BIOGAS PRODUCTION FROM RICE CHAFF

BY

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DECLARATION

I, Jwalshik Pantong Luka, state the authenticity of this work carried out by myself under supervision in the Department of Chemical Engineering, Federal University of Technology, Minna. The works of other researchers referred were duly acknowledged.

No part of this project has been previously presented elsewhere for the award of any degree

09/02/2010

Jwalshik P. Luka

Date

CERTIFICATION

The research is an original work carried out by Jwalshik Pantong Luka under the supervisor of Engr. P.E Dim and meets the regulations and requirements for the Award of Bachelor Degree in Chemical Engineering by the Federal University of Technology, Minna and is applied for its literary presentation and contributions to scientific knowledge.

Engr. P.E Dim (Project Supervisor)	09/02/10 Date
Engr. J.O Okafor (Act Head of Dept.)	Date
External Examiner	5/03/2010 Date

DEDICATION

To the anchor and fulcrum of my life: Jesus Christ, the eternal overcomer.

And my late mother; Jeno'mi Luka Jwalshik who was the strongest and most impacting force of my life.

ACKNOWLEDGEMENT

I would like to first of all, acknowledge the help and guidance of Jesus Christ, My Saviour and Lord, in writing this project. I have enjoyed His strength and wisdom through His Holy Spirit in me.

My family members also deserve my sincere gratitude. My beautiful and loving parents; Da Luka and Na Jeno'mi, who have supported and encouraged me form the beginning of my educational pursuit. My brothers; Carol, Wilford and Fwangshak, my sisters, Catherine, Mildret and Nantap for their confidence, God-fearing and nice. It was not easy being away from home but you guys stood by me day and night. I always know whom to call when I got stranded.

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CHAPTER ONE

1.0 INTRODUCTION

We have had it good for many years, using and misusing fuel supplies at will for countless decades. In the United States, the average consumption of oil equates to three gallons per day.

That is for every man, woman and child of the population! This makes an annual consumption of over 2 billion gallons. This is most wasteful of the developed nations, but still not extremely far ahead of the others.

This practice will necessarily have to come to a halt at some point in the near future, since the present rate of consumption should exhaust the known reserves of refineable crude oil in about thirty years. The constant efforts of our oil companies to sell more and more of the black gold make it unlikely that today's consumption will not increase in the future (Simeon, 1975).

Obviously, the number one priority is to do some serious thinking about the use of power per head and in total. The second pressing need is to find an alternative and ecologically sound source of power for the future, unless we want to face rocketing power price and possible rationing in our lifetimes. And we already have possible alternative on our doorstep. One huge source that has barely been used up to now is methane (Nasir, 2001).

Millions of cubic metres of methane in the form of swamp gas or biogas are produced every year by the decomposition of organic matters, both animals and vegetables. It is almost identical to the natural gas pumped out of the ground by the oil companies and used by many of us for heating our houses and cooking our meals (Balogun, 1991).

In the past, however, biogas has been treated as a dangerous by-product that must be removed as quickly as possible, instead of being harnessed for any useful purposes. It is only really in very recent times that a few people have started to view biogas in an entirely different light, as a new source of power for the future (Balogun, 1991).

One of these pioneers is Ram Bux Singh (1960), now the director of Gober Gas Research Station in Aiitmal, Northern India. Research was done into this topic in Europe during the fuel shortage of the Second World War, and biogas in various forms was indeed used in a restricted fashion, but the centre of biogas research is today to be found in India.

The utilization of biomass as an energy resource can be accomplished by various processes involving different degrees of technological skills. Biogas technology is a modern ecological oriented form of appropriate technology based on the decomposition of organic materials at appropriate temperature. It is generally accepted that fuel consumption represents a measure of a nation's index of development, and improved standard of living. As a result of this, there has been an increase in the use and demand for fuel in terms of transportation and power generation. These have so far been extracted from our stock of fossil fuels such as crude oil and to a lesser extent coal and natural gas. These sources are energy capitals and essentially finite in nature, as they took million of years to form through the agencies of bacteria, temperature and above all are environmentally damaging.

Despite its numerous advantages, the potential of biogas technology could not fully be harnessed or tapped, as certain constraints are also associated with it. Most common among these are: the high hydraulic retention time 30-60 days, low gas production in the harmattan, etc.

1.1 Aims and Objectives

a. To enhance biogas production rate/yield by seeding with bacterial (digested sludge) under experiment conditions using rice chaff.

b. Energy production and utilization.

c. Production of high quality fertilizer.

d. Treatment of organic wastes in a broad range of organic loads and substrate concentrations.

e. Collect, analyze and interpret quantitative data and technical data.

1.2 Justification of Study

a. To popularize biogas technology especially in the rural areas.

b. Documented information on biogas production from rice chaff is limited.

c. Diversified energy source and free more crude oil for export.

d. An effective tool for waste management and pollution control.

1.3 Scope and Limitation

The scope of research on this project would go beyond the production of biogas from rice chaff in search of techniques to enhance gas production rate. The research work presupposes the effect of seeding with digested sludge and temperature as the main focus, much as it is the desire of the researcher to investigate the various factors that affect biogas production, it may not be possible to investigate the effect of all the parameters which makes of the operation because of limited information, time and financial constraints.

CHAPTER TWO

2.0 LITERATURE REVIEW

The literatures reviewed in this work are presented in this chapter.

2.1 Exploitation and Potential of Animal Waste for Generating Biogas

Nigeria has great potentials in animal resources. For instance, livestock accounted for about 5% of the Nation's Gross Domestic Product (GDP) in 1994 and plays a central role in meeting the national requirements for animal protein intake, internal and external trades.

Moreover, the average annual population of some livestock between 1984 and 1995 has been estimated at 14,423,719 herds of cattle. 19,476,497 herds of sheep, 31,403,052 herds of goats and 3,361,539 pigs (RMRDC, 1996).

In addition to exploiting livestock for their meat and hides, man has also utilized animal feaces as manure to improve his agricultural productivity.

Furthermore, the potentials of animal feaces as materials for generation of biogas has been recognized by countries such as China, Japan, India, Indonesia, Bangladesh, Kenya and Tanzania to mention but a few.

Exploitation of animal, human, agricultural and industrial waste for production of biogas in Nigeria is at its infancy: the pioneer biogas plants are a $10m^3$ biogas plants constructed in 1995 by the SERC in Zaria and a $18m^3$ biogas plants constructed in 1996 at Ojokoro Ifelodun Piggery Farm, Lagos by the Federal Institute of Industrial Research, Oshodi (FIIRO) Lagos (ECN, 1997).

Most of the biogas researchers in Nigeria use cow dung as substrate. A few have explored other substrates such as donkey dung (Nwagbo et al, 1991), Most of the biogas researchers in Nigeria use cow dung as substrate. A few have explored other substrates such as donkey dung (Nwagbo et al, 1991), water-hyacinth (Audu, 1994), palm oil effluent (Ogbeide, 1988), poultry droppings (Itado et al, 1992). Poultry, donkeys, horses, sheep, and goats are domestic animals whose faces are potential raw materials for biogas production. Yet the exploitation of this dung as sources of biogas has remained largely a conception.

Potentially, all organic waste materials contain adequate quantities of the nutrients essentials for the growth and metabolism of the anaerobic bacterial in biogas production. However, the chemical composition and the biogas availability of the nutrients contained in these materials vary with species, factors affecting growth and age of the animal or plant (Wolfe, 1971).

Moreover, Kallah and Adamu (1988) observed that the quantity of manure accumulated in a livestock enterprise is a function of factors intrinsic to the animal and factors related to the management; the amount is determined by species, breed, age and size of the animal, and nature of feed ingested, seasonal variation, and whether or not bedding is used.

For instance, the estimated daily faces excreted as Dry Matter (DM) for cattle is 1,500g/head, sheep is 200g/head, goat is 240g/head and poultry is 39g/head. It is therefore to be expected that the biogas potential of faces from different animals will vary both in quantity and quality.

2.2 Biodegradation of Organic Matter

The process of conversion of complex organic matter to one containing a smaller number of carbon atoms is degradation (Bu'lock and Kristiensen, 1985). If the degradation is aided or assisted by living cells like micro-organism and enzymes, it is called biodegradation.

Biodegradation can therefore be broadly defined as the process whereby micro-organisms consume, grow on organic matter and decompose them to simpler units in their environment (Young, 1985).

If the degradation yields alcohol as the primary product, the process is called Fermentation, but when methane and carbon dioxide are formed as the products, the process is better termed Digestion (Schilgerl, 1987). The chemical process of waste materials usually organic takes one of two methods – aerobic and anaerobic digestion. The former takes place in an oxygen environment and yields carbon dioxide, water and new cells as the products while the latter produces biogas, ammonia, hydrogen sulphide and water vapour as traces of associated gas.

Table 2.1 Composition of Biogas

SUBSTANCES	PERCENTAGE (%)
Carbon (IV) oxide (Co_2)	20.0 – 40.0
Hydrogen (H_2)	< 1.0
Hydrogen Sulphide (H_2S)	0.1 – 3.0
Nitrogen (N_2)	0.5 – 5.0
Methane (CH_4)	50.0 – 80.0
Oxygen (O_2)	< 0.4

Source: Gober Gas

Research Station (1960)

2.2.1 Microbiology and biochemistry of the digestion process (Biogas production)

The biogas production involves the Microbiology and Biochemistry of the different micro-organisms engaged in the fermentation of the raw materials

ABSTRACT

Pilot scale experiments were carried out to produce biogas from rice chaff. Investigations have also been carried out to determine the amount of biogas that can be produced using rice chaff as substrate. The experiments were set at an average temperature of 35^0C and gradually dropped to an average temperature of 28^0C and 27^0C for unseeded and seeded respectively. It was discovered that gas production increases gradually and decreases with decreased in temperature. Seeding has also been found out to increase the gas production by 11.1%.

required for the process. The degradation of organic matter to produce methane, relies on the complex interaction of several different group of these bacterial group be in the dynamic and harmonious equilibrium and the result in the buildup of intermediates which may inhibits the overall process.

2.2.2 Stages of Fermentation

Methanogenesis, which essentially defines biogas generation, is the production of methane and carbon (IV) oxide through the action of methanogens in a four-stage process consisting of hydrolysis, fermentation, acetogenesis/acidogenesis and finally methanogenesis (Ladapo and Barlaz, 1993).

The hydrolysis is the slowest of the four stages and through it, a consortium of various bacterial, fungi, actinomycetes and some species of protozoa convert complex polymers of carbohydrate, lipids and proteins to simple sugar, lipids and amino acids, proteins, bacillus, vibro, staphylococcus. Bacteriodes and clostridium are some of the bacterial species involved in the process. Most of the bacterial species die off after exhausting their substrate or due to the depletion of oxygen (Walther, 1993).

In the second stage, simple organics are fermented to alcohols, hydrogen and carbon dioxide by different species of fermenting bacterial such as bacillus, staphylococcus and clostridium through the secretion of exo-enzymes. The organisms are classified on the substrate they act upon. The variety and amount of bacterial usually also varies with the variety and quantity of the organics present although the organism generally decline in members due to the depletion of substrate or oxygen (Walther, 1993).

Hydrogen-producing acetobacterium xylium and some species of clostridium are involved in the third stages of acetogenesis and acidogenesis where with others. Mathematical models- a simplified mathematical description of how a biogas plant works provides a way of doing this (Garba et al, 2003).

A good model should roughly predict how much gas a degester can get each day given that a particular design uses a particular feed stock under defined condition. Several different models have been suggested for biogas production, many based on simpler biological systems. The most effective seems to be the first order Kinetic model (Garba et al, 2003).

2.5.4 First order kinetic model

This is represented by the equation

$$W = Wo(1-e^{-kt}) \quad \ldots\ldots (1)$$

Where Wo is the maximum amount of the product that would be obtained at infinite time, W is the amount of product generated at time t, and k is the rate constant. The logarithm of the rate constants product formation can be plotted as a function of reciprocal of temperature (1/T) to obtain activated energy.

2.5.5 Monod model

Where the concentration of microorganisms involved, need to be evaluated, Monod model is the most applicable. Lawrence and McCarthy (1969) presented the basic equation as:

$$\frac{ds}{dt} = \frac{ksx}{ks + s} \quad \ldots\ldots (2)$$

Which is normally used in combination with the growth rate equation. The Monod model has been applied to several wastes as has been pointed out by Chin (1981) and has been the basic of most anaerobic digestion models.

Where s = substrate concentration in digester (g/m^3)

Ks = saturated constant (g/m^3)

K = kinetic constant (day^{-1})

t = time (day)

2.5.6 Diffusional model

The combination of the rate equation together with mass transfer limitation equations results in the following overall rate equation (Suidan et al, 1981).

$ds = ks^{0.5}$ ....(3)

where k is an apparent kinetic constant

s is the substrate concentration (gm^{-3})

2.5.7 Chen and hashimoto model

The Chen Hashimoto model is a modification of that of Contois, adapted to the anaerobic digestion process. The Contois model is an expanded form of the Monod model, which takes into account the fact that mass transfer limitations may cause the specific growth rate to vary with population density. Hence, the Contois model can be considered as a specialized form of the Monod (Contois, 1959).

The Contois Model is normally applied directly to describe gas generation in terms of methane produced per kilogram. The basic equation is given as follows:

$$U = \frac{Ums/so}{K + (1-k)s/so} \quad \text{.. (4)}$$

Where U = the specific microorganism growth rate (day^{-1})

Um = maximum specific microorganism growth rate (day^{-1})

K = Chen Hashimoto Kinetic constant (dimensionless)

S = substrate concentration in digester (g/m^3)

So = substrate concentration (g/m^3)

If the death and decay of microorganisms are neglected, then microorganisms balance can be described as:

$$\frac{dx}{dt} = Ux \quad \ldots\ldots (5)$$

Singh Model

This is given by the following equation:

$$\frac{ds}{dt} = \frac{-ks}{1+t} \quad \ldots\ldots (6)$$

Where k is the first order kinetic constant (day^{-1})

S is the substrate concentration (g/m^3)

T is the time (day)

2.6 Anaerobic Digseter

Almost any organic material can be processed in a digester. This includes biodegradable waste. Materials such as waste paper, grass chippings, leftover food, sewage and animal waste. Anaerobic digester can also be fed with specially grown energy crops to boost biodegradable content and hence increase biogas production. After sorting or screening to remove inorganic or hey catabolize higer fatty acids to yield hydrogen and acetic acid. Long-hain fatty acids produced in the second stage are also further degraded in his stage of hydrogen and acetic acid. Although, the shortest in duration, the hird stage is of particular importance because growth of methanogenic bacterial leading to the final stage is induced by the formation of acetate and urther reduction of the microbial environment (Walther, 1993).

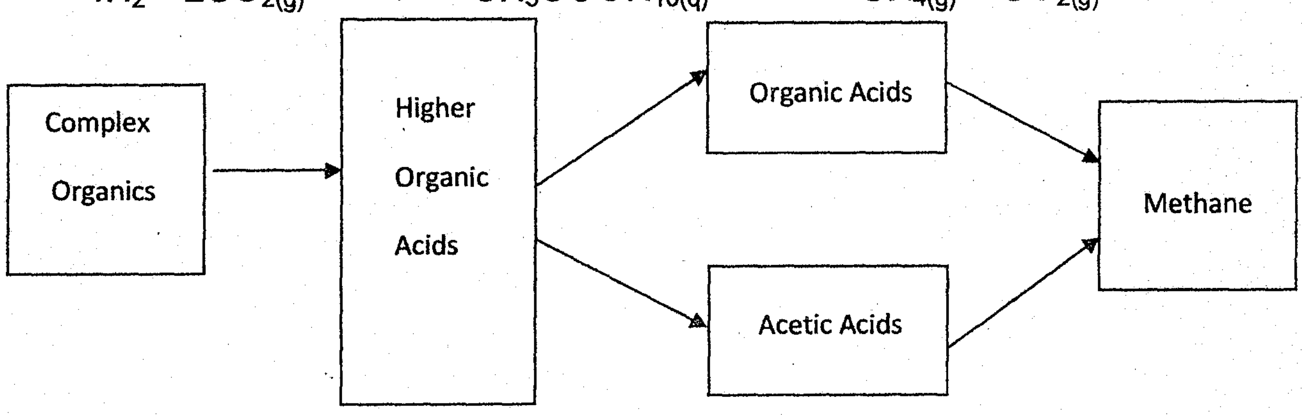
Parkinson and Allen (2000) defined the fourth and final stage as methanogenic stage where acetate, carbon dioxide and hydrogen are the typical substrates. The authors identified three routes of methane formation at this stage:

1. Cleavage of acetate molecules to form methane and carbon (IV) dioxide.
2. Reduction of carbon dioxide to form methane and water.

   $$4H_{2(g)} + CO_{2(g)} \longrightarrow CH_{4(g)} + 2H_2O_{(l)}$$

3. Combination of carbon dioxide and hydrogen results in the formation of acetate that cleaved into methane and carbon dioxide.

   $$4H_2 + 2CO_{2(g)} \longrightarrow CH_3COOH_{10(q)} \longrightarrow CH_{4(g)} + CO_{2(g)}$$



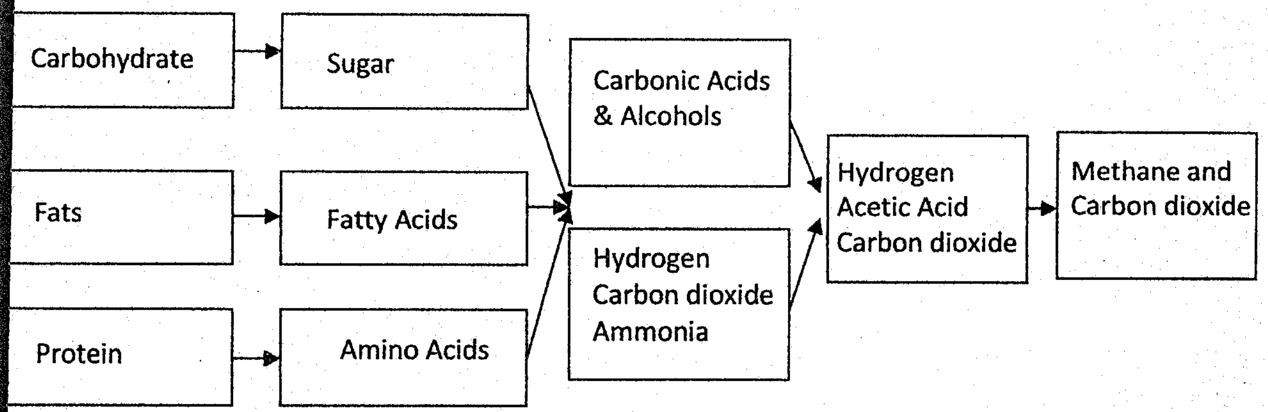
Stage 1: Hydrolysis & Fermentation

Stage 2: Acetogenesis & Dehydrogenation

Stage 3: Methanogenesis

Figure 2.1: Flow Chart Showing Stages of Fermentation

Source: Van Broeck (1996)



Hydrolysis Acidogenesis Acetogenesis Methanogenesis

$$C_6H_{12}O6 \longrightarrow 3CO_2 + 3CH_4$$

Figure 2.2: Flow Chart Showing Stages of Methanogenesis

Source: Parkinson and Allen (2002)

2.2.3 By-Product of Anaerobic Digestion

There are three principal by-products of anaerobic digestion.

Biogas, a gaseous mixture comprising mostly of methane and carbon dioxide, but also containing a small amount of hydrogen and occasionally trace levels of hydrogen sulphide (See Table 2.1).

Biogas can be burned to produce electricity, usually with a reciprocating engine or microturbine. The gas is often used in a cogeneration arrangement, to generate electricity and waste heat to warm the digester or to heat buildings. Excess electricity can be sold to electricity suppliers. Electricity produced by anaerobic digester is considered to be green energy and may attract subsidies such as renewable obligation certificates.

Since the gas is not released directly into the atmosphere and the carbon dioxide comes from an organic source with a short carbon cycle biogas does not contribute to increasing atmospheric carbon dioxide concentrations; because of this, it is considered to be an environmentally friendly energy source (www.enwikipedia.org).

The second by-product (acidogenic digestate) is a stable organic material comprised largely of lignin and chitin, but also of a variety of mineral components in a matrix of dead bacteria cells; some plastic may be present. This resembles domestic compost and can be used as compost or to make low grade building products such as fiber board (www.enwikipedia.org).

The third by-product is a liquid (methanogenic digestate) that is rich in nutrient and can be an excellent fertilizer dependent on the quality of the material being digested. If the digested materials include lows of toxic heavy metals or synthetic organic materials such as pesticides or PCBs, the effect of digestion is to significantly concentrate such materials in the digester liquor. In such cases, further treatment will be required in order to dispose of this liquid properly (www.enwikipedia.org).

2.3 Associated Technologies

The following associated technologies are common:

2.3.1 Mechanical biological treatment

New developments in anaerobic digestion have led to systems being integrated with sorting units. Mixed waste streams such as unsorted household waste can undergo a technical pretreatment stage. These systems come under the category of mechanical biological treatment. They enable the recovery of organic fraction of the waste in a form that can be processed in anaerobic digester (www.enwikipedia.org).

2.3.2 Inhibition of methanogenesis and production of alcohols

Anaerobic digestion can be inhibited from reaching the methanogenic stage. The organic acids (i.e carboxylic acids) form the acidogenic and acetogenic stages of the digestion can be recovered. The acid can then undergo chemical transformations into useful chemicals and fuels.

2.3.3 Potential in the hydrogen economy

An anaerobic digestion is a renewable source of methane. It offers the potential to contribute to the hydrogen economy; Steam Methane Reforming (SMR) is the most common method of producing commercial bulk hydrogen. It is also the least expensive method at high temperature (700-1100°C) and in the presence of a metal based catalyst, steam reacts with methane to yield carbon monoxide and hydrogen

$$CH_4 + H_2O \longrightarrow CO + 3H_2$$

2.4 Factors affecting Biogas Production

Tambuwal et al (1997), reported carbon/nitrogen ratio, temperature, pH level, concentration stirring and seeding with bacterial as the factors that affect biogas production. However, level of oxygen, substrate loading and residence time are also reported to affect biogas production.

Aliyu (1993) reported that anaerobic bacterial need a neutral environment. Therefore, a pH range of 0.4 to 7.2 is required for optimum biogas production.

Loading and residence time are environmental factors that determine the quality of substrate available for microbial attack, limits the time during which the substrate is available for such attacks as well as the time permitted for microbial reproduction. Residence time is the time required to convert the decomposable materials into methane with suitable allowance made for terminating the process at the point of diminishing returns (Singh et al, 1993).

Seeding with bacterial has been found to be one of the factors that affect biogas production. Tambuwal et al (1997) reported that, normally after feeding the digester with substrate, it takes some time before the gas production starts, but when seeded with bacteria, gas is produced immediately and the yield is improved.

Lincoln (1960) caution on the composition of the seed medium. He stated that growing the culture in the 'final-type' medium minimizes the lag time in fermentation. Lincoln argument is an important one, so the seed development medium should be sufficiently similar to the production medium to minimize any period of adaptation of the culture to the production medium, thus reducing the lag phase and the fermentation time.

Stirring is one of the factors affecting biogas production. It was found that gas production was low when slurry was stored continuously and also a drop in gas production when the stirring is completely avoided due to scum formation. Therefore, for optimum gas production, there should be occasional stirring (Tambuwal et al, 1997).

There are two types of biogas production; the mesophilic type of temperature of 30-40°C and the thermophilic type at temperature of 45-60°C (Tambuwal et al, 1997). The thermophilic digestion at 50-60°C has the advantages of rapid rate of solid destruction, greater gas yield and more readily denatured residue. However, time is required to adapt a culture to thermophilic conditions or develop a culture of thermophiles through enrichment (Rabac et al., 1959).

De Baere and Verstraete (1994) caution on the levels of oxygen allowed into digesters during fermentation because of the great liability of methanogens to get inhibited by oxygen.

Tambuwal et al, (1997) reported that for optimum gas production, the slurry should not be too thick or too dilute. The best ratio for dry cow dung to water is 1:4 w/v and for fresh cow dung, the ratio is 1:1 w/v.

2.5 Optimization and Mathematical Modeling of the Digestion Process

Optimizing a chemical process, according to Bu'lock et al, (1985) is to find the best optimum operating conditions of the process that would minimize the product yield using the most economical way. The method employed during optimization is usually to set up objective functions and work to achieve the objective (Levenspere, 1985).

Anaerobic fermentation and methane production is a complex process carried out by well organized community of several microbial populations. Some of the microbial groups involved are slow growing and sensitive to changes in operating conditions. This will cause instability in fermentation during both the start-up phase and at steady state operation of the fermentation of biomass in biogas plants. The biogas production will be more commercially attractive, if the risk of instability has been overcome through optimization of the process. There is room for optimization by improving operation conditions as pH of 7-8, low level of salt, temperature, Carbon to Nitrogen ratio of about 25:1 and eliminating factors limiting metabolism of the methane-producing microorganism. In a study funded by the energy research program, the followings were being suggested.

2.5.1 Online monitoring of the biogas process

Although much has been done to improve process design, most anaerobic digesters are poorly monitored. Therefore, the strategy for avoiding mismanagement is to operate below the maximum capacity of the reactor, thereby reducing the risk for over-loading. The study stated that until now, most research has been directed towards identifying parameters, which may be used to monitor the process and give a warning of reactor instability. Some of the most commonly used indicators include periodic measurements pH, alkalinity, volatile fatty acid (VFA), gas production rate and gas composition.

According to the study, a better strategy is to monitor and control the process precisely via innovative online monitoring in which sensor will be developed and tested in pilot digesters and the efficiency tested during shock loading and increasing doses of inhibitory components.

2.5.2 New process designs

New and improved process design includes system for the separation of the acidogenic and methanogenic phases to optimizing the conditions for the various bacteria. This can be achieved by coupling two or more digesters in series.

2.5.3 Mathematical modeling

In biogas studies, the results of all the measurements on laboratory scale test-site and field digesters need to be analyzed and interpreted. Although, a detailed investigation may result in thousands of different data points. They must be resolved into two or three figures that allow the performance of a plant design or the digestibility of feed stock to be assessed and compared hazardous materials such as metals and plastics, the materials to be processed are often shredded, mixed, or hydro crushed to increase the surface area available to microbes in the digester and hence increase the speed of digestion. The material is then fed into an airtight digester where the anaerobic treatment takes place (Finstein et al., 2004).

A digester should provide a suitable environment for naturally occurring anaerobic bacteria to grow, multiply and convert manure to biogas. Made of concrete, steel, brick or plastic and shaped like a silo, though basin or pond. Marchain et al (1992) report that the plant design of a digester should be patterned after the sludge digestion design with the chief design criteria being the size of the tank, reactor, its gas collection and sludge heating system, method of mixing the culture and recirculation of the solids. The authors reported that air should be excluded from gas storage facilities that is either incorporated in the tank or provided separately to avoid the dangers of explosion that could occur if methane attains a concentration of 5.0% in air.

Walther (1993) reported that digester should be single or multiple unit digesters that may be operated in parallel or in series with some operational solids admitted continuously or intermittently. Digesters are classified into either high-rate digesters or two stage (series) digesters. Marchain et al (1992) reported that with sufficient time of reproduction as the underlying factor, a proper design for a digester should entail one that gives room for the replacement of lost cells with effluent sludge and population size adjustments which follow fluctuation in organic loading and generation of volatile acids and other substrates. If the rate at which bacteria are lost from the digester with effluent slurry exceeds the growth rate of the methanogens, the bacteria population in the digester may be washed out of the system.

The size of the digester and the cost-effectiveness of the digester operations are important points for consideration as large digesters usually encourage wash-out (Marchain et al, 1992).

2.6.1 Anaerobic digester performance

Anaerobic digester is a simple process looked at after by nature and with its slow reaction rate needs little attention. The digester performance can be determined by measuring the following ratios:

2.6.1.1 Ratio 1 – gas: sludge

Divide the daily (or weekly or whatever time interval chosen) gas production by the raw sludge feed volume; the significant is that, if the raw sludge is consistent, then the ratio will be. If the ratio is not consistent day by day, either the sludge dry matter is varying or the digester is not performing, because Ratio 1 is approximately equal to:

(Raw sludge % TS) X (%VS) X (% VSD)/100

Where: TS = Total solid

VS = Volatile solid

VSD = Volatile solid Destruction

2.6.1.2 Ratio 2 – gas: digester capacity

Again monitor the gas production, expressed as m^3/day. Divide this figure by the digester capacity (m^3) to give the second ratio. This tells how hard your digester is working on a 15-day retention time with a value of ratio 1 calculated to be 21.6; Ratio 2 of such a digester would give a value of 1.44. He stated that a figure less than 1.0 means that one could be working the digester much harder, a figure more than 1.5 is good for the conventional sewage sludge digester. He went further to state that high solid digesters have been known to achieve a figure of more than 4 (Marchain et al., 1992).

2.6.1.3 Ratio 3 – CH_4:CO_2

It can be assumed for this ratio that the biogas comprise only CH_4 and CO_2. The gas quality can be monitored by two ways – using an expensive instrument, either permanently or portable to measure the CH_4 content of the gas, or a "Draeger" tube with a portable set of bellows to measure the CO_2 content. Whether CH_4 or CO_2 is measured, the important issue is the Ratio 3 should be consistent from day to day; for a sludge digester, it is normally about 1.5. A fall in ratio 3 indicates a rising CO_2 content, which in turn indicates that the methane forming stage of the anaerobic digestion process might lead to failure (Marchain et al., 1992). The idea is to measure the ratio 3 regularly; for optimum performance, the ratio should not vary.

CHAPTER THREE

3.0 METHODOLOGY

In the production of biogas, the materials and equipment used are shown in Table 3.1 and 3.2 respectively.

3.1 Materials and Equipments

Table 3.1: List of Materials used for experiment

S/N	EQUIPMENT	SOURCE	REMARKS
1.	Digester	Thermoline (4600ml)	Plastic
2.	Pressure Tank (Water)	Thermoline (3000ml)	Plastic
3.	Cylinder	Technico, England	Glass
4.	Beaker, graduated	Pyrex, England 500ml	Glass
5.	Water Trough	Pentagon Plastic (3 Litres)	Plastic
6.	Delivery Tube,	Thermoline (1.5cm)	Plastic
7.	Weighing Balance	Camry Emperor Chain (10kg)	Electronic
8.	Thermometer	Zeal, England 300°C range	Glass

Table 3.2 List of Equipments used for Experiment

S/N	MATERIALS	SOURCE	REMARKS
1.	Distilled Water	Biochemistry Lab Uni Jos (1000ml)	Liquid
2.	Sodium Chloride	Fabrique par Layal salt (50g)	Solid
3.	Active Slurry	Jos Water Board (1000ml)	Liquid
4.	Sulphuric acid	Biochemistry Lab UniJos	Liquid

3.2 Experimental Procedures

Rice chaff: The rice chaff used for this study was collected from rice milling machine at chip village, Pankshin, Plateau State.

Seeding is the addition of small part of active slurry to the substrate to enhance the rate of gas (biogas) production. Seeding has been found to be one of the factors that affect the rate of biogas production. The methods employed are outlined below.

3.2.1 Preparation of digester/reactors

The 4500ml plastic flasks was fabricated, it has a mouth with a cover. Three holes were bored on it – one hole was for insertion of thermometer. (300^0C range, 80mm immersion) and the other two for inlet pressure water and collection of gas. It was thoroughly cleaned and used as batch digester at mesophilic temperature. It was made airtight.

3.2.2 Preparation of Slurry

The rice chaff slurry was prepared by mixing thoroughly 250g of rice chaff with 1200cm^3 of water in the beaker. The slurry formed was fed into the digester through the normal inlet (mouth) on the digester. The inlet was then sealed to ensure airtight.

3.2.3 Biogas generation

The unattached end of the delivery tube of the digester described in 3.2.1 was positioned under a gas measuring apparatus: a 1 litre measuring cylinder filled with water and inverted into acidified saline solution (50g of table salt in 3 litres of water) in a trough such that the outlet of the tube was directed upward. This permit collection of biogas by downward displacement of the water in the measuring cylinder. Retord stand was used to hold the cylinder in vertical position without slanting.

Another experiment was also repeated for the digester with content seeded 1250cm^3 of active sludge from water board.

Regular stirring was manual shaking of the entire digester: by loosing it from the joint in the morning and before taking the readings at 4:00pm. This was to break any hard scum on the surface of the slurry, which prevent the release of biogas.

3.2.4 Data collection and analysis

The gas production was monitored daily while the daily temperature was equally noted through the thermometer. The average temperatures over these periods were 31.92^{o}c.

The collection of biogas is by downward displacement of the water in the measuring cylinder: the delivery valve is opened, whereby gas is discharged, which causes a downward displacement in the water level and the valve is closed back after 6 – 10 seconds. This is repeated each day and taking note of the temperature as it changes.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4:1 Results

This chapter comprises of the results obtained from the various experiments carried out in the study and the results are presented as follows:

Table 4:1: Influence of Temperature on Biogas Production

Time (Days)	Temperature (°C)	Volume of Gas Produced without seeding (cm^3)
1-5	35	2250
6-10	33	830
11-15	32	225
16-20	29	73
21-25	30	12
26-28	28	23

Table 4:2: Influence of Temperature and seeding on Biogas production

Time (Days)	Temperature (°C)	Volume of Gas produced with seeding (cm^3)
1-5	35	2410
6-10	34	880
11-15	31	300
16-20	32	120
21-24	30	29

4.2 Discussion

The results of the experiments are presented in Tables 4.1 and 4.2. From the Table, it can be observed that the total quantity of biogas obtained in 28days from the control (unseeded) set up was 3415cm^3 and seeded. That is 450cm^3 of biogas was obtained per day from day one to the fifth day (on the average). Between day six and the tenth day, 166cm^3 was obtained. The highest average temperature recorded during the experiment was 35°C from day one and from then it started declining with the least temperature being 28°C. About 90.2% of the total gas produced in first ten (10) days from the control (unseeded) and 86.7% from the seeded set up was obtained in the first ten days of the experiment as shown in the Tables 41 and 4:2. It was noticed that the unseed produced 3415cm^3 while seeded produced 3790cm^3 in twenty eight days with varying temperature. That is the first five days and average temperature of 35°C (highest) and 27°C as the least temperature. On the average 482cm^3 was produced per day during the first five days. Thus increasing the gas production by an average of 11.1% over the period of twenty eight days which is statistically significant.

A plot of the volume of gas generated against time shows the effect of seeding on biogas production at mesophilic temperature (33-27^{0}C). It can be observed that gas production started increasing immediately after seeding with active sludge and that for the first five days production in the seeded digester was greater than that of the unseeded one.

Production was also recorded in the seeded digester for the greater part of the twenty-eight days despite the drop in temperature recorded during the experiment. In the case of control, (unseeded) gas production was only found to be reasonable during the fifteen days before the temperature dropped to 29°C. From day five upward production continue declining and by day, twenty five production were very small. This could be attributed to either low temperature or to the bacterial might have used all the substrate present. *The rise and fall in biogas production could be due to the* microorganism working actively on the substrates for some times and stopping and after which they might continue again. This is evident in the volume of biogas production from the sixth to the day where by the gas produced by the unseeded was greater than that of the seeded. There are other factors that could be attributed to gas production but seeding and temperature were considered in the preset work.

CHARPTER FIVE

5.0 CONCLUSION AND RECUMMENDATION

5.1 Conclusion

The conclusion from the findings of the study are outlined below

i. Biogas production could be affected by some parameters such as temperature and seeding with bacteria

ii. Seeding with active sludge could enhance the production of biogas and the digestion carried out at mesophilic temperature

iii. There was gas production within the first five days in each set up and on the overall, there was remarkable gas production in the seeded set up for twenty eight days when compared to the unseeded experiment

5.2 Recommendation

i. Animal wastes are generally used as feedstock in biogas plants. But the availability of these substrates is one of the major problems hindering the successful operation of biogas digester, on reviewing the literature however, one find a long list of alternate feedstock and their potential for biogas production. It is strongly recommended that various substrates be explored for biogas production

ii. Organic matters are of diverse constituents, properties and nature and different types are known to give different amount of biogas at the same digester condition. It is therefore important that the biomasses be chemically characterized. Content of total solid, volatile solids, composition of organic matter (carbohydrates, proteins, Liquids), nitrogen and ammonia level should be determined.

iii. It is high time substrate-specific biocatalysts are made available to reduce the long period of biomethanation during the start-up furthermore, designs to suit the microbial catalyst have been discussed for long, but have yet to be realized. This indicates that the technology transfer is not completed, and the requires co-ordinate efforts of scientist and engineers to overcome these limitations

iv. With relatively cheap technology, pollution control, improvement of sanitary condition, abundant raw materials and favourable climatic condition for biogas production, the use of biogas can be implemented in Nigeria as a whole. This will stop the practice of indiscriminate felling of trees for fuel purpose as Nigeria is already faced with desert encroachment.

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APPENDIX 1

1. GDP:- Gross Domestic Product
2. RMRDC:- Raw Material and Research Development Council
3. SERC:- Sokoto Energy Research Centre
4. FIIRO:- Federal Institute of Industrial Research Oshodi
5. ECN:- Energy Commission of Nigeria
6. Total quantity of gas obtained:

   Unseeded = 2250+830+225+73+12+26 = 3415cm^3

   Seeded =2410+880+300+120+29+55 = 3794cm^3

7. Percentage of gas produced in the first ten days:

   I. Quantity of unseeded = 2250+830 = 3080cm^3

   3080cm^3 = x%

   3415cm^3 = 100%

   $$X\% = \frac{3080cm^3 \times 100\%}{3415cm^3} = 90.2\%$$

   II. Quantity of seeded = 2410+880 = 3290cm^3

   3290cm^3 = x%

   3794cm^3 = 100%

   $$X\% = \frac{3290cm^3 \times 100\%}{3794cm^3} = 86.7\%$$

8. Average temperature for the first five days:

$$= \frac{32+35+34+36+33}{5}$$

$= 35°C$

9. Quantity of gas obtained in the first five days:

Unseeded = 190+245+360+565+890

= $2250cm^3$

Seeded = 269+350+440+580+771

= $2410\ cm^3$

10. Total quantity of gas produced:

Unseeded = $3415cm^3$

Seeded = $3794cm^3$

Difference = 3794 – 3415

= $379cm^3$

Percentage increase (x%)

$379cm^3 = x\%$

$3415cm^3 = 100\%$

$$X\% = \frac{379cm^3 \times 100}{3415cm^3} = 11.089\%$$

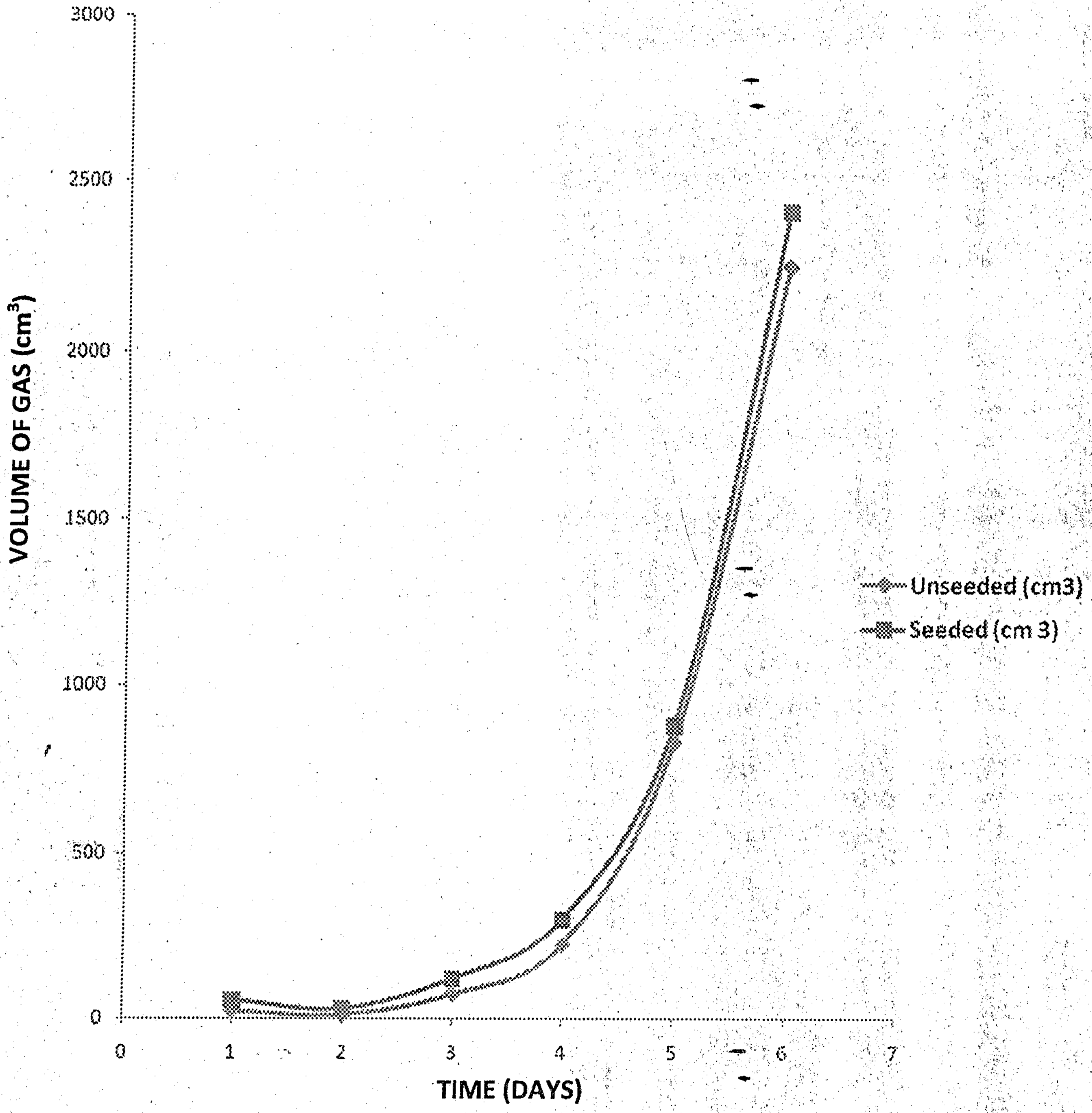
11. The number of days (time) are arranged in this order:

1-5 ≡ 6

11. The number of days (time) are arranged in this order:

1-5	≡ 6
6-10	≡ 5
11-15	≡ 4
16-20	≡ 3
21-25	≡ 2
26-28	≡ 1

APPENDIX II


3000
2500
2000
1500
1000
500
0
VOLUME OF GAS (cm3)
0
1
2
3
4
5
6
7
TIME (DAYS)
Unseeded (cm3)
Seeded (cm 3)