RODUCTION OF BIOGAS FROM PLANT AND ANIMAL WASTE

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DECLARATION

I, Mohammed Kabiru Kaura declares that this project is the result of my work and has never been submitted anywhere for the award of degree.

Signature

09/12/05

Date

CERTIFICATION

This is to certify that this research work was carried out by Mohammed Kabiru Kaura (2000/11137EH) and is fully adequate in scope and quality for the award of degree of Bachelor of Engineering (B.Eng) in Chemical Engineering. Federal University of Technology, Minna.

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DEDICATION

This project is dedicated to my parent, Alhaji Namadi Umar Kaura and Hajiya Hauwau Namadi Umar and most especially to Almighty Allah for his mercies.

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My immeasurable thanks goes to ALLAH (S.W.T) "The sovereign, the great helper", who gave me the opportunity to carry out this research work successfully.

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ABSTRACT

This project was aimed at producing biogas and comparing the productivity of the plant and animal wastes using rice husk and cow dung respectively. For each of the wastes a plastic digester was employed. The operating conditions for this digestion were temperature at 28^0C - 35^0C, pH value at 7.5 and 42 days retention times.

From the experiment results, it was observed that the total volume of biogas produced for the period of time observed were 1767.0 cm^3 for the rice husk, 2280.0cm^3 for the cow dung and 1575.0cm^3 for the mixture of cow dung/rice husk respectively. In addition the percentage composition of methane (CH4) obtained were 56.92%, 61.80% and 54.84% for the rice husk, cow dung and the mixture of cow dung/rice husk. From the data obtained above, it could be concluded that the total volume of biogas produced was found to be higher from the cow dung than the rice husk. Also the quality of the gas obtained was observed to be higher from the cow dung than the rice husk.

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CHAPTER ONE

1.0 INTRODUCTION

Biogas is a combustible gas generated by fermentation of organic materials, such as animal, human, agricultural and industrial wastes, in the absence of air. Thus, biogas is produced as a result of anaerobic digestion.[10] Anaerobic decomposition occurs naturally in swamps, water - logged soils and rice fields, deep bodies of water etc. Energy obtained from this gas can be used for cooking, lighting, electricity generation and water pumping. Energy plays a crucial role in the technological and economic development of nation.

Crude oil has been the main source of energy in most countries over the years. The need to offset some of economic set back brought by increasing fuel costs and chronic lack of foreign currency reserves compelled many developing countries to search for native renewable energy source. One of the alternatives is the use of biological raw materials in the production of higher value fuels.

Currently, the animal generation of agricultural and domestic waster in the rural and urban areas runs into the thousands of tones. In most parts of the world anaerobic digestion of these wastes has received the most attention as a potential sources of gaseous fuels. Many digesters have been installed by industry and from owners for combined waste treatment and energy application. The primary benefit of these digesters is waste treatment and fertilizer production with biogas production as secondary.[2]

The medium biotechnology unit gas produced is almost always used for domestic cooking or lighting. The feedstock is usually human or animal waste and plants waste. The designs of anaerobic digesters are basically of two types; batch and continuous type digester.

The overall technology involved is within the reach of local experts hence the exploration into the utilization of this is in both vital and practicable, so that people living in the remote areas tropical or subtropical countries, where electricity is not available and fuel gas is hard to get have a very cheap abundant and efficient fuel of the gas from cow dung or other agricultural wastes such as rice husk.

Research activities have continued worldwide to develop, improved process for combined waste disposal and methane production system. Much of the current research is aimed at improvement of the digestion process to reduce the cost, to increase methane yield and production rates.

The aim of this research work is to produce biogas and compare the productivity from animal and plant waste using cow dung and rice husk as sources of raw materials.

1.2 AIMS AND OBJECTIVES:

The aim of this project is to produce biogas and compare the productivity of plant and animal waste using rice husk and cow dung respectively. And the project objectives are as follows: -

1. Utilization of the animal and plant waste to produce profitable fuel and fertilizer for farming.
2. Curbing out the problem of mass deforestation.
3. Improvement of the digestion process to reduce methane cost through increase in the methane yield and production.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 FUEL:

Fuel generally refers to any substance that will easily combine with oxygen to release intense heat that could be used to meet the need of society. It is particularly useful if it is readily available in large quantities reasonable cost.

There are variety of fuels, but could be classified as;

- Solid fuels such as coal, wood, paper etc.
- Liquid fuels such as paraffin, light fuel oil, heavy fuel oil.
- Gaseous fuel, such as cooking gas, natural gas and biogas.

2.2 HISTORICAL ORIGIN OF BIOGAS:

Cooking gas has been well known in the middle of nineteenth century by the Europeans who mainly used animal refuse through biological anaerobic fermentation. After the war in 1945 to the early periods, of 1973 the increasing availability of petroleum products of which cooking gas is one, the said gas from petroleum based resources. This joy did not thrive very long. It was short lived because of the unilateral like in price of crude oil by OPEC in the middle of 1973 which sent shock waves to all the highly industrialized nations.

Since then, industrialized nations have been looking for alternative raw materials resources and of recent, developing countries are showing interest in doing the same as even the continued existence of crude petroleum and natural gas deposits are becoming more and more uncertain.

With this state of anxiety, the industrialized nations and some developing nations are looking back to fast methods (i.e. using biomass) as being one of the most viable remedy with the aim of improving it and increasingly becoming profitable.

At present, China is a good example of a country where the advantages associated with biogas is greatly exploited. In 1976, there was 410,000-biogas plant in the country.

But the world centre of biogas research is today to be found in Indian. These were found to have biogas plant in operation ranging in size from about 8 cubic meters per day to 500 cubic meters per day.[3]

2.3 BIOMASS AND ITS TYPES:

Biomass can have broader definitions, but in the context of biotechnology, it is generally taken to mean "all organic matter that grows by the photosynthetic conversion of solar energy". The sun either directly or indirectly to the principal source of energy on earth. Its power converted to organic form – biomass by green plant, algae and photosynthetic bacteria. The biomass produced annually, by photosynthesis on land and in the oceans, contains an estimated 3×10^{21} joules of energy. Some 10 times the yearly worldwide human consumption.[8]

There are numerous types of biomass, which include: -

I. Agricultural waste e.g. plant remains i.e. cornstalk, sorghum stalk and leaves rice husk etc. and animal waste product.
ii. Plant produce and animal remains such as cow dung.
iii. Energy crops (wood, grains).
iv. Municipal waste.
v. Aquatic plants algae

2.3.1 GENERAL CONSTITUENTS:

Biomass could be generally said to consist of the following:

I. Polysaccharides
ii. Proteins
iii. Non-protein Nitrogenous compounds

iv. Lipids

v. Volatile fatty acids

vi. Water (if fresh)

The percentages of each of these vary from one types of biomass to the other.[9]

2.3.2 BIOMASS RESOURCE BASE:

The current and future contribution of biomass to energy supplies will be based on the following systems:

- Growing aquatic plant species on energy farms, solely for their conversion to energy.
- Collecting forest, agricultural and animal residues for energy.
- 930 harvesting forest trees, which are not suitable for lumber, paper or other forest products.

2.3.3 CONVERSION OF BIOMASS TO USEFUL ENERGY FORMS:

Many processing options can be applied to the conversion of biomass to energy or chemicals. These processes range in state of development from laboratory scale to commercially proven processes. Fig. 1.0 shows these alternative processing paths, as well as the range of products and markets. These products can be used directly or can be upgraded further to serve markets with more critical needs or to produce more economically transportable products. For example, direct combustion.

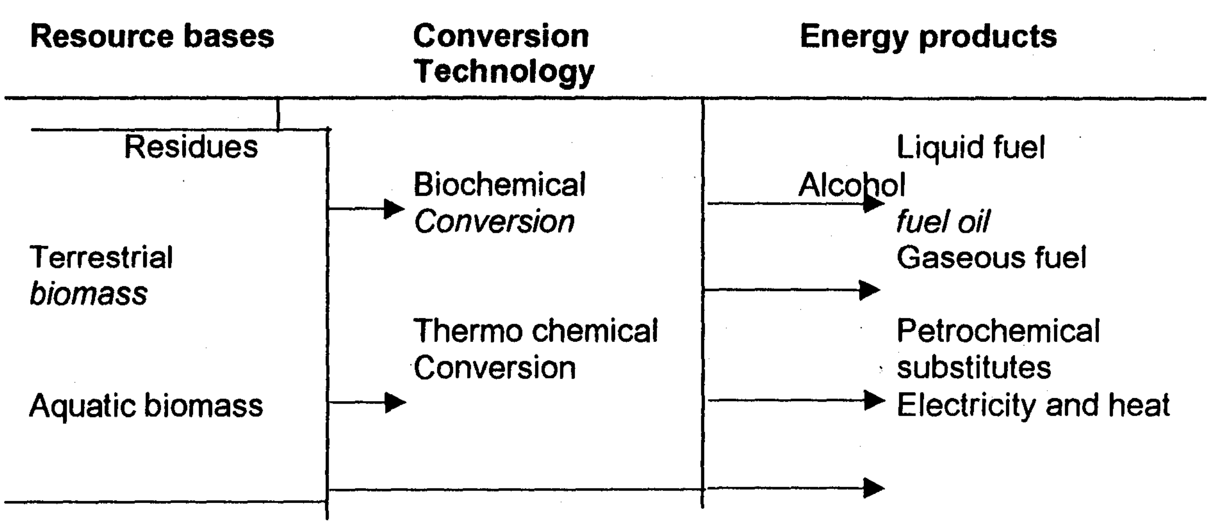

Fig. 1.0 Alternative processing paths and products for biomass resources.[3]

Biomass can produce steam for direct use for electricity generation. Also ethanol from fermentation of biomass can be used directly as a motor fuel or can be converted to ethylene, a major petrochemical feedstock for polymers. Biomass can also be converted to useful fuels by either biochemical or thermo chemical process. In the former, biological organisms are used to process the biomass, followed by initial chemical breakdown in some cases. High temperatures, catalysts and sometimes-high pressures.

2.3.4 CONVERSION EFFICIENCY:

Conversion efficiency varies considerably with the biomass feedstock, which is used. The biomass will vary in heating value, ultimate analysis, moisture content and bulk density. Some of these characteristics differ only slightly among various forms of biomass, while others vary greatly.

The energy content or heating value determined of biomass varies with water content, chemical composition and density. The fresh weights of plant tissue include range from 95% to water to 30 to 35% moisture for some words. The ultimate analysis is biomass describes its composition in terms of amounts of each constituent present.

The bulk density of biomass greatly affects the economics of using biomass for fuels, since those forms of biomass, which are less dense, more costly to transport and require more storage space.

2.3.5 ADVANTAGES AND DISADVANTAGES OF BIOMASS AS A SOURCE FOR BIOGAS:

1. Their use serves in most cases as an environmental pollution control.
2. It is continually renewable energy source.
3. It is cheap and readily available
4. The by-product from animal waste digestion is useful as high-grade manure for farm crops.
5. Small scale conversion system is inexpensive to manufacture.[11]
6. The use leads to no long – term increase in the atmospheric carbon dioxide content.

2.3.6 DISADVANTAGES:

1. Their availability may be periodical and non-commercial guaranty wise.
2. The kinetics of reaction is not well known in the anaerobic digestion of animal waste; hence design of digesters using performance equation is not encouraging.[11]
3. Large – scale production of energy from biomass faces competition with the synthetic fuels, in particular, there is currently not a large energy market for ethanol and methanol liquid fuels produced from biomass.[11]

2.4 ANIMAL AND AGRICULTURAL WASTES:

Animal wastes are the undigested parts of food taken by an animal. They are derived directly or via the food chain from plants, which have been consumed as food by the animals. Because the animal for metabolic processes has not used it, they are called waste products.

In agricultural terminology, anything which is either part of an animal or a plant or a product there form which has no use or is put to use agricultural are termed agricultural waste, through they may be useful in one way or the other.[10]

2.4.1 CHARACTERISTIC OF ANIMAL WASTE:

The characteristics of animal waste is by and large that of the original food taken by an animal except that during digestion most of the digestion have been digested and the resulting wastes are therefore deficient in these constituents when compared to the original feed.[12]

Also, the waste product do contain some bacteria from the digestive tract and other foreign material due to enzymatic secretions during digestion and contact with other material after being passed away, such as urine, sand etc. the table 1.0 gives further insight into the composition of animal waste.[12]

Table1: COMPOSITION OF ANIMAL WASTE:

MATERIAL	HEN (2KG)	PIG (50KG)	BEEF CATTLE	DIARY CATTLE
Total solid dry Wt Kg/day	0.026	0.315	3.48	4.92
Volatile (% dry basis)	70.00	85.00	80.00	80.00
Nitrogen (% dry basis)	5.00	4.50	3.70	5.00

Other compounds or elements may be present in traces due to contamination earlier mentioned. Animal waste of cattle and poultry are usually solid under normal condition while those of pugs are more often than not in slurry form. Other constituents likely to be present in minute quantities are: -

- Ammonia
- Urea

- Lactic acid
- Acetic acid
- Moisture
- Salts etc.

2.4.2 AVAILABILITY OF ANIMAL WASTE:

Several factors determine the availability of animal wastes. They are:

1. Availability of animal
2. Mode of keeping the animal
3. Accessibility to animal waste sites

Animal waste as a source of biomass has the advantage that it is not competing with others less. In Nigeria animals of different species are abundant with varied availability from location to location. It is not surprising that the source of animal protein for most Nigerians is beef and chicken.

The waste considered in this experiment for methane production is that of cattle cow dung and poultry droppings are relatively cheap when viewed form the fact that they are mostly considered waste although they could be used as farm manure. However, this practice is fast fading out due to the improved performance of chemical fertilizer. 80% of farmers in Nigeria now adopt the chemical fertilizer procedure. In view of the above biogas production from biomass offers a cheaper production rate when compared with that produced from petroleum resources.

2.4.3 PRODUCT YIELD:

Many researchers have been carried out on the product yield from animal wastes.

In product yield of cattle, pigs and poultry are given in table 2.

Table 2.0 METHANE YIELDS OF ANIMAL WASTERS:

ANIMAL	TYPICAL EXPERIMENTAL YIELD/KG MANURE	THERMAL CONTENT		
		CH_4	C_{O2}	MJ/M^3
Cattle	200 – 350L	57.5	46.5	23.0
Poultry	550 – 650L	70.0	30.0	28.0
Pig	400 – 500L	65.0	35.0	26.0

The table shows that the CH_4 yield pig waste is second highest, but considering the fact that other factors such as population of animals and physical condition of animal wastes militate against its choice, it is therefore obvious that cow dung and poultry chopping are the better choice in Nigerian context.

2.4.4 ENERGY CROPS:

Crops wastes, if not used, are assumed available for collection and recycled fro their energy and nutrient value, if crops are to grown expressly for energy purpose, a number of factors must be considered.

- Crop yield, i.e. sohr energy conversion efficiency.
- Energy i.e. ratio of energy in the crop yield to those energy inputs for plantation, cultivation and harvesting.
- Water usage
- Ease and method of conversion

Five plant categories considered for their energy value are trees, forest and starch crops, algae and wastes. Crops wastes are from the competitive use point of view ideal but their low density and variable quality make them most conducive to local use. As approximation half of each crop is 'waste' cellulose, increased crop

2.5 FERMENTATION AND DIGESTION:

Fermentation and anaerobic digestion are the two-biochemical processes of interest. In a board sense fermentation refers to any chemical change of organic matter that is accompanied by effervescence without participation of oxygen.(13) It is also referred to DIGESTION.

Alcohol (ethanol) is the principal product of the fermentation processes appropriate to biomass conversion. Anaerobic digestion is the decomposition of any organic material by the metabolic action of bacteria without the participation of atmospheric oxygen. Methane and carbon dioxide are the main products of the decomposition. The source of oxygen in the carbon dioxide is the combined oxygen in the organic molecules and in the waste. The important difference between fermentation and anaerobic digestion are the nature of the product produced and the character of biological contribution. Fermentation produces a liquid product in the presence of enzymes while anaerobic digestion yields a gaseous product as a result of the metabolic activity of bacteria.

There are two main types of digestion namely:

i. Aerobic Digestion: This type of digestion needs the present of air or rather oxygen and in which without it digestion will not take place. The bacteria responsible for this type of process cannot function without oxygen.

ii. Anaerobic Digestion: This type is the type of substrate digestion in which the substrate is essentially oxygen – free or air free.

2.5.1 BIOCHEMICAL CONVERSION BY ANAEROBIC DIGESTION:

As mentioned earlier, the anaerobic decomposition of complex organic molecules to methane and CO_2 is carried out by May different species of organism (bacteria) acting together in the total absence of oxygen.

The biological polymers, which are usually present in biomass such as polysaccharides, protein and lipids, must be broken down to simpler substances before they could be conversed to methane.

The overall aerobic digestion may be broken down or divided into three stages process. The first stage process consists of microorganism attacking the complex organic molecules such as cellulose and starch converting them into soluble organic compounds such as fructose and glucose. Thus polymers are transformed into soluble monomers through enzymatic hydrolysis.

$n (C_6H_{10}O_5) + n H_2^O \xrightarrow{\text{enzyme hydrolysis}} C_6H_{12}O_6$ (I)

The monomers become the substrate for the micro-organism in the second stage where soluble matter are converted into soluble organic acids and by products like C_{02}, H_2, NH_3 and H_2^O by a group of bacteria collectively called "acid formers".[5]

$n (C_6 H12O_6) \xrightarrow{\text{acid forming bacteria}} 3n CH_3 COOH$ (ii)

In the third and the last stage, methanogenic bacteria act on the organic acids producing CH_4 and Co_2 in two distinctive routes. One is by reducing Co_2 in the presence of hydrogen produced by other bacterial species i.e.

$Co_2 + 4H_2 \xrightarrow{\text{reduction}} CH_4 + 2H_2O$

The other route is by metabolizing the acetic acid i.e.

$CH_3COOH \xrightarrow{\text{Methane forming bacteria.}} CH_4 + CO_2$

Other important reaction in the production of methane include hydrolysis of carbon (iv) oxide into carbonic acid that is further reduced to methane and water i.e.

$Co_2 + H_2^0 + \xrightarrow{\text{hydrolysis}} H_2Co_3$

$H_2Co_3 + 4H_2$ reduction $CH_4 + 4\ 3H_2^0$.

Cellulose has the basic structure of polymerized glucose units formed in a chain of indefinite length and can complex branching networks. Bacteria having cellulose capacity reduce the chain and branches first to diametric and then nonnumeric sugar molecules. These are then convert to organic acids.

In the reaction sequence four different bacterial groups are involved as shown in

Fig. 2.0 below.

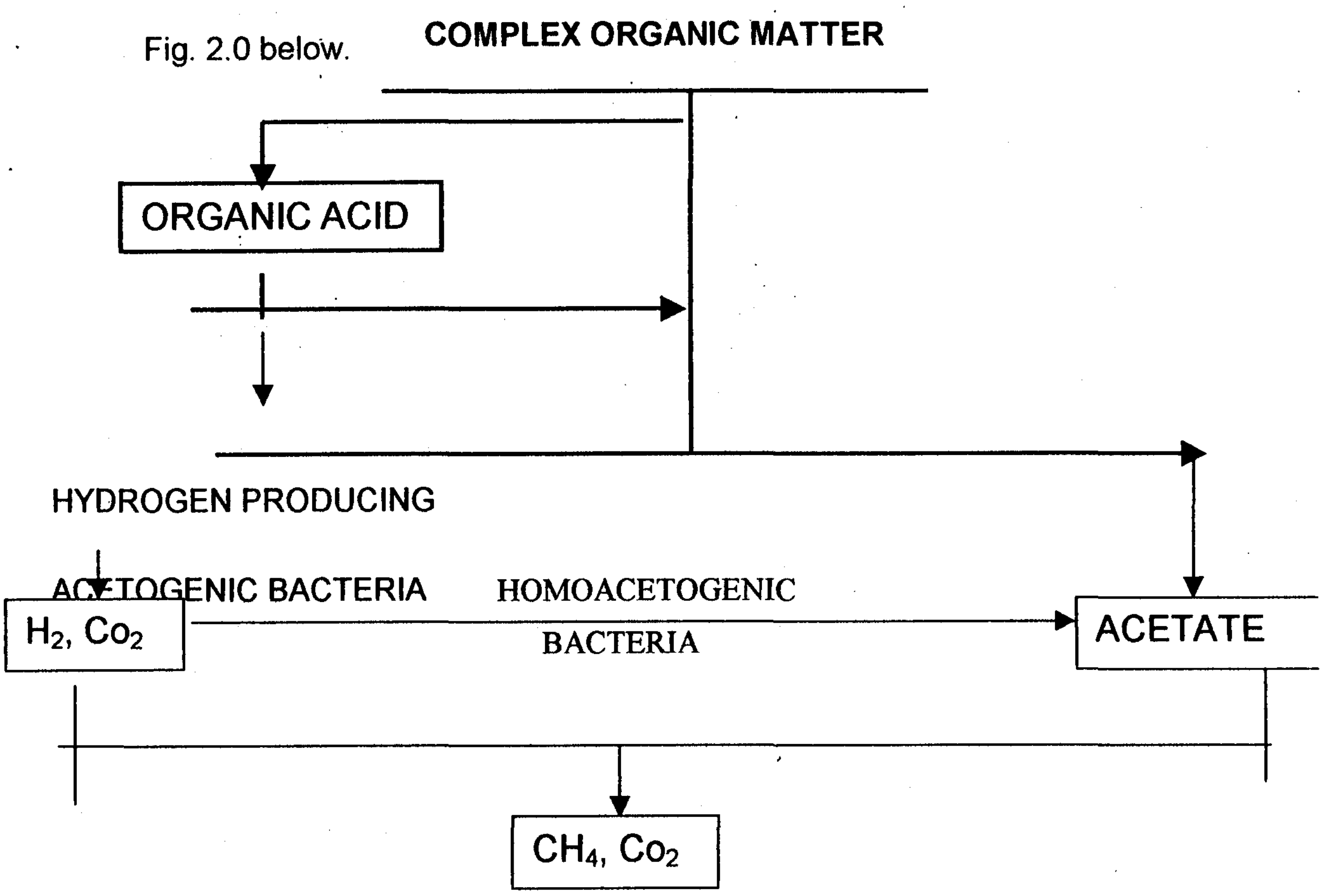

Fig 2.0 SUCCESSIVE STAGES IN ANAEROBIC DIGESTION

2.5.2 METHANE (BIOGAS) FROM ANAEROBIC DIGESTERS:

Methane is a gas that contains molecules of methane with one atom of carbon and four atoms of hydrogen (CH_4). It is the major component of the "natural gas used in many homes fcr cooking and heating. It is odorless, colorless and yield about 1,000 British Thermal Unit (BTU) {252 kilocalories (kcal)} of heat energy per (0.028 cubic meters) when burned.[2] National gas is a fossil fuel that was created years ago by the anaerobic decomposition of organic materials. It is often found in associated with oil and coal.

The same type of anaerobic bacteria that produced natural gas also produces methane today. Anaerobic bacteria are some of the oldest forms of life on earth. They evolved before the photosynthesis of green plants released large quantities of oxygen into atmosphere. Anaerobic bacteria down or digest organic materials in the absence of oxygen and produce "biogas" as a waste product. (Aerobic decomposition, or composing, requires large amounts of oxygen and produces heat). Anaerobic decomposition occurs naturally in swamps, water – logged soils and rice field, deep bodies of water and in the digestive system of termites and large animals. Anaerobic processes can be managed in a "digester" (an air tight tank) or a covered lagoon (a pond used to store manure) for waste treatment and odor control. Except in very large systems, biogas production is a highly useful but secondary benefit.

Biogas produced in anaerobic digesters consists of methane (50% - 80%) carbon dioxide (20% - 50%) and trace levels of other gasses such as hydrogen, carbon monoxide, nitrogen, oxygen and hydrogen sulfide. The relative percentage of these gasses in biogas depends on the feed material and management of the process.[2]

2.5.3 DIGESTER DESIGNS:

Anaerobic digesters are made out of concrete, steel, brick, or plastic. They are shaped like basins or ponds and may be placed underground or on the surface. All designs incorporate the same basic components for using the biogas and a system for distributing or spreading the effluent (the remaining digested material). There are two basic of digesters: batch and continuous.

Batch type digesters are the simplest to build. Their operation consists of loading the digester with organic materials and allowing it to digest. The retention time depends on temperature and other factors. Once the digestion is complete, the effluent is removed and the process is repeated.

In continuous digester, organic material is constantly or regularly fed into the digester. The material moves through the digester either mechanically or by the force of the new feed pushing out digested material. Unlike batch-type, continuous-type, produce biogas without the interruption of loading material and unloading effluent. They may be better suited for large-scale operations.

There are three types of continuous digesters: Vertical tank system, horizontal tank or plug-flow system and multiple tank system. Proper design, operation and maintenance of continuous digester produces a steady and predictable supply of useful biogas.

Many livestock operations store the manure they produce in waste lagoons, or ponds. A growing number of these operations are placing floating covers on their lagoon to capture the biogas. They use it to run an engine/generator to produce electricity.

2.5.4 THE DIGESTION PROCESS:

Anaerobic decomposition is a complex process. It occurs in three basic stages as a result of the activity of a variety of microorganism. Hydrolytic bacteria are utilized in the first steps of production by reducing large macromolecules (proteins, carbohydrates) into much smaller molecules such as amino acids, sugars and alcohols. Transitional bacteria further reduce these molecules into acetic, H_2 and $C_{02.}$ The final step of break down is accomplished by mathanogenic bacteria, which reduce the molecules into methane (CH_4) and carbon dioxide (CO_2).

Biogas production is also a temperature – dependent process. The process takes place in either psychophysics (<25^{0}C) mesophiplic (25 - 40^{0}C) or thermophlic (45^{0}C - 60^{0}C) temperatures.[2] There are advantages and disadvantages of each. The use of mesophilic temperatures, allow the process of production to be more stable by helping to inhibit excessive ammonia (NH_3) production, but these temperatures do not destroy potentially harmful bacteria. Thermophilic temperature, while destroying bacteria and allowing increased loading rates due to faster degradation, also cause greater instability because of increased free ammonia load. Though some ammonia is necessary for biogas production, the combination of the two (thermophilic temperature and excessive free ammonia), can inhibit and destroy the bacteria that is necessary for biogas production (Ange lidaki and Ahrıng 1994). Also found that reducing the temperature to 55^{0}C when the NH_3 loading rate was high increased stability within the process and also increased biogas yield. Kottwitz and Schulte (1982) demonstrated that biogas from beef cattle manure could be produced in a mixed, low moisture content digestion process at a rate of 0.3L per g of volatile solids.

To optimize the digestion process, the digester must be kept at a consistent temperature as rapid changes will upset bacterial activity. In most area of the United States, digestion vessels require some local of insulation or heating. Some installation circulate the coolant from their biogas – powered engines in or around the digester to keep it warm, while other burn part of the biogas to heat the digester. In a properly designed system, heating generally results in an increase in biogas production during colder periods. Studies on digesters in the north-central areas of the country indicate that maximum net biogas production can occur in digesters maintained at temperature as low as 72^{0}F (22.2^{0}C).[2]

2.5.5 PRODUCING AND USING BIOGAS:

As long as proper conditions are present, anaerobic bacteria will continuously produce biogas. Minor fluctuations may occur that reflect the loading routine. Biogas can be used for heating, cooking and to operate an internal combustion engine for mechanical and electric power. For engine application, it may be advisable to scrub out hydrogen sulfide (a highly corrosive and toxic gas). Very large-scale systems/producers may be able to sell the gas to natural gas companies, but this may require scrubbing out the carbon dioxide.

2.5.6 ECONOMIC CONSIDERATION:

An aerobic digester system costs vary widely. Systems can be put together using off-the-shelf material. There are also a few companies that build system components. Professionals whose major focus is research, not low cost, have designed sophisticated systems. Factors to consider when building a digester are costs, size, the local climate and the availability and type of organic feedstock material.

In the United States, the availability of inexpensive fossil fuels has limited the use of digesters solely for biogas production. However, the waste treatment and order reduction benefits of controlled anaerobic digestion are receiving increasing interest, especially for large-scale livestock operation such as diaries, feedlots and slaughterhouses. Where costs are high for sewage, agricultural, or animal waste disposal and the effluent have economic value, anaerobic digestion and biogas production can reduce overall operating costs. Biogas production for generating cost effective electricity requires manure from more than 150 large animals.[2]

Below ground, concrete anaerobic digesters have proven to be especially useful to agricultural communities in parts of the world such as China, where fossil fuels and electricity are expensive or unavailable. The primary purpose of these anaerobic digesters is waste (sewage) treatment and fertilizer production. Biogas production is secondary.

2.6.0 RICE HUSK AND ITS UTILIZATION:

Rice husk continues to remain the largest identifiable non-intensively developed agricultural commodity existing on earth. The use or disposal of husk has frequently proved difficult because of the tough, woody, abrasive nature of the husk, their low nutritive properties, and resistance to weathering, great bulk and high ash content. On a worldwide basis, about 80 million (20 percent of paddy production) tones of husk must be disposed off annually.[14] This is generally done in an unscientific manner, which reflects the inadequate development being applied to this highly arranged commodity.

2.6.1 STRUCTURE AND COMPOSITION OF RICE HUSK:

The lemma and pale a together with the sterile glumes and a short section of rechilla constitute the husk of rice. The husk content in different cultivars varies from 14 percent to 28 percent ( ) longer; thinner paddy had greater proportion of husk.[14]

Four different structural layers have been identified; they are:-

a. The outer epidermis, coated with a thick cuticle of high-solidified sinuous cells, among which the surface hairs are found.

b. Spongy parenchyma cells, both elongated with rather waxy outline and short or quadrilateral.

c. Sclorenchyna or hypoderm fibres, also with thick and some what lignified and silicified walls; and

d. Inner epidermis of generally isodiametric cells.

The composition of rice husk varies widely.(14) Crude protein, 1.70 to 7.26 percent, crude fat, 0.38 percent, nitrogen free extract, 24.70 to 38.79 percent; crude fibre, 31.71 to 49.92 percent; ash 13.16 to 29.04 percent; pentasans, 16.94 to 16.94 to 21.95 percent; cellulose 34.34 to 43.80 percent lignin, 21.40 to 46.97 percent. Cellulose in the major carbohydrate of husk, with hemicelluloses (chiefly pentasans) in somewhat small quality. Total acids extracted from husks were 57.8I 1.4meg per kg of which 30.3 meg or 52 percent were organic acids.[14] The following aromatic acids are frolic, vanillic and p – coumaric acids. The following organic acids (meg/kg) are in rice husk; acetic 3.5, aromatic 1.34,citric, 5.76, fumaric, 2.38, mateic 3.20, oxalic 11.47 and succinic 2.28.

2.6.2 PROPERTIES OF RICE HUSK:

The peculiar silica – cellulose structural arrangement of the husk result in an object that dos not turn or even liberate heat in a manner reassembling that of any organic substance. These minutes silica crusted tubular structure offer an inherent resistance to burning. In its normal available shape the protective envelope has apparent density that is quite low, usually 112.13 to 144.17kg. Im^3. After grinding the apparent density is 271.31 to 400.46kg/ m^3 well below that normally expected, since rice husk have a density of approximately 720.83kg/ m^3.[14]

2.6.3 INDUSTRIAL USES OF RICE HUSK:

✓ **FERMENTATION:** A process has developed by the USDA, NRL, using the organic clostidium acetobutylicum for fermenting of xylose or pentose or sugars present in husk to liquid fuels or solvent.

✓ **HYDROGENATION:** Bench – scale experiment on the conversion of paddy husk to fuel oil by reaction with carbon-monoxide and water gas in the presence of catalyst and water carried out, under optimum conditions more than 99 percent of organic matter in the husk was converted into liquid and gaseous products. Out of this, 40 – 50 percent is benzene – soluble liquid product and the rest are gaseous.[14]

✓ **HUSK AS FUEL:** Husk is one of the most abundant renewable agricultural based fuel materials in the world that can be feasibly collected. The production of rice husk is about 80million tones per year, equivalent in energy to about 170million barrels of oil. However, the husk supply must be a realistically appraised for its potential, not purely by multiplication. The wider spread, very small sources of husk production affect critically the potential for commercial or beneficial utilization.

2.7.0 MAJOR PRODUCTS OF ANAEROBIC DIGESTION:

The major product as discussed earlier is methane and carbon dioxide.

a. **Methane:** This is a saturated hydrocarbon, which exists in gaseous from at room temperature and atmospheric pressure. It is the most reduced or least oxidized carbon atom whose subsistent H_2 atoms form a regular tetrahedron. It is combustible and has characteristics similar to the members of the alkane homologous series, itself being the first member of the series. On combustion, it burns to give water and carbon dioxide according to the reaction.[9]

$CH_4 + 2O_2 \longrightarrow 2H_2O + Co_2$

Other physical properties of methane are given below:-

Vapour pressure at 20^0C	=	- 191.8mmHg
Density	=	0.7167 G/R
Specific gravity	=	0.415
Molecular weight	=	16.04g
Boiling point	=	$161.4C^0$
Solubility in water	=	0.40CC(from Ref. 9)

b. Carbon dioxide: This is the most oxidized and least reduced carbon atom. It is an odorless, colorless and tasteless gas, which turns limewater milky. It is denser than ordinary air and has the ability to extinguish fire. Hence, its quantity is high proportion in a normal cooking gas is highly undesirable. Other physical properties of Co_2 gas are given below: -

Vapour pressure at 20^0C	=	114.4mmhg
Density	=	1.9768 G/L
Molecular weight	=	44g
Melting point	=	57.5^0C
Heat of fusion	=	1900 cal/mol
Boiling point	=	78.4^0C
Heat of vaporization	=	6030 cal/mol.

Gas evolved from a properly functioning an aerobic digester will contain approximately the mixture of gasses shown in table below which in turn represent the products of the several simultaneous fermentation.[9]

2.7.1 INHIBITORY CONDITIONS:

✓ **Temperature Effect:**

The production of CH_4 depends on the bacterial population and activity and temperature is the primary factors affecting the growth rate of microorganisms. Temperature of 5^0C and below tends to keep even the low temperature adopted bacteria in a state of dormancy. While that above 7^0C leads to denaturisation of bacteria and in most cases, death. Therefore, the wrong temperature range for any particular digestion will inhibit the reaction.

For thermophlic methanogens which is the case with those in cow dung temperature of 35^0C and below are inhibitory.[9] Disturbance of temperature by more than 3^0C has profound effect on the bacterial population. Therefore, reoccurrence of this may lead to cease of CH_4 production. This is more prominent in thermophillic digesters. Thermophlic processes generally have the highest decomposition rates and hence have reduced residence time. Small-scale processes are better operated under mesophilic condition.

Concentration of feed slurry: A too solid or high concentrated slurry is not suitable for digestion since homogenous mixing will be difficult.[9] so also a too dilute slurry is not suitable either, as the bacteria will get enough substrate to act on. Therefore, in digestion, the substrate should be relatively dilute equivalent to solids concentrations of 7 – 12% of the original biomass material.

✓ **PH of slurry:**

Although it is necessary to maintain a mildly acidic regime, there is usually a tolerance around the neutral value of PH scale. A highly acidic medium will tend to hydrolyze the cellulose and hemicelluloses in substrate into hexosans (Glucose) and pentosans (Xylose) while a highly or medium basic regime will even have an accelerated hydrolysis of cellulose to Glucose and Xylose. Therefore, the PH should be maintained between 6.8 to 8.0.[2] and preferably between 7.0 and 7.2. This need adjustment during starting up period.

✓ **Non-Mixing Effect:**

Without mixing it has been discovered that the rate of CH_4 production is highly reduced. This is because of possible overcrowding of microorganism. Also bacteria action will be slowed down because of poor escape of gaseous product from slurry that inhibits their actions.[9]

✓ **Retention Period:**

This means the number of days the waste has remained in the digester before it is drawn off a supernatant fluid. The volume of gas produced per unit weight increase rapidly with increase in retention period up to threshold point. A longer retention period would need bigger tanks that also will increase the gas production.

2.8.0 THE IMPORTANCE OF BIOGAS PRODUCTION:

Biogas plant generates both cheap fuel and manure and the fuel can be used for heating, lighting, running oil engines, cooking, generating electricity and water pumping. The fully digested sludge remaining in the digester can be used as farm manure as it is finely divided and can mix very well with soil particles. Biogas production reduces facial pathogens and increase public health. Other benefits of biogas production include direct monitory returns from saving on wood charcoals, income from chemical fertilizer and additional income higher agricultural yields. The various products of a biogas plant such as methane carbon dioxide and hydrogen can be used in the production of many industrial chemicals as outlined below:-

1. Methane is used in the production of methanol, which is an important industrial alcohol used in the making of methylated spirit. The chlorination of methane through photocatalysis yields chloroform and carbon tetrachloride. Carbon tetrachloride is used in dry cleaning and in fire extinguisher.
2. Carbon dioxide is used in the manufacture of ammonium sulphate from powered anhydrite as described in his chemical reaction.

$CaSo_4 + 2NH_4OH + Co_2 \longrightarrow CaCo_3(s) + (NH_4)_2So_4 + H_2^0$

It can also be used for the product of urea as shown in the reaction below: -

$Co_2 + 2NH_3 \longrightarrow CO(NH4)2 + H2O(L)$

Urea can be utilized as fertilizer and in the manufacture of plastics. Other uses of carbon dioxide include the manufacture of organic chemicals, also coolant in nuclear reactors, for the aeration of soft drinks, for storing fruits while blocks of solid carbon dioxide are use as a refrigerant.

2.8.1 THE BIO-REACTORS:

The bioreactors are the digesters in which the process of anaerobic digesters take place. The digesters may be designed for use in low technology rural situation or for sophisticated industrial applications.

2.8.1.1 TYPES OF ANAEROBIC DIGESTERS:

1. Solid Form Batch Digesters (SFBD): Usage of slurry feed in lieu of slurry. Reactor size is usually small but digestion reaction is usually slow.
2. Unstirred Slurry Digester (USD) or contact Digester (CD): Solids are separated from residues after they emerge from the digester and partly dewatered. They are then returned to the reactor. Efficient usage of slurry with minimization of waste. Its disadvantages is based on the unnecessary removal of microorganism from their steady – state environment and hence up setting their final equilibrium.
3. Packed Bed Digester (PBD): Often employed specifically for effluent of low solid content. Cylindrical ware is packed with either ceramic or polymeric material in form of rescaling rings etc. It is not suitable for influent having high concentration of solids as this will definitely easily result to clogging. In view of this, it is not suitable for anaerobic digestion of livestock waste. Large surface area is available for reaction ad hence, high extent of yield is obtainable.

4. Mixed Flow Digester (MFD) or Stirred Tank Digester (STD): It is composed of cylindrical ware holding the slurry which is being digested with effluent equipment and gas collection chamber with stirrer, stirring the tank contents (slurry). The major problem is mixing which may not be homogeneous. However, it is relatively simple, highly efficient, steady state condition is maintained.

5. Multistage Digester (MSD): This is based on the knowledge that anaerobic digestion is a multistage reaction. It has an increased efficiently in terms of biogas yield, quality, separation of liquid from undigested slurry etc. However, it major disadvantage is that its plant set up is complex and costly.

6. Plug Flow Digester (PFD): A plug flow slurry is allowed to react as it traverses, the entire length of the reactor and comes out with the gas, separated and sent to user while having at the same time, an effluent sludge stream to be used as form manure. It can be used with dispensation of any form of agitation, gives acceptable reaction rate and product yields. But however, there is no adequate provision for quick product gas removal. Even when done, it may be difficult to achieve efficient removal using simple method only.

7. Batch Digester (BD): It is a form mixed flow digester but without any continuous influent feed or effluent removal during reaction. It is simple to operate and maintain at isothermal conditions. But there is a non-steady stale condition hence, no constant rate of methane production overtime.

2.8.2 RETENTION TIME AND LOADING RATE:

The hydraulic retention time (HRT) i.e. the length of time of liquid added remains in the digester, is given by the expression;

$$\text{HRT} = \frac{\text{Digester Volume}}{\text{Volume of waste feed daily}}$$

The solids retention time will be longer than this if particles are retained in the digester e.g. in a plug flow type design. Simple waste may pass through digesters with microorganism retention. Complex wastes such as animal manures are digested at RTS of 10 days or more. In digesters with no provision for microbial retention, came must be taken to prevent washout, especially of slower growing methanogens at retention time below three days.

The loading rate or at which solids are added to the digester is a function of both the volume added daily and the solid, content of this feed material. It is expressed as weight of organic matter (usually kg. Vs per m^3 of digester per day).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 MATERIALS

The materials used in this project research were cow dung and rice husk.

A. Collection of materials:

The rice husk and cow dung was collected from a rice milling and cow ranch in Ungwanbiri area of Boss Minna, Niger state of Nigeria.

B. Pre treatment of materials

These involved three stages, which include; drying, grinding and mixing.

- Drying: - This was carried out using natural sun drying process
- Grinding: - This was conducted by pulverizing, using mortar and pestle.
- Mixing: - This was conducted by mixing the materials with water in the ratio of 1:5 W/V after which it was feed into the digester for gas production.

3.1.1 Chemical/reagents used

i. Concentrated hydrochloric acids (50%)

ii. Concentrated sodium hydroxide solution (50%)

3.1.2 Equipments

- 500ml measuring cylinder
- 3 (1000ml) volumetric flask
- 3 plastic digester (5 litres)
- 3 delivery tubes
- 600ml glass beaker
- Glass tube
- Glass thermometer
- Digital weighing balance
- Electric oven
- PH meter
- Muffle furnace

- Gas collector (1.5 litre capacity)

3.2 METHODS

3.2.1 Experimental procedure

3.2.1.1 Determination of pH value

The pH value of the samples was measured using pH meter and the pH value was maintained at specified range by continuous addition of sodium hydroxide solution or dilutes hydrochloric acid.

3.2.1.2 Determination of total solid (T.S)

The total solid were estimated after subjecting the samples into the drying oven at a temperature of 102^{0}C for about 2 hours. The weight of the dried samples is the measured of the total solid.

3.2.1.3 Determination of moisture content (MC)

The moisture contents of the dung, husk and their mixture were estimated after being subjected to dryness in an oven at a temperature of 102^{o}C for about 2 hours. This was sufficient to give a constant weight of moisture free dung, husk and mixture in three subsequent weighing.

3.2.1.4 Determination of volatile solids (V.S)

The dried samples was transformed to the muffle furnace and ignited at 5000C for about two hours until change in weight becomes constant. The loss in weight was calculated and this represented the volatile solid.

3.2.1.5 Determination of biogas composition

Each of the three samples of biogas collected in the gas collection bags were passed through gas chromatography to determine the percentage mole composition of the biogas in the big and the results obtained are presented in table 6.0.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 RESULTS: The results are presented in tables 3.0-6.0 below.

TABLE 3.0 For Total solid (T. S), Volatile solid (V. S), Moisture content (M.C)

Type of waste	Total solid (%)	Volatile solid %	Moisture content (%)
Cow dung	79.55	83.36	20.45
Rice husk	82.83	88.0	17.17
Mixture	81.57	87.5	18.43

Table 4.0: Gas production per week.

No of weeks	A (cm^3)	B (cm^3)	C (cm^3)
1	572.0	647.0	158.0
2	345.0	628.0	108.0
3	385.0	530.0	355.0
4	160.0	215.0	604.0
5	95.0	145.0	250.0
6	210.0	115.0	100.0

Table 5.0: Cumulative gas production per week.

No of weeks	A (cm^3)	B (cm^3)	C (cm^3)
1	572.0	647.0	158.0
2	917.0	1275.0	266.0
3	1302.0	1805.0	621.0
4	1462.0	2020.0	1225.0
5	1557.0	2165.0	1475.0
6	1767.0	2280.0	1575.0

Table 6.0: Result of gas analysis

Sources of gas	Composition of gas mixture in %					
	CH_4	CO_2	O_2	H_2	N_2	H_2S
Rice husk	56.92	41.39	0.12	0.63	0.94	Trace
Cow dung	61.80	33.81	0.07	0.48	3.84	Trace
Mixture Rice husk/ Cow dung	54.84	41.26	0.11	0.50	3.29	Trace

4.2 DISCUSSION OF RESULTS

The results of the research are summarized in tables 3.0, 4.0, 5.0 and 6.0. From table 3.0 the total solid (TS), volatile solid (VS) and moisture content (MC) were observed to be 82.83, 88.0 and 17.17% for the rice husk and 79.55, 83.36 and 20.45%s for the cow dung and also 81.57, 87.5 and 18.43% for the mixture of cow dung/rice husk. For the slight difference in total solids between the rice husks has the highest solid content and of course the slight difference suggest that both materials are valuable substrate to bio-digester. Also observed was that rice husk offers a higher percentage of volatile solids than the mixture and cow dung has the least. The moisture content of the cow dung was also observed to be higher than the mixture and followed by the rice husk that has a remarkable effect on the production of the gas. From these results, substrate with higher moisture content has shown a production than substrate with low moisture content.

From Table 5.0 it shows a weekly cumulative gas production; a total gas of 1767.0cm^3 was produced by digester A. 2280cm^3 by B and 1575cm^3 was produced by C which gave a difference in the quantity of biogas produced. The results shows that cow dung containing in digester B produces higher volume of gas, followed by rice husk and then the mixture of cow dung/rice husk has the least volume under the same operational conditions. This was due to the biodegradability of the waste (cow dung). Comparative analysis of these results obtained in cow dung 2280.0cm^3 of the gas shows a difference with the predicted values (11,025cm^3) that 1kg of volatile solid in cow dung yield 0.25m^3 biogas.(Energy and Environmental Technology 1996.). The presence of the already stated inhibitory factors and experimental errors can affect the biogas production and amount of gas produced also depends on retention time and extent of degradation.

From the results of gas analysis in table 6.0 shows that the quality of biogas produced was found to be higher in cow dung with 61.8% methane (CH_4) and 33.81% carbon dioxide (CO_2) than in the mixture with 54.84% CH_4 and 41.26% and followed by the rice husk with 56.92% CH_4 and 41.39% CO_2 respectively. This was due to the fact that the lower the percentage composition of the carbon dioxide the better the calorific value of the biogas. (Abdurahman 1994).

From the values of the composition of the major components (CH_4 and CO_2) obtained, it could be said that is within the range of accepted values (CH_4) 50-80% and carbon dioxide 20-50 %.(Gobar gas research station India 1960.)

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Based on the experimental results obtained and analyzed some of the following conclusions can be drawn from the research work. Different organic wastes gave different biogas productivity if digested at the same conditions.

The experimental research shows that under the same operational conditions, cow dung gave a higher gas yield than rice husk whose yield was in turn greater than that of the cow dung/rice husk mixture.

The quality of biogas obtained was observed to be higher from the cow dung than the rice husk.

5.2 RECOMMENDATIONS

1. A long-term fermentation should be investigated to determine the ultimate yield of each type of substrate.
2. A more effective and reliable method of collection of the gas should be designed so as prevent impurities entering the produced gas.
3. Research works should be conducted with the aim of finding some materials that can increase the biogas production.
4. Reactor design kinetics should be studied so as to ensure efficiency of the digester performance at steady state.
5. Government on its hand should fund research works on biogas technology so as to reduce the fuel problem facing our fast growing population.

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APPENDIX 1

Tables showing daily biogas production in each week. At Temperature between 28^0C and 35^0C.

Table A. First week gas production

No of days	A (cm^3)	B (cm^3)	C (cm^3)
1	NGP	125.0	18.0
2	NGP	70.0	10.0
3	142	45.0	18.0
4	120	75.0	12.0
5	80	90.0	30.0
6	90	115.0	NGP
7	140	127.0	70.0

Table B. Second week gas production

No of days	A (cm^3)	B (cm^3)	C (cm^3)
1	100.0	98.0	18.0
2	50	85.0	15.0
3	50	100.0	10.0
4	NGP	80.0	NGP
5	NGP	80.0	20.0
6	80	85.0	15
7	650	100.0	30.0

Table C. Third week gas production

No of days	A (cm^3)	B (cm^3)	C (cm^3)
1	75.0	85.0	20.0
2	65.0	80.0	30.0
3	60.0	70.0	35.0
4	25.0	75.0	45.0
5	25.0	70.0	65.0
6	95.0	75.0	65.0
7	40.0	75.0	95.0

Table D. Fourth week gas production

No of days	A (cm^3)	B (cm^3)	C (cm^3)
1	30.0	60.0	100.0
2	25.0	55.0	110.0
3	25.0	40.0	120.0
4	15.0	NGP	30.0
5	20.0	30.0	110.0
6	25.0	20.0	14.0
7	20.0	10.0	120.0

Table E. **Fifth week gas production**

No of days	A (cm^3)	B (cm^3)	C (cm^3)
1	10.0	15.0	120.0
2	NGP	20	60.0
3	NGP	15.0	10.0
4	NGP	15.0	15.0
5	20.0	20.0	15.0
6	25.0	30.0	20.0
7	40	30.0	10.0

Table F. **Sixth week gas production**

No of days	A (cm^3)	B (cm^3)	C (cm^3)
1	30.0	15.0	20.0
2	40.0	20.0	40.0
3	20.0	10.0	30.0
4	30.0	20.0	10.0
5	50.0	10.0	NGP
6	25.0	25.0	NGP
7	15.0	15.0	NGP

Key

A = Digester Containing Rice husk

B = Digester Containing Cow dung only

C = Digester Containing Mixture of Cow dung and Rice husk

NGP = No gas produced

APPENDIX 2

CALCULATIONS:

FOR TOTAL SOLID

COW DUNG

Weight of empty tray (X) = 116.0g

Weight of empty tray + sample before drying (Y) = 182.5g

Weight of empty tray + sample after drying (Z) = 168.9g

Total solid = Z – X = 168.9 - 116.0 = 52.9g

$$\therefore \% \text{ Total solid (T.S)} = \frac{168.9 - 116}{182.5 - 116} \times 100 = 79.55\%$$

Rice Husk

Weight of empty tray (X) = 113.3g

Weight of empty tray + sample before drying (Y) = 192.5g

Weight of empty tray + sample after drying (Z) = 78.9g

Total solid = Z – X = 178.9 - 113.3 = 65.6g

$$\therefore \% \text{ Total solid (T.S)} = \frac{178.9 - 113.3}{192.5 - 113.3} \times 100 = 82.83\%$$

MIXTURE

Weight of empty tray (X) = 116.0g

Weight of empty tray + sample before drying (Y) = 192.5g

Weight of empty tray + sample after drying (Z) = 178.4g

Total solid = Z – X = 192.5 - 178.4 = 14.1g

$$\therefore \% \text{ Total solid (T.S)} = \frac{178.4 - 116}{192.5 - 116} \times 100 = 81.57\%$$

FOR VOLATILE SOLID

COW DUNG

Weight of empty tray + sample after drying (Z) = 168.9g

Weight of empty tray + sample after Ignition (M) = 124.8g

Loss of Weight = Z – M = 44.1

% volatile solid = $\frac{168.9 - 124.8}{168.9 - 116} \times 100$ =

= 83.36%

Rice Husk

Weight of empty tray + sample after drying (Z) = 192.5g

Weight of empty tray + sample after Ignition (M) = 122.8g

Loss of Weight = Z – M = 69.7

% volatile solid (V.S) = $\frac{69.7\ 8}{192.5 - 113.3} \times 100$

= 88.0%

Mixture

Weight of empty tray + sample after drying (Z) = 178.4g

Weight of empty tray + sample after Ignition (M) = 123.8g

Loss of Weight = Z – M = 54.6g

% volatile solid (V.S0 = $\frac{54.6}{178.4 - 116} \times 100$

= 87.5%

FOR MOI STURE CONTENT

COW DUNG

Moisture Content (M.C) = Y – Z = 182.5 - 165.9 = 13.6g

% M.C. = $\frac{Y - Z}{Y - X} \times 100 = \frac{13.6}{182.5 - 116} \times 100$ 20.45%

Rise Husk

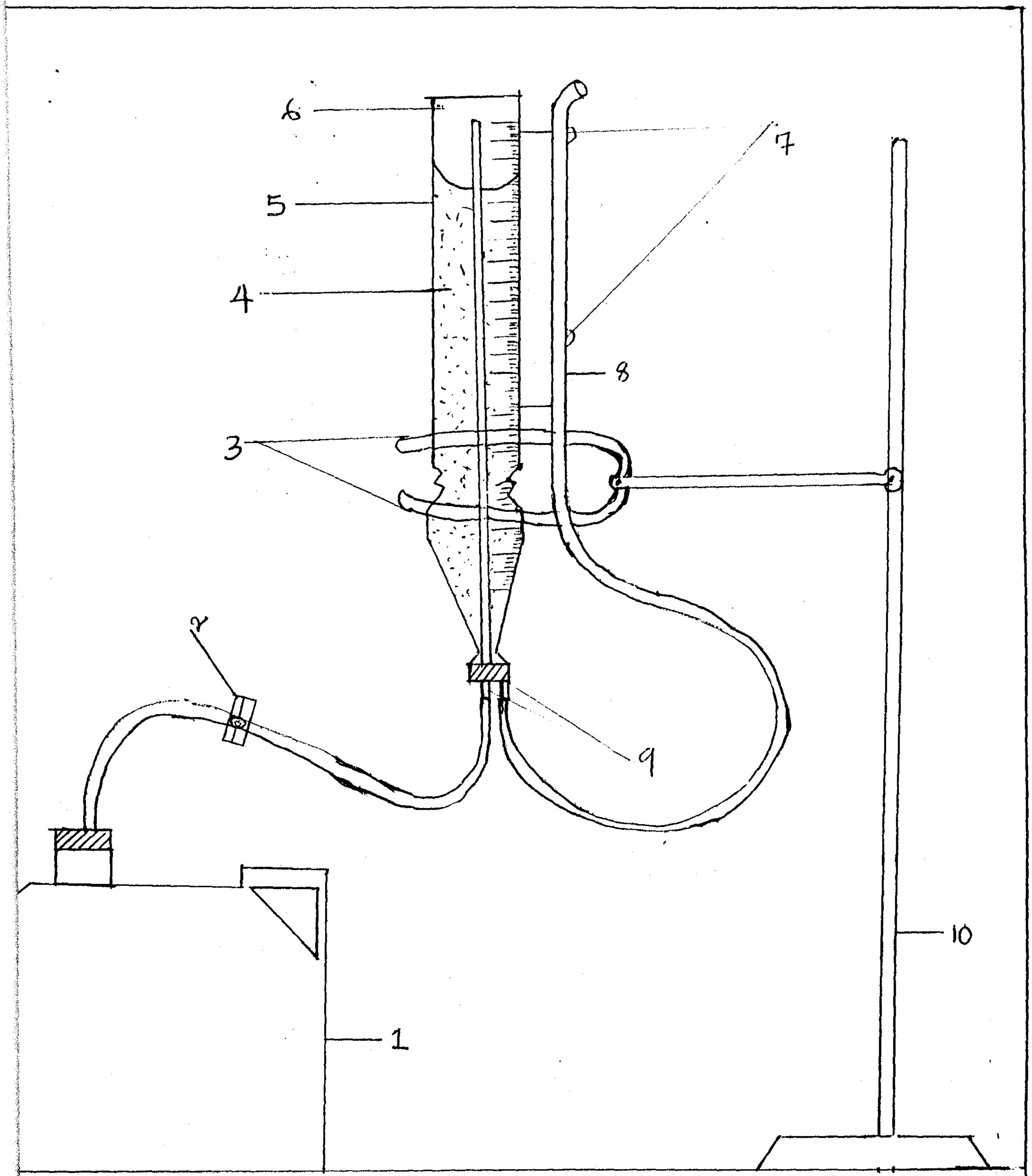
Moisture Content (M.C) = Y – Z = 192.5 - 178.9 = 13.6g

% M.C. = $\frac{Y - Z}{Y - X} \times 100 = \frac{13.6}{192.5 - 113.3} \times 100$ 17.17%

Mixture

Moisture Content (M.C) = Y – Z = 192.5 - 178.4 = 14.1g

$$\% M.C. = \frac{Y - Z}{Y - X} \times 100 = \frac{14.1}{76.5} \times 100 \; 18.43\%$$



SCHEMATIC DIAGRAM OF BIOGAS APPARATUS

KEY:

1. LABORATORY SIZED DIGESTER
2. CONTROL CLIP
3. RETORT CLAMP
4. WATER
5. BIOGAS COLLECTOR
6. BIOGAS
7. FASTENER
8. RUBBER TUBINGS
9. GLASS TUBINGS
10. RETORT STAND