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Design and Fabrication of Biogas Plants, Comparing the Biogas Output of Three Agricultural Wastes

Daberechi Blessing Mounford[1,a], Akani Oko Akani[1,b], Okechukwu Uzoma Iheme[2]

[1] Department of Agricultural and Bio-Resources Engineering, Michael Okpara University of Agriculture, P.M.B. 7267, Umuahia, Abia State, Nigeria

[2] Key Laboratory of Vegetation Restoration and Management of Degraded Ecosystem, South China Botanical Garden, Chinese Academy of Sciences, China

[a,b]E-mail addess: dabsmounford@gmail.com , akanioko68@gmail.com

ABSTRACT

Energy is a crucial element in the industrialization and socio-economic development process of any nation. While in developing economies, proactive measures are taken towards making for energy adequacy, the need to develop an alternative source of energy cannot be over-emphasized. This project suggests a way forward in exploiting and developing biogas from different substrates for rural communities. Biogas technology from animal dung is feasible for smallholders with livestock producing 5kg manure per day, an equivalent of 4 pigs or 2 cows. The size of the digester was focused on achieving the desired output which is the biogas itself using anaerobic digestion and the substrates used were cow dung, pig dung, and poultry droppings. This fabrication was made to show a simple demonstration of biogas production by decomposition of cow dung, pig dung, and poultry dropping. Three digesters were made from plastic tanks of 9-liter capacity. The digester was connected to the water displacement setup for the gas collection. Each substrate had two (2) replicas, so as to get average and more accurate results, making a total of nine (9) fabricated digesters. The water displacement method of gas collection was adopted. The mode of feeding used was batch feeding (discontinued feeding). From the comparisons, it was evaluated that 5kg of Poultry droppings produced approximately 0.0133 liters of biogas per day. An adult pig, which produces about 5kg of manure daily (out of which is 90% water, a 7% volatile solid), produces an average of 0.2301 liters of biogas daily, and 5 kg of Cow dung produces about 0.0052 liters of biogas – all under 30 days retention time, and same environmental conditions.

Keywords: biogas, energy, digesters, agricultural waste, anaerobic digestion

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1. INTRODUCTION

Energy is one basic tool for development. Its application ranges from domestic uses to industrial applications for heating furnaces, lighting and running electric motors, and other transport applications. It can thus be referred to as a cornerstone of economic and social development (El-Saeidy, 2010). Due to over-dependence on biomass and fossil fuels, developing countries like Nigeria face added dilemmas regarding environmental protection.

Adaramola & Oyewola (2011) opined that Nigeria is endowed with a huge volume of conventional energy resources (crude oil, tar sands, natural gas, and coal) as well as a reasonable amount of renewable energy resources (e.g. hydro, solar, wind and biomass). The projected refining capacity only supports 443,000 barrels a day and the actual output of these refineries is far below capacity (Okoye 2007). Solar energy, wind energy, thermal and hydro sources of energy, and biogas are all renewable energy resources. Biogas is distinct from other renewable energies because of its unique characteristics of using, controlling, and collecting organic wastes and at the same time producing fertilizer and water for use in irrigation. Biogas does not have any geographical limitations it does not require advanced technology to produce energy. It is very simple to use and apply (Okafor, 2010).

Fossil fuel is one of the principal sources of energy. 86% of all the energy consumed comes from fossil fuels (Kaliyan & Morey, 2009). There are many problems associated with fossil fuels such as high costs and fluctuation of prices, increase in demand, disruption in supply, and environmental pollution. These problems arise because fossil fuels give off carbon dioxide when burnt thereby causing a greenhouse effect. It is therefore a major contributory factor to global warming experienced today.

Agricultural residues and animal wastes are increasingly being diverted for use as domestic fuel to reduce environmental pollution and reduce the emission of greenhouse gases. Cassava solid wastes, amongst other plant wastes, have been widely used (Oladeji, 2012). Agricultural residues in their natural forms cannot yield the desired result as they are mostly loose and of low density. More so, their combustion cannot be effectively controlled (Oladeji, 2012). Agricultural residues are thus combined with animal wastes and used in the production of biogas.

According to Mshandete & Parawira (2009), Nigeria produces about 227,500 tons of fresh animal waste daily. This shows that Nigeria can potentially produce about 6.8 million m^3 of biogas every day from animal waste only if properly managed. Mitel (1996) also reported that the sludge obtained from the bio-fermentation process contains a high concentration of nutrients and organic matter. The application of this sludge at a rate equivalent to traditional chemical fertilizer increases the yield of maize up to 35.7%, wheat to 12.5%, rice to 5.9%, cotton to 27.5%, carrot to 14.9%, and spinach to 20.6%.

In the present economic recession in the country, biogas energy can be one of the most reliable, easily available, and economically feasible sources of alternative and renewable energy which can be managed by locally available materials and simple technology for both urban and rural dwellers. The biogas system also provides a barrier protecting groundwater from contamination with untreated waste (Ocwieja, 2010). Furthermore, with the enormous cattle population in the country, millions of tonnes of dung released daily emit a lot of methane gas into the atmosphere, which is 320 times more harmful to human health than carbon dioxide. A biogas plant is an anaerobic digester that produces biogas and natural fertilizer from animal, food waste, or plant waste.

Although, the biogas plant is not a new technology to many developed and some developing countries of the world, in Nigeria the technology is still on a skeletal basis. Biogas can provide a clean, easily controlled source of renewable energy from organic waste materials for small labor input. This will go a long way to replace firewood or fossil fuels which are becoming more expensive as supply falls below demand. Biogas is generated when bacteria degrade biological material in the absence of oxygen, in a process known as anaerobic digestion. Since biogas is a mixture of methane (also known as marsh gas or natural gas, CH_4), hydrogen sulfide (H_2S), and carbon dioxide, it is a renewable fuel produced from waste treatment.

Biogas is a mixture of methane and carbon dioxide, produced by the breakdown of organic waste by bacteria without oxygen (anaerobic digestion). It contains methane and carbon (IV) oxide with traces of hydrogen sulfide and water vapor. It burns with pale blue flame and has a calorific value of between 25.9-30 J/m^3 depending on the percentage of methane in the gas. Biogas production is a profitable means of reducing or even eliminating the menace and nuisance of urban waste in many cities in Nigeria. Consequently, biogas can be utilized in all energy-consuming applications designed for natural gas.

Biogas refers to the gas produced by the biological breakdown of organic matter in the absence of oxygen. Organic waste such as dead plant and animal material, animal dung, and kitchen waste can be converted into a gaseous fuel called biogas. Biogas is produced by the anaerobic digestion or fermentation of biodegradable materials such as biomass, manure, sewage, municipal waste, green waste, plant material, and crops (Cheshire, 1979). Biogas comprises primarily methane (CH_4) and carbon dioxide (CO_2) and may have small amounts of hydrogen sulfide (H_2S), moisture, and siloxanes. The gases methane, hydrogen, and carbon monoxide (CO) can be combusted or oxidized with oxygen. Biogas is a renewable fuel, so it qualifies as a renewable energy substitute in some parts of the world. Biogas can also be cleaned and upgraded to natural gas standards when it becomes bio-methane.

The residues from agriculture and forest could provide 20% of the world's energy constituents. Biogas contributes to the technological and economic advancement of an economy by reducing energy costs and contributing to the social structure. It is an alternative source of energy in many countries of the world. Apart from the great potential, it does not contribute to global warming Biogas production takes different times depending on the temperature, and process adopted. All types of organic wastes are suitable for producing biogas by the process of anaerobic digestion in a bio plant. Animal waste, poultry waste, and so on are easier in biogas. The organic materials sourced from human, animal, and plant wastes, are reduced to 3-6 mm in size for adequate digestion (Eze *et al*., 2009). Also, water is needed in the bioconversion process. It enables quicker decomposition and fermentation of the wastes. It is sourced from streams, ponds, rain, and underground sources.

Energy consumption in Nigeria increases at a relatively high rate. On a global scale. (Iywayemi, 2011) opined that the Nigerian energy industry is one of the most efficient in meeting the needs of its customers. Poor energy supply has led to energy scarcity and fluctuation in prices. This is most evident in the persistent disequilibrium in the markets for electricity and petroleum products, especially kerosene and diesel. The dismal energy service provision has adversely affected the living standards of the population and exacerbated income and energy poverty in an economy where the majority of the people live on less than 2 USD a day. Coupled with high levels of environmental pollution and contamination as a result of present poor management of solid wastes, call for the design and fabrication of a simple, agricultural cost and effective device for the management of the selected solid wastes on one hand and production of fuel (Biogas) on another hand. Anaerobic fermentation is a simple and low-cost process that can be economically carried out in rural areas where organic wastes are generated aplenty which otherwise pollute the environment and pose health hazards (Labatut., 2011).

Unfortunately, biogas technology has not been optimally used on a large scale in Nigeria compared with the level obtained from reports in other countries such as China, Korea, and the Philippines. According to Ezeokoye *et al*. (2013), there is a need to popularize biogas technology in Nigeria in view of the large population of brewery plants and agricultural operations. This is to provide effective utilization of brewery effluents and a good check of environmental pollution caused by their disposal. This project is therefore meant to come up with a prototype design and fabricated unit that will optimally produce biogas for households in Delta state and Nigeria as a whole. The large quantities of agricultural residues produced in Nigeria can play a significant role in meeting her energy demand.

The aim of this project is to design and fabricate a medium-sized Agricultural waste biogas plant for three (3) different substrates under equal conditions.

The specific objectives are to design an agricultural waste biogas plant, to fabricate a prototype of an agricultural waste biogas plant, and to compare the amount of biogas produced by the 3 different substrates (cow dung, pig dung, and poultry droppings).

This study is limited to the production of biogas from agricultural waste obtained from 3 different substrates namely; cow dung from the cattle ranch close to the engineering workshop in the Michael Okpara University of Agriculture, Umudike (MOUAU), chicken droppings from the poultry section (deep litter) in MOUAU, and Pig dung from the piggery section in MOUAU, Abia State, and comparing the biogas output of the three agricultural wastes.

2. MATERIALS AND METHODS

2. 1. Design of biogas plant

A biogas plant is an anaerobic digester for waste treatment, generating biogas and organic fertilizer for agriculture. For successful construction and operation of biogas plants factors such as the right selection of plant site, construction materials used, and skilled construction workers are paramount. Selection of an appropriate size for the biogas plant is very important. Because a big biogas plant when underfed would result in low gas production which ultimately would be insufficient to displace the digested slurry into the outlet chamber. While a small biogas plant when overfed, can cause the slurry to flow through the gas pipe and into the appliances (Edward, 2017).

This biogas model presented below is based on a successful model implemented in Nigeria. It is one of the most popular models adopted across Africa and is known as a Fixed-batch biogas plant. This model is simple in design and requires less construction and maintenance cost (Edward, 2017). It has been calculated that the daily input influent required for this prototype biogas plant is 0.75 kg influent and hydraulic retention time (HRT) of about 30 days (Edward, 2017). The digesters would consist of 9 plastic tanks of nine (9) litre capacity. Two replications would be made for the 3 different samples to get an average.

$$Volume\ covered\ by\ input\ feedstock = 8960\ \text{cm}^3/30\ \text{days} \approx 298.67\ cm^3/\text{day}$$

Theoretically, the volume required for a digester is 298.67 cm^3/day and, the other volume requirements include gas storage, gas collection, etc. However empirical data suggests a plant of 9000 cm^3 size for 4kg input feed with 30 days of HRT (Edward, 2017). The design is made up of a 9-litre capacity plastic as a prototype biogas plant, plant to inspect the anaerobic digestion in producing biogas. The digester would be operated in batch and daily gas produced from the plant would be observed for 30 days. The digester would be fed within the ratio of 1:1 of dung to water respectively. The operating temperatures of the digester would be maintained within mesospheric conditions.

2. 2. Components of the setup

The components of the experimental setup include a weighing scale (measuring both the weight of biomass, and the volume of biogas produced), A hand drill with a bit diameter of 10 mm, for boring holes, Connectors, a Rubber tube, a Digester Vessel, Outlet gas pipe, and a Removable manhole cover.

Figure 1. Images of **a)** digester vessel, **b)** gas pipe connector, and **c)** removable manhole cover.

This fabrication was made to show a simple demonstration of biogas production by decomposition of cow dung, pig dung, and poultry dropping. The digester, made of a plastic tank with a capacity of 9 liters, was used for setup. The experimental setup is shown in Figure 3b, the full setup for this model was the connection of the digester to the water displacement setup for the gas collection. The water displacement method of gas collection is a method in which gas is allowed to replace water at an equal volume of water displaced and this was used to determine the volume of gas produced daily. The mode of feeding used was batch feeding (discontinued feeding). This means loading the digester at once and maintaining a closed environment throughout the retention period.

The procedures taken during the feeding of the digester are as follows: 4 kg of the cow dung was weighed and water was mixed thoroughly with the waste in a ratio of 1:1. The mixture of the waste (slurry) was poured into the digester. The digesters were operated at a temperature in the mesophilic range with a hydraulic retention time of 30 day.

Figure 2. Images of **a)** outlet gas pipe, and **b)** tyre tube

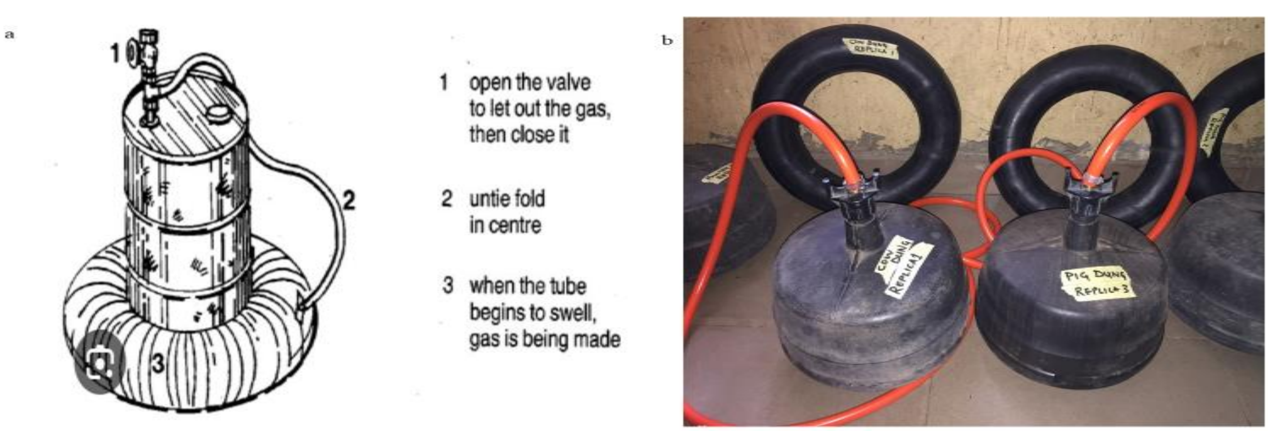


Figure 3. Images showing **a)** a schematic diagram of the experimental set-up for anaerobic digestion of cow dung, and **b)** the experimental setup

2. 3. Experimental Procedures

In this study, biogas production was done in a batch system, in which the slurry was added once in the digester for the whole duration of the process. In the combined waste experiment, the digester was fed 4 kg of cow dung mixed with water at a ratio of 1:1 respectively. In the single dung experiment, 4 kg of pig dung was introduced into another digester at the same ratio. 4 kg of poultry dropping was introduced into another digester at the same ratio. The digesters were provided with suitable arrangements for feeding, gas collection, and draining residues. The digesters were connected to different calibrated measuring cylinders with paraffin oil displacement arrangements to measure the volume of biogas produced. The slurry was allowed to ferment anaerobically for 30 days under the mesophilic temperature of 26-35 °C.

Table 1. Biogas production potential per kg weight of different substrates (Cow, Poultry, and Pig waste).

	Ratio (C/N) (Ideal: 20-30)	**Per Kg Dung (m^3)**
Cattle (Cows and Buffaloes)	24	0.023 – 0.040
Pig	18	0.040 – 0.059
Poultry	10	0.065 – 0.116

2. 4. Digester description

A biogas chamber of 8kg slurry capacity was constructed and used for this experiment. The diameter and height of the digester are 28 cm and 22.319 cm respectively. The biogas digester was built to maintain the anaerobic condition. The gas production was measured via the connection of a calibrated measuring cylinder with paraffin oil displacement arrangement. The digester was fed by opening the cover of the digester.

2. 5. Construction Site Selection Requirement

The following are very crucial while deciding the construction site for the biogas digester plant: a proper temperature of about 35 ºC is very crucial for the best performance of the biogas plant, so, a sunny side should be preferred. To avoid the wastage of raw feedstock and minimum transportation plant should be close to the feedstock supply. The gas pipe length should be as close as possible.

2. 6. Determination of required feedstock for a medium size biogas plant

Cattle dung, pig dung, and Poultry dropping are agricultural waste from undigested residue of consumed food material being excreted. It is a mixture of feces and urine in a ratio of about 3:1. It's primarily composed of lignin, cellulose, and hemicelluloses, and twenty-four other different minerals like nitrogen, potassium, along with a trace amount of Sulphur, iron, magnesium, copper, cobalt and manganese, etc. The dung and dropping of indigenous farm animals have comparatively more calcium, phosphorus, zinc, and copper than the crossbreed farm animals (Amaza, 2010).

Biogas production potential of cow manure is 35-40 liter/kg when mixed with an equal amount of water and put at an ambient temperature of 24-26 °C for hydraulic retention time (HRT) of 55-60 days. Some bacteria such as *Pseudomonas* sp., *Azotobacter* sp., and other purple sulfur or purple non-sulfur bacteria are capable of producing more methane than photosynthetic bacteria present in cow dung (Amaza, 2010).

2. 7. Temperature regulation

The temperature range between the mesophilic temperatures (20 to 40 °C) is the best range for producing biogas (Olaoye *et al*., 2014; Sibiya *et al*., 2014; Ukpai *et al*., 2015; Mir *et al*., 2016). For this project, a temperature range of 20 to 35 °C was maintained throughout the research to avoid the effect of ambient temperature influencing the temperature of the slurry.

2. 8. Design calculation

According to Ajibade, (2015) and Babatola, (2008), the total volume of the digester, V_T is the addition of the Slurry volume, V_s, and the storage capacity of the gas, V_g.

$$V_T = V_S + V_g \tag{1}$$

The digester was fed once, but the calculation was based on daily feeding with the design criteria of 30 30-day retention period, 5 kg of Cow dung each was fed into a different digester, with an equal volume of water for mixing, waste and water are in 1:1. 1 kg is equivalent to 1 liter; using 4 kg of waste. A total of 4 kg is fed for 30 days at a rate of 0.13 kg/day.

$$V = \pi r^2 h \tag{2}$$

In designing a cylindrical digester tank with a height of 0.28m, Equation (5) is used below as used by (Okoyeuzu, 2017), and the diameter is given as 23 cm

From the design calculations, we have that the Diameter of the Digester = is 22.319, therefore the radius of the digester cylinder = is 11.16 cm (0.116m), and the height of the digester, H_d = 23 cm (0.23m)

Using Equation (2), the total volume of digester, V_O is given as 9 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 the slurry rise and for biogas as reported (Babatola, 2018).

Table 2. Design calculation for the digester plant for cow dung.

Parameter	Symbols	Values(units)
Volume of the digester	V_d	9 litres
Volume of Gasholder	V_g	40 cm^3
Volume of Gas collecting chamber	V_c	1.103 litres

Volume of fermentation chamber	V_f	8.156 litres
Height of the digester	H_D	23 cm
Height of Gas collecting chamber	H_C	45 cm
Height of fermentation chamber	h_f	15 cm
Diameter of cylinder	D_c	22.319 cm

Table 3. Design calculation for the digester plant for pig dung.

Parameter	Symbols	Values (units)
Volume of the digester	V_d	9 litres
Volume of Gasholder	V_g	40 cm^3
Volume of Gas collecting chamber	V_c	1.093 litres
Volume of fermentation chamber	V_f	8.2301 litres
Height of the digester	H_D	23 cm
Height of Gas collecting chamber	H_C	45 cm
Height of fermentation chamber	h_f	15 cm
Diameter of cylinder	D_c	22.319 cm

Table 4. Design calculation for the digester plant for poultry droppings.

Parameter	Symbols	Values (units)
Volume of the digester	V_d	9 liters
Volume of Gasholder	V_g	40 cm^3
Volume of Gas collecting chamber	V_c	1.0717 litres
Volume of fermentation chamber	V_f	8.3978 liters
Height of the digester	H_D	23 cm
Height of Gas collecting chamber	H_C	45 cm
Height of fermentation chamber	h_f	15 cm
Diameter of cylinder	D_c	22.319 cm

Tables 2, 3, and 4, show the results obtained from the determination of selected design parameters of the cow dung, pig dung, and poultry droppings for digester plants used in the study.

Volatile solid loading rate is a measure of the biological conversion of the anaerobic digestion system (Muzenda, 2014). For cow dung, the rate of biogas production is about 0.04 m^3/kg of added volatile solid (Zurbrügg, 2014).

The amount of biogas generated each day, G_d (m^3/day) was calculated using Equations (2), and (3) below, on the basis of the daily substrate, input (volatile solids content) and specific gas yield of the substrate (Babatola, 2018), Hence;

2. 9. Daily gas production, G_d

Volume of Slurry, Vs = 4 liters of waste + 4 liters of water = 8 litres

G_d = Volatile solids content x the specific gas yield solids

Volatile solids content = 0.13kg/day

For cow dung;

Specific gas yield = 0.04 m^3/kg (3)

G_d = 0.13 kg/day × 0.04 m^3/kg = 0.0052 litres/day

Total volume of gas after 30 days = G_d × 30 days = 0.156 litres (4)

For Pig dung;

Specific gas yield = 0.059 m^3/kg

G_d = 0.13 kg/day × 0.059 m^3/kg = 0.00767 litres/day (5)

Total volume of gas after 30 days = G_d × 30 days = 0.2301 litres (6)

Total volume of Digester, 8.156 × 1.093 = 9 litres (7)

For Poultry Droppings;

Specific gas yield = 0.102 m^3/kg

G_d = 0.13 kg/day × 0.102 m^3kg = 0.01326 litres/day (8)

Total volume of gas after 30 days = G_d × 30 days = 0.3978 litres (9)

Total volume of Digester, 8.3978 Litres × 1.0717 Litres = 9 litres (10)

3. RESULTS AND DISCUSSION

Tables 2, 3, 4, and Fig. 4, show a relative increase in the volume of fermentation chamber level and Total biogas produced in the cow dungs digester, pig dungs digester, and poultry digester, and a decreasing trend in the volume of gas collecting chamber at a constant digester volume of 9 litres.

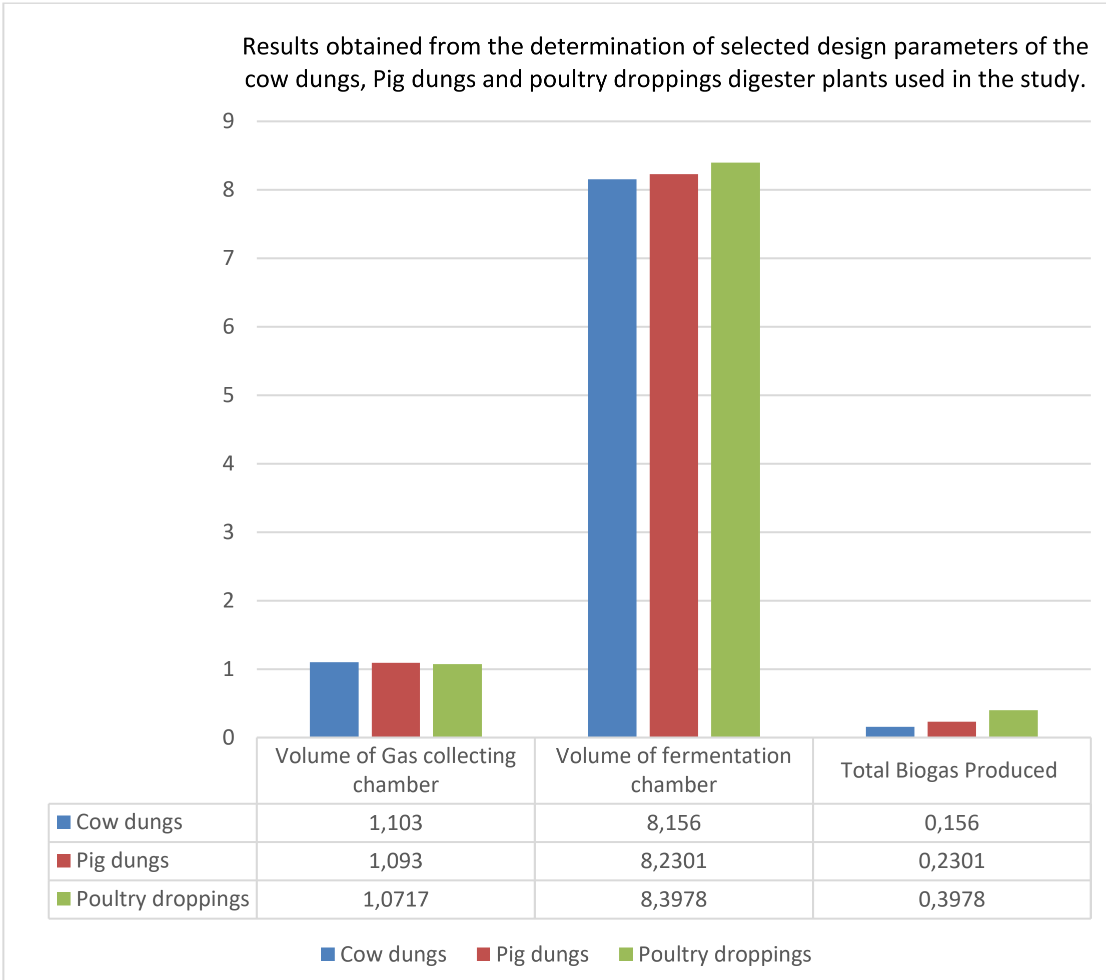


Fig. 4. Results obtained from the determination of selected design parameters of the cow dung, pig dung, and poultry droppings digester plants used in the study.

3. 1. Physiochemical Properties

Tables 5, 6, and 7, show the results obtained from the determination of selected physiochemical properties of the cow dung, pig dung, and poultry droppings used in the study.

Table 5. Properties of fresh cow dung, used in the study.

Properties of cow dung	Values	Test method used
pH	7.6 at 30 °C	Hydrogen-electrode method
Total solids (TS)	63.75g	ALPHA 2005 method
Volatile solids (VS)	50.4g	ALPHA 2005 method

Table 6. Properties of fresh pig dung used in the study.

Properties of pig dung	Values	Test method used
pH	7.3 at 30 °C	Hydrogen-electrode method
Total solids (TS)	60g	ALPHA 2005 method
Volatile solids (VS)	48g	ALPHA 2005 method

Table 7. Properties of fresh poultry droppings used in the study.

Properties of poultry droppings	Values	Test method used
pH	6.7 at 30 °C	Hydrogen-electrode method
Total solids (TS)	76.5g	ALPHA 2005 method
Volatile solids (VS)	61.2g	ALPHA 2005 method

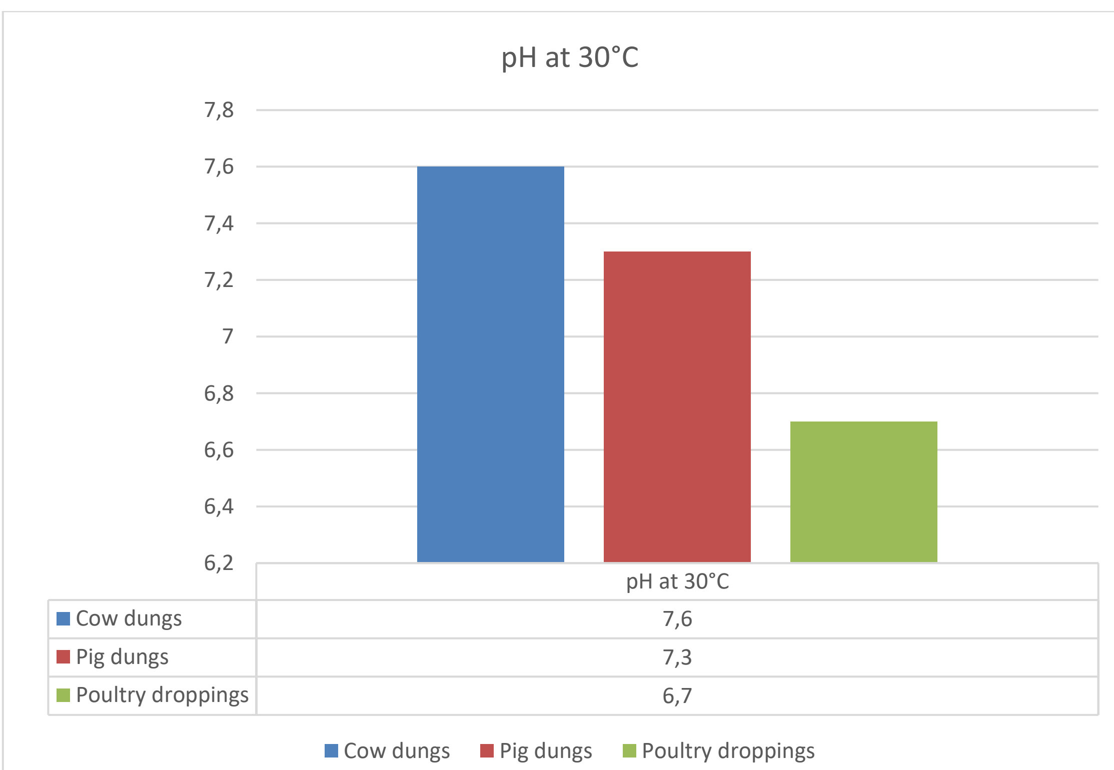


Fig. 5. pH of materials used at 30 °C

The pH influences the activity of microorganisms in destroying organic matter into biogas, whereas the total solids are useful in determining the organic loading rate of the biodigester and predicting when maintenance is needed. Volatile solid is used in estimating the quantity of the substrate that has the potential to produce methane, while the chemical oxygen demand provides information on how much energy is contained in the sample. The calorific value determines the heat of combustion or the calorific value of any solid or liquid.

3. 2. Proximate Analysis and pH Determination and Results

Proximate composition of the dung was carried out according to the method of AOAC as described in Ukpabi *et al*., (2011). The slurry pH was determined electrometrically using a glass electrode pH meter on the 1st, 4th, 8th, 12th, 15th, 20th, 25th, 28th, and 30th, day. The pH was measured at the ratio of 1:1 dung/ water suspension. Recent studies have shown that the production of biogas is partly dependent on pH and the volume of the slurry in the digester. Thus, in the course of the experiment, attention was given to the pH within the digester, with the avoidance of much volume of the slurry in the digester. Gas production was recorded daily via the connection of the tire tube, while the pH values were measured from a small slurry taken from the digester.

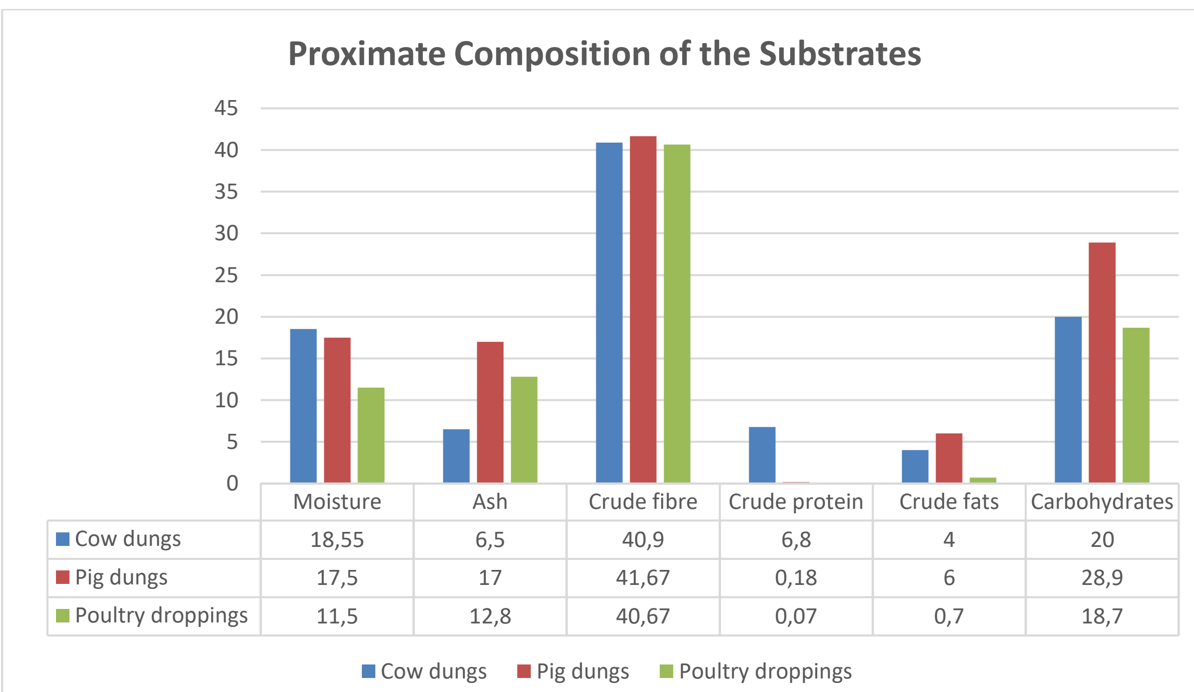


Fig. 6. Proximate composition of the substrates

The composition of the 3 substrates is presented in Figure 6 and Table 8. The result showed that the three feedstocks contained energy-yielding nutrients but at varying concentrations. For instance, the carbohydrate values of the pig dung (28.90 g/kg) and cow dung (20.00 g/kg) were relatively ($p<0.05$) higher than the poultry droppings (18.70 g/kg). The significant concentrations of energy-yielding nutrients in the food wastes may suggest that food wastes used as feedstock would provide more energy for the microorganisms to live and sustain the process.

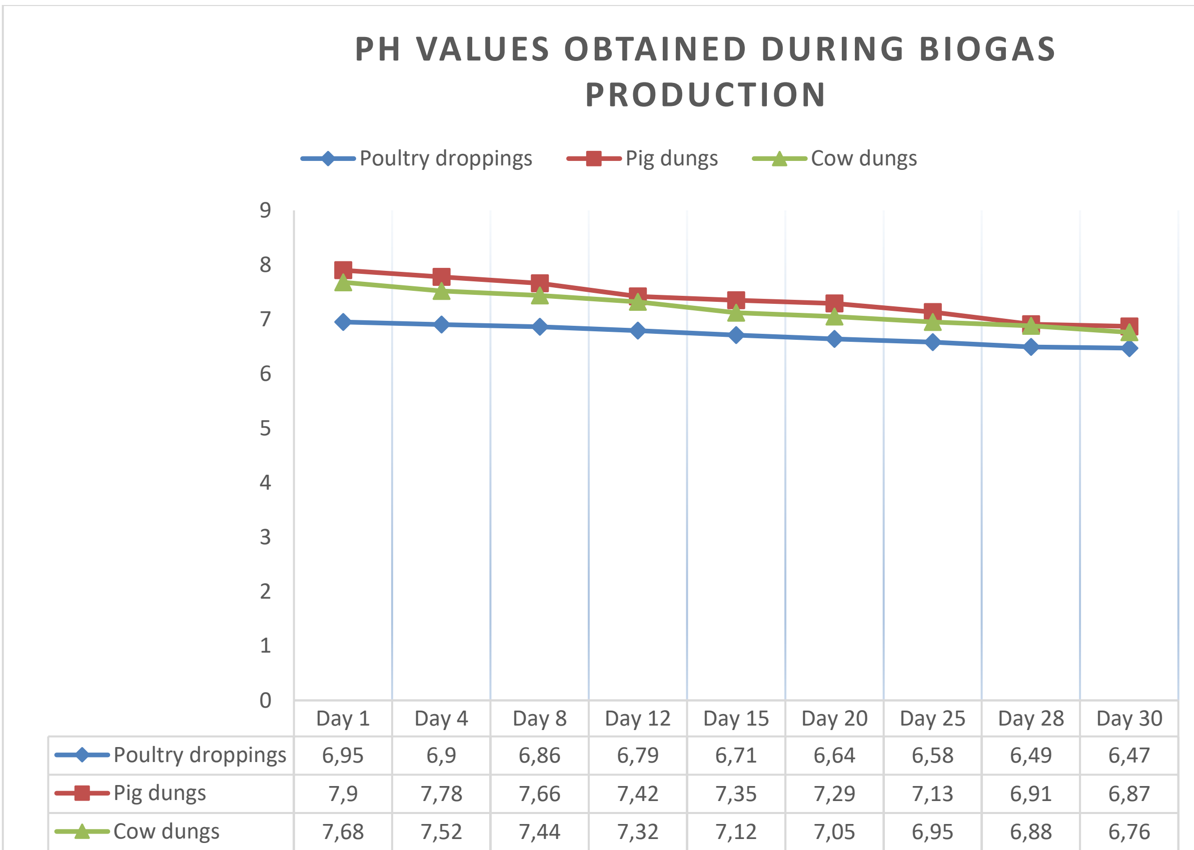
Table 8. Proximate composition of the substrates

Parameters (g)	Poultry droppings	Pig dung	Cow Dung
Moisture	11.5%	17.50%	18.55%
Ash	12.8 % wt	17% wt	6.5% wt
Crude fibre	40.67	41.67	40.90
Crude protein	0.07	0.18	6.80
Crude fats	0.7	6.00	4.00
Carbohydrates	18.70 g/kg	28.90 g/kg	20.00 g/kg

Table 9. pH values obtained during biogas production

Day	Cow dungs	Poultry Droppings	Pig dungs
1	7.68	6.95	7.90
4	7.52	6.90	7.78
8	7.44	6.86	7.66
12	7.32	6.79	7.42
15	7.12	6.71	7.35
20	7.05	6.64	7.29
25	6.95	6.58	7.13
28	6.88	6.49	6.91
30	6.76	6.47	6.87

Table 9 and Fig 7 also revealed that the pH decreased as the bacteria produced acids in the digester. The decrease was more observed in the cow dung slurry as it was recorded as acidic on the 25th day. The pig dung slurry was recorded as acidic on the 28th day, but the poultry droppings slurry was recorded as acidic on the 2nd day. This indicates that acids (mostly amino and fatty acids) are produced which causes the decrease in the pH of slurry. 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 (Lasisi, 2018). These changes assisted the microorganisms in the system to perform well which led to an increase in the production of the biogas. In the first week, the lower level of the pH recorded by the three substrates explains the first stage of anaerobic digestion-hydrolysis and acetogenesis.



	Day 1	Day 4	Day 8	Day 12	Day 15	Day 20	Day 25	Day 28	Day 30
Poultry droppings	6,95	6,9	6,86	6,79	6,71	6,64	6,58	6,49	6,47
Pig dungs	7,9	7,78	7,66	7,42	7,35	7,29	7,13	6,91	6,87
Cow dungs	7,68	7,52	7,44	7,32	7,12	7,05	6,95	6,88	6,76

Fig. 7. pH values obtained during biogas production

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 6.49 after the first two weeks of digestion. 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 favors the methanogenic bacteria.

Fig. 8 shows the volume of biogas production with respect to a number of days under the various slurries. It can be deduced from the data that the gas production rate increased slightly in the earlier days of the experiments and then started increasing greatly as acid concentration increased as indicated by the decrease in pH. This observation was more pronounced in the cow dung waste slurry (~10 days) than in the poultry droppings slurry (~7 days). This agrees well with the earlier work of Suyog, (2011), that pH reduces as bacteria produce fatty acids.

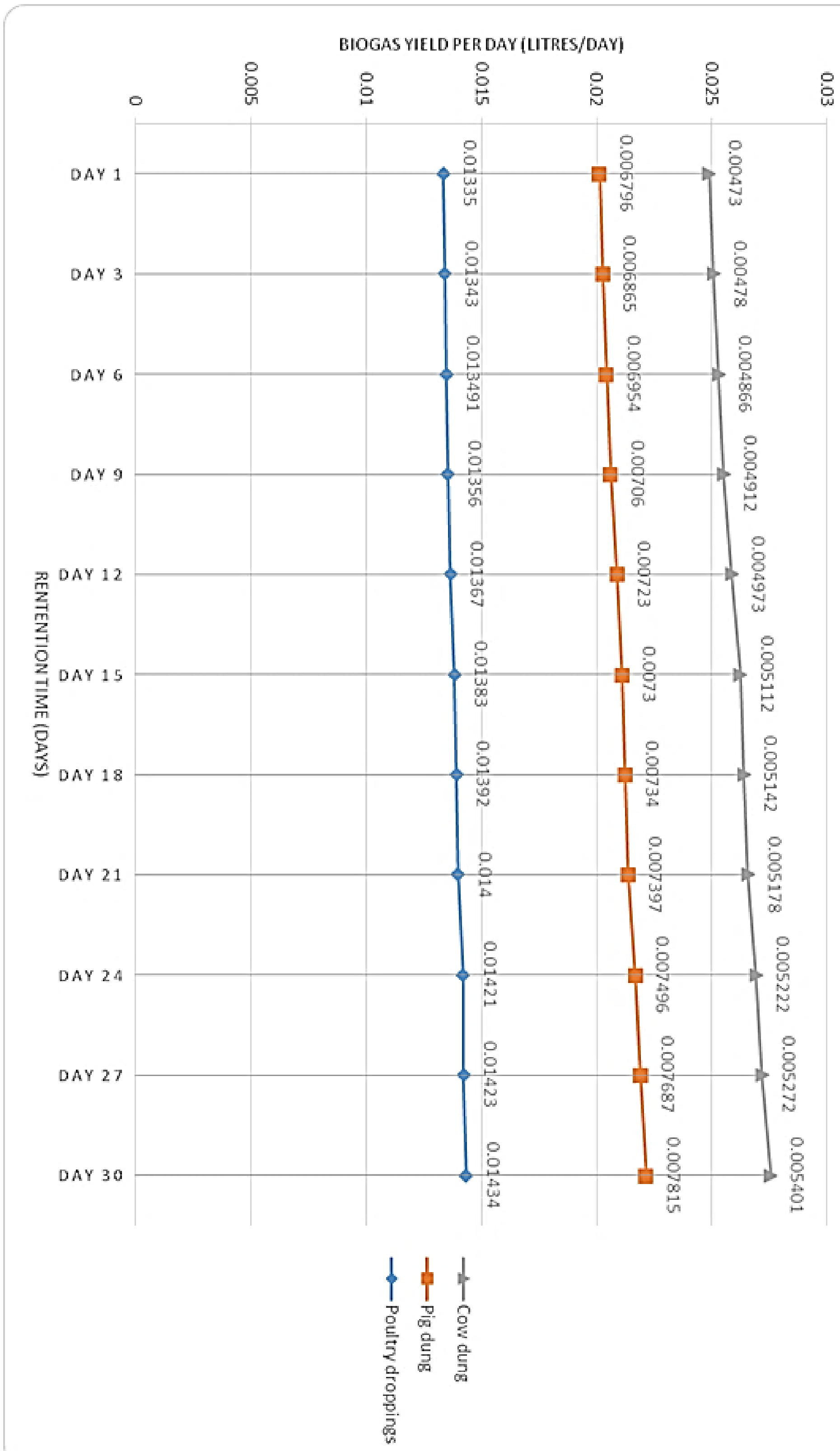


Fig. 8. Biogas yield production rate

Table 10. Biogas yield profile with respect to retention time for the biogas digester

Retention Time (days)	Poultry droppings (Litres/day)	Pig dungs (Litres/day)	Cow dungs (Litres/day)
Day 1	0.01335	0.006796	0.00473
Day 2	0.01338	0.006830	0.00477
Day 3	0.01343	0.006865	0.00478
Day 4	0.013452	0.006901	0.00483
Day 5	0.013471	0.006927	0.00485
Day 6	0.013491	0.006954	0.004866
Day 7	0.013510	0.006982	0.004879
Day 8	0.013530	0.00701	0.004892
Day 9	0.01356	0.00706	0.004912
Day 10	0.0136	0.00712	0.004932
Day 11	0.01363	0.00718	0.004952
Day 12	0.01367	0.00723	0.004973
Day 13	0.01372	0.00760	0.005019
Day 14	0.01377	0.00728	0.005065
Day 15	0.01383	0.00730	0.005112
Day 16	0.01386	0.00732	0.005122
Day 17	0.01389	0.007328	0.005132
Day 18	0.01392	0.007340	0.005142
Day 19	0.01394	0.007352	0.005153
Day 20	0.01397	0.007364	0.005163
Day 21	0.01400	0.007397	0.005178
Day 22	0.01404	0.007430	0.005192
Day 23	0.01405	0.007463	0.005207
Day 24	0.01421	0.007496	0.005222
Day 25	0.01410	0.007530	0.005237
Day 26	0.01417	0.007608	0.005269
Day 27	0.01423	0.007687	0.005272
Day 28	0.01430	0.007768	0.005291

Day 29	0.01432	0.007792	0.005337
Day 30	0.01434	0.007815	0.005401
	0.4147 litres	**0.2406 litres**	**0.1519 litres**

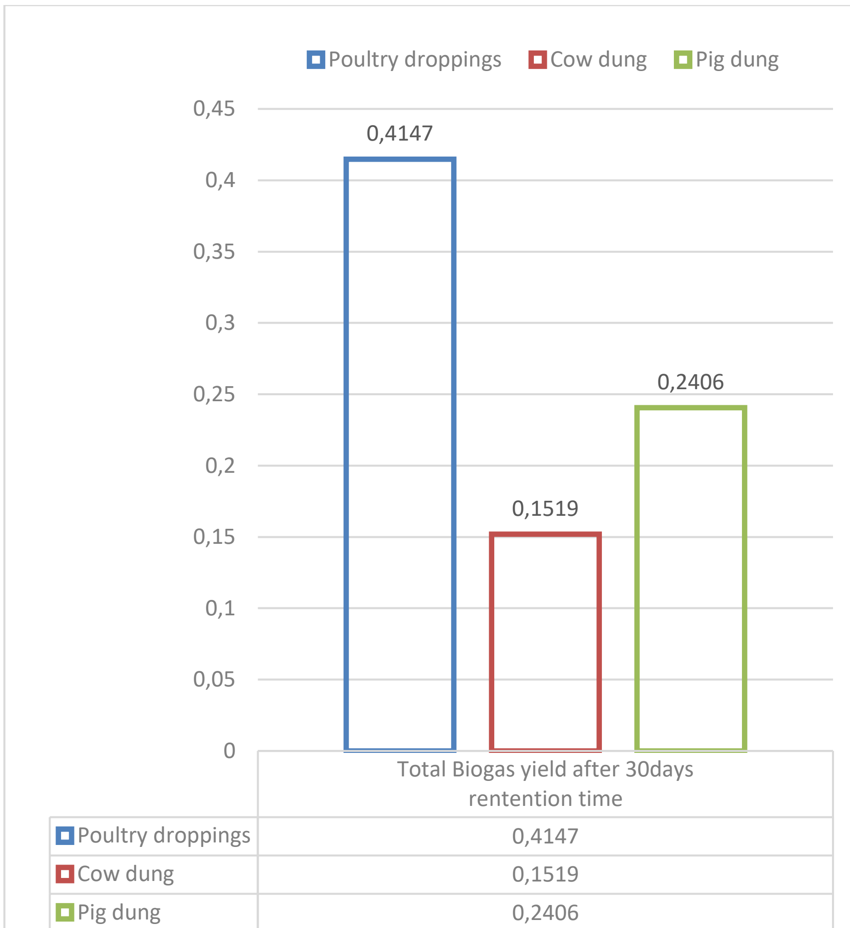


Fig. 9. Total biogas yield produced after 30 days RT

From Table 10 and Fig 9, the result supported the observation that acid concentration greatly affects biogas production (Ojolo, 2008). Thus, the poultry waste slurry produces more gas (414.7 ml) than cow and pig waste slurry (151.9 ml) and (240.6 ml) as they contain more fatty acids than the poultry droppings. 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*. (2015) reported that it is important to maintain the pH of an anaerobic digestion process within 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 favors the methanogenic bacteria.

4. CONCLUSIONS

The need to adopt alternative sources of energy is justified and cannot be over-emphasized. Biogas is an environmentally friendly, renewable energy source produced by the breakdown of organic matter, in the absence of oxygen. From the comparisons, it was evaluated that 5kg of Poultry droppings produced approximately 0.0133 liters of biogas per day, which is the highest amongst the other substrates. This is followed by the pig dung. An adult pig, which produces about 5kg of manure daily (out of which is 90% water, a 7% volatile solid), produces an average of 0.2301 liters of biogas daily, and 5 kg of Cow dung produces about 0.0052 liters of biogas – all under 30 days retention time, and same environmental conditions. It was also observed that the concentration of acid in the digester, affects the production of biogas Thus the poultry waste slurry produces more gas (4l4.7 ml) than cow and pig waste slurry (151.9 ml) and (240.6 ml) as they contain more fatty acids than the poultry droppings. This study would be of great value in bulk biogas production, so as to give biogas producers an end picture of the amount of biogas that would be produced if either of the 3 substrates are digested.

From the study result above, the microbes in the digester convert 20-30% of volatile compounds into biogas. You can use cow dung as the only feedstock for your digester. A cow dung gas plant can be an efficient solution to manage and utilize this abundant waste product. Utilizing cow manure biogas production techniques, the plant can significantly reduce the environmental footprint associated with dairy farming while also providing a sustainable source of energy.

Again, it is not advisable to use pig manure alone because it has high nitrogen content and low amounts of carbon. It is also very alkaline, meaning that it can inhibit the growth of methane-producing bacteria. Methanogens prefer acidic conditions. However, you can improve pig manure biogas production by mixing it with cow dung or other biomass materials. Poultry waste has a high nitrogen content, which the microbes in a biogas plant struggle to digest. You can improve the quality of poultry biogas by mixing chicken waste with carbon-rich materials such as biomass or cow dung.

Currently, all the manure digesters in the market, process organic matter in the form of a slurry. While it is possible to digest dry manure, the fermentation is very slow and makes the system uneconomical. The addition of water increases the surface area available to the microbes that break down nitrogen into methane.

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