DEVELOPMENT OF ANAEROBIC DIGESTER FOR THE PRODUCTION OF BIOGAS USING POULTRY AND CATTLE DUNG .

BY

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NIGER STATE

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BEING A FINAL YEAR PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BARCHELOR OF ENGINEERING (B.ENG.) DEGREE IN AGRICULTURAL & BIORESOURCES ENGINEERING.
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE.

FEBRUARY, 2012

DECLARATION

I hereby declare that this project work is a record of research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certification at any university or institution. Information derived from personal communications, published and unpublished work were duly referenced in the text.

Rohjy, Habeeb Ajibola

01-03-2012

Date

CERTIFICATION

This is to certify that the project entitled "Development of Anaerobic Digester for the Production of Biogas using Poultry and Cattle dung" by Rohjy Habeeb Ajibola meets the regulation governing the award of the degree of Bachelor of Engineering (B. ENG.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literally presentation.

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DEDICATION

This project work is dedicated to Almighty ALLAH and Rohjy's family.

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My profound gratitude goes to Almighty ALLAH, the creator and controller of the universe, who has given me great knowledge and understanding throughout my study.

My sincere appreciation goes to my versatile supervisor Dr. K. A. Adeniran for his effort and advice during the research work.

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My greatest appreciation, which is still an understatement, goes to my parents Rohjy's family and the family of Alhaji and Alhaja Apaokagi for their financial, moral and spiritual support throughout my life; without you, I would not have made it this far. Thanks a lot for your sincere investment in human resource.

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TABLE OF CONTENTS

Cover page	
Title page	ii
Declaration	iii
Certification	iv
Dedication	v
Acknowledgement	vi
Table of content	vii
Abstract	ix
List of Tables	x
List of Figures	xi
List of Plate	xii
Abbreviation	xiii
Chapter One: Introduction	
1.1 Background to the study	1
1.1.1 Renewable and Non Renewable Energy	1
1.1.2 Evolution of Biogas	2
1.1.3 Utilization of Biogas	4
1.2 Statement of the Problem	5
1.3 Justification	5
1.4 Aim and Objectives of the Research Project	6
1.5 Scope and limitation of the work	6
Chapter Two: Literature Review	
2.1 Biogas Production	9
2.2 Sources of Biogas	10
2.3 Biogas system	10
2.3.1 Biogas formation	11
2.3.2 Anaerobic digester	11
2.3.3 Component of Biogas	13
2.4 Biogas Digester	13
2.4.1 Ballon Digester	14
2.4.2 Fixed Dome Digester	15
2.4.3 Floatind Drum ndigester	17
2.4.4 Cost benefit of Biogas Digester	20
2.4.5 Benefit of Anaerobic Digestion	21
2.4.6 Feedstock	22
2.4.7 Feeding Method	25

2.4.8 Fermentation Slurry 26
2.4.9 Sludge 26
2.4.10 Loading Rate 28
2.4.11 Opearting Temperature 29

Chapter Three: Material and Method

3.1 Materials 31
3.1.1 Component of a Biogas 31
3.1.2 Slurry mixing tank 31
3.1.3 Digester 31
3.2 Digester construction procedure 31
3.3 Material for Biogas production 32
3.4 Feedstock (Cattle dung and Poultry manure) 33
3.5 Digester construction material 34
3.6 Methods 38
3.6.1 Mixture rate of feedstock 38
3.6.2 pH 38
3.6.3 Retention Period 38
3.6.4 Yield of Biogas 38
3.7 Reseach methodology 38

Chapter Four: Results and Discussion of results

4.0 Result and Discussion 40
4.1 Presentation of results 40
4.2 Discussion of results 44
4:2.1 Two factor Experiment Design 46
4,2.2 Limitation of the study 48
4.2.3 Conclusion 48
4.3 Hazard of biogas 48

Chapter Five: Conclusions and Recommendations

5.0 Conclusions and Recommendations 50
5.1 Conclusions 50
5.2 Recommendations 50
References

ABSTRACT

The amount of waste generated in developing countries such as Nigeria has steadily increased over the last decade as a result of population expansion and lack of effective waste management strategy. To this end, in this work, a comparative study of biogas production from poultry waste and cattle dung in different proportion was conducted under the same operating conditions. For the experimental design, different mix regimes were adopted for the three digesters employed. In this case, for digester 1, 225g of poultry waste and 75g of cattle were mixed with 150ml of water, 150g of poultry waste and 150g of cattle dung were accordingly mixed with 150ml of water for digester 2, while into digester 3,75g of poultry waste and 225g of cattle dung were added. Results obtained show that biogas production started on the 2nd day, and reached apex on the 6th day for digester 1, production reached its peak on the 6th day in digester 2, for digester 3, it's started on the 3rd day and attained maximum on 6th day. The average gas production from 75% 25%, 50% 50% and 25% 75% of poultry and cattle dung respectively was 3.84ml, 3.55ml, and 3.19ml. Based on the results, waste is practicable managed through conversion into biogas, turning waste into wealth which is a source of income generation for the society.

LIST OF TABLES

2.1 Component of Biogas 10

3.1 Construction Material 28

4.1 Digester A Poultry 75%, Cattle dung 25% 35

4.2 Digester B Poultry 50%, Cattle dung 50% 35

4.3 Digester C Poultry 25%, Cattle dung 75% 36

4.4 Mean of Biogas produced in the three digesters 36

4.5 Average yield of digester A ml/day 36

4.6 Average yield of digester B ml/ day 37

4.7 Average yield of digester C ml/ day 37

4.8 Two way Analysis of Variance 41

4.9 Duncan Multiple Range Test for Digesters 42

4.10 Duncan Multiple Range Test for Days 42

4.11 Estimated Marginal mean for Days x digesters 42

LIST OF FIGURES

2.1	Source of Biogas	8
2.2	Biogas yield	12
2.3	China fixed – dome digester	13
2.4	Fixed – dome plant Nicarao design	13
2.5	Floating – drum digester	14
2.6	Fixed – dome digester	15
2.7	Biogas yield	19
4.1	Multiple graphs showing Biogas production of Digester A1, A2 and A3	37
4.2	Multiple graphs showing Biogas production of Digester B1, B2 and B3	38
4.3	Multiple graphs showing Biogas production of Digester C1, C2 and C3	38
4.4	Multiple graphs showing Biogas production of Digester A, B and C	39

LIST OF PLATE

Plate 3.1	Digester set up	29
Plate 3.2	Magnetic stirrer used to agitate the slurry	29
Plate 3.3	Digester set up	30
Plate 3.4	Electronic weighing balance	30
Plate 3.5	Poultry were the waste was collected	31
Plate 3.6	Measuring cylinder 500ml used to prepare the slurry	31

ABBREVIATION

HRT = Hydraulic Retention Time, days

Vd = Digester Volume, m^3

Fr = Feed rate, m^3/day

Mm = Mass of manure, kg

H = Headspace

Vs = Volume of slurry m^3

Chapter One

1.0 Introduction

1.1 Background to the study

The rapid increase in world population and the great developments in industrial, commercial, agricultural sectors require large quantities of energy, and create large quantities of wastes that should be disposed off with minimum environmental negative impacts and costs. In addition to that, the limited sources and quantities of non renewable energy (oil, natural gas, and fossil coal) with their negative impacts on our health and environment, necessitates the search for new and renewable sources for energy with least negative impacts. This study deals with a technology that produces fuel and organic fertilizer from organic wastes which is biogas technology.

1.1.1 Renewable and Non-Renewable Energies

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

1.1.2 Evolution of Biogas

Scientific interests in the gas produced by decaying organic wastes dates back to around 1700 (Wikipedia, 2011). Amongst those interested was Robert Boyle. However, one of the earliest scientists to mention biogas was Van Helmot in 1630 in a communication about an inflammable gas emanating from decaying organic matter. In 1776, Alessando Volta became the first to conduct experiments with biogas from the bottom sediments of ponds in Northern Italy (Sathianathan, 1999). Interests in the organisms involved in the process has continued ever since amongst bacteriologists. However, it was not until the begining of 20th century that the design of waste treatment plant took account of the importance of the process (Abbasi et.al., 1990). The transformation from the use of cess-pools to the more controlled performance of septic tank and finally anaerobic digester took place simultaneously in several countries (Mitel, 1996). Much of the initial interests came from India where the obvious raw material has been cow dung. It is a common practice for cow dung to be dried and then used directly as a solid fuel for cooking. With anaerobic fermentation, however, wet dung provided gaseous fuel more versatile than the dung together with a slurry which could be used as fertilizer (Freeman and Ryle, 1997). The evolution of biogas technology in India was initiated in 1937 by Desai of the Division of Soil Chemistry, Imperial Agricultural Research Institute (IARI). Three models of biogas plants were popularized at different places considering the environmental conditions for optimal gas production (Hajamis and Ranade, 1992). Sathianathan (1999) reported that the first plant for obtaining methane from human waste was built in 1990 at the Homeless Lepers Asylum, Matunga now known as Acworth Zeprocy Hospital, Wadala, India. However, the idea of biogas production from domestic and farmyard wastes and its utilization in rural India originated in the late thirties with the Khadi Movement which was concerned with the scale of falling trees in rural areas for firewood.

Hajamis and Ranade (1992), also reported that after the World War I, a form of septic tank involving the anaerobic digestion of municipal sewage began in Germany. Methane produced in such system was either used for fueling the town truck yard to be fed into the public gas supply network. In Egypt, the first biogas digester was in Elgabel el-Asfer farm in 1939; this was designed to treat sewage sludge (Abbasi et.al., 1990). After that, many digesters built in Egypt by scientists were to evaluate biogas production and the materials which can be used to feed the digeter and its effect on biogas production as well as methane concentration in the gas. Hill and Brath (1997) mentioned that the use of anaerobic digestion process for treating waste waters has grown tremendously in Europe during the past decade. It is estimated that European plants comprise 44% of the installed base with only 14% located in North America. A considerable number of the systems are located in South America, primarily Brazil, where they are used to treat the "Vinasse Co." Mitel (1996) reported that the sludge obtained from biofermentation process contain high concentration of nutrients and organic matter. The application of this sludge at the rate equivalent to traditional chemical fertilizer increased the yeild of maize up to 35.7%, wheat 12.5%, rice 5.9%, cotton 27.5%, carrot 14.9% and spinach 20.6%. Biogas is highly relevant in energetic environment of Brazil as a tropical country with more than 30 million inhabitants who depend on wood burning as fuel. As far as 1950, the fact that biogas was obtained from forest sources presented a relative reduction in its total production. The emergence of biogas from sugarcane by-products, however, made significant contribution to its availability in rural Brazil (Sayigh, 1992). In Philippines, the Department of Environment and Natural Resources has been promoting biogas production as a means of waste management and pollution control in large pig farms especially those already equipped with waste lagoon. Unlike India, cattle farms are few in the Philippines where there are many pig and poultry farms (FAO, 1996). In Africa, trials have been conducted to produce biogas in different countries. The rapid population growth in rural areas of these countries continue to increase concern over environmental issues. Nigeria has been reported to be losing nearly

14,000 hectares of tropical forest per annum due to wood burning in form of charcoal (FAO, 1996). Exploitation of animal dung for production of biogas in Nigeria is in its infancy. The pioneer biogas plants are 10m^3 biogas plant constructed in 1995 by the Sokoto Energy Research Centre (SERC) in Zaria, and the 18m^3 biogas plant constructed in 1996 at Ojokoro Ifelodun Piggery Farm, Lagos by the Federal Institute of Industrial Research Oshodi (FIIRO) Lagos (Zuru *et al.*, 1998). Generally, it is now recognized that biogas/biomass projects can be more than a means of handling manure or sewage sludge, disposing of unwanted straw, incinerating municipal solid waste, treating industrial effluents or utilizing residues from sawmills. Purposeful grown biogas offers possibilty of generating electricity or liquid fluids for domestic uses such as cooking gas.

1.1.3 Utilization of Biogas

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

1.2 Statement of the Problem

It has been reported that the non-renewable gases are environmentally unfriendly, relatively costly and subject to rapid depletion (Rai, 1989). On the other hand, the renewable gases are of less pollution, capable of being renewed at a short period and may be relatively cheaper than non-renewable gases. It has been observed that the importance of biogas for economic and waste management is increasing with environment aims as the main driving force. The abundant availabilty of animal manure in Nigeria (particularly from poultry enterprises), which could cause health hazards on decay could be turned to biogas for utilization by the rural communities and later in the future commercialised for sale to urban dwellers. That is to say that turning waste to wealth. There is yet another wave of renewed interest in biogas usage due to increasing concerns of climate change, indoor air pollution and increasing oil prices (Earth Trends, 2005). This trend obviously gives rise to the need to further explore the seemingly large or huge potential derivable from animal waste, especially dungs.

1.3 Justification

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

1.4 Objectives of the Study

The main objective of this research project is to generate biogas from poultry and cattle dung. Secondary objectives of the study includes:

The secondary objectives of the study include, namely:

a. To assess the quantities of biogas potential from poultry droppings and cattle dung.
b. Evaluate digester performance as a function of its design.

1.5 Scope and Limitation of the study

The scope of this project is to develop a biogas digester. The performance of the digester was tested using poultry and cattle dung. The experiment was not exhaustive because of the following reasons;

1. The compositions of the two animal wastes were not uniformly distributed among the three digesters i.e. keeping the % ratio constant and varying the weight ratio and vice versa. That would have resulted to three distinct experiments for each digester.
2. More time or days should have been allowed for the experiment so as to determine the optimum value as in the case of Digester B and least/minimum possible values of the Digesters.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Biogas Production

Biogas was used for heating bath-water in Assyria during the 10th century B.C. and in Persia in the 16th century (Wikipedia, 2011). Marco Polo mentioned the use of covered sewage tanks for the production of biogas (Nagamani and Ramasamy, 2007). It probably goes back 2000 – 3000 years in ancient Chinese literature when they used deep cone-shaped in-ground lined pits to store animal and human manure, food wastes and other organics then collected; in the process methane gas is usually emitted for use as a cooking and heating fuel. The approach has lasted throughout the centuries and thousands of family-based digesters operate in China, India and other developing countries today (Chaurla, 1986). Thus, the technology or process dates back a long time since anaerobic treatment has been used by various communities and societies. There are reports of successful methane production units in several parts of the world, and many farmers wonder if such small scale methane production units can be installed at their farms to convert waste into wealth (Lewis, 1983). The first digestion plant to generate biogas was built at a Leper Asylum Colony in Bombay (now Mumbai), India in 1859. India as a country with many biogas reactors installed today, has a quite long history of biogas development. Many countries subsequently become aware of biogas technology by the middle of twentieth century. However, real interest in biogas aroused in 1970's with the onset of energy crisis which drew general attention to the depletion of fossil fuel energy resources and the need to develop renewable sources of energy, such as biogas. The importance of biogas as an efficient, non-pollution energy (or renewable source) is now well recognized.

2.2 Sources of Biogas

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

Almost any type of organic material can be processed (by anaerobic digestion) into biogas as shown in figure 2.1.

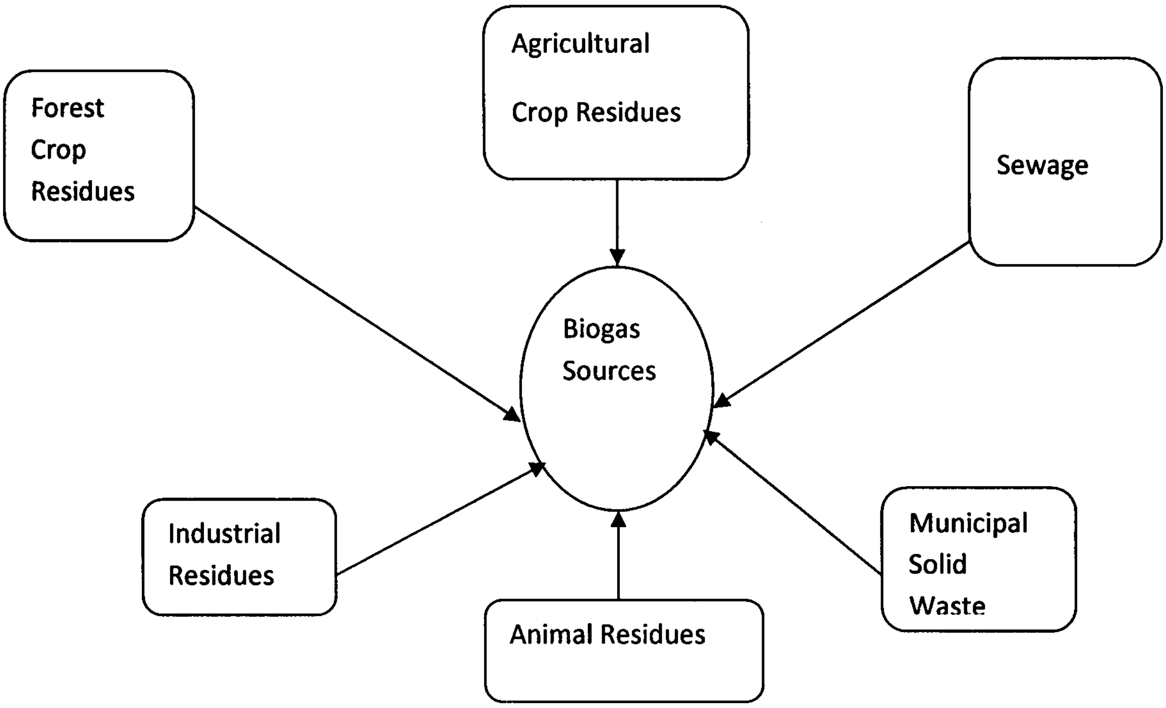

Fig 2.1 Sources of Biogas

Source: – Crow, 2006

2.3 Biogas Systems

Biogas can be produced either by anaerobic digestion (fermentation) of biodegradable materials producing gas which mainly contains methane and carbon dioxide or by gasification of wood and other biomas materials to produce wood gas that cotains nitrogen, hydrogen and carbon monoxide with trace amount of methane (Wikipedia, 2011). Biogas systems involve the construction and incorporation of technology for digesting organic wastes anaerobically to produce:

- ✓ Combustible gas for the generation of electricity and heating,
- ✓ Effluent as an excellent fertilizer
- ✓ To dispose of agricultural resources, aquatic weeds, animal and human excrement and other organic wastes (Ilic and Mitelic, 2006).

2.3.1 Biogas Formation

Biogas is formed by the process of converting organic wastes in two major ways:

- ✓ Uncontrolled anaerobic digestion in:
  - Wetlands and ponds, and
  - Landfills
- ✓ Controlled anaerobic digestion by use of:
  - Sewage treatment plants, and
  - Organic treatment plants/digesters.

2.3.2 Anaerobic Digestion

Anaerobic digestion process occurs in three stages:

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

Separate as they are, these stages of anaerobic digestion can occur simultaneously within a single digester vessel. They are strongly dependent on one another and when things are not working well, they can cause mutual inhibition. For this reason, amongest others, it is critical that the content of the digester are agitated or mixed as they would stratify if left alone. Anaerobic process depends largely on methane-formers because they are more environmentally sensitive than acid-formers. Methane bacteria are strict anaerobes and cannot tolerate oxygen in their environment. They are best at temperature of about 35°C. They are equally sensitive to pH and slow in growing than the acid formers. The optimum pH requirement for their survival ranges between 6.8 – 7.4 (Bouallagui et.al., 2005). The speed of this process is mainly influenced by the composition of the feedstock. The digestion times differ from close to infinity (lignin degradation), several weeks (celluloses), a few days (hemicelluloses, fat, protein) to only a few hours (low molecular sugars, volatile fatty acids, alcohols). Therefore, woody biomass is not suitable for biogas production due to its high lignin content. Gas is expected to start discharge to the collector after 14 days and steadily progressed (Volkmann 2004). Emission of the biogas dwindles, depending on the type of substrate being used, after the fifth week due to the declining amount of carbon in the substrates. Biogas is odourless, colourless and lighter than air (FAO, 1996).

Table 2.1 Composition of Biogas

Substances	Symbols	%
Methane	CH_4	50 – 70
Carbon dioxide	CO_2	30 – 40
Hydrogen	H_2	5 – 10
Nitrogen	N_2	1 – 2
Water vapour	H_2O	0 – 3
Hydrogen sulphide	H_2S	0.1

Source (FAO,1996)

2.4 Biogas Digester

An anaerobic biogas digester is also known as biodigester or Waste-to-Energy (WTE) digester. It is an apparatus that can be made out of concrete, steel, bricks or plastics fitted with an exit and a safety valve. It is shaped like silo, trough, basin or pond and may be placed underground or on the surface. All anaerobic digestion system designs incorporate the same basic components:

- ✓ A pre-mixing area or mixing tank,
- ✓ A digester vessel(s),

- ✓ A system for storage using the biogas (tank, pipping and burner and so on), and
- ✓ A system for distributing or spreading the effluent (the remaining digested material).

Anaerobic digesters apply the process of oxygen-free decomposition in which bacteria in the animal or plant digested wastes, called slurry, produces gas (a mixure of methane, carbon dioxide and other gasses) and an effluent as the syetem left over (Brown, 2004). Anaerobic digesters are either horizontal or vertical in their configuration and can be classified into three categories:

- ✓ Balloon digesters,
- ✓ China fixed-dome digesters, and
- ✓ Floating-drum digesters.

2.4.1 Balloon Digester

These digesters are usually made of plastic or rubber bags. Gas is stored in the upper part while inlet and outlet of infflUent and affluent slurry are attached directly on the skin the ballon. Fermentation is facilitated by agitation through slight movement of the balloon. This movement facilitates digestion process.

- ✓ The advantages of this type of digesters are:
- ✓ Low construction cost,
- ✓ Ease of transpotation,
- ✓ High digester temperature,
- ✓ Ease of cleaning, emptying and maintenance, and

The disadvantages are:

- ✓ Short lifespan (about five years),
- ✓ Easily damaged, and
- ✓ Do not create employment opportunities.

Materials used for ballon digesters include red-mud-plastic (RMD), trevira and butyl (Sasse, 1988).

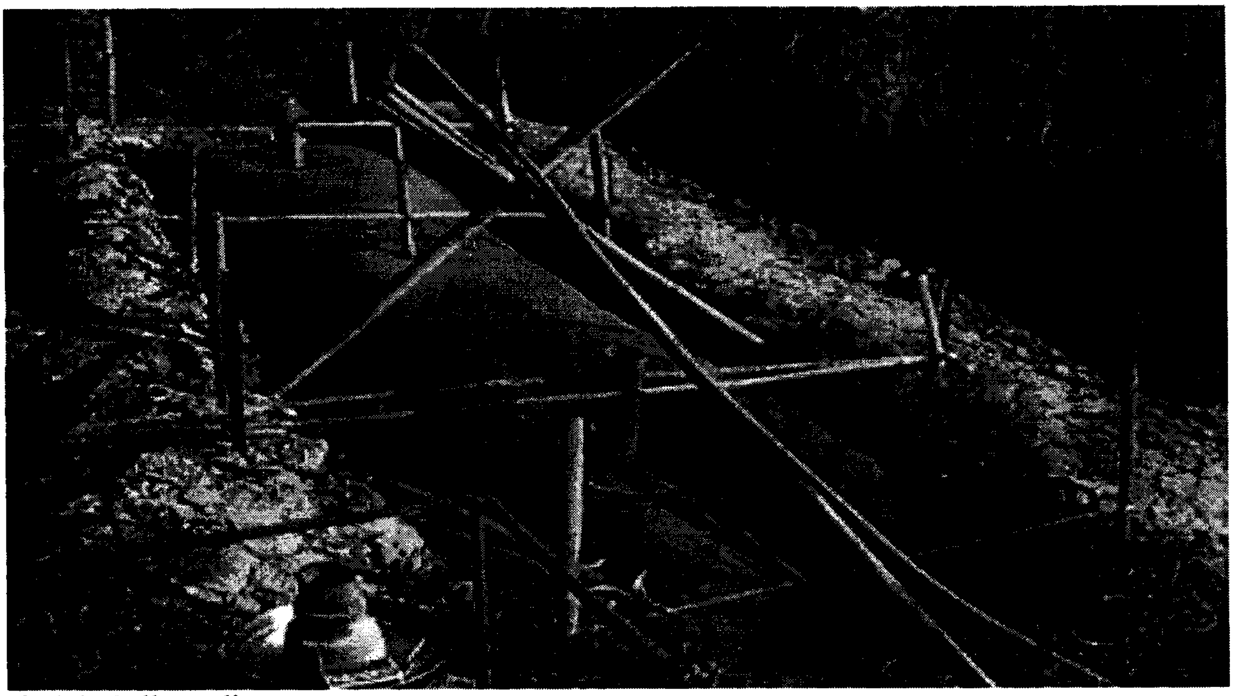
Fig 2.2 Balloon digester.

Source: FAO, 1996

2.4.2 Fixed-dome Digester

A fixed-dome digester consists of an enclosed digester with a fixed non-movable gas space where gas is stored. The gas pressure increases with the volume of the gas stored. The advantages of this type of digester include:

- ✓ Low construction costs,
- ✓ No moving parts,
- ✓ No rust steel part,
- ✓ Long lifespan, and
- ✓ Underground construction afford protection from local environment.

The disadvantages are:

- ✓ Do not provide complete air-tight enclosure (porosity and cracks),
- ✓ Gas pressure fluctuates, and
- ✓ Low digester temperature (Brown, 2004).

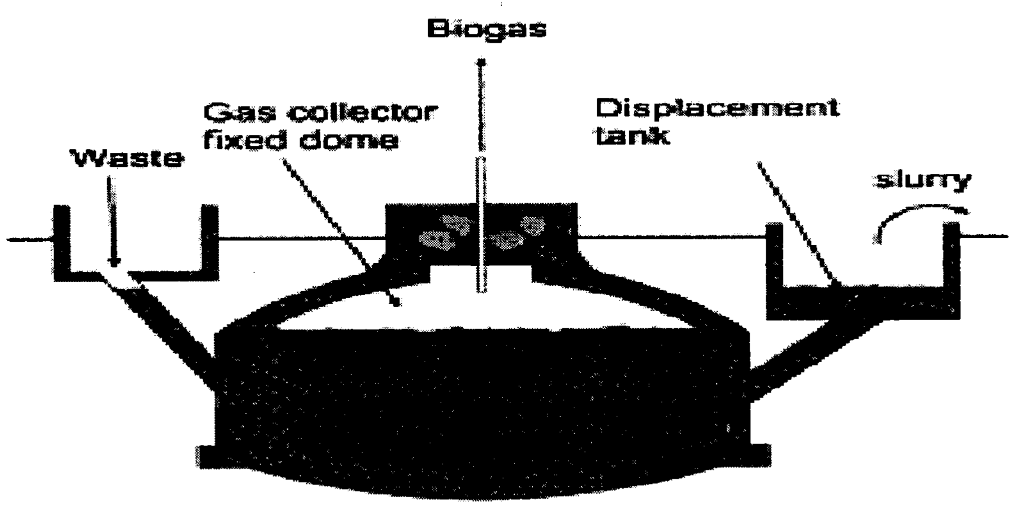

Fig 2.3. China fixed- dome digester

Source – Hassan, 2004

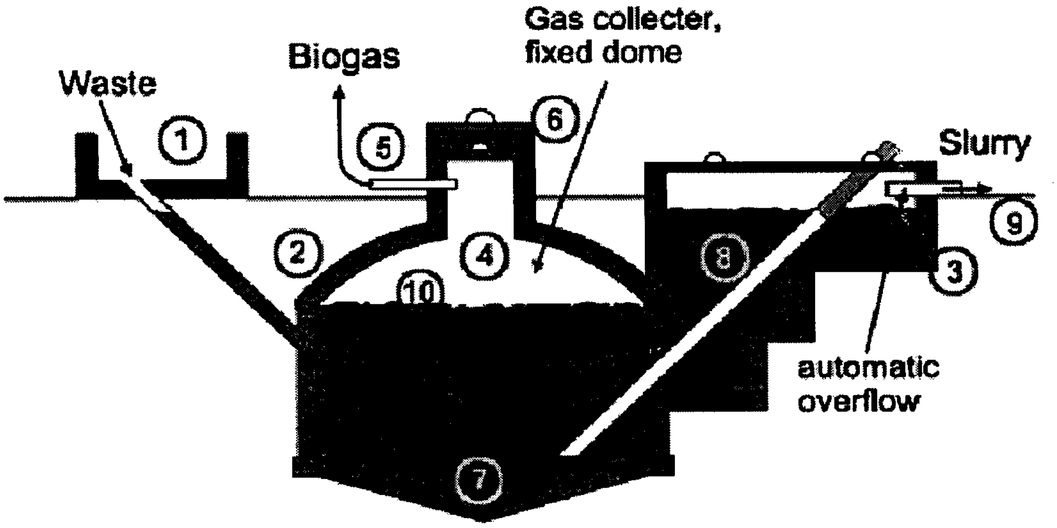

Fig 2.4. Fixed dome plant Nicarao design

Source; Hassan, 2004

2.4.3 Floating-Drum Digesters

Floating-drum digesters consists of a digester and a moving gas holder that floats to the direction of the collected gas. The gas holder may either float directly on the fermentation slurry or in a water jacket of its own. The materials used are mainly steel and sometimes oil drums (which are also made of mild steel or plastics) are welded together depending on the digester size needed (Sasse, 1988). The advantages of the floating-drum digesters are:

- ✓ Simplicity of construction,
- ✓ Ease of operation,
- ✓ Constant gas pressure provided,
- ✓ Volume of stored gas directly visible, and
- ✓ Gives little room for construction mistakes (since they are exposed above the ground).

The disadvantages of these digesters are:

- ✓ High contruction costs,
- ✓ Steel part is liable to corrosion,
- ✓ Short lifespan,
- ✓ Require regular maintenance, and
- ✓ Difficulty in transpotation.

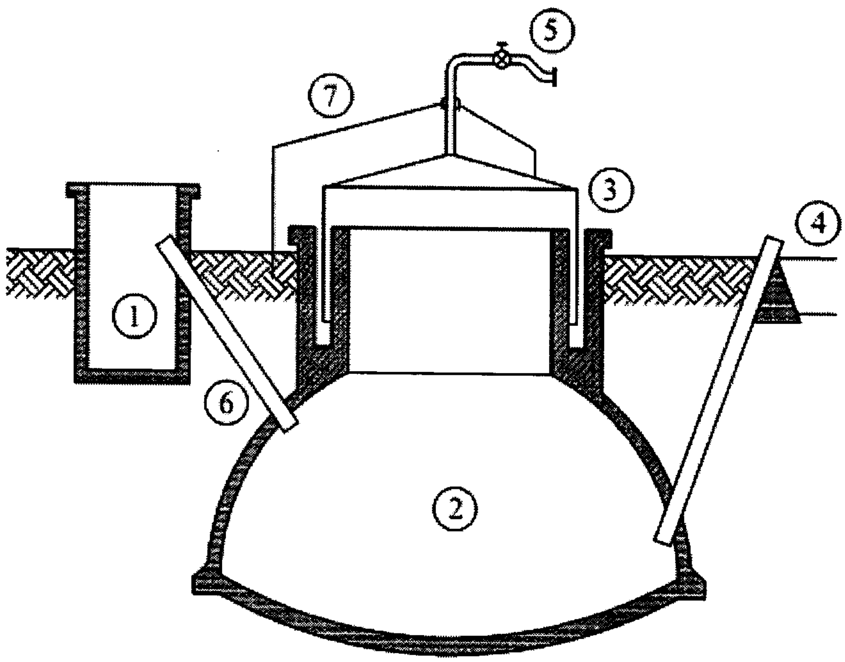

Fig 2.5 Floating- drum digester

Source – Hassan 2004

Part of floating type with external guide frame: 1. Collecting pit, 2. Digester, 3. Gas chamber, 4. Slurry store, 5. Gas pipe, 6 Fill pipe, 7. Guide frame.

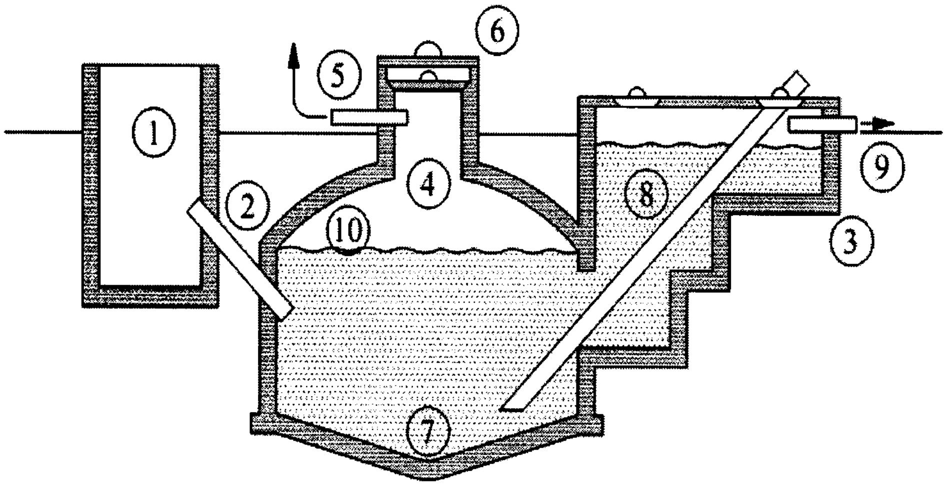

Fig 2.6. Fixed- dome digester

Source: Hassan 2004

Collecting tank with inlet pipe and sand trap, 2. Digester, 3. Compresation and removal tank, 4. Gas chamber, 5. Gas pipe, 6. Entry hatch, with gas tight seal, 7. Accumulation of thick sludge, 8. Outlet pipe, 9. Refrence level, 10. Supernatant scum, broken up by varying level.

However, inspite of these disadvantages, floating-drum plants are always recommended because of their reliability and high performance (Sasse, 1988). The floating-drum is also noted to be well suited for treatment of dung and poultry manure as they have good mixing conditions even as solids (Mattocks, 1994). Floating-drum digesters can also be vertically constructed, which are usually made underground. They are usually made with cemented concrete. Vertical digesters are suited for most substrates as long as the flow rate is enough. Effluent removal does not pose any problem since most vertical digesters are fitted with a special device for mechanically removing such.

2.4.4 Cost Benefits of Biogas Digesters

The costs of establishing and running a biogas digester are dependent on specific type and size of the digester. Generally, these costs may either be capital or operational costs. Capital costs of establishing a biogas plant includes invesmentts in financing the plant, interest rate on loan, equity, and so on, (Green, 2005) which are dependent on the size of the plant. To reduce capital costs, the digester may be built with local construction materials to local specifications.Costs of aquisition of raw materials, water for mixing the materials, feeding and operating the plant, preventive and on-going maintenance, supervision, storage and disposal of slurry, gas distribution and utilization as well as administration are all operational costs associated with the running of a biogas plant (Green, 2005).

2.4.5 Benefits of Anaerobic Digestion

Anaerobic digestion provides a variety of benefits. These may be classified into three groups, viz. environmental, economic and energy benefits:

a. The environmental benefits include:

✓ Elimination of malodorous compounds.

✓ Reduction of pathogens.

✓ Deactivation of weed seeds.

✓ Production of sanitized compost.

✓ Decrease in GHGs emission.

✓ Reduced dependence on inorganic fertilizers by capture and reuse of nutrient

✓ Protection of groundwater and surface water resources.

✓ Improved social acceptance

✓ It also appears that the process reduces the biological oxygen demand (BOD) in the liquid fraction of the treated manure.

b. Anaerobic digestion is advantageous in terms of energy in the following manner:

✓ Anaerobic digestion is a net energy-producing process.

✓ A biogas facility generates high-quality renewable fuel.

✓ Surplus energy as electricity and heat is produced during anaerobic digestion of biomass.

- ✓ Anaerobic digestion reduces reliance on energy imports.
- ✓ Such a facility contributes to decentralized, distributed power systems.
- ✓ Biogas is a rich source of electricity, heat, and transportation fuel.

c. The economic benefits associated with a biomass-to-biogas facility are:

- ✓ Anaerobic digestion transforms waste liabilities into new profit centers.
- ✓ The time devoted to moving, handling and processing manure is minimized.
- ✓ Anaerobic digestion adds value to negative value feedstock.
- ✓ Income can be obtained from the processing of waste (tipping fees), sale of organic fertilizer, carbon credits and sale of power.
- ✓ Power tax credits may be obtained from each kWh of power produced.
- ✓ A biomass-to-biogas facility reduces water consumption.
- ✓ It reduces dependence on energy imports.
- ✓ Anaerobic digestion plants increases self-sufficiency.}

2.4.6 Feedstocks

The feedstocks, otherwise called substrates, for an anaerobic digestion can be a very wide range of biodegradable materials, but generally do not include materials high in lignin (woody products) as these are very slow to break down under anaerobic condition. During the past two decades, developing countries and particularly Nigeria has witnessed increased level of waste generation due to population explosion, increased agricultural activities, and the growth of industries. Consequently, there is intense scrutiny of possible alternative of solid waste utilization through biogas production using organic residues, which includes poultry droppings, cattle dung, and kitchen wastes. The feedstock can be grown especially for the digester, such as maize silage, or constitute a waste product of one sort or the other. The waste products might be from livestock farms (mostly manure), abattoirs, grasses and other sources. The ideal mix of the feedstocks will contain carbohydrates, protein and fat. Manure is often a useful base feedstock as it contains healthy anaerobic bateria. Gas production from a given amount of feedstock depends on the type of feedstock used (Earth Trends, 2005).

Biogas can be produced from a broad range of feedstocks that are suitable for anaerobic digestion. Most easily biodegradable biomass materials are acceptable as feedstocks for anaerobic digestion. Common feedstocks include livestock manure, food-processing waste, and sewage sludge. The energy (methane) production potential of feedstocks varies depending on the source, level of processing or pretreatment, and content of organic biodegradable material. Listed below are feedstocks that can be commonly used in anaerobic digesters:

- ✓ Livestock manures
- ✓ Waste feed
- ✓ Food-processing wastes
- ✓ Slaughterhouse wastes
- ✓ Farm mortality
- ✓ Corn silage (energy crop)
- ✓ Ethanol stillage
- ✓ Glycerine as the product from biodiesel production
- ✓ Milkhouse wash water
- ✓ Fresh produce wastes
- ✓ Industrial wastes
- ✓ Food cafeteria wastes
- ✓ Sewage sludge (Nagamani and Ramasamy, 2007).

Livestock manures are generally lower-energy feedstocks due to the fact that they are predigested in the gastrointestinal tract of the animals. Manure, however, is an easy choice for anaerobic digestion because it generally has a neutral pH and a high buffering capacity (the ability to resist changes in pH); contains a naturally occurring mix of microbes responsible for anaerobic degradation, provides an array of nutrients, micronutrients, and trace metals; and is available in large quantities which can be transfered by pump. A second consideration related to the feedstock will be moisture content. The wetter the material, the more suitable the material will be to handling with pumps instead of screw presses and physical means of movement. Also, the wetter the material, the more volume and area it takes up relative to the levels of gas that are produced. The level of contamination of the feedstock material is a key consideration. If the feedstock to the digesters has significant levels of physical contaminants such as plastic, glass or metals then pre-processing will be required in order for the material to be used. If it is not removed then the digesters can be blocked and will not function efficiently. It is with this logic in mind that mechanical and biological treatment plants based on anaerobic digestion are designed. High water content limits the use of certain feedstock because of low biogas yield per ton fresh mass as illustrated in Fig 2.6. The figure shows that maize silage has the highest biogas yield of the described feedstock (waste like grease or molasses offer an even higher biogas output). Due to its high water content, liquid manure has the lowest yield and therefore should be processed close to where it accumulates in order to save transportation costs.

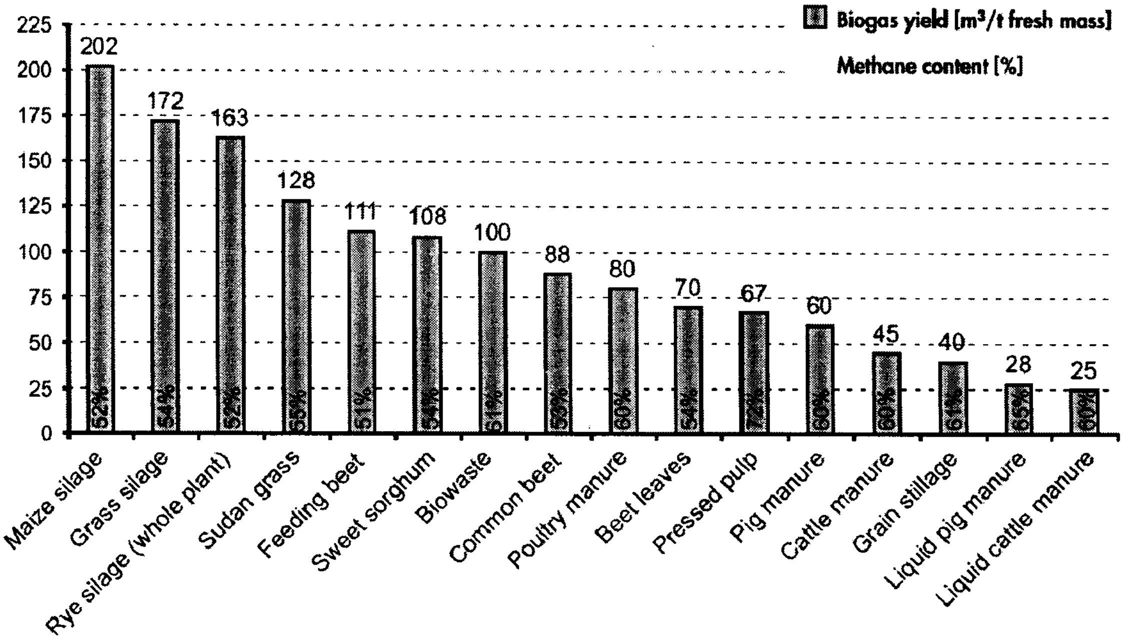

Fig. 2.7 - Biogas yields

Source: (Handreiching 2006)

2.4.7 Feeding Methods

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

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

$$HRT = \frac{Vd}{Fr} \qquad (2.1)$$

where : $HTR =$ Hydraulic Retention Time, days

$Vd =$ Digester Volume, m^3

$Fr =$ Daily Feed Rate, m^3/day.

The major disadvantage of these digesters is that the cost of maintenance is usually higher than that of the batch system.

2.4.8 Fermentation Slurry

All organic materials consists of :

- ✓ Organic solids,
- ✓ Inorganic solids, and
- ✓ Water.

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

2.4.9 Sludge

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

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

Beside being used for soil enrichment, other uses of the sludge includes:

- ✓ Substitute for bedding materials,
- ✓ Potetial substitute for cattle feed,
- ✓ Feed for aquaculture and fish farming,

- ✓ Used as pesticides on plants,
- ✓ Control weed seeds and pathogens,
- ✓ Reduce air pollution since odour is reduced, and
- ✓ Serves as good soil conditioner (Gupta,2006).

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

2.4.10 Loading Rate

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

Loading rates varies form 0.7 – 5.0kg/m^3.day for different substrates. Navickas (2007) determines the organic loading rates of a family size digester for certain substrates at wet basis as follows:

- ✓ Cattle dung: 2.5 to 3.5kg/m^3.day
- ✓ Pig manure: 3.0 to 3.5kg/m^3.day, and

- ✓ Poultry manure: 2.0 to 3.0kg/m³.day

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

$$Vs = \frac{Mm}{Vd} \qquad (2.2)$$

where: Vs = Specific loading rate, kg/m³

Mm = Mass of manure, kg/day

Vd = Digester volume, m³

According to Torsten and Andreas (2002), loading rates of a biodigester depends on the following factors:

- ✓ Size of the digester,
- ✓ Operating system (whether batch or continous),
- ✓ Energy requirement,
- ✓ Type of influent used,
- ✓ Retention time.

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

2.4.11 Operating Temperature

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

A digester can operate on different temperature ranges depending on the stage of digestion. Illic and Mitelic (2006) determine different ranges temperature ranges for different stages of digestion:

- ✓ Psychophiles: below 20°C
- ✓ Mesophiles: 20 to 45°C
- ✓ Thermophiles: 45 to 65°C.

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

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

2.5 Gas Handling and Storage

Unless biogas produced is immediately used, it should be collected and stored in some form of gas holder or tank. Storage systems are, therefore, employed to smooth out variations in gas production, gas quality and gas consumption. The storage component also acts as a buffer, allowing down stream equipment to operate at a constant pressure. The basic reasons for gas storage therefore, are:

- ✓ Storage for later on-site usage, and
- ✓ Storage before and/after transpotation to off-site points (Sathianathan, 1999).

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

- ✓ Safety,
- ✓ Storage volume,
- ✓ Pressure of the gas, and
- ✓ Location of the storage facilty.

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

CHAPTER THREE

3.0 MATERIALS AND METHOD

All the materials and method adopted (Batch method) for carrying out the study was explained below:

3.1 Materials

3.1.1 Components of a biogas plant

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

3.1.2 Slurry Mixing Tank

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

3.1.3 Digester

The digester is an enclosed cylindrical flask where the mixture of poultry manure and water (otherwise called slurrry) decomposes to produce gas due to bacterial activity. For this study, the digester employed contained the following characteristric namely:

- ✓ Inlet – through which the slurry is being introduced in form of liquid slurry,
- ✓ Outlet – where the produced gases pass through
- ✓ Mixer – a magnetic stirrer that agitates and provides proper mixture of the slurry for effective gas formation,
- ✓ Water storage tank- About 500ml volume of water was filled in the tank
- ✓ Water collector – measuring cylinder used to collects water displaced by the gas.

3.2 Materials for Biogas Production

For this study, the materials used for biogas production or generation include the followings, namely:

- ✓ Poultry waste
- ✓ Cattle dung.

The poultry waste and cattle dung were chosen because of the following reason:

- ✓ Avalaibility of the materials
- ✓ Methane yield of the feedstock
- ✓ Nearness of the feedstock

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

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

3.3 Digester Set Up Materials

The materials used for the construction of the biogas plant are as given in Table 3.1

Table 3.1: Construction Materials

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

Similarly, other relevant equipments used in the course of the study are as listed in Plates 3.1 — 3.4.

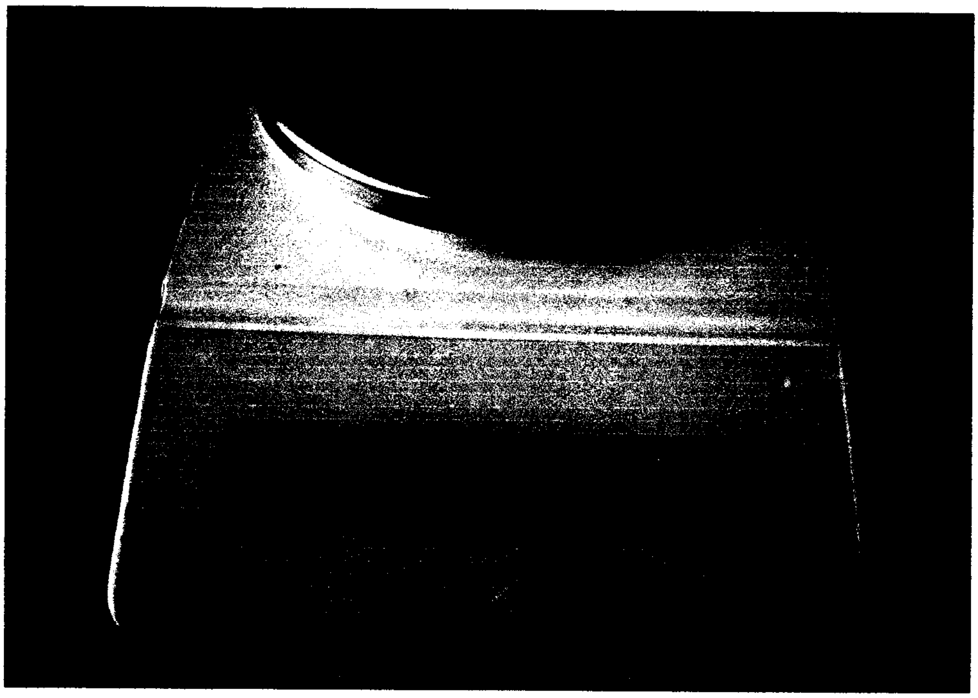

Plate 3.1 Electronic scale Ohaus adventurer (Arc 120)

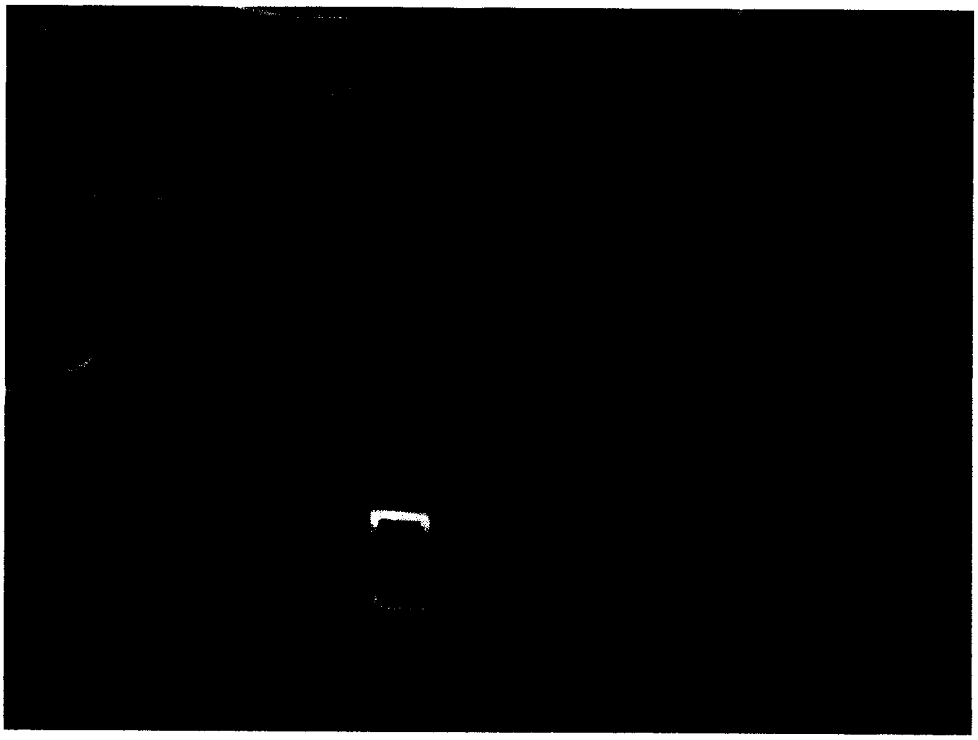

Plate 3.2 Magnetc stirrer Gallenkamp

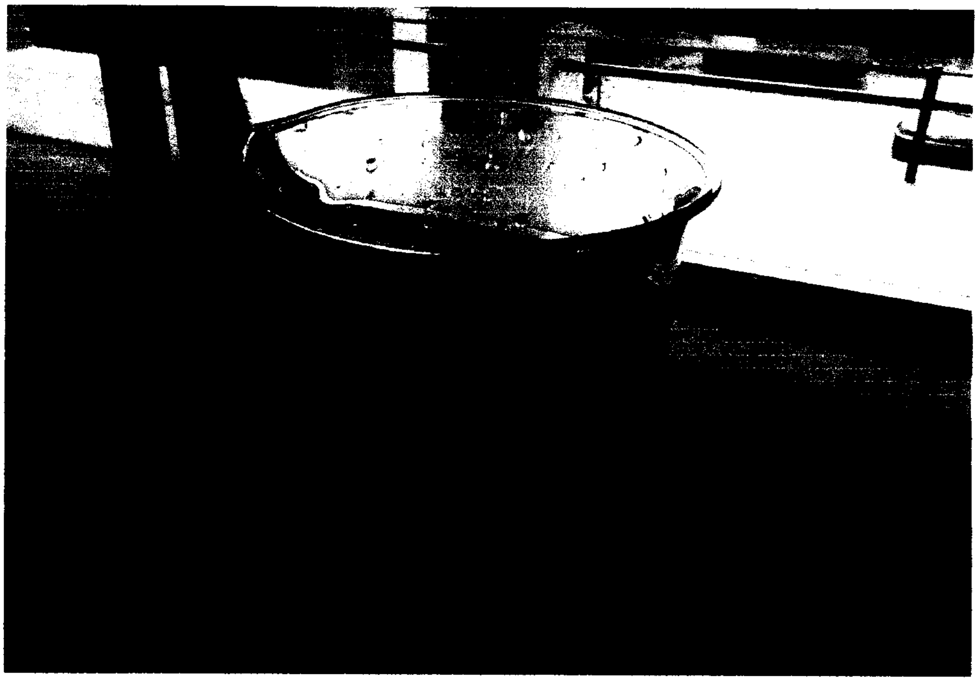

Plate 3.3   500ml cylinder for mixing the slurry

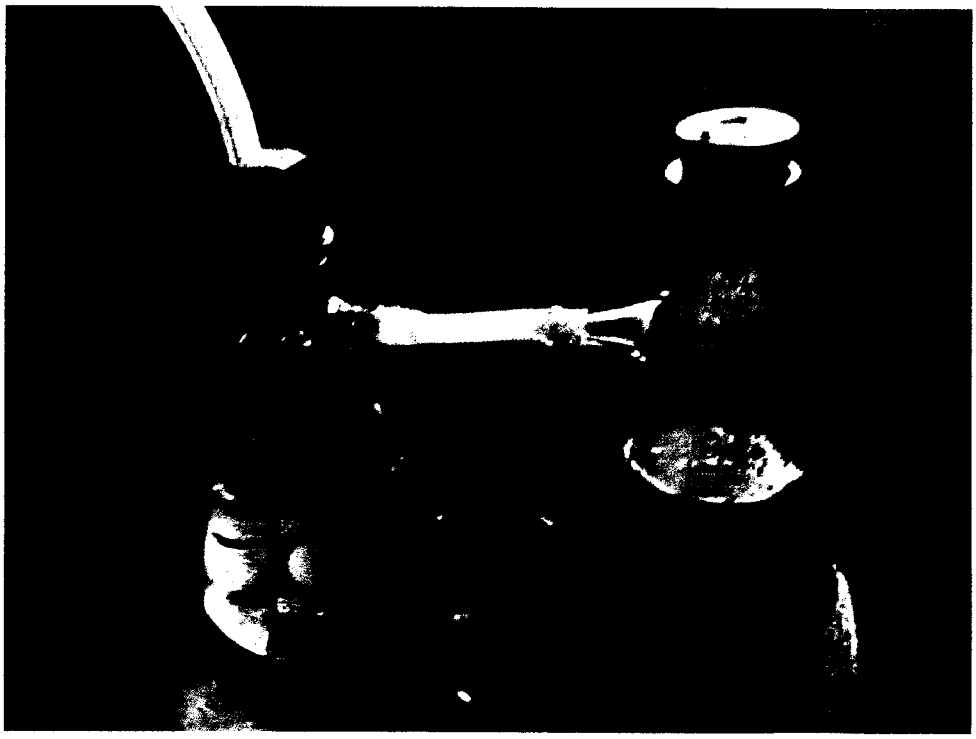

Plate 3.4   Unrisen slurry in the digester

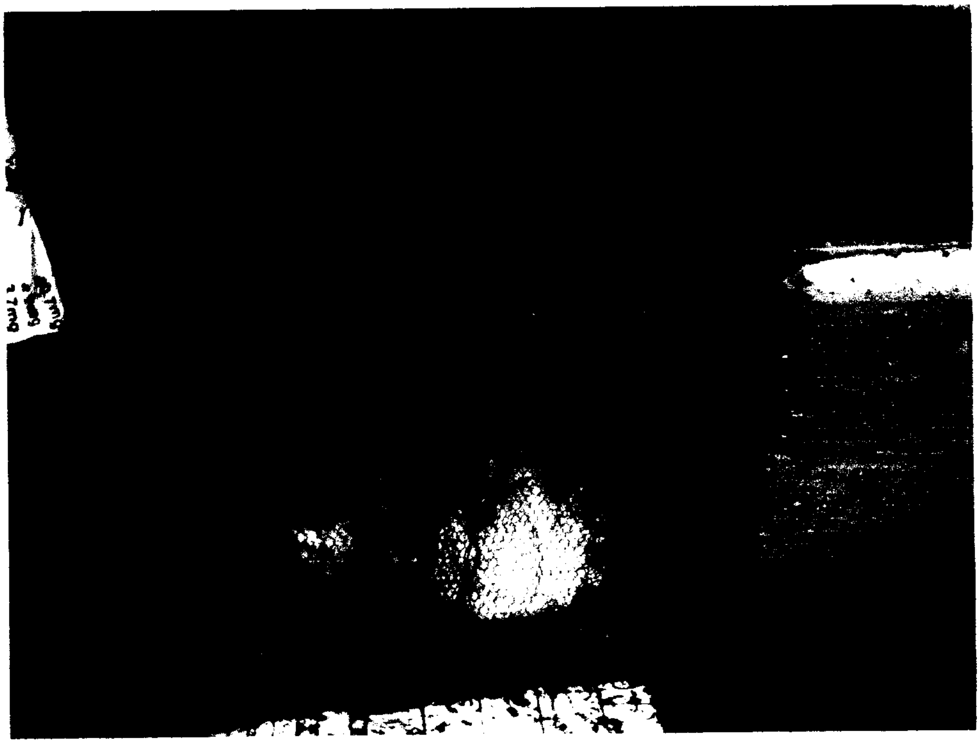

Plate 3.5 Poultry where waste was collected

Plate 3.6 Risen slurry in the digester

3.4 Measurement of Biogas Yield

3.4 Measurement of Biogas Yield

The quantity of biogas produced from a digester was measured using the water displacement method. Two containers were used, the first was connected via an airtight tube into the digester. The biogas produced moved under the digester pressure through the tube into a water- filled container. The water- filled container has a tube that led from its interior to the second container (measuring cylinder) to receive displaced water. This tube was again air tight around the water filled- container with its inner end well below water within the water filled container. The volume of the gas entering into the container was equal to the volume of water displaced through the tube leading out into the measuring cylinder to receive displaced water (Itodo 2010). The water displaced was periodically collected from 12 noon of the starting day to the 12 noon, the following day (24hrs) and was measured using a measuring cylinder. The volume of biogas produced in a given time was equal to the volume of water displaced within the period. The set- up is as illustrated in Plate 3.4 and 3.6.

3.5 Methods

The methods employed for this study can be concisely stated as follows:

The batch system was used because all the three digesters were loaded at the same time; this approach is seemingly cheaper.

The use of animal dung, poultry droppings and cattle dung in different propotion was used for this study. Digester A (Cattle dung 25% of 300g, Poultry waste 75% of 300g), Digester B (Cattle dung 50% of 300g, Poultry waste 50% of 300g), while Digester C has (Cattle dung 75% of 300g, Poultry waste 25% of 300g).

Biogas is easy to extract when digester is above the ground than when its dugged the ground, digester will also be easy to maintain when above the ground. Thus, the digester was positioned above the ground.

The operations were kept at room temperature.

3.5.1 Mixture rate of feedstock

Poultry droppings and cattle dung were used as feedstock. 300g of dung and 150ml of water was mixed together in the ratio of 1:1/2 and fed into the digester using batch method.

3.6 Methodology

Methodology of this study is to properly mix cattle dung and poultry waste (feedstock) in three different proportion. Analysis of these proportions were fully explained below:

Digester volume = 500ml

Volume of slurry = 450ml

Headspace = 50ml

Slurry means weight of manure + water in ratio of 1:1/2 for (cattle and poultry dung) and water respectively.

i.e 300g of poultry and cattle dung + 150ml of water.

DIGESTER A	DIGESTER B	DIGESTER C
Cattle dung 25%	Cattle dung 50%	Cattle dung 75%
Poultry waste 75%	Poultry waste 50%	Poultrywaste 25%

Digester A

Cattle dung 25% of 300g = (0.25 x300)

= 75g

Poultry 75% of 300g = 300 - 75

= 225g

Digester B

Cattle dung 50% of 300g = (50 x 300)/100

= 150g

Poultry 50% of 300g = 150g

Digester C

Cattle dung 75% of 300g = (0.75 x 300)

= 225g

Poultry waste 25% of 300g = 300 -225

= 75g.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 RESULTS

The performance of the conical flask as digester plant was very satisfactory. The problem of rusting or corrosion which typically affects the production of biogas was solved through the use of non corroding materials. The digesters were charged with cattle dung and poultry waste in different proportions, i.e 25%, 75%, 50%, 50% and 75%, 25% of waste respectively. About 450ml of slurry was fed into the digesters in the of ratio 1:0.5. The quantity of biogas produced daily from cattle dung and poultry waste in diferent proportions over a period of 7 days as tabulated in Table 4.1, 4.2 and 4.3, respectively.

TABLE 4. 1 DIGESTER A (volume in ml) Cattle 25% = 75g, Poultry 75% = 225g

DAYS	DIGESTER A1 (ml)	DIGESTER A2 (ml)	DIGESTER A3 (ml)	MEAN
1	0.00	0.00	0.00	0.00
2	1.50	1.46	1.48	1.48
3	2.30	2.40	2.37	2.36
4	4.70	4.70	4.65	4.68
5	5.50	5.55	5.50	5.52
6	7.50	7.48	7.50	7.49
7	5.30	5.35	5.33	5.33

TABLE 4.2 DIGESTER B (volume in ml) Cattle 50% = 150g, Poultry 50% = 150g

DAYS	DIGESTER B1 (ml)	DIGESTERB2 (ml)	DIGESTER B3 (ml)	MEAN (ml)
1	0.00	0.00	0.00	0.00
2	1.20	1.18	1.22	1.20
3	2.00	2.02	2.00	2.00
4	4.40	4.35	4.00	4.25
5	5.20	5.22	5.18	5.20
6	5.00	5.00	5.00	5.00
7	7.20	7.21	7.22	7.21

TABLE 4.3 DIGESTER C (volume in ml) Cattle 75% = 225g, Poultry 25% = 75g

DAYS	DIGESTER C1 (ml)	DIGESTER C2 (ml)	DIGESTER C3 (ml)	MEAN (ml)
1	0.00	0.00	0.00	0.00
2	0.80	0.75	0.78	0.78
3	1.60	1.62	1.60	1.61
4	4.00	4.01	3.99	4.00
5	6.70	6.73	6.73	6.72
6	4.70	4.68	4.70	4.69
7	4.50	4.50	4.50	4.50

TABLE 4.4: Mean of gas produced in three digesters (volume in ml)

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

TABLE 4.5: Average yield of digester A ml/ day

DIGESTER A	TOTAL VOLUME (ml)	AVERAGE YIELD (ml/day)
A1	26.80	3.83
A2	26.94	3.85
A3	26.83	3.83

TABLE 4.6: Average yield of digester B ml/ day

DIGESTER B	TOTAL VOLUME (ml)	AVERAGE YIELD (ml/day)
B1	25.00	3.57
B2	24.98	3.57
B3	24.62	3.52

Table 4.7: Average yield of digester C ml/ day

DIGESTER C	TOTALVOLUME(ml)	AVERAGE YIELD (ml/day)
C1	22.30	3.18
C2	22.29	3.18
C3	22.30	3.18

For the respective digesters, A, B, and C, the response graph are as presented in figure 4.1 — 4.4

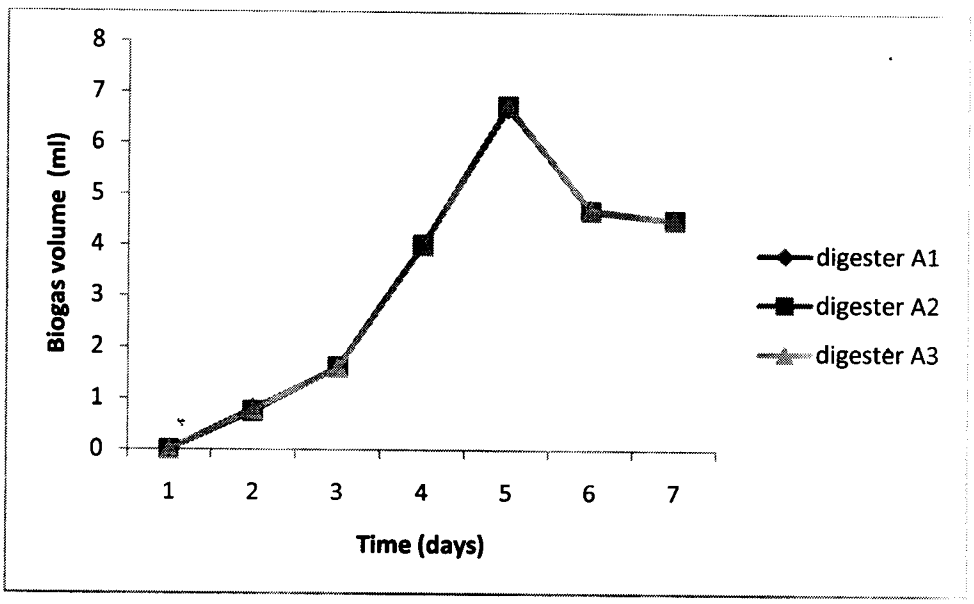

Fig 4.1 multiple graph showing biogas production of digester A1, A2 and A3

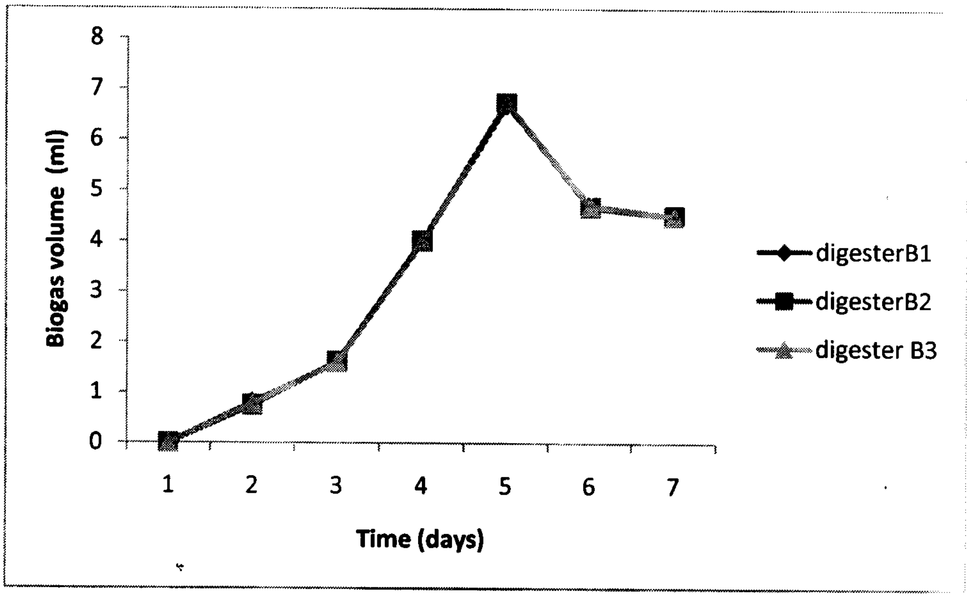

Fig 4.2 multiple graph showing biogas production of digester B1, B2 and B3

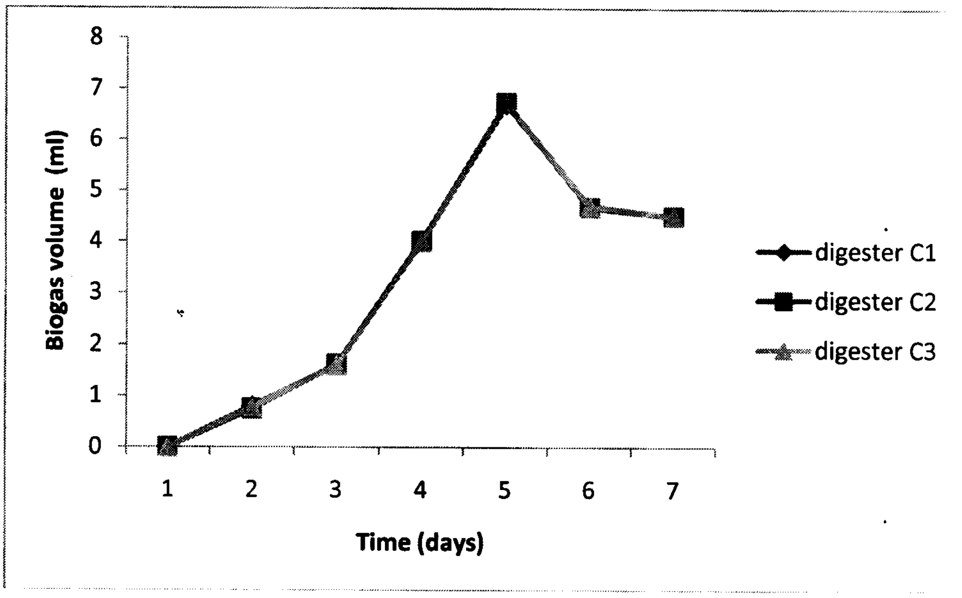

Fig 4.3 multiple graph showing biogas production of digester C1, C2 and C3

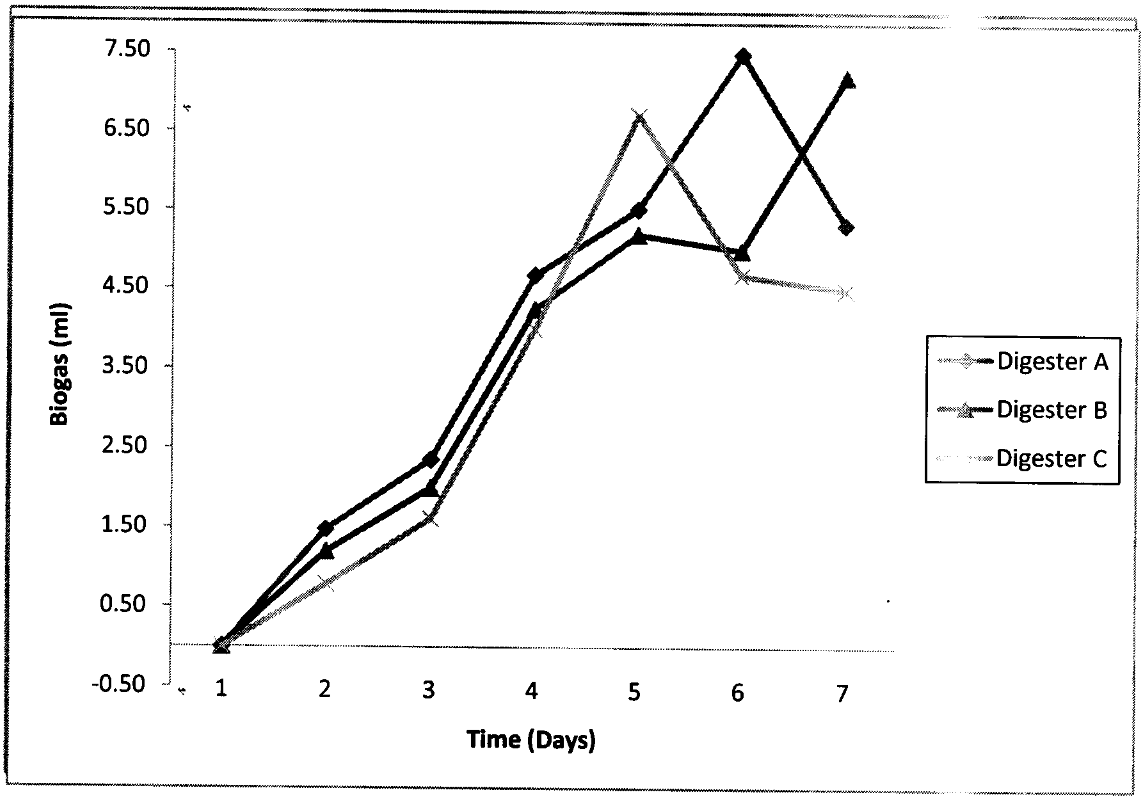

Fig 4.4 multiple graph showing mean Biogas production of digester A, B and C

4.2 DISCUSSION OF RESULTS

A cursory look at the figure 4.4 reveals the following:

1. Digester A recorded the highest biogas production of about 7.49ml compared to the other two digesters on the sixth day of the experiment. The Biogas production from this Digester A was also seen to have increased progressively from day one through day six and declined sharply on the seventh day.This scenerio connotes the attainment of optimium production point per day.

2. Digester B increase steadily from day one through day five and dropped relatively on the sixth day but then went up sharply on the seventh day to about 7.21ml. Based on this, it can be said that optimality in Biogas was not attained in this case as there was evidence from the graph to suggest further production.

3 Digester C rose progressively from 0.00ml from the start of the experiment to about 6.72ml in day 5 and then decreased following the two remaining days of the experiment. Optimality could be said to be attained in the fifth day since it recorded the highest mean biogas within the time frame so far allowed as far as digester C is concerned.

4 Generally speaking, it could be said that biogas production increases from the start of the experiment as the day's increases and reaches an optimum value in a given time and may decrease in a later time/day.

From the gas production analysis, the total volume of biogas was maximum in digester A (P= 75%, C= 25%) produced 26.86ml, followed by digester B (P= 50%, C= 50%) which produced total biogas of 24.86ml and digester C(P= 25%,C=75%) producing least bioags of 22.30ml. This may be due to higher nitrogen content in poultry droppings as compared to other feedstocks. The higher biogas production from poultry droppings could also be attributed to the available nutrient in the droppings. The higher biogas production from poultry droppings could also be attributed to the available nutrient in the droppings. Providing adequate mixing facilities can reduce the scum formation during anaerobic digestion. Biogas production from poultry manure of large farms is an ecologically and economically effective technology. Greater percentage of carbon oxygen demand (COD) reduction can take place with larger biogas volume produced for every proportion of degraded organic matter. Referring to fig 4.1 □ 4.3 above, biogas production started in all the three digesters on the 2nd day after loading. The figure 4.1 □ 4.3 also showed that the total biogas production from each of the digester and suggests that digester A produced the highest quantity of biogas (26.68ml) in 7days, while digester C produced the least (22.30ml). The figure also revealed thatbiogas yield from the digester over the retention period. There was no gas production in 1st day in all the digesters. This may be due to the fact that the waste has not been fully decomposed. It can be seen that biogas production stated on 2nd day and increased gradually on subsequent days then suddenly attained maximum value on the 6th days for digester A and reduced on the 7th day . Production reached its peak on the 7th in digester B, while production dropped drastically in digester C after attaining maximum on the 5th day. Average biogas production from digester A, B and C were 3.84ml/day, 3.55ml/day and 3.19ml/day respectively.

An analysis of variance and test of significance (Tables 4.5 □ 4.7) was carried out to test whether there are differences in the biogas production or in the digester.This is to establish if any of the three designs may have been appropriate for the experiment.

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

4.2.1 Two Factor Experimental Design

Table 4.8: Two Way Analysis of Variance

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

Table 4.9: Duncan Multiple Range Test for Digesters

		Subset		
Digester	N	1	2	3
Digester C	18	3.7161		
Digester B	18		4.1444	
Digester A	18			4.4761
Sig.		1.000	1.000	1.000

Table 4.10: Duncan Multiple Range Test for Days

		Subset				
Day	N	1	2	3	4	5
Day Two	9	1.1522				
Day Three	9		1.9900			
Day Four	9			4.3111		
Day Seven	9				5.6789	
Day Six	9				5.7289	
Day Five	9					5.8122
Sig.		1.000	1.000	1.000	.064	1.000

Table 4.11: Estimated marginal means for Days x Digester

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

Table 4.11 is the result of the investigation on the effect of types of Digester and Days of the experiment using two way analysis of variance. The analysis revealed that both Types of Digester and days of experiment were significant at 99% confidence level. The hypothesis of equal mean treatment effect of Digester and Days of experiment is therefore rejected. These may imply the followings:

1. That the days of the experiment do not record the same mean values of biogas production in millilitre. This assertion was confirmed using Duncan multiple range test as seen in Table 4.10. This table indicates that if Digester is not the case, then day five generally recorded the highest mean value of biogas which is significantly higher than that recorded from day six and day seven. Days six and seven produced relatively the same quantity of biogas but were statistically higher compared to the yield from days four, three and two, respectively.

2. The three digesters were formulated using different composition of cow and poultry waste. These digesters proved to be statistically different from each other as suggested by the Table 4.1. Further investigation using Duncan multiple range test showed that Digester A produced the highest mean biogas of approximately 4.50ml; this value is significantly higher than that produced from the two other Digesters (B and C, see Table 4.10).

The result of the estimated marginal means test presented in Table 4.4 revealed that Digester A produced higher mean values of biogas in all the days of the experiment except day seven. On the other hand, digester B was also seen to perform more than Digester C in terms of biogas production.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSIONS

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

5.2 RECOMMENDATIONS

1. More attention should be given to animal dung as feedstock for anaerobic digestion plants.
2. Production of biogas from dung is not a dream anymore but a reality, other researchers should focus on using the gas for generation of electricity.
3. If the biogas produced is going to be used to run engines, it has to be cleaned because it contains impurities that can damage engines.

4. Gorvenment agencies should take an active part in biogas project as it was done in other countries like India, Nepal, and philipinne e.t.c.
5. Checking for toxic gases like hydrogen sulphide and ammonia with gas detection equipment should be carried out before entering an empty digester.

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