PRODUCTION OF BIOGAS FROM POULTRY LITTERS

BY

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

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DECLARATION

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 Information derived from personal communications, published and unpublished work were duly referenced in the text.

Arinze Igbokwe ______________________ 31/01/2011 ______________________

Igbokwe, Arinze Onyemaechi Date

CERTIFICATION

This is to certify that the project entitled "Production of Biogas from Poultry Litters" by Igbokwe, Arinze Onyemaechi meets the regulations governing the award of the degree of Bachelor of Engineering (B. ENG.) of the Federal University of Technology, Minna, and it is the approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

I dedicate this to my Maker, God and my beloved savior, Jesus Christ and my lovely mother and siblings.

ACKNOWLEDGEMENTS

I give all glory to God for his mercy despite my shortcomings and for preserving me all these years.

My profound gratitude goes to my supervisor Engr. Dr. P.A. Idah for his immense contribution to the success of this project. I also thank the project coordinator of the department Engr. Dr. O. Chukwu and the head of the department Engr. Dr. A.A. Balami and to the entire lecturers and staff in the department for all the knowledge they have imbibed in me for the past five years.

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My Heart goes out to all my friends and colleagues, God bless you all.

ABSTRACT

The effort towards keeping the environment clean of all waste is a task that needs the participation of everybody. In this study a biogas digester was designed and fabricated to produce biogas gas from poultry litters. The system has a cylindrical tank (biodigester) an absorption chamber and a burner. The results of the test performance carried out show that the methane gas produced by anaerobic digestion of poultry litters was too slow and did not combust easily. It was observed that water vapour was found condensed in the digester and along the outlet pipe.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of study

The need for alternative energy supplies is increasingly apparent. Our fossil fuel reserves will eventually be exhausted. Moreover, these reserves are unequally distributed and are becoming too costly for many countries that must purchase them. In addition, the cost of transportation may sharply limit the use of fossil fuels in the rural areas of many developing countries .As recent events have shown, the cost and the availability of this fuel are determined by market forces than the decisions of the producing nations. The present energy-generating systems in developing countries depend largely on local resources: wood, straw, or dung for burning. (Gerard, 1981).

During the last 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 which includes poultry dropping, cow dung, kitchen wastes. Government and industries are constantly on the lookout for technologies that will allow for more efficient and cost – effective waste treatment (Guruswanny *et al*., 2003). One important waste in the world today that is increasing in large deposit is poultry waste. This is because the poultry industry has been in existence for centuries with every families, private enterprise and nations having poultry farms. More than 50 million chickens are reared annually for meat and eggs. Majority of poultry farmers uses the intensive farming technique among other practice in rearing birds (Dennis, 1997).

Poultry industry is not all about the growing of birds for meat and eggs only, which are the reasons for most establishments. Many owners of poultry farm have a good knowledge about breeding of birds, the composition rate of their feeds, type of treatment to offer to any kind of disease that may occur and what to do to avert threats from human and rodents. But most owners lack the knowledge of what to do with the poultry litters they generate from their farms. One of the most common ways adopted by farmers in disposing of waste is heaping or spreading waste in open fields. Some of these fields are close to residential houses and their sight creates irritation and breeding ground for both flies and mosquitoes (Sangygeday, 1999). One technology that can successfully convert this waste is the use of biogas technology which involves production of biogas through the process of aerobic and anaerobic digestion (hill, 1983). It has the advantage of producing energy, yielding high quality fertilizer and also preventing littering of our environment.

1.2 Objective

I. To design and fabricate a digester to produce pure methane from chicken litters.

1.3 Justification of the Study

In recent times there has been increase in the cost of fossil fuel in the world coupled with the danger posed by the continuous use of fossil fuel to the environment. The need has arisen to use biogas technology as a suitable alternative energy source for domestic use. This will help boost environment protection and increase total energy supply. Therefore there is a need to analysis poultry litters to ascertain whether it is suitable for biogas production. To ensure a safety environment and address the energy crisis by reducing over dependence on costly fossil fuels.

1.4 Scope of the Study

This work is stream lined to analysis poultry litter for biogas production using an anaerobic digester.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Profiles on Poultry Litters

During the past decades the poultry industry has changed dramatically. Today poultry farming has been transformed into an organized industry. It plays a major role in the fight against malnutrition and poverty among the rural dwellers. The importance of poultry sector in solving problems of unemployment and under-employment is well-conceived by Government and private sectors. Among all livestock ventures, poultry farming requires only less capital investment and also ensures quick returns in a short run (Amanullah *et al.*, 2010).

Everyday tonnes of poultry litters are generated by various poultry farms all over the world, the need for appropriate disposal of litters become a concern. Some countries have been able to convert poultry litters into raw material for producing energy and organic fertilizers for crop growth. In some advanced countries, they have been able to establish biogas generating plant. For instance, In North Ireland, a 100 million pounds plant was built to run on 242,500 tonnes per year of poultry litters (Gibson, 2007). The Fibowatt Thatford poultry power plant in United Kingdom is one of the largest plants in Europe, it generates 38.8MW of electricity which is distributed to 93,000 homes. Recently, Netherland built a biogas generating plant that will be converting one third of the country's total of 1.2 million tons of poultry waste produced per year to about 36.5magawatts of electricity, estimated to power approximately 90,000 homes (Kimberley, 2009).

There is serious Concern in the management of chicken litters, as poultry farmhouses continue to increase and practice modern intensive technique in daily production. Odour during production, spreading, storage of manure, contamination of water and soil and other negative consequences could be harmful to animal health as well as human. It has been shown that some pathogen and bacteria are present in poultry litters and any of these processes of production could be a medium of distributing them (Stegmenn and Bade, 2005).

Poultry litters is the mixture of bedding materials, manure, feathers resulting from intensive poultry product. The most commonly use materials on the floor of sheds are saw dust, wood shavings, rice hulls, straws and paper products. Sand is used in countries with limited forest reserouces. Litters are used in poultry house to keep the floor dry and warm for birds. The litter material is spread approximately in the same depth across the pens before birds are brought. (Amanullah *et.al.*, 2010).

2.2 Chemical Composition of Poultry Litters

Poultry litter comprises of protein, carbohydrate, lipids and fats with carbohydrates responsible for the majority of biogradable material in the form of cellulose, starch and-sugars. Poultry litter consists of all the essential elements that can be used for nutrients (animal feed) and for making fertilizer (Ludwig, 1998). These include nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), manganese (Mn), copper (Cu), zinc (Zn), chlorine (Cl), boron (B), iron (Fe) and molybdenum (Mo). The amounts of these nutrients can also be varied as a result of the age and diet of the flock, as well as the moisture content and age of the manure. Table 2.1 below summarizes the chemical composition of poultry litter in dry state.

Table 2.1 Poultry litter Analysis

Characteristics	Average	Range
PH	8.1	6.0 – 8.8
*Electricity Conductivity ^Ds/m	6.8	2.0 – 9.8
Dry matter(%)	75	40 – 90
Nitrogen N (% of dry matter)	2.6	1.4 – 8.4
Phosphorus P (% of dry matter)	1.8	1.2 – 7.8
Potassium K (% of dry matter)	1.0	0.9 – 2.0
Sulphur S (% of dry matter)	0.6	0.45 – 0.75
Calcuim Ca (%of dry matter)	2.5	1.7 – 3.7
Magnesium Mg (% of dry matter)	0.5	0.35 – 0.8
Sodium Na (% of dry matter)	0.3	0.25 – 0.45
Carbon C (% of dry matter)	36	28 – 40
Weight per m^3 (Kg)	550	500 – 650

* Electrical Conductivity is a measure of salinity measured as a 1.5 suspension in water

Source: New South Wales department of primary industries (2004)

2.3 Analysis of Poultry litter for biogas Production

The composition of poultry litters varies with the type of birds (broilers, layers, and crooker) and the type of poultry manure - deep litter manure, broiler manure, cage manure and high rise manure. The deep litter manure is produced by layers during their laying period. Deep litter for laying hens is usually made of wood shavings in a layer of 10-15 cm deep. During production, the accumulating manure gets mixed with the litter. When excreta are added, the litter becomes moist but remains aerobic. Broiler house manure is similar to deep litter poultry manure, but the litter is changed more frequently and there is less ammonia loss because of restricted decomposition. (Amanullah, 2010).

Therefore, Litters should be sampled to know the specific composition before used for biogas production. It has been long recognized that poultry litters are a good source of nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, potassium and a number of trace elements. Carbon - nitrogen ratio affect biogas production from poultry litters. A mixture of nitrogen – rich manure and carbon – rich litter will give a high gas production (Ludwig, 1998).

Ojolo (2007) carried out an analysis on three waste materials, poultry litters, cow dung and kitchen waste. Same sample of each waste was collected and mixed with water i1n the right proportion and then loaded into a rector. The biogas produced was measured for a period of 40 days at an average mesophilic temperature of 30°.5 C and a PH value 7.1 to 8.1. It was shown that poultry litters produced more gas than cow dung and kitchen waste. The higher biogas production was attributed to the available nutrients in poultry litter. According to Hills (1984) substrate should contain adequate amount of carbon, oxygen, hydrogen, nitrogen, surphur, phosphorus, calcium, magnesium and other trace element to enable the achievement of appropriate volume of biogas.

The presence of pathogens which are very common with poultry litter and high chemical oxygen demand (COD) can reduce the amount of gas that should be produced from poultry litters Gunaseelen (1987), revealed that greater percentage of COD reduction can take place with larger biogas volume produced for every proportion of degraded organic matter with 15 – 40 days retention. offensive odour could be reduced, greater number of pathogens could be deduced and organic nitrogen could be converted to ammonia, thereby reducing environment hazards. Ojolo (2007) also revealed that the main disadvantage of chicken litters is that it produce a proportion of hydrogen sulphite, which, even in only small proportion, corrodes metal fittings.

2.4 Biogas

Biogas is generated when bacteria degrades organic materials in the absence of oxygen in a process known as anaerobic digestion. Basically, there two types of organic decomposition that can occur aerobic (in the presence of oxygen) and anaerobic (in the absence of oxygen) decomposition. All organic material, both animal and plant can be broken down by these two processes, but the product of decomposition will be quite different in the two cases. Aerobic decomposition (fermentation) will produce carbondioxide, ammonia and some other gases in small quantities, heat in large quantities and final product that can be used as fertilizer. Anaerobic decomposition will produce methane, carbon dioxide, hydrogen and other gases in trace, very little heat and a final product with a higher nitrogen content than is produced by aerobic fermentation. (Habmigern, 2003)

Anaerobic digestion is a sample process carried out in a number of steps over any organic material as a substrate. It occurs in a digestive system, mashes, rubbish, lagoons and septic tank. Biogas can be produced in a control system by providing a small digester of specific size. The digester is simply build and operated with no complications in any of the processes of extraction of the gas. To get biogas, organic material are loaded inside a dome-shaped structure constructed beneath the ground then allow to decompose for some time to undergo a metabolic break down in the presence of some bacteria. Unlike biogas produced from fossil fuel which contains hydrocarbons as impurities, biogas produce from control system contains methane and carbon dioxide, hydrogen sulphite, others gases in traces as impurities. These impurities can be separated using simple techniques

2.5 Biogas Product

Biogas is a naturally occurring byproduct of the breakdown of organic material, and is actively produced from a variety of sources, including animal waste, municipal solid waste, sewage and agricultural wastes using a process called anaerobic digestion. The main constituent of biogas is methane. When further cleaned and upgraded, biogas can be turned into biomethane, a high-quality methane fuel that is indistinguishable from non conventional. Biogas is mainly composed of 50 to 70 percent methane, 30 to 40 percent carbon dioxide (CO_2) and low amount of other gases as shown in Table 2.2

Table 2:2 Composition of biogas

Substances	Symbol	Percentage (%)
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	Traces

Source: Yadava and Hesse (1997)

Biogas is about 20 percent lighter than air and has an ignition temperature in the range of 650 to 750°C. It is an odourless and colourless gas that burns with clear blue flame similar to that of LPG gas (Sathianathan, 1975). Its calorific value is 20 Mega Joules (MJ) per m^3 and burns with 60 percent efficiency in a conventional biogas stove.

2.6 Biogas production process

Anaerobic biodegradation process of organic materials for the production of methane is a process involving microbes that grow in the absence of air. Difference groups of bacteria act upon complex organic materials to produce biogas. The process takes place in three stages (Meynell, 1981) or four stages (Knandelwal and Mahdi, 1986). The four stage process seems to be acceptable (Maishanu, 1994)

Stage 1: Hydrolysis. The waste materials of plant and animal origins consist mainly of carbohydrates, lipids, proteins and inorganic materials. Large molecular complex substances are solubilized into simpler ones with the help of extracellular enzyme released by the bacteria. This stage is also known as polymer breakdown stage. For example, the cellulose consisting of polymerized glucose is broken down to dimeric, and then to monomeric sugar molecules (glucose) by cellulolytic bacteria (Hoerz *et al*, 1999).

Stage 2: Fermentation: The simple organic compounds are fermented to alcohols, hydrogen and carbon dioxide by bacteria which by bacteria which secretes enzymes on the compounds. The bacteria are divided into cellulose- splitting, fat splitting and protein splitting, based on the type of the substrate they act upon (Maishanu, 1994).

Stage 3: Acidification. The monomer such as glucose which is produced in Stage 1 is fermented in stage 2 under anaerobic condition into various acids with the help of enzymes produced by the acid forming bacteria. At this stage, the acid-forming bacteria break down molecules of six atoms of carbon (glucose) into molecules of less atoms of carbon (acids) which are in a more reduced state than glucose. The principal acids produced in this process are acetic acid, proponic acid, and ethanol. (Maishanu, 1996).

Stage 4: Methanization: The principle acids produced in Stage 3 are processed by methanogenic bacteria to produce methane. The reaction that takes place in the process of methane production is called Methanization and is expressed by the following equations (Karki and Dixit, 1984).

a. By the breakdown of acetates molecules to form methane and carbon dioxide

$$CH_3COOH \longrightarrow CH_4 + CO_2$$

Acetic acid — Methane — Carbon dioxide

b. By the reduction of carbon dioxide to form methane and water

$$CO_2 + 4H_2 \longrightarrow CH_4 + 2H_2O$$

Carbon dioxide   Hydrogen   Methane   Water

The stage of methane production from organic residue are illustrated in the fig 2.1below:

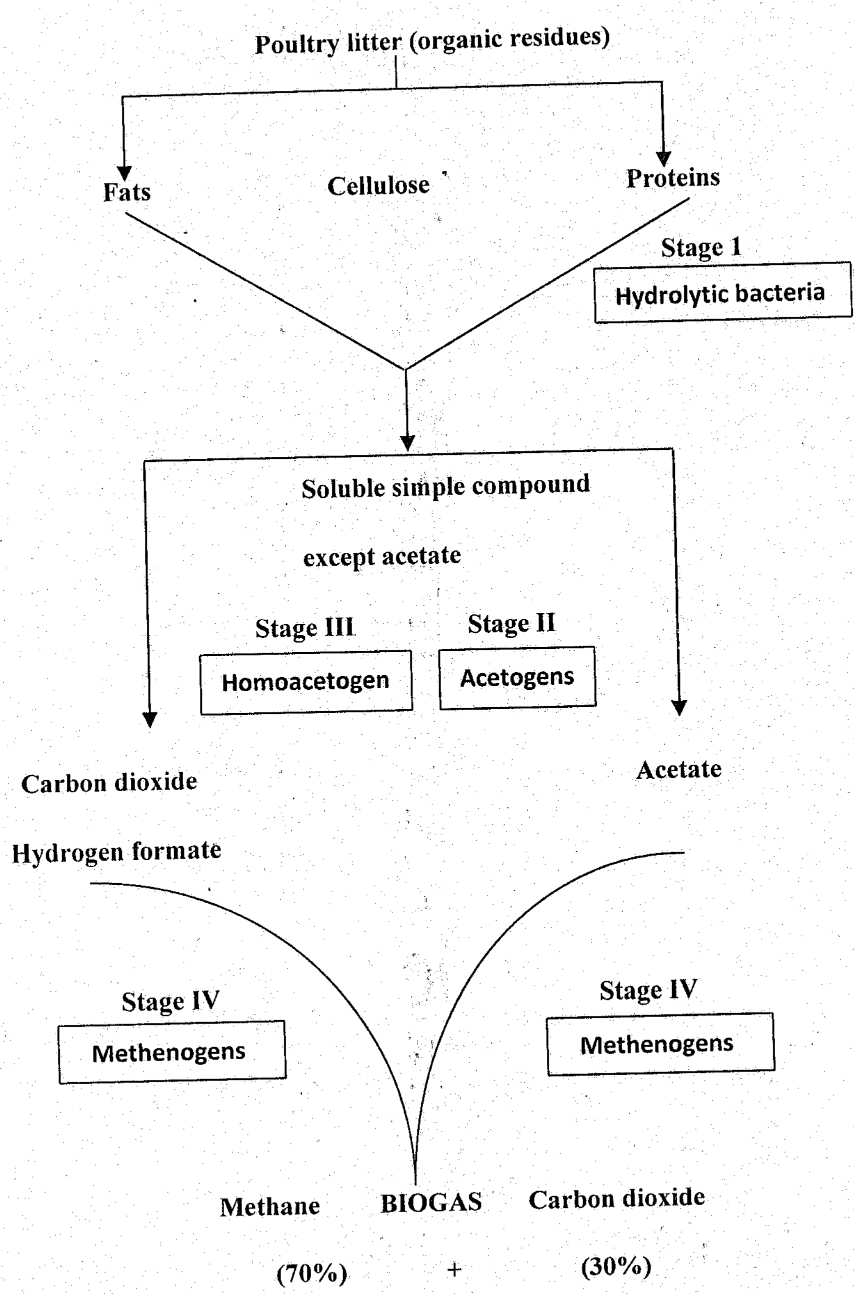

Fig 2.1 Stages of Methane Production(Source : Maishanu 1994)

2.7 Biomethane

Biomethane production involves upgrading, or cleaning-up biogas to a higher quality gas. This involves primarily removal of carbon dioxide, hydrogen sulphide, water vapour, as well as trace gases. The resulting biomethane will have a higher content of methane and a higher energy content making it essentially identical to conventional natural gas. (Patrick, 2010).

The primary steps in the biogas upgrading process are:

- Removal of Carbon dioxide (CO_2)
- Removal of Hydrogen sulphide (H_2S)
- Water (H_2O) removal
- Removal of other contaminants

2.7.1 Removal of carbon dioxide (CO_2)

Reducing the relative amount of carbon dioxide (CO_2) in the biogas is the main task of the biogas upgrading process. Biogas contains typically 60 – 70% methane and 30 – 40 carbon dioxide and biomethane contains 97 – 99% methane and 1 – 3% carbon dioxide. Carbon dioxide can be removed by passing biogas through a solution of lime, caustic soda or by bubbling it in water (Chen, 2010).

2.7.2 Removal of hydrogen sulphide (H_2S)

Hydrogen sulphide is a contaminant present in biogas, produced during the digestion process. Depending on the biomass feedstock and biogas production process, the Hydrogen Sulphite content of the biogas varies. Hydrogen Sulphide should be removed early in the production process because of its corrosive nature. In addition, the release of the compound into the atmosphere is carefully regulated as it is extremely toxic and it contributes to air pollution.

Ways in which Hydrogen suphide (H_2S) can be removed is by pass biogas through Iron fillings, oxidation with air and bubbling through a solution of acetates (Chen, 2010).

2.7.3 Water Removal

Raw biogas is sat urated with water vapour. Depending on the biogas upgrading technology used, later stages in the biogas upgrading process may also be fully or partially saturated with water. The water vapour in biogas can be removed by using moisture traps or vapour condensers along the distribution line (Chen, 2010).

2.7.4 Removal of Other Contaminants

In addition to H_2S, H_2O and CO_2, there may be other trace contaminants present in the biogas which are potentially harmful to equipment and/or people and must therefore be removed or reduced to acceptable levels. These additional contaminants include particles, halogenated hydrocarbons, ammonia, nitrogen, oxygen and organic silicon compounds (e.g siloxanes). A number of effective, available technologies exist to reduce or eliminate these contaminants including filters, membranes, activated carbon and other absorption media (Chen, 2010).

2.8 Requirements and Factors of Biogas Generation

In the generation of biogas for organic waste, the following requirement is necessary for the process.

2.8.1 Feedstock Material

Organic or cellulosic materials are needed for bioconversion into biogas. Feedstock may be sourced from animal, human and plant wastes that can be obtained from farms, livestock yard, poultry houses, septic tanks, pit latrines, abattoirs and aquatic crops. The amount of gas that can be generated varies with the nature of the feedstock materials (VITA, 1979). Gaadi and Usmani (1981), suggest that feedstock should be reduced to a size 3mm-6mm for adequate digestion.

2.8.2 Water

This is very essential in the biodegradation process. The micro organisms needed for bioconversion need an appreciable amount of water to initiate and sustain the process. Water can be sourced from streams rain collected and underground sources. Water from taps (i.e. town supply) is not usually used because of the presence of chlorine and/or other chemicals which are toxic to the micro organisms. A waste to water ratio of 1:1 or 1:2 (Itodo, 1993) is offered as ideal for using wet feedstock. A waste concentration of 5- 10 % of solid wastes (Abubakar, 1990 and Gaadi and Usmani, 1981).

2.8.3 Influent Solids Content (Solution)

Production of biogas is inefficient if fermentation materials are too dilute or too concentrated, resulting in, low biogas production and insufficient fermentation activity, respectively. Experience has shown that the raw-material (domestic and poultry wastes and manure) ratio to water should be 1:1, 1:2, 1:3 i.e., 100 kg of excrete to 100 kg of water. In the slurry, this corresponds to a total solids concentration of 8 - 11 per cent by weight.

2.8.4 Carbon –Nitrogen ratio

The relationship between the amount of carbon and nitrogen present in organic materials expressed in terms of the Carbon/Nitrogen (C/N) ratio. A C/N ratio ranging from 20 to 30 is considered optimum for anaerobic digestion. If the C/N ratio is very high, the nitrogen will be consumed rapidly by methanogens for meeting their protein requirements and will no longer react on the left over carbon content of the material. As a result, gas production will be low. On the other hand, if the C/N ratio is very low, nitrogen will be liberated and accumulated in the form of ammonia (NH_4).

2.8.5 Temperature

The methanogens are inactive in extreme high and low temperatures. The optimum temperature is 35° C. When the ambient temperature goes down to 10 °C, gas production virtually stops. Satisfactory gas production takes place in the mesophilic range, between 25° C to 30° C. Proper insulation of digester helps to increase gas production in the cold season. When the ambient temperature is 30 °C or less, the average temperature within the dome remains about 4°C above the ambient temperature (Lund et al, 1996).

2.8.6 The pH Value

The optimum biogas production is achieved when the pH value of input mixture in the digester is between 6 and 7. The pH in a biogas digester is also a function of the retention time. In the initial period of fermentation, as large amounts of organic acids are produced by acid forming bacteria, the pH inside the digester can decrease to below 5. This inhibits or even stops the digestion or fermentation process. Methanogenic bacteria are very sensitive to pH and do not thrive below a value of 6.5. Later, as the digestion process continues, concentration of NH_4 increases due to digestion of nitrogen which can increase the pH value to above 8. When the methane production level is stabilized, the pH range remains buffered between 7.2 to 8.2 (Dennis, 2001).

2.8.7 Seeding

This is the addition of a small part of active slurry to the feedstock to hasten or initiate the biogas production process. It has been shown by Aliyu *et al.* (1996) that seeding increases the rate of biogas production. Seeding material can be sourced from an existing working digester stagnant ponds or from an earlier fermented waste.

2.8.8 Stirring

Periodic stirring or agitation of the digester is essential or maximum generation of the gas, to avoid formation of solids of accumulation of scum in the digester. Agitation should be done for a few minutes at least once daily (Meynell, 1981; Abubakar. 1990). Agitation can be provided either by mechanical stirring, liquid or gas circulation. Continuous stirring however reduce gas production (Aliyu, 1994).

2.8.9 Retention time

Retention time (also known as detention time) is the average period that a given quantity of input remains in the digester to be acted upon by the methanogens. It should be great enough to allow methane formers convert organic acids biogas. Normally the retention time for animal manure digestion is 7 – 30 days. (Aliyu 1994) and give the retention time for tropical regions of the world to be 30 days while gaady and usmani (1981), gives the optimum retention time to be 20 days.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Digester Plant

The system is made compised of the following component;

i **Biogas Digester –** The biogas digester is the most important part of the biogas plant. It is an enclosed airtight tank, designed in such way to enhance generation of gas under anaerobic condition. The steel drum – type for small needs was suggested by Twidell and Anthony (1986).

ii **Gas Storage Unit –** This is designed to collect the gas that is generated and hold it prior the time it will be used. This will be designed using a steel drum.

iii **Gas Lines -** The gas line are provided to distribute the gas from the point of generation to a the storage unit and then to the burner. They are made up of galvanized pipe, flexible rubber hose and control valve to prevent air to be drawn along the gas line.

iv **Hydrogen Sulphide Absorption Chamber:** this is a separating unit designed for upgrading of the biogas. An iron filling is used as the subtenant which will react with hydrogen sulphide.

Zv Burner - This burns the gas to produce heat using the atmosphere method as suggested by Musa (1999).

3.1.1 Other Features

There are some other materials used in the biogas plant that also play important role They include ;

- The inlet and outlet valve for feeding and empting of slurry from the digester.
- The Stirrer a mechanical device that helps agitates the slurry in the digester to prevent it from forming scum (solid waste).
- The drain valve placed at the base of the digester to drain the content of the digester when the need arises.
- Control valve to direct the flow of gas out of storage when needed for use.

3.2 Design Parameters and Dimension of Biogas plant

The substrate feed into the anaerobic bio-digester is calculated in terms of total solid. The total solid (TS) contains concentration of organic materials that made up the feed composition.

Solid part: Total solid contain certain amount of materials usually used the material unit to indicate the biogas production. Most favourable is value desired is 0.8%

Liquid part: The respective water content of each substrates are given in the table 3.1 below

Fig 3.1 Composition of Total Solid (TS) Discharge per Day

Types	Body Weight(kg)	Discharge per day(kg)	TS value of fresh discharge(% by wt)	Water to be added with fresh discharge to make the TS value 5%(kg)
Humans	50	0.5	20	0.75
Cow	200	10	16	10
Chicken	1.5	0.1	20	0.15
Pig	50	5	20	7.5

The required temperature, P_H values and Carbon- Nitrogen for good formation is given as;

a) Temperature: Mesophilic 20°C to 35°C

b) pH value: Natural pH and ranges 6.8 to 7.2

c) C/N ratio: Range from 20:1 to 30:1

The Geometric dimension usually adopted and the various chambers are as shown in figure 3.1

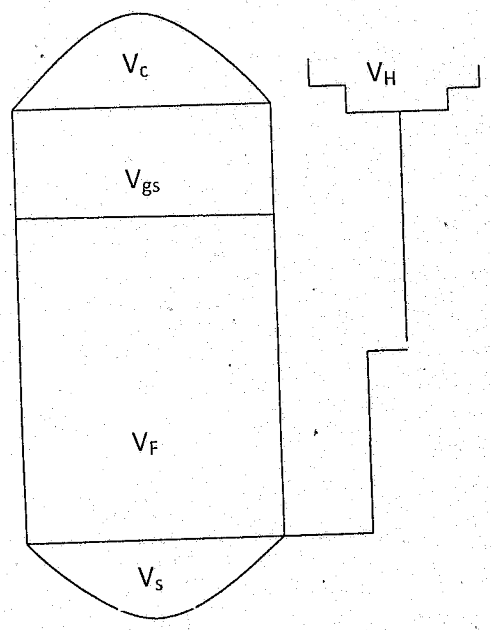

Fig 3.1 Geometrical sketch of a biogas digester

Volume of gas collection chamber = V_C

Volume of gas storage chamber = V_{gs}

Volume of fermentation chamber = V_{Fm}

Volume of hydraulic chamber = V_H

Volume of sludge layer = V_s

Total volume of digester $V = V_C + V_{gs} + V_F + V_s$

The assumption for the design and the relationship usually used are shown in following equations;

$$V_c \leq 5\% V$$

$$V_s \leq 15\% V$$

$$V_{gs} + V_{fm} = 80\% V$$

$V_{gs} = V_H$

$V_{gs} = 0.5(V_{gs} + V_f + V_s)K$

3.3 Volume of the Digester and hydraulic Chamber

3.3.1 Volume of the Biogas digester Chamber

A 75litres size steel drum was made and retention time of 14 days was adopted (Yisa and Manga ,2004).

$$V = 75L = 0.075m^3$$

Where,

V = Volume of digester

3.3.2 Volume of the gas collecting chamber, V_c

This the space within the digester that gas a stored for collection or direct use. The volume of the gas collecting chamber is determined in the given equation;

$$V_c \leq 5\%\, V$$

Where,

V_c = Gas collection chamber

V = volume of digester

$$V_c = 5\%\ of\ 0.075$$

$$= 0.05 \times 0.075 = 0.00375$$

$$V_c = 0.00375m^3 = 3.75L$$

3.3.3 Volume of sludge layer, V_s

The sludge occupies about 15% of the total digester and its volume is determined by the given equation;

$$V_s \geq 15\% \, V$$

$$V_s = 0.15 \times 0.075$$

$$= 0.001125m^3 = 1.1L$$

3.3.4 Volume of gas chamber, V_{gs}

The volume of the gas chamber is determined by the given equations;

$$V_{gs} + V_{fm} = 80\% \quad (1)$$

$$V_{gs} = 0.5(V_{gs} + V_{fm} + V_s)K \quad (2)$$

From Equation (1) ,

$$V_{gs} + V_{fm} = 80\%V$$

$$V_{gs} + V_{fm} = 0.8 \times 0.075$$

$$V_{gs} + V_f m = 0.06$$

$$V_{gs} = 0.06 - V_{fm} \quad (3)$$

From equation (3),

$$V_{gs} = 0.5(V_{gs} + V_{fm} + V_s)K$$

$$V_{gs} = 0.5(\{V_{gs} + V_{fm}\} + V_s)K$$

$$V_{gs}' = 0.5(0.06 + 0.01125)K$$

Where K gas production rate per m^3 digester volume per day $m^3/_{m^3}\,d$. For poultry litters

K=0.23

$$V_{gs} = 0.5(\{V_{gs} + V_{fm}\} + V_s)K$$

$$V_{gs} = 0.5(0.06 + 0.01125)0.23$$

$$= 0.0082m^3$$

$$V_{gs} = 8.2L$$

3.3.5 Volume of fermentation chamber, V_f

The volume of the fermentation chamber is given by the equation;

$$V_{gs} + V_{fm} = 0.06$$

$$V_{fm} = 0.06 - V_g$$

$$= 0.06 - 0.0082 = 0.518m^3$$

$$V_{fm} = 5.2L$$

3.3.6 Volume of Hydraulic chamber V_H

The volume of the hydraulic chamber is calculated using the equation;

$V_{gs} = V_H$

$V_{gs} = 0.0082L$

$V_H = 0.0082L$

$V_H = 8.2L$

Therefore total volume of the digester

$V = V_c + V_s + V_{gs} + V_{fm}$

$= 0.00375 + 0.01125 + 0.0082 + 0.0518$

$= 0.075m^3$

$= 75L$

3.3.7 Calculation of daily slurry and daily gas generated volume

The drum – type digester was used for the biogas generation for a small family as suggested by Twidell and Anthony (1986). Assuming a 75litres ($0.075m^3$) steel drum is therefore used in the design and a chosen retention time of 14 days Gaddy and usmani (1981). The volume of slurry is to be determined from the given equation;

$$V = V_f \times R_t$$

Where,

V = Volume of biogas digester

V_f = Volume of fliud per day

R_t = Retention time

Thus,

$$V_f = \frac{V}{R_t}$$

$$V_f = \frac{0.075}{14}$$

= 0.0053

= 5.3 of litres daily

Volumetric flow rate, $V_f = 0.0053m^3 = 5.3L/day$

The mass of solid required to make up this amount of slurry was obtained from the below equation.

$$V_f = \frac{m_o}{\rho_m}$$

Where,

V_f = volume of fluid per day

m_o = mass of dry solid input(kg)

ρ_m = density of solid input(kg/m^3)

Twidell *el al* (1986) gave the density(ρ_m) for dry poultry litters as 50m^3/kg.

$m_o = V_f \times p_m$

$m_o = 0.0053 \times 50 = 0.265$

$\cong 0.3kg$ dry poultry litters

Hence, 8% of slurry is the total solid,

$m_s = 8\%\ of\ m_o$

Where,

m_s = mass of total solid in substrate

$=0.08 \times 0.265 = \frac{0.0212kg}{d} TS$

The daily gas generated from the digester was also determined from the given equation.

$$m_s = \frac{V_s}{c}$$

Where,

V_s = Volume of gas generated (m^3)

c = Biogas yield per unit dry massof solid $\left(\frac{m^3}{kg}\right)$ given between $0.2\frac{m^3}{kg}$ to $0.4\frac{m^3}{kg}$ for cattle and poultry litters Yisa and Manda (2004).

$V_s = m_o \times c$

$V_s = 0.0212 \times 0.2 = 0.0424m^3$

$= 4.2L$

3.3.8 Size of the Gasholder

Practical experience shows that 40 to 60% of the daily gas production has to be stored Thomas *et al.* (2009).

This is,60% $0f\ V_s = V_g$

$60\% \times 0.0042 = 0.025m^3$

Given a 0.4m diameter empty steel drum gas holder the maximum height of storage space should be obtained from;

$$V = A \times h;$$

thus, $h_g = {}^{V_g}/_{A}$

where,

h_g = height of gas storage (m)

V_g = volume of storage space (m^3)

A = Area of storage space (m^2)

$h_g = {V_g}/{A} \quad and \quad A = {\pi d^2}/{4}$

$h_g = {4V_g}/{\pi d^2}$

$= 4 \times 0.025/3.142 \times 0.4^2$

$= 0.1/0.50272$

$= 0.198m$

$h_g = 0.2m$

A 5% safety factor is added to take care of excess gas production.

$0.05 \times 0.2m = 0.0099m$

$0.2 + 0.0099 = 0.2099m$

$\cong 0.21m$

3.3.9 Determination of efficiency of Gas produced

The efficiency of the gas produced is given by;

$$\text{Generation efficiency, } e = \frac{\text{volume of gas generated}}{\text{Expected volume}} \times 100$$

$$e = \frac{0.0042}{0.0071} \times 100 = 59.2\%$$

Gas consumption, $C_g = \frac{\text{volume of biogas}}{\text{Duration of use}}$

Assuming the gas burner will be used for 3hrs in a day,

Expected, $C_g = \frac{0.0071}{3} = 0.0024m^3/hr$

Consumption, $C_g = \frac{0.0042}{3} = 0.0014\, {m^3}/{hr}$

Efficiency, $e = \frac{0.0014}{0.0024} = 58.3\%$

3.3.10 Proportion of slurry mixture

To determine the initial volume of slurry that will be added to digester, Volume of the fermentation chamber is added to the volume of the sludge chamber as shown

$= V_{fm} + V_s$

$= 0.0518 + 0.001125$

$= 0.052925m^3$

Substrate input(Q_s) = Biomass (B) + Water (W) m^3/day

In the ratio B: W =1:3

$V_{slurry} = 52.9L$ B $= \frac{V_{slurry}}{4} \times 1 = \frac{52.9}{4} = 13.23L$

W $= \frac{V_{slurry}}{4} \times 3 = \frac{52.9}{4} \times 3$

$= \frac{158.7}{4} = 39.68L$

Initial loading,

To fill 52.9L slurring volume, 13.23L of biomass and 39.68L of water is required.

For Continuous Loading,

The influent rate daily

$Q_s = 5.3L$

This is equivalent to

Biomass (B) = $\frac{5.3}{4} \times 1 = 1.325L$

Water (W) = $\frac{5.3}{4} \times 3 = 3.975L$

3.4 Material Selection

The fabrication and economic requirement determines the material selected for the construction of the various parts of the plant. The fabrication requires that the material should be ductile, malleable, machinable, good tensile strength to withstand-inbuilt pressure, corrosion resistant. The economic requirement takes into account the cost of the materials, cost of fabrication and availability of the material.

Resistance to heat, corrosion and cost of fabrication are the main service requirement of the burner head and mixing. A stainless steel was used for nozzle because of its resistances to corrosion.

3.5 Fabrication

The fabrication process involved cutting, welding, brazing. Turning, and drilling. The individual components were fabricated based on the design and was assembled according to the working drawing. Detailed explanation of how units where constructed is given as follows;

3.5.1 Digester: The digester was fabricated from a steel sheet of 12mm gauge. The fabrication process involves cutting, turning and welding according to the design specifications. The top was covered with a steel sheet shaped into a cone. A mechanical stirrer was built from a 20mm shaft rod with a stirring handle. The stirrer was guided with bearing at the top and bottom of the digester respectively. The slurry inlet was formed and welded 100mm above the base at an angle of 45^{o}.A drain plug was placed at the base of the digester for removing the exhausted slurry. The digester was coated with black paint inside and outside. The hydrogen sulphide chamber and the gas storage chamber was cut made into cylindrical shapes from steel sheet. Other works include plumbing of the pipes in each unit. All welded joints were sealed with body feeler.

3.6 Biogas preparation and production process

The materials used for the production process include chicken litters, water, weighing balance, measuring cylinder, conical flask, milling stone, ironing fillings.

Procedure:

- The empty digester cylinder and the hydrogen iron fillings absorption chamber were prepared.

- The poultry litters was first grinded on a milling stone to get a fine particle before it was mixed with water in the appropriate ratio of 1:3 to make up the required 8% total solid concentration.

- 1kg of iron filling was prepared and poured into the hydrogen sulphide absorption chamber.

- The storage chamber was aired tight with the tap well closed to prevent leakages.

3.7 Testing

The testing of the biogas plant started from the day the feedstock was loaded to the end of the period. Gas was tested for by ignited the burner for flames.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results

The presentation of results and the observation made during the period of feeding the biogas digester is shown in Table 4.1.

Table 4.1: Result obtained

Number of Days	*Feeding	**Observation (Flame Test)
1	Charged	No Flame
2	Not charged	No Flame
3	Not charged	No Flame
4	Not charged	No Flame
5	Not charge	No Flame
6	Not charge	No Flame
7	Charged	No Flame
8	Not charge	No Flame
9	Not charge	No Flame
10	Not charge	No Flame
11	Not charge	No Flame
12	Not charge	No Flame
13	Not charge	No Flame

*feedstock: Charged – Show when feedstock was loaded into the digester.
Not charged –show when feedstock was loaded into the digester.
**Observation: No Flame-Show when flame was tested for on the burner.

4.2 Discussions

From table 4.1 it is observed that no flame was found during the digesting period which is as results of no gas generated. There was a lot of water vapour found in the digester and along the pipes. This water vapour was generated inside the digester due to the exposure of the digester to sun light.

Problem encountered during the process include loading the slurry in the digester. Lumps of undissolved feedstock are found blocking the inlet channel of the digester when pouring fresh slurry. Continuous contact with the slurry might be infectious. Evacuating exhausted slurry known as scum from the digester also constitutes a major problem as rightly observed by Gaady and Usmani (1981)

4.3 Design Analysis: The table below shows the summary of the materials used for the design of the biogas plant.

Table 4.2 Summary of design

Part	Component	Material	Dimension
Digester unit	Digester size	Steel Sheet	$0.075m^3$(0.6m × 0.4m dia)
	Stirrer	Steel Rod	0.8m × 0.02m dia
	Stirrer handle	steel Pipe	0.2m
	Slurry inlet Pipe	Steel pipe	0.8m × 0.1m dia
	Bearing	steel	
	Drain plug	Galvanized	(1/2")
Gas storage unit	Gas Storage	Steel Sheet	0.2m × 0.4m dia
	Inlet Pipe	Galvanized	0.18m(3/4")
	Outlet Pipe	Galvanized	0.15m(3/4")
Absorption unit	Absorption Chamber	Steel Sheet	0.3m ×0.2m dia
	Inlet pipe	Galvanized	0.3m(3/4")
	Outlet pipe	Galvanized	0.2m(3/4")
Burner	Burner head	Steel sheet	0.25m × 0.025m
Gas Line	Gas Line	Flexible Rubber Hose	3m(3/4")
	Control Valves	Standard	Standard

4.4 Cost Analysis

As rightly stated under the selection of material for the design of the biogas plant that such material has to be cheap and available to get. Due to this reason and couple with the fact that, a product is incomplete unless the cost of designing and fabricating are rightly evaluated, the cost analysis is thus discussed as follows:

I. Material cost
II. Labour cost
III. Overhead cost
IV. Total cost

Material cost: - this is the cost of the materials used in the fabrication of the biogas plant. The table below shows the detail of the quantity prices of material used for the fabrication.

Table 4.3: Cost of Materials

Material	Qty. Reqd	Unit Cost(N)	Total cost(N)
Steel Sheet	1	10000.00	5000.00
Steel Rod	1	400.00	400.00
Flips	1(1m)	400.00	400.00
Galvanized pipe(3/4”)	1(1m)	800.00	800.00
Elbow joint (3/4”)(Galvanized)	4	60.00	240.00
Control valve	2	250.00	500.00
Flexible hose (3/4”)	3m	80.00	240.00
Slurry Drain plug	1	400.00	400.00
Paint	2	800.00	1600.00
Burner	1	2000.00	2000.00
Poultry litters	50kg	1000.00	1000.00
Iron Fillings	1kg	300	300.00
Total			12880.00

Labour cost: - This is the total labour cost charged for constructing the biogas plant. Direct labour cost is taking as 25% of the material cost. (Olanrewaju, 2005)

Labour cost $= \frac{25}{100} \times material\ cost = 0.25 \times 12880 = \#3220.00$

Overhead cost: - this comprises the cost of design, construction supervision and other miscellaneous expenses involved during the construction of the biogas plant. Overhead cost is taking as 30% of the material cost.

Overhead cost $= \frac{30}{100} \times material\ cost = 0.3 \times 12880 = \#3860.00$

Total cost: - is the summation of all the aboved cost. (i.e. $\sum$ (material cost + labour cost + overhead cost).

Total cost = # (12880.00 + 3220.00+ 3864.00) = #19,640.00

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The biogas system was designed and fabricated to generate biogas from poultry litter. No gas was produced during the digestion period due to some conditions that was not meet.

5.2 Recommendations

For a successful production of biogas from poultry litters the following recommendations is made:

i. Poultry litters should be analysed properly to know the type that should be suitable for biogas production.

ii. Adequate time should be given to carry out the project for proper supervision and observations.

iii. Poultry litters unlike cow dung does not generate much gas therefore catalysis should be use to speed up digestion process.

iv. Gas produced from organic waste has less compression like natural gas therefore the system should be air tight.

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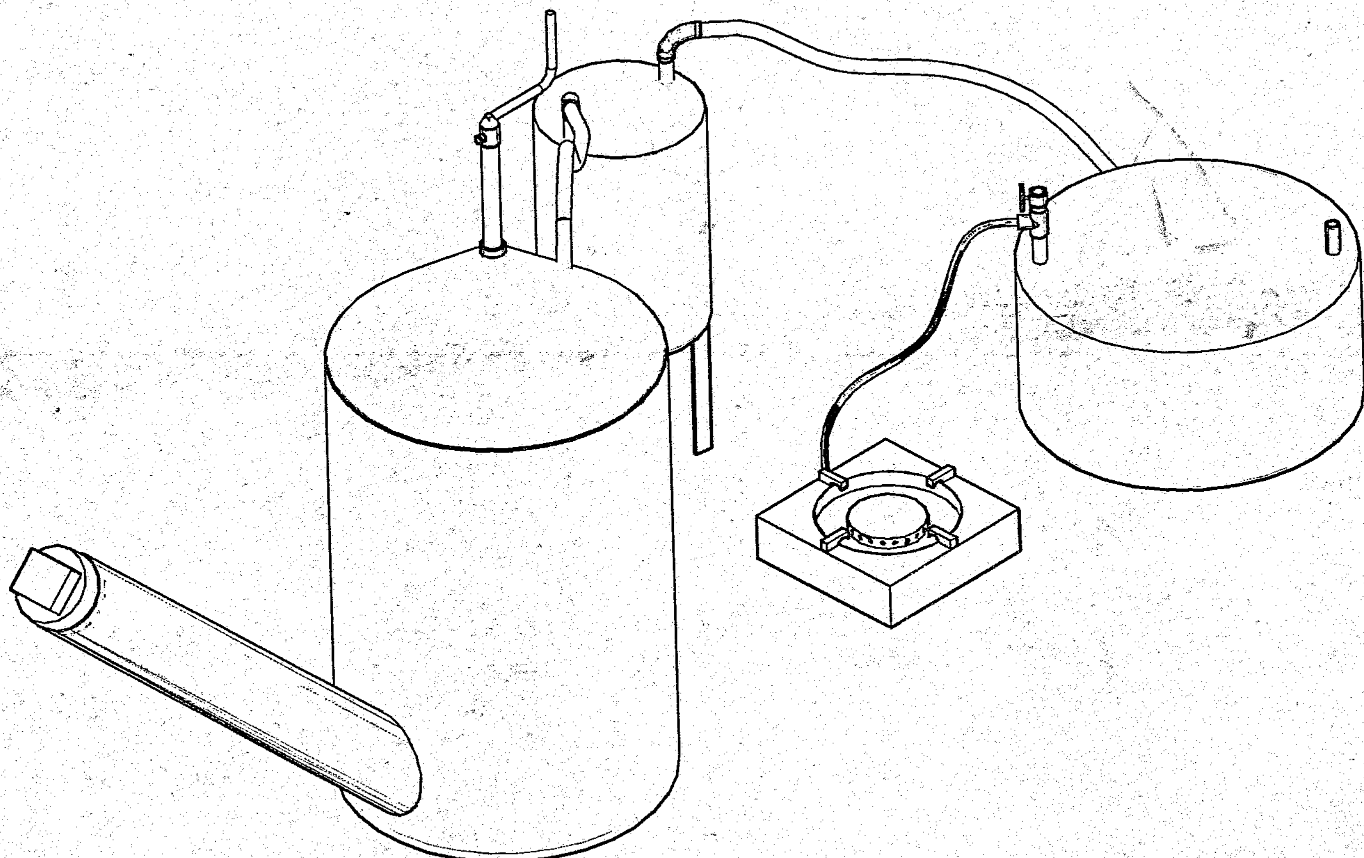

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APPROVED BY	DR. P.A. IDAH	SIGN:		
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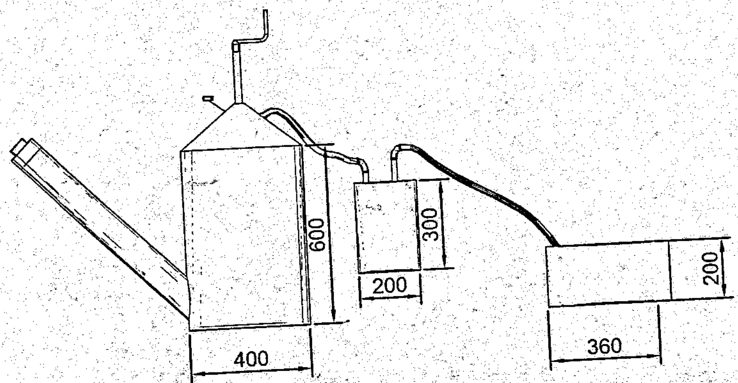
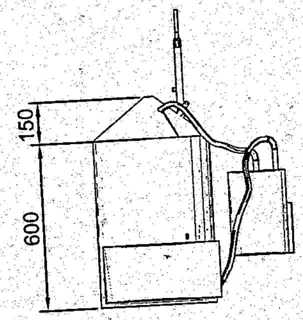


FRONT VIEW



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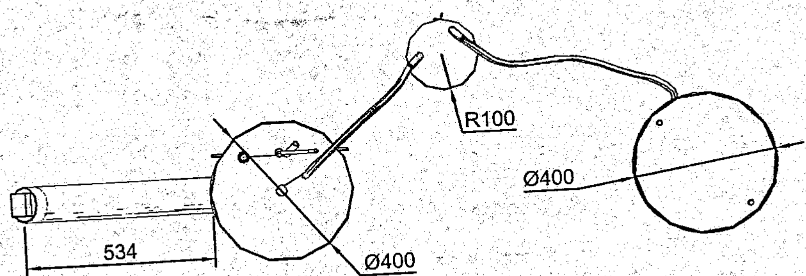
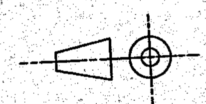


PLAN



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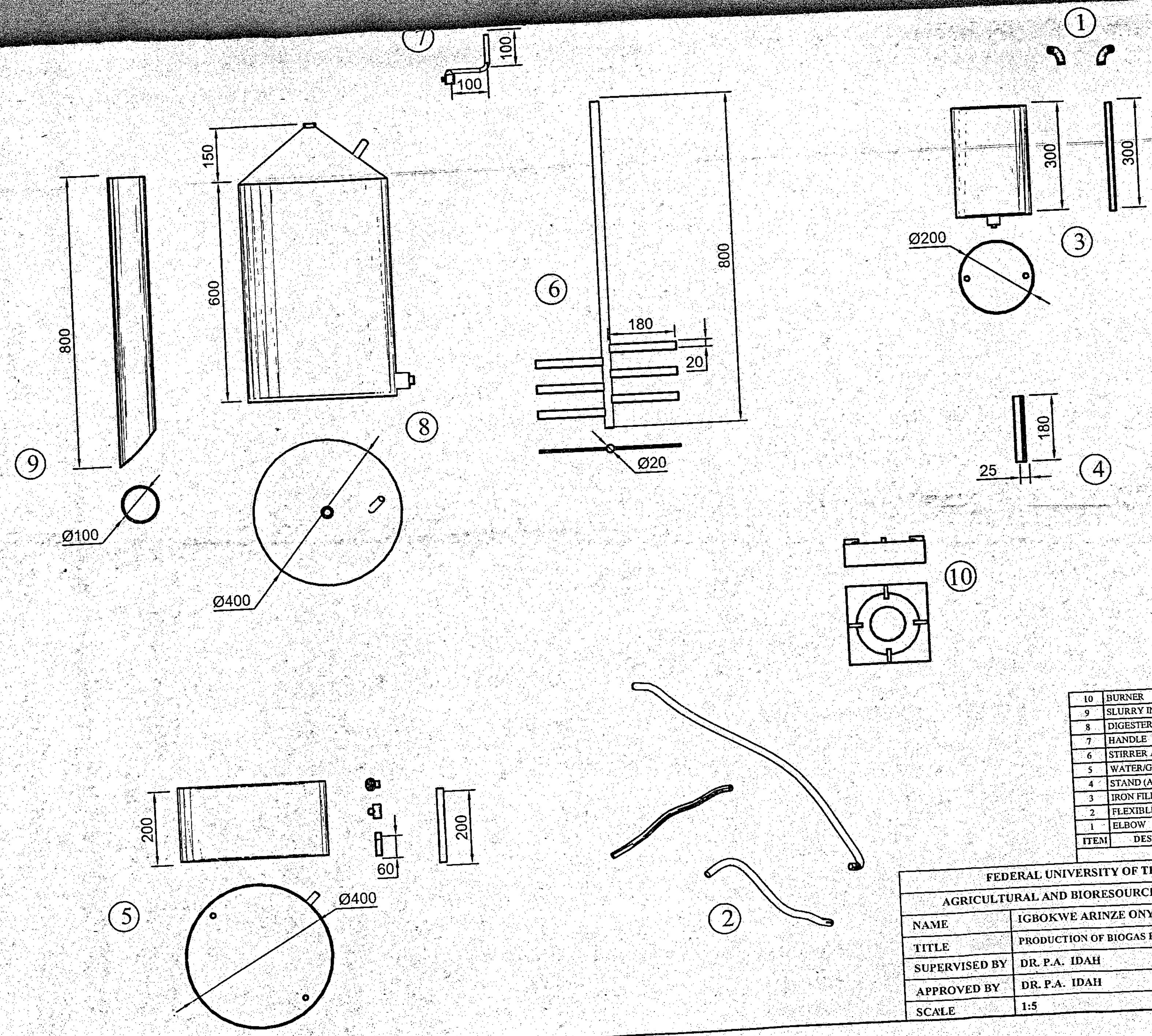

ITEM	DESCRIPTION	MATERIAL
10	BURNER	MILD STEEL
9	SLURRY INLET	MILD STEEL
8	DIGESTER	MILD STEEL
7	HANDLE	MILD STEEL
6	STIRRER AND FLIPS	MILD STEEL
5	WATER/GAS STORAGE TANK	MILD STEEL
4	STAND (ANGLE BAR)	MILD STEEL
3	IRON FILLING CHAMBER	MILD STEEL
2	FLEXIBLE HOSE	RUBBER
1	ELBOW	GALVANIZE

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