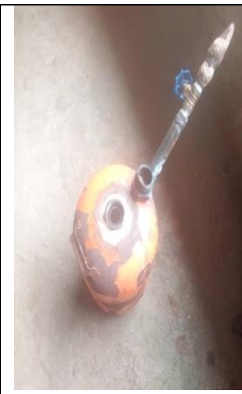

Figure 3: Fabrication process of the digester

Procedure for Anaerobic Digestion of Cow Dung and Chicken Droppings with *Cymbopogon citratus* (Lemon grass)

Cow dung was soaked for a period of 12 hours and then made into a paste. The same process was done on the chicken droppings. *Cymbopogon citratus* (Lemon grass) was obtained from a nearby land space after which it was dried for 12 hours and subsequently mildly crushed into mulch. The dried feed materials (cow dung and chicken droppings) were then mixed vigorously in order to achieve a homogeneous mixture.

The substrate (cow dung, poultry droppings) was mixed in the ratio 1:1 and an additive to substrate ratio of 1:4 was used. Also, the water to substrate ratio was 1:1.4 to result in a total slurry content of 6 litres.

For the extraction process, the gas was collected over water, one end of the rubber hose was connected to the digester gas outlet and the other end of the hose was connected to graduated container for collection and measurement.

To calculate the quantity of substrate in the digester, this approach was adopted.

$Qs = Cs \times V$

Where Qs = Quantity of Substrate

Cs = Concentration

V = Volume

IV. RESULTS

Anaerobic digesters were fabricated for the digestion of the two substrates with *Cymbopogon citratus* (Lemon grass) in this study. The results obtained during the conduct of the experiment were tabulated. They are presented in tables, graphs, and bar charts.

Table 1: Composition of substrate by Quantity

S/N	COMPOSITION	QUANTITY
1.	Substrate (cow dung and chicken droppings)	2kg
2.	Water	3.5kg
3.	*Cymbopogon citratus* (Lemon grass)	500g
	TOTAL	6kg

Daily temperature reading for Biogas Production

Table 2: Retention time (Days) against Temperature (^{0}C)

Retention Time (Days)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Temperature (^{0}C)	34.4	30.2	29.9	30.8	32.7	31.8	33.4	29.3	28.9	30.3	30.4	29.6	26.6	24.4

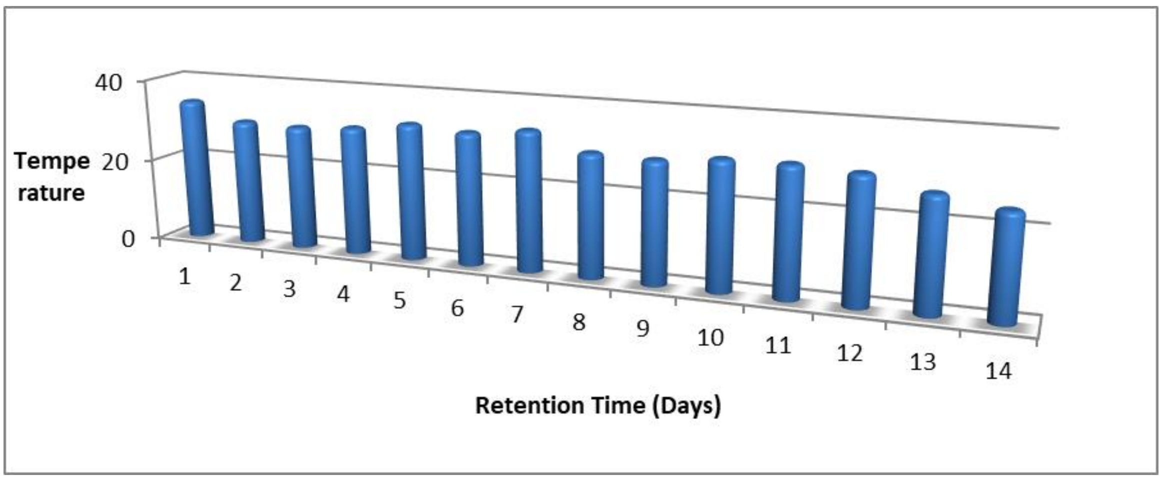

Figure 4: Temperature (^{0}C) of Biogas digester against Retention time (Days)

Daily Biogas Production Reading

Table 3: Biogas Production

Retention Time (Days)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Temperature (^{0}C)	0	51.2	55.9	54.8	59.7	56.8	57.7	52.9	55.7	56.0	54.6	51.1	50.3	48.3

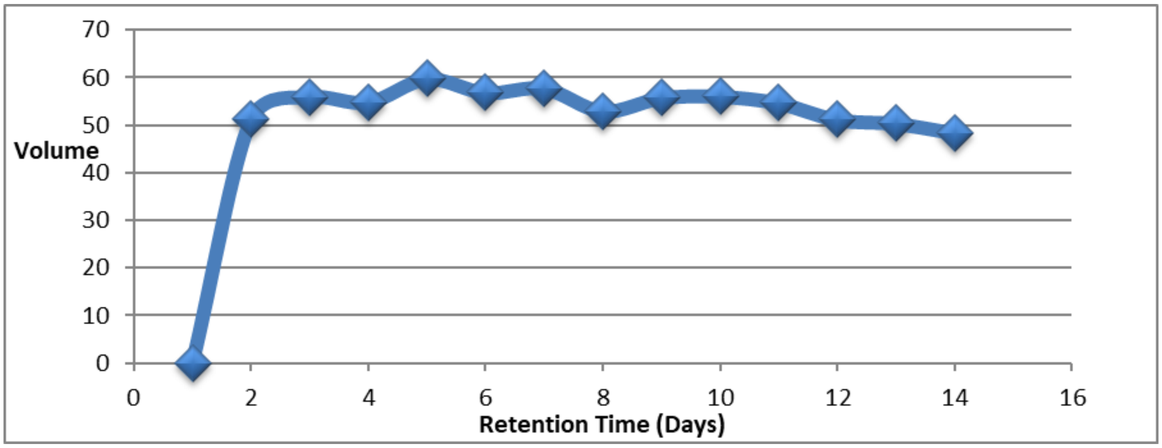

Figure 5: Biogas production rate

DISCUSSION

Table 1 shows the results of the composition of the substrate by quantity in kg. The quantity of substrate, water and additive were 2.0, 3.5, and 0.5kg respectively. This was done to ensure that the cylinder contains the total content. The implication of this is that, the results obtained is dependent on the type of substrate used, quality and operating condition.

Table 2 shows the daily temperature reading, beginning from the first day that the digester was loaded which was taken as 34.4^{0}C at room temperature. The increase in temperature was observed to be proportional to the yield increase in production of biogas. Meanwhile from the biogas production rate (Fig. 6), it was observed that there was decrease in the production of biogas from the substrate following the addition of the additive (*Cymbopogon citratus*) compared to the biogas yield in the absence of the additive. The gas produced, can be further processed for the generation of electricity, thermal energy for cooking and also as transportation fuel.

CONCLUSION

From the study, the following conclusions were made;

i. Cow dung and chicken droppings are good substrate for biogas production.
ii. *Cymbopogon citratus as* additive contributed to the low biogas yield experienced during the experiment therefore, not a good catalyst for the production of biogas.
iii. Biogas production technology is a technology with great potential which could exercise major influence in the energy scene in rural areas.
iv. The percentage yield of biogas produced depends on the type of substrate used and its chemical constituents.

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