X-Ray Digester Types and Anaerobic Digestion of Pig Manure

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ABSTRACT

The development of new methods of production and use of renewable energy sources that suit the economic and the geographical conditions of the developing countries will be required in order to solve the problems of energy crisis and climate change. Today, climate change is everyone's concern and is among the leading problems, if not the only one, linking the international community and drawing much attention. Fossil resources were given much attention in the past before climate change became a major concern. The time has come, and the time is now where attention should now be shifted from fossil fuels to renewable energy sources.

The anaerobic bio digester process is not a new technique of converting waste material into usable product. However, there is a need for further investigation to improve the process especially in this era of climate change. Conventionally, the anaerobic digestion (AD) process should occur in a strict anaerobic environment with no free available oxygen. Such aerobic (oxygen presence) invasions can or may deteriorate the performance of the digestive system. Biogas is a combustible gas consisting mainly of methane and carbon dioxide. Carbon dioxide being one of the principal greenhouse gases, its concentration in the atmosphere is increasing expeditiously since the advent of industrialization This study investigated anaerobic digestion of pig manure at uniform heating interval. The maximum cumulative biogas yield of 143.8 liters occurred at 25 min time.

The daily biogas yield peaked at day 16. The %total solid decreased from 9.7% to 6.2% with the untreated sample. The initial pH value of the feedstock was determined to be 6.5. This paper also reviewed the types and the use of the most popular bio-digesters for the production of biogas. Reviewing the popular bio-digester is meant to get in-depth knowledge on bio-digester technology currently in use. This understanding is necessary for the development of biogas based renewable energy sources in the future.

(Keywords: bio-digester, pig manure, total solid, pretreatment, biogas, renewable energy)

INTRODUCTION

Biogas is another source of renewable energy, it is produced when biomass is subjected to biological gasification and a methane-rich gas is produced from the anaerobic digestion of organic materials [1]. Achieving solutions to possible shortage in fossil fuels and environmental problems that the world is facing today requires long-term potential actions for sustainable development. In this regard, renewable energy resources appear to be one of the most efficient and effective solutions [2].

Biomass is the biological organic materials that are renewable and can be recycled to produce biogas. A huge amount of wastes is generated daily from the various processing industries in Nigeria. The wastes that are usually disposed off either into the sea, river, or on the land as a solid amendment materials, which causes support for breeding of flies, and constitute health hazards to people living around the area are converted into biogas by anaerobic fermentation [3].

What is considered as waste many years ago have in recent time become useful that it can be inferred that in life, nothing is a 'waste'. They are only waste when they lack the useful technology for their transformation and application. The biomass wastes are held in a digester or reactor.

The gas is produced from a three-phase process namely, hydrolysis, acid-forming and methane-forming phases. It is a biological engineering process in which a complex set of environmentally sensitive micro-organisms are involved. The gas is typically composed of 50-70% methane, 30-40% carbon dioxide, 1-10% hydrogen, 1-3% nitrogen, 0.1% oxygen and carbon monoxide, and trace of hydrogen sulphide [4], [5].

Biogas is also a waste management technique because the anaerobic treatment process eliminates the harmful micro-organisms. The anaerobic digestion is characterized by a series of biochemical transformations caused by the degradation of organic matter [6]. The whole process involves several distinct stages. (i.e., hydrolysis, acidogenesis, acetogenesis, and the final stage methanogenesis) (Figure 1).

In stage 1, fats, complex carbohydrate and proteins are hydrolysed to their monomeric form by enzymes. In stage 2, the monomers are further degraded into short chain acids and these short chain acids are converted to hydrogen, carbon dioxide and acetate and in the final stage which is stage 3, the intermediate products are converted to methane and carbon dioxide by Methanogen [7].

Factors for Optimum Performance

Anaerobic digester is a promising technology for treating waste and producing energy at the same time. Digestion is dependent on several factors for the well-being of a stable digester. Factors such as pH, temperature, organic loading rate, hydraulic retention time and carbon-to-nitrogen (C/N) ratio play a significant role during the bio-degradation of the solid material. There are three temperature region in which anaerobic digestion can be conducted, pychrophilic (10-20°C), mesophilic (20-45°C), and thermophilic (45-68°C) [6].

The most common temperature ranges used to run anaerobic digesters are either mesophilic (with an optimum at 35°C) or thermophilic (with an optimum at 55°C) [9].

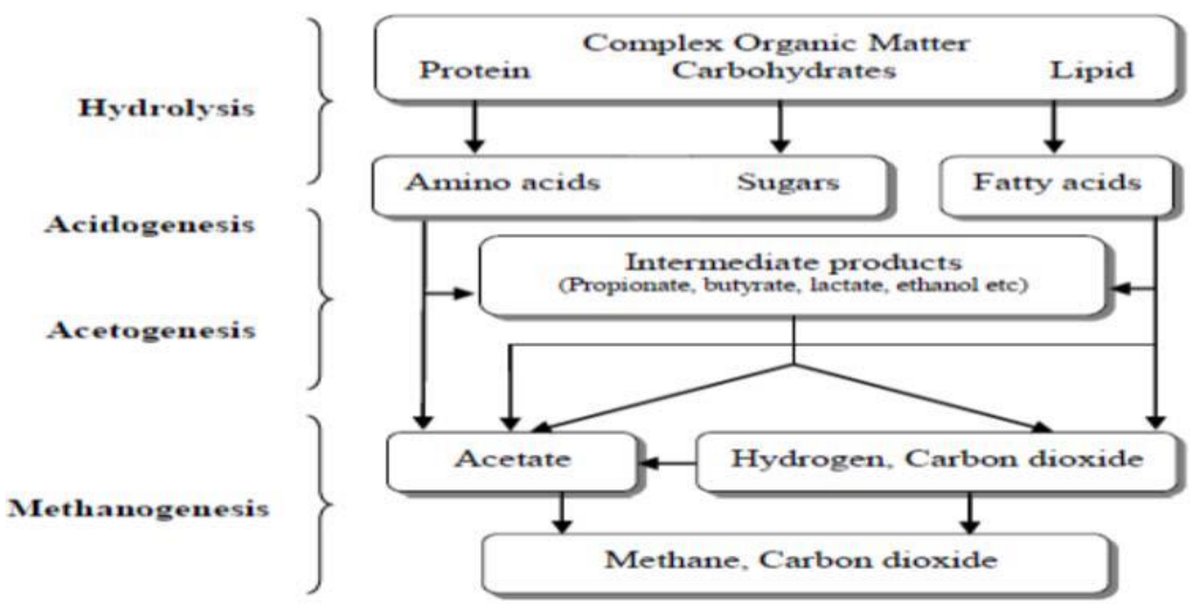

Figure 1: Anaerobic Digestion Pathways of Organic Degradable Substrate [8].

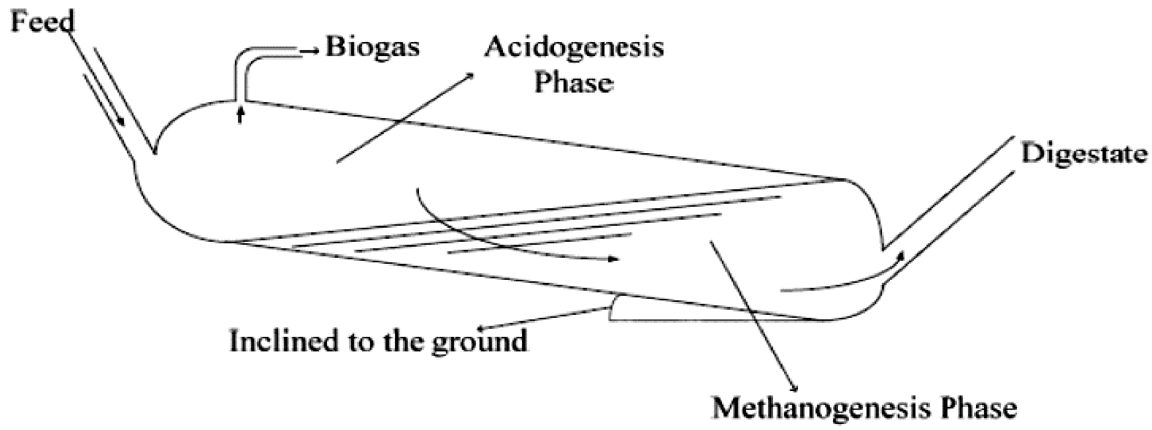

Figure 2: Schematic Representation of a Plug Flow Digester [6].

TYPES OF DIGESTERS

Plug Flow Digesters

This is a type of anaerobic digester that uses a long, narrow horizontal tank in which a material (manure) is added at a constant rate and that force other material to move through the tank and be digested Figure 2. Typically, a plug flow digester vessel is five times longer than it is wide, is insulated and heated, and is made or reinforced concrete, steel, or fiberglass [6]. A plug flow digester has no means of agitation. The term "**plug flow**" derives from the fact that the manure in principle flows through the digester vessel as a "plug," gradually being pushed toward the outlet as new material is added. In fact, the situation is more complicated and some parts of the manure travel faster than others on their way through the vessel, or may even settle or float and remain in the digester [10].

The first documented use of this type of design was in South Africa in 1957 [11]. The main advantage of the plug-flow design is that it is simple and economical to install and operate. However, it is not as efficient or as consistent as the completely mixed design. Plug-flow units are limited to applications with low amounts of sand, dirt, or grit, because these substances will tend to stratify and settle out inside the digester, requiring significant effort to clean out [12]. Complete mix units are more expensive to install and operate than plug flow units, because they require both the capital equipment and the energy for mixing [12].

Fixed dome digesters

A well and a dome are made out of cement concrete. Fixed dome Chinese model biogas plant (also called drumless digester) was built in China as early as 1936 [13]. Fixed dome digesters are usually built underground [14]. The dome is fixed and hence the name given to this type of plant is fixed dome type of biogas plant. The function of the modified fixed dome digester plant is similar to the floating holder type biogas plant as shown in Figure 4, the only difference is the fixed top part of the digester.

The used slurry expands and overflows into the overflow tank [15]. Disadvantages of fixed dome digesters are that special sealants are required, high technical skills are required for construction, and gas pressures fluctuate, which causes complication of gas use [13]. The difference between Figure 3 and 4 is that, in Figure 3 the upper part of the digester is fixed (i.e., it does not experience any movement on the upper side when the gas starts to fill up the available empty space as compared to the floating tank type digester).

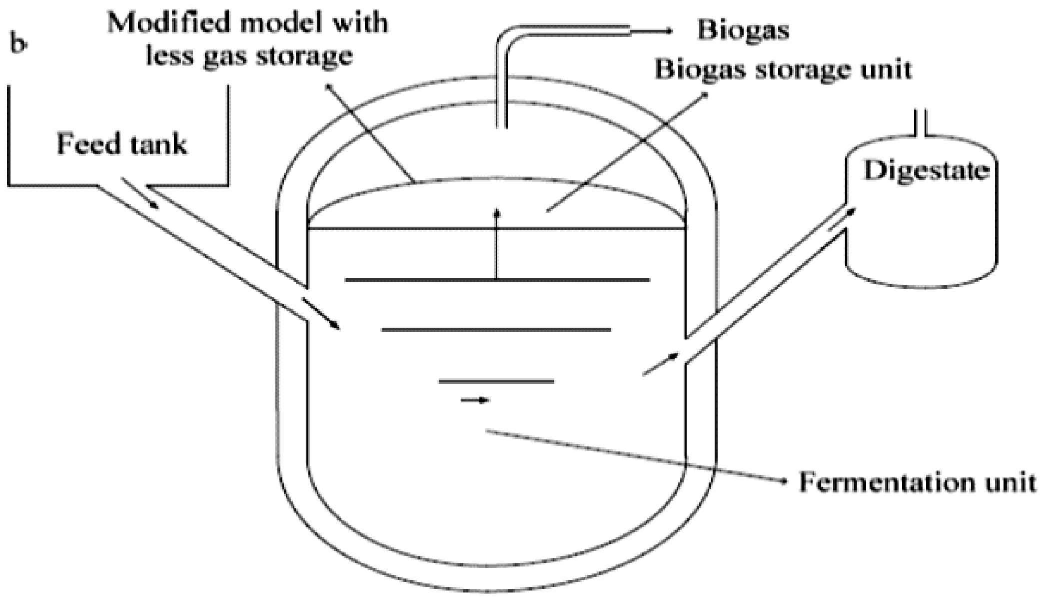

Figure 3: Schematic Representation of a Fixed Dome Digester [6].

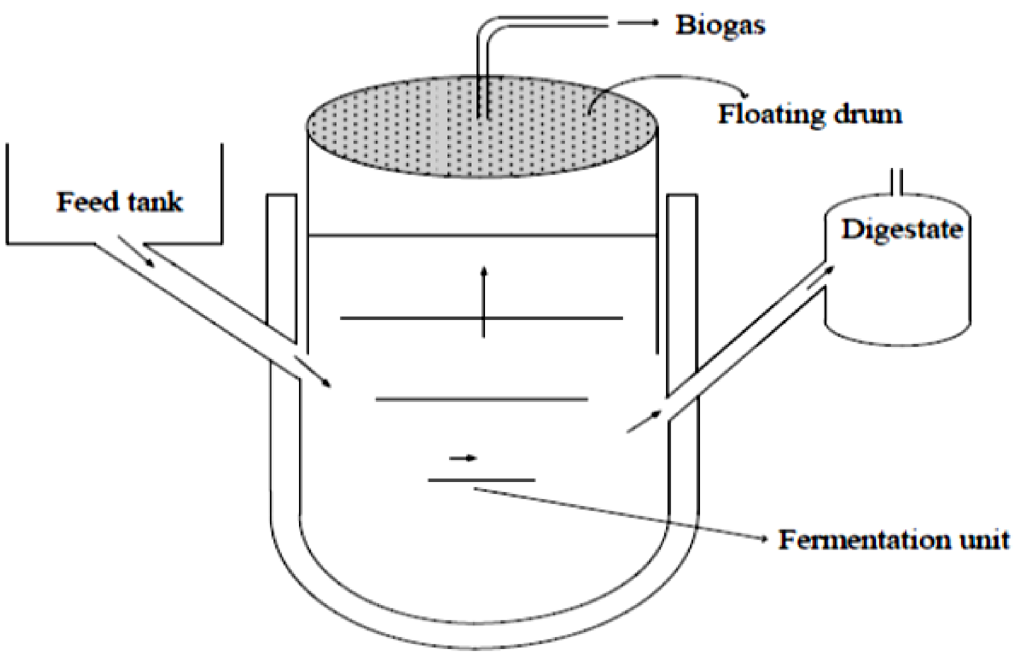

Figure 4: Schematic Representation of a Floating Drum Digester [17].

Floating Drum Digesters

An experiment on biogas technology in India began in 1937 [16]. In 1956, Jashu Bhai J Patel [16], developed a design of floating drum biogas plant popularly known as Gobar Gas plant. In 1962, Patel's design was approved by the Khadi and Village Industries Commission (KVIC) of India and this design soon became popular in India and the world [6]. It is divided into two parts. One side has the inlet, from where slurry is fed to the tank as shown in Figure 4.

The tank has a cylindrical dome made of stainless steel that floats on the slurry and collects the gas generated. Hence the name given to this type of plant is floating gas holder type of biogas plant. The slurry is made to ferment for about 50 days. More gas is made by the bacterial fermentation, leading to the pressure inside the gas collecting dome to increase. The gas can be taken out through an outlet pipe. The decomposed matter expands and overflows into the next small holding tank [15].

The shortcomings of these digesters discussed above relative to this research is that the pressure cannot be manipulated or maintained to a specific value for a certain period of time in order to observe the effect it has on the composition of the gas and on the activity of the bacteria. The digester design for this particular research will take into account the accommodation of pressure manipulation.

Plastic Bag Digester

The low cost tubular plastic bag digester was first develop CONDRIT (Consutorias el para el Desarrollo Integrado del Trapico) located in Cali, Columbia i early 1980s. The digester was based on a design First promoted in Taiwan, known as the "Red Mud PVC" bio-digester (CONDRIT Lida, 1995).

In East and Southern Africa region, the technology was introduced in 1993 through the technical cooperation program of FAO executed in Tanzania, which aimed the transfer and adaptation of technologies that has been validated in other tropical developing countries. Later, in 1994, a local NGO known as SURUDE (Foundation for sustainable Rural development), submitted project proposals to DANCHURCHAID and FAO/SIDA Farming systems program (FSP) for the widespread promotion of low bio-digesters in Tanzania.

Currently more than 40 bio-digesters have now been installed in various villages of Tanzania. SURUDE has also made initiatives to popularize the technology in Kenya and Uganda (Lekule, 1996) [25] with support from FSP. Most of the digesters installed have a volume of $5m^3$ with a capacity of providing gas at a rate of $0.354m^3/m^3$per day which is enough for a family of six people.

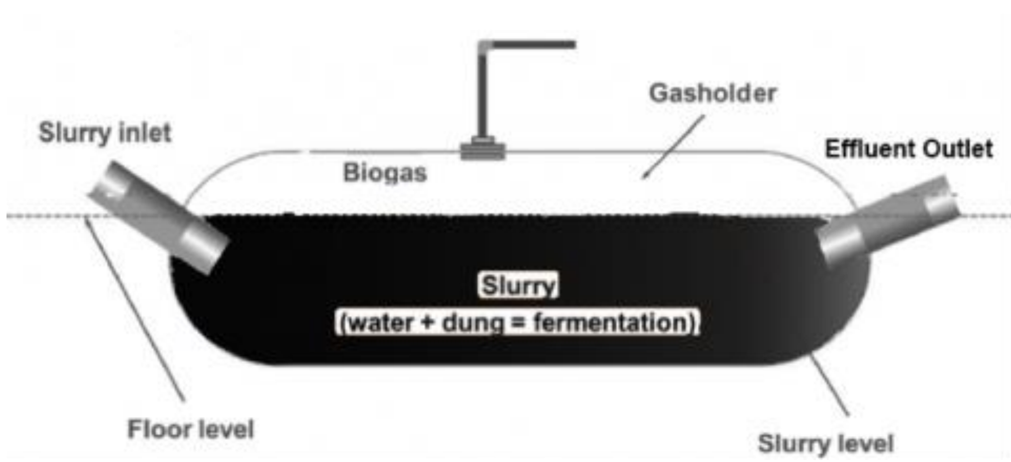

Figure 5: Schematic Representation of a Plastic Bag Digester.

Anaerobic Treatment

Anaerobic treatment is the use of biological processes, in the absence of oxygen, for the breakdown of organic matter and the stabilization of these materials, by conversion to methane and carbon dioxide gases and a nearly stable residue [18]. As early as the 18th Century the anaerobic process of decomposing organic matter was known, and in the middle of the 19th Century, it became clear that anaerobic bacteria are involved in the decomposition process. But it is only a century since anaerobic digestion was reported to be a useful method for the treatment of sewage and offensive material [18].

Since that time, the applications of anaerobic digestion have grown steadily, in both its microbiological and chemical aspects. The environmental aspect and the need for renewable energy are receiving interest and considerable financial support in both Developed and Developing Countries, expanding research and application work in these directions, and many systems using anaerobic digestion have been erected in many countries (Satyanarayan, 1977) [19].

Anaerobic digestion provides some exciting possibilities and solutions to such global concerns as alternative energy production, handling human, animal, municipal and industrial wastes safely, controlling environmental pollution, and expanding food supplies. Most technical data available on biogas plants relate primarily to two digester designs, the floating cover and fixed dome models. Promising new techniques such as bag, dry fermentation, plug flow, filter, and anaerobic baffled reactors should be explored to establish a firmer technical base on which to make decisions regarding the viability of biogas technology.

Along with this increase in interest, several newer processes have developed, that offer promise for more economical treatment, and for stabilizing other than sewage materials - agricultural and industrial wastes, solid, organic municipal residues, etc. - and generating not only an alternative energy source, but also materials that are useful as fodder substitutes and substrates for the mushroom and greenhouse industries, in addition to their traditional use as organic fertilizers. Other benefits of anaerobic digestion include reduction of odors, reduction or elimination of pathogenic bacteria (depending upon the temperature of the treatment) and the use of the environmentally acceptable slurry.

The technology of anaerobic digestion has not yet realized its full potential for energy production. In most industrialized countries, biogas programs (except for sewage treatments) are often hindered by operational difficulties, high costs of plants and as yet low energy prices. In most Developing Countries, expansion of biogas programs have been hindered because of the need for better economic initiatives, organized supervision and initial financial help, while in other Developing Countries, on the other hand, slow development has been observed, and a lack of urgency, because of readily available and inexpensive non-commercial fuels, such as firewood.

Biogas technology is also potentially useful in the recycling of nutrients back to the soil. Burning non-commercial fuel sources, such as dung and agricultural residues, in countries where they are used as fuel instead of as fertilizer, leads to a severe ecological imbalance, since the nutrients, nitrogen, phosphorus, potassium and micronutrients, are essentially lost from the ecosystem. Biogas production from organic materials not only produces energy, but preserves the nutrients, which can, in some cases, be recycled back to the land in the form of slurry. The organic digested material also acts as a soil conditioner by contributing humus.

Fertilizing and conditioning soil can be achieved by simply using the raw manure directly back to the land without fermenting it, but anaerobic digestion produces a better material. Chinese workers report that digested biomass increases agricultural productivity by as much as 30% over farmyard manure, on an equivalent basis. This is due in part to the biochemical processes occurring during digestion, which cause the nitrogen in the digested slurry to be more accessible for plant utilization, and to the fact that less nitrogen is lost during digestion than in storage or comporting.

In the area of public health and pollution control, biogas technology can solve another major problem: that of the disposal of sanitation wastes. Digestion of these wastes can reduce the parasitic and pathogenic bacterial counts by over

90%, breaking the vicious circle of re-infection via drinking water, which in many rural areas is untreated. Industrial waste treatment, using anaerobic digestion, is also possible. With the growing significance of this process, it is appropriate to mention some the historical developments which have occurred during the last 100 years of anaerobic digestion. In many cases, this may help to clarify the state-of-the-art at the end of the 20th Century (Satyanarayan, 1977).

Short Historical Background on Anaerobic Digestion

The appearance of flickering lights emerging from below the surface of swamps was noted by Plinius and Van Helmont recorded the emanation of an inflammable gas from decaying organic matter in the 17th Century [18]. Volta is generally recognized as putting methane digestion on a scientific footing. He concluded as early as 1776 that the amount of gas that evolves is a function of the amount of decaying vegetation in the sediments from which the gas emerges, and that in certain proportions, the gas obtained forms an explosive mixture with air.

In 1804 - 1810 Dalton, Henry and Davy established the chemical composition of methane, confirmed that coal gas was very similar to Volta's marsh gas and showed that methane was produced from decomposing cattle manure [18]. France is credited with having made one of the first significant contributions towards the anaerobic treatment of the solids suspended in waste water.

In 1884 Gayon, a student of Pasteur, fermented manure at 35°C, obtaining 100 liters of methane per m of manure. It was concluded that fermentation could be a source of gas for heating and lighting. It was not until towards the-end of the 19th Century that methanogenesis was found to be connected to microbial activity.

In 1868, Bechamp named the "organism" responsible for methane production from ethanol. This organism was apparently a mixed population, since Bechamp was able to show that, depending on the substrate, different fermentation products were formed. In 1876, Herter reported that acetate in sewage sludge was converted stoichiometrically to equal amounts of methane and carbon dioxide (Patel, V., Madamwar, D., 1994).

Components of A Biogas System

Biogas technology is a complete system in itself with its set objectives (cost effective production of energy and soil nutrients), factors such as microbes, plant design, construction materials, climate, chemical and microbial characteristics of inputs, and the inter-relationships among these factors. Brief discussions on each of these factors or subsystems are presented in this section.

Biogas

This is the mixture of gas produced by methanogenic bacteria while acting upon biodegradable materials in an anaerobic condition. Biogas is mainly composed of 50 to 70 % methane, 30 to 40 % carbon dioxide (CO_2) and low amount of other gases as shown in Table 1.

Biogas is about 20 percent lighter than air and has an ignition temperature in the range of 650 to 750 ˚C. It is an odorless and colorless gas that burns with clear blue flame similar to that of LPG gas. Its calorific value is 20 Mega Joules (MJ) per m^3 and burns with 60 percent efficiency in a conventional biogas stove (Lagrange, 1979) [21].

Methanogenic Bacteria/Methanogens

These are the bacteria that act upon organic materials and produce methane and other gases in the process of completing their life-cycle in an anaerobic condition. As living organisms, they tend to prefer certain conditions and are sensitive to microclimate within the digester.

There are many species of methanogens and their characteristics vary. The different methane forming bacteria have many physiological properties in common, but they are heterogeneous in cellular morphology. Some are rods, some cocci, while others occur in clusters of cocci known as sarcine. The family of methanogens (Methanobacteriacea) is divided into following four genera on the basis of cytological differences [6]:

Table 1: Composition of Biogas [18].

Substance	Symbol	Percentage
Methane	CH_4	0-70
Carbondioxide	CO_2	0-40
Hydrogen	H_2	5-10
Nitrogen	N_2	1-2
Water Vapor	H_2O	0.3

Table 2: Anaerobic Decomposition of Organic Material in Biogas Digesters [18].

FIBROUS	→	**BIOGAS**	→	**COMBUSTIBLE**
FIBROUS	→	**SCUM**	→	**INSULATOR**
LIQUID	→	**SUPERNATANT**	→	**BIOLOGICAL**
SOLID/LIQUID	→	**EFFLUENT**	→	**FERTILIZER**
SOLID	→	**INORGANCS SOLID (Sand/Gravels)**		

a) Rod-shaped Bacteria
i- Non-sporulating, Methanobacterium
ii- Sporulating, Methanobacillus

b) Spherical
i- Sarcinae, Methanosarcina
ii- Not in sarcinal groups, Methanococcus

A considerable level of scientific knowledge and skill is required to isolate methanogenic bacteria in pure culture and maintain them in a laboratory. Methanogenic bacteria develop slowly and are sensitive to a sudden change in physical and chemical conditions. For example, a sudden fall in the slurry temperature by even 2˚C may significantly affect their growth and gas production rate (Lagrange, B. 1979) [21].

Biodigesters

The biodigester is a physical structure, commonly known as the biogas plant. Since various chemical and microbiological reactions take place in the biodigester, it is also known as bio-reactor or anaerobic reactor. The main function of this structure is to provide anaerobic condition within it. As a chamber, it should be air and water tight. It can be made of various construction materials and in different shape and size. Construction of this structure forms a major part of the investment cost.

Table 2 shows the various stages of decomposition and the forms of the material at each stage. The inorganic solids at the bottom of the tank are rocks, sand, gravel, or other items that will not decompose. The effluent is the semisolid material left after the gases have been separated. The supernatant is biologically active liquid in which bacteria are at work breaking down the organic materials.

A scum of harder-to digest fibrous material floats on top of the supernatant. It consists primarily of plant debris. Biogas, a mixture of combustible (burnable) gases, rises to the top of the tank. The content of biogas varies with the material being decomposed and the environmental conditions involved. The largest, and for fuel purposes the most important, part of biogas is methane.

Pure methane is colorless and odorless. Spontaneous ignition of methane occurs when 4-15% of the gas mixes with air having an explosive pressure of between 90 and 104 psi [18]. The explosive pressure shows that biogas is very combustible and must be treated with care like any other kind of gas. Knowledge of this fact is important when planning the design, building, or using of a digester.

MATERIALS AND METHODS

There are various designs of biogas digesters and suggested by researchers, end users and engineers respectively. This includes the floating steel drum, fixed dome, tunnel and plastic bag bio digester design [23]. In this research, fixed dome design was used, where the digester mainly consists mainly of fermentation chamber, gas accumulation chamber and pressure balancing unit.

The pressure balancing unit is made of welded steel construction joined to the side of fermentation chamber which also serve as feed tank and temporay storage for digestrate. The top of the drum is slightly coned with a mixing arm. An inlet for feeding fresh substance and simultaneously flushing out digested materials. Nagamani, and Ramasamy (1990) [22] reported that the performance of floating dome biogas plant was better than the fixed dome gas plant.

Measurement of the volume of biogas produced was done by volume displacement method. The gas tap was connected with one inch hose to calibrated gas measurement cylinder, filled with water and inverted upside down. The biogas tap was opened and the volume of water displaced was measured. This volume of water displaced was equivalent to the volume of biogas produced. The gas displaces water, being insoluble, where the height of the cone was measured as the amount of gas collected. The mass ratio of seeding material to water to feedstock used was 1:2:1.

The feedstock was pre-treated by conventional heating at uniform rate for different time interval of 5 min, 10 min, 15 min, and 20 min, respectively. The first digester of 50 liters was not pre-treated by heating to serve as our reference experiment. A 50 liters digester capacity was used for the experiment. The seeding material used was digested pig manure. The experiment was performed under atmospheric conditions. The atmospheric pressure balancing unit at 1 atm and atmospheric temperature range of 22°C -30°C. The pH of the feedstock before and during the anaerobic digestion process was determined with the help of litmus paper and other pH determination apparatus.

Determination of Total Solids

Total solid is made up of the digestible and non-digestible material in the waste. Meynell (1982) [24] method was used. 3g of the raw waste was dried in an oven at 105^{o}C for 5 hours. The dried sample was cooled in a desiccator and then weighed [24]. The weight obtained after all moisture loss is the total solid.

$$\% \text{ T.S} = \frac{B-C}{g} x \frac{100}{1}$$

T.S = Total solid
B = Weight of crucible + dry residue
C = Weight of crucible
g = Original weight of sample.

Determination of Volatile Solids

The volatile solid is the true organic matter available for bacterial action during digestion. The method of Meynell (1982) [24] was used. The solid residue from the total solid determination was heated in a muffle furnace at 600^{o}C for 2 hours. The heated residue was cooled in a desiccator and weighed.

$$\text{Volatile solid (VS)} = \frac{B-C}{g} x \frac{100}{1}$$

B = Weight of dried residue from total solid determination
C = Weight of residue after further heating at 600^{o}C
g = Original weight of sample.

Carbon Content Determination

Walkey-Black (1934) method was used. 0.05g of the finely ground sample was weighed into a 500ml conical flask. 10ml of 1M potassium dichromate was poured inside the flask and the mixture was swirled. 20ml of conc. H_2SO_4 was added and the flask was swirled again for 1 minute in a fume cupboard. The mixture was allowed to cool for 30 minutes after which 200ml of distilled water; 1g NaF and 1ml of diphenylamine indicator were added. The mixture was shaken and titrated with ferrous ammonium sulphate. The blank was also treated in the same way.

$$\% \text{ carbon} = \frac{B - T \times M \times 1.33 \times 0.003 \times 100}{g}$$

Where,

B = Titration volume (Blank)

T = Titration volume (Sample)
M =Molarity of Fe solution
g = Weight of sample.

RESULTS AND DISCUSSION.

The experiment performed gave the graph of cumulative biogas yield for pig manure in Figure 6. There was significant increase in cumulative biogas yield for the pig manure. The presence of seeding material help in more biogas yield by introducing more fermentation bacteria in the system. The Cumulative yield increased from 0 liters to 62.9 liters for the untreated sample, then increased from 0.5-95.3 liters for the 5 minutes treated time. The 10 minutes treated time gave yield of 0.7-123 liters. The cumulative volume yield of 15 minutes treated sample was 1.5 to 129.9 liters, while the 20 minutes heated feedstock gave value range of 1.3 -143.8 liters.

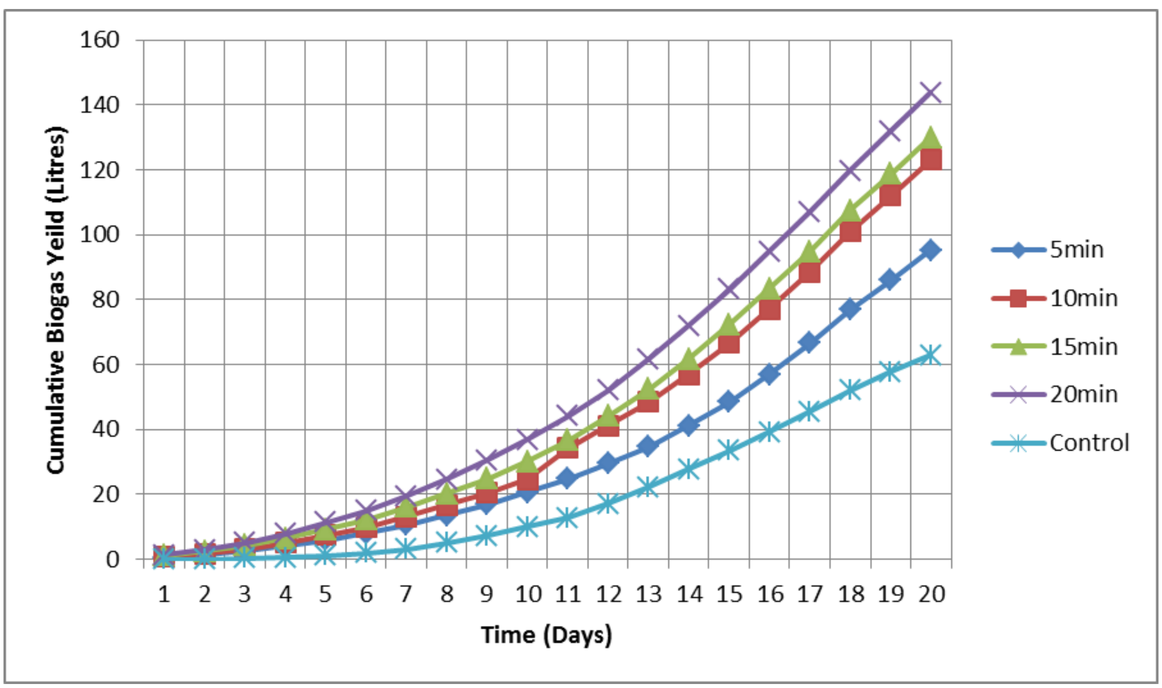

Figure 6: Cumulative Biogas Yield versus Time at varying Pre-Treated time for Pig Manure.

Table 3: Cumulative Biogas Yield at Different Pre-Treated time for Pig Manure.

Days	5 min	10 min	15 min	20 min	Control
1	0.5	0.7	1.1	1.3	0
2	1.4	1.7	2.5	3	0
3	2.6	3.2	4.3	5	0.3
4	4	5.1	6.5	7.9	0.6
5	5.8	7.4	9.2	11.3	1.2
6	8	9.9	12.2	15	2
7	10.6	13.1	16.1	19.5	3.2
8	13.6	16.7	20.3	24.7	5
9	17	20.5	24.8	30.6	7.3
10	20.7	24.6	30.1	36.8	10.1
11	24.9	34.3	36.7	44.1	12.7
12	29.6	41.1	44.2	52.1	17.2
13	34.7	48.4	52.4	61.7	22.3
14	41.2	57	61.8	71.9	27.8
15	48.5	66.7	72.3	83.3	33.4
16	57	77	83.4	94.9	39.2
17	66.6	88.6	94.9	107	45.5
18	76.8	100.9	107.4	119.7	52
19	86	112.1	118.8	132	57.7
20	95.3	123	129.9	143.8	62.9

Ukpai et al., 2012 [1] did a work on cow dung and had the highest cumulative biogas yield of 124.3 L/total mass of slurry (TMS).There was clear evidence of great increase in cumulative biogas yield at 5 minutes treated time from the above results in Table 3.

The graph also showed clear evidence of increasing biogas yield due to anaerobic digestion at 10, 15, and 20 minutes of treated time respectively. The initial pH value of the feedstock was determined to be 6.5. A pH value of 7.4 and 8.1 was determined for the reference sample on the day 8 and day 12 of the anaerobic digestion, respectively. The %volatile solid concentration of the 10 min pre-treated feedstock was determined to be 49% on day 7. The Carbon/Nitrogen ratio of the feedstock before pre-treatment was 28/1.

The daily biogas generation increased progressively for the four treated feedstock from day one to day 20 expect for few cases. The day one and day two of the untreated feedstock had no biogas yield. The treated time of 5min, 10min, 15 min and 20 min witness yield at day one respectively. This shows that pre-treatment of feedstock has significant effect on biogas generation.

The treated time of 5 min yielded 0.5 liters -9.3 liters. The 10 min pre-treatment gave biogas yield of 0.7 liters to 10.9 liters and 15 min of heating yield 1.1 liters to 11.1 liters. The 20 min of also had significant yield of 1.3 liters to 11.8 liters. Ukpai et al., 2012 [1] recorded 3.9 liters of daily biogas yield on anaerobic digestion of cassava peeling.

Table 4: Daily Biogas Yield at different Pre-Treated time for Pig Manure.

Days	5 min	10 min	15 min	20 min	Control
1	0.5	0.7	1.1	1.3	0
2	0.9	1	1.4	1.7	0
3	1.2	1.5	1.8	2	0.3
4	1.4	1.9	2.2	2.9	0.3
5	1.8	2.3	2.7	3.4	0.6
6	2.2	2.5	3	3.7	0.8
7	2.6	3.2	3.9	4.5	1.2
8	3	3.6	4.2	5.2	1.8
9	3.4	3.8	4.5	5.9	2.3
10	3.7	4.1	5.3	6.2	2.8
11	4.2	5.7	6.6	7.3	3.6
12	4.7	6.8	7.5	8	4.5
13	5.1	7.3	8.2	9.6	5.1
14	6.5	8.6	9.4	10.2	5.5
15	7.3	9.7	10.5	11.4	5.6
16	8.5	10.3	11.1	11.6	5.8
17	9.6	11.6	11.5	12.1	6.3
18	10.2	12.3	12.5	12.7	6.5
19	9.2	11.2	11.4	12.3	5.7
20	9.3	10.9	11.1	11.8	5.2

The total solid decreased as anaerobic digestion increases. The decrease in total solid is in an agreement with the volume of biogas generation. The more the total solid decreases the more biogas is generated from Figure 8.

The % total solid for the untreated feedstock was 9.7% -6.2%. The % total solid for 5 min treated time ranges from 8.6% to 5.5%. Kiely et al, [26] reported that the influent total solid rises from 4.25% for the first 30 days to about 7% from day 40 onwards. The 10 min pre-treated sample gave 7.8% to 4.6% of percentage total solid. The significant decreased of 6.7% to 3.6% was noticed for the 15 min sample.

An improved value of % total solid of 6.1% to 3.2 % was also noticed in 20 min treated feedstock. The large cumulative biogas yield noticed from the 20 min treated time was as result of large decrease in % total solid of the pig manure during anaerobic digestion. The daily biogas yield of 10 min, 15 min, and 20 min treated time were larger than the control and 5 min respectively due to large degradation of percentage total solid during the anaerobic digestion.

CONCLUSION

This work x-rayed the various biogas digester used for biogas generation, ranging plug flow digester, fixed dome digester, floating drum digester and plastic bag digester. Anaerobic digestion can convert energy stored in organic matter present in manure into biogas. Sustainable resource management of waste and the development of alternative energy source are the present challenges due to economic growth.

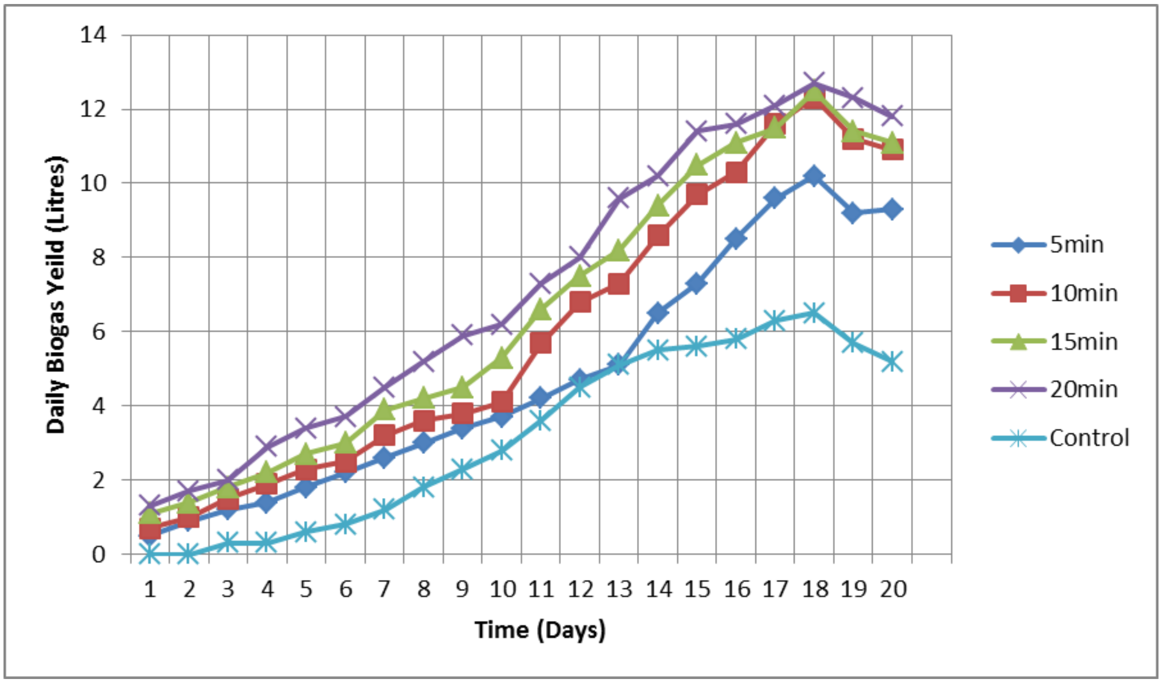

Figure 7: Daily Biogas Yield versus Time at Different Times using Pig Manure.

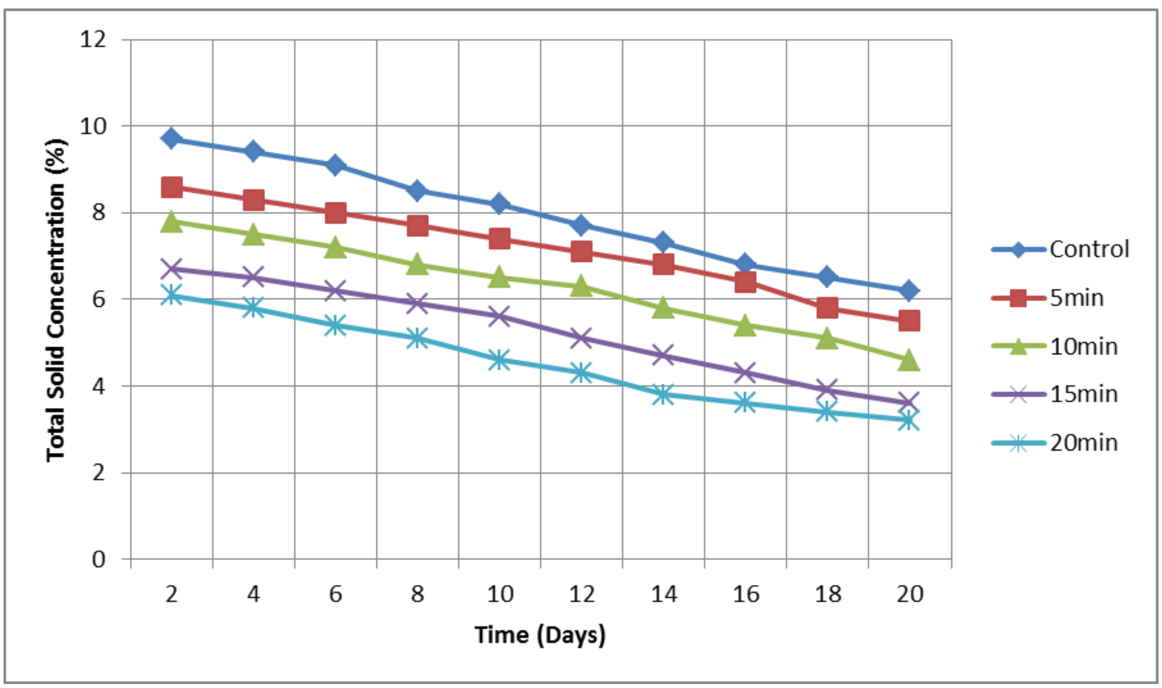

Figure 8: Total Solid Concentration versus Time at Different Times using Pig Manure.

The history of waste utilization shows independent developments in various developing and industrialized countries. Energy supplied from fossil fuels is not easily recycled and takes a long time to form, hence is exhaustible and not renewable. Renewable energy has remained one of the best alternatives for sustainable energy development since the grid electricity has become too expensive.

Sources of renewable energy are wind, hydro, ocean waves, geothermal energy resources and solar energy. Heat-based technologies developed for the utilization of heat energy from the sun (solar thermals).They are applied in water heaters, drying, chick-brooding, cooking, manure dryers, biogas and thermal refrigerators. The study also highlighted pre-treatment of feedstock to produce more volume of biogas. The time of the pre-treatment was 5 min, 10 min, 15 min and 20 min respectively. The maximum cumulative biogas yield was 143.8 liters recorded at 20 min of pre-treatment. The daily yield had maximum value of 11.8 liters. The % total solid for the untreated feedstock was 9.7% -6.2%.

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