BIOGAS PRODUCTION FROM KITCHEN WASTE

A Seminar Report submitted in partial fulfillment of the requirements for Bachelor of Technology (Biotechnology)

Submitted By

SUYOG VIJ

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Guided by

Prof. Krishna Parmanik

Department of Biotechnology and Medical Engineering

National Institute of Technology, Rourkela.

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NATIONAL INSTITUTE OF TECHNOLOGY ROURKELA, ORISSA

Certificate of Approval

This is to certify that the thesis entitled "**Biogas production from kitchen waste & to test the Quality and Quantity of biogas produced from kitchen waste under suitable conditions"** submitted by **SUYOG VIJ** has been carried out under my supervision in partial fulfillment of the requirements for the Degree of ***Bachelor of Technology (B.Tech.)*** in ***Biotechnology Engineering*** at National Institute Of Technology Rourkela and this work has not been submitted elsewhere for any other academic degree/diploma to the best of my knowledge.

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Prof. Krishna Parmanik

Professor

Department Of Biotech & Medical Engg.

National Institute of Technology

Rourkela-769008, Odhisha

Date :

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SUYOG VIJ

107BT016

Department of Biotechnology & Medical Engineering

NIT Rourkela, ODHISA

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ABSTRACT

In our institute we have seven hostels and all having their own individual mess, where daily a large amount of kitchen waste is obtained which can be utilized for better purposes. Biogas production requires Anaerobic digestion. Project was to Create an Organic Processing Facility to create biogas which will be more cost effective, eco-friendly, cut down on landfill waste, generate a high-quality renewable fuel, and reduce carbon dioxide & methane emissions. Overall by creating a biogas reactors on campus in the backyard of our hostels will be beneficial. Kitchen (food waste) was collected from different hostels of National Institute of Technology, Rourkela's Mess as feedstock for our reactor which works as anaerobic digester system to produce biogas energy. The anaerobic digestion of kitchen waste produces biogas, a valuable energy resource Anaerobic digestion is a microbial process for production of biogas, which consist of Primarily methane (CH4) & carbon dioxide (CO2). Biogas can be used as energy source and also for numerous purposes. But, any possible applications requires knowledge & information about the composition and quantity of constituents in the biogas produced. The continuously-fed digester requires addition of sodium hydroxide (NaOH) to maintain the alkalinity and pH to 7. For this reactor we have prepared our Inoculum than we installed batch reactors, to which inoculum of previous cow dung slurry along with the kitchen waste was added to develop our own Inoculum. A combination of these mixed inoculum was used for biogas production at 37°C in laboratory(small scale) reactor (20L capacity) In our study, the production of biogas and methane is done from the starch-rich and sugary material and is determined at laboratory scale using the simple digesters.

CHAPTER 1

1.1 INTRODUCTION

Due to scarcity of petroleum and coal it threatens supply of fuel throughout the world also problem of their combustion leds to research in different corners to get access the new sources of energy, like renewable energy resources. Solar energy, wind energy, different thermal and hydro sources of energy, biogas are all renewable energy resources. But, biogas is distinct from other renewable energies because of its characterstics of using,controlling and collecting organic wastes and at the same time producing fertilizer and water for use in agricultural irrigation. Biogas does not have any geographical limitations nor does it requires advanced technology for producing energy, also it is very simple to use and apply.

Deforestation is a very big problem in developing countries like India, most of the part depends on charcoal and fuel-wood for fuel supply which requires cutting of forest. Also, due to deforestation It leads to decrease the fertility of land by soil erosion. Use of dung , firewood as energy is also harmful for the health of the masses due to the smoke arising from them causing air pollution. We need an ecofriendly substitute for energy .

Kitchen waste is organic material having the high calorific value and nutritive value to microbes, that's why efficiency of methane production can be increased by several order of magnitude as said earlier.It means higher efficiency and size of reactor and cost of biogas production is reduced. Also in most of cities and places, kitchen waste is disposed in landfill or discarded which causes the public health hazards and diseses like malaria, cholera, typhoid. Inadequate management of wastes like uncontrolled dumping bears several adverse consequences: It not only leads to polluting surface and groundwater through leachate and further promotes the breeding of flies , mosquitoes, rats and other disease bearing vectors. Also, it emits unpleasant odour & methane which is a major greenhouse gas contributing to global warming.

Mankind can tackle this problem(threat) successfully with the help of methane , however till now we have not been benifited, because of ignorance of basic sciences – like output of work is dependent on energy available for doing that work. This fact can be seen in current practices of using low calororific inputs like cattle dung, distillery effluent, municipal solid waste (MSW) or seweage, in biogas plants, making methane generation highly inefficient. We can make this system extremely efficient by using kitchen waste/food wastes.

In 2003, **Dr. Anand Karve**[2][4] (President ARTI) developed a compact biogas system that uses starchy or sugary feedstock material and the analysis shows that this new system is 800 times more efficient than conventional biogas plants..

Why this type of plant ?

The proper disposal of NIT ROURKELA's Hostel kitchen waste will be done in ecofriendly and cost effective way. While calculating the cost effectiveness of waste disposal we have to think more than monetory prospects. The dumping of food in places and making the places unhygienic can be taken good care of. It adds to the value of such Biogas plants. Using the natural processes like microorganisms kitchen waste & biodegradable waste viz paper, pulp can be utilized

Anaerobic digestion is controlled biological degradation process which allows efficient capturing & utilization of biogas (approx. 60% methane and 40% carbon dioxide) for energy generation. Anaerobic digestion of food waste is achievable but different types, composition of food waste results in varying degrees of methane yields, and thus the effects of mixing various types of food waste and their proportions should be determined on case by case basis.

Anaerobic digestion (AD) is a promising method to treat the kitchen wastes. While Anaerobic digestion for treatment of animal dung is common in rural parts of developing countries, information on technical and operational feasibilities of the treatment of organic solid waste is limited in those parts. There are many factors affecting the design and performance of anaerobic digestion. Some are related to feedstock characteristics, design of reactors and operation conditions in real time. Physical and chemical characteristics of the organic wastes are important for designing and operating digesters, because they affect the biogas production and process stability during anaerobic digestion. They include, moisture content, volatile solids, nutrient contents, particle size, & biodegradability. The biodegradability of a feed is indicated by biogas production or methane yield and percentage of solids (total solids or total volatile solids) that are destroyed in the anaerobic digestion. The biogas or methane yield is measured by the amount of biogas or methane that can be produced per unit of volatile solids contained in the feedstock after subjecting it to anaerobic digestion for a sufficient amount of time under a given temperature which is taken to be laboratory temperature in our case.

In recent times varied technological modifications and improvements have been introduced to diminish the costs for the production of biogas. Different Methods have been developed to increase speed of fermentation for the bacteria gas producers, reduction of the size of the reactors, the use of starchy, sugary materials for their production , the modification of the feeding materials for fermentation and the exit of the effluent for their better employment, as well as compaction of the equipments to produce gas in small places like back-yard, among others.

Larger facilities operating costs can be reduced, per unit, to the point that, in the current economic framework, very large Anaerobic Digestion facilities can be profitable whereas small ones are not this is what is Economics of scale. If energy prices continue to rise and the demand for local waste treatment, and fertilizers increases, this framework may change.

1.2 BIOGAS

BIOGAS is produced by bacteria through the bio-degradation of organic material under anaerobic conditions. Natural generation of biogas is an important part of bio-geochemical carbon cycle. It can be used both in rural and urban areas.

Table-1. Composition of biogas.

Component	**Concentration (by volume)**
Methane (CH_4)	55-60 %
Carbon dioxide (CO_2)	35-40 %
Water (H_2O)	2-7 %
Hydrogen sulphide (H_2S)	20-20,000 ppm (2%)
Ammonia (NH_3)	0-0.05 %
Nitrogen (N)	0-2 %
Oxygen (O_2)	0-2 %
Hydrogen (H)	0-1 %

1.3 CHARACTERSTICS OF BIOGAS

Composition of biogas depends upon feed material also. Biogas is about 20% lighter than air has an ignition temperature in range of 650 to 750 0C.An odorless & colourless gas that burns with blue flame similar to LPG gas. Its caloric value is 20 Mega Joules (MJ) /m3 and it usually burns with 60 % efficiency in a conventional biogas stove.

This gas is useful as fuel to substitute firewood, cow-dung, petrol, LPG, diesel, & electricity, depending on the nature of the task, and local supply conditions and constraints.

Biogas digestor systems provides a residue organic waste, after its anaerobic digestion(AD) that has superior nutrient qualities over normal organic fertilizer, as it is in the form of ammonia and can be used as manure. Anaerobic biogas digesters also function as waste disposal systems, particularly for human wastes, and can, therefore, prevent potential sources of environmental contamination and the spread of pathogens and disease causing bacteria. Biogas technology is particularly valuable in agricultural residual treatment of animal excreta and kitchen refuse(residuals).

1.4 PROPERTIES OF BIOGAS

1. Change in volume as a function of temperature and pressure.
2. Change in calorific value as function of temperature ,pressure and water vapour content.
3. Change in water vapour as a function of temperature and pressure.

1.5 FACTORS AFFECTING YIELD AND PRODUCTION OF BIOGAS

Many factors affecting the fermentation process of organic substances under anaerobic condition are,

- The quantity and nature of organic matter
- The temperature
- Acidity and alkanity (PH value) of substrate
- The flow and dilution of material

TABLE 2:- GENERAL FEATURES OF BIOGAS

Energy Content	6-6.5 kWh/m3
Fuel Equivalent	0.6-0.65 l oil/m3 biogas
Explosion Limits	6-12 % biogas in air
Ignition Temperature	650-750 *C
Critical Pressure	75-89 bar
Critical temperature	-82.5 *C
Normal Density	1.2 kg/m3
Smell	Bad eggs

1.6 BENEFITS OF BIOGAS TECHNOLOGY **:**

- Production of energy.
- Transformation of organic wastes to very high quality fertilizer.
- Improvement of hygienic conditions through reduction of pathogens.
- Environmental advantages through protection of soil, water, air etc.
- Micro-economical benefits by energy and fertilizer substitutes.
- Macro-economical benefits through decentralizes energy generation and environmental protection.

CHAPTER 2

2.1 PRODUCTION PROCESS

A typical biogas system consists of the following components:

(1) Manure collection

(2) Anaerobic digester

(3) Effluent storage

(4) Gas handling

(5) Gas use.

Biogas is a renewable form of energy. Methanogens (methane producing bacteria) are last link in a chain of microorganisms which degrade organic material and returns product of decomposition to the environment.

2.2 PRINCIPLES FOR PRODUCTION OF BIOGAS

Organic substances exist in wide variety from living beings to dead organisms . Organic matters are composed of Carbon (C), combined with elements such as Hydrogen (H), Oxygen (O), Nitrogen (N), Sulphur (S) to form variety of organic compounds such as carbohydrates, proteins & lipids. In nature MOs (microorganisms), through digestion process breaks the complex carbon into smaller substances.

There are 2 types of digestion process :

- Aerobic digestion.
- Anaerobic digestion.

The digestion process occurring in *presence of Oxygen* is called **Aerobic digestion** and produces mixtures of gases having carbon dioxide (CO_2), one of the main "green houses" responsible for global warming.

The digestion process occurring *without (absence) oxygen* is called **Anaerobic digestion** which generates mixtures of gases. The gas produced which is mainly methane produces 5200-5800 KJ/m^3 which when burned at normal room temperature and presents a viable environmentally friendly energy source to replace fossil fuels (non-renewable).

CHAPTER 3

3.1 ANAEROBIC DIGESTION

It is also referred to as biomethanization, is a natural process that takes place in absence of air (oxygen). It involves biochemical decomposition of complex organic material by various biochemical processes with release of energy rich biogas and production of nutrious effluents.

BIOLOGICAL PROCESS (MICROBIOLOGY)

1. HYDROLYSIS
2. ACIDIFICATION
3. METHANOGENESIS

HYDROLYSIS: In the first step the organic matter is enzymolysed externally by extracellular enzymes, cellulose, amylase, protease & lipase ,of microorganisms. Bacteria decompose long chains of complex carbohydrates, proteins, & lipids into small chains. For example, Polysaccharides are converted into monosaccharide. Proteins are split into peptides and amino acids.

ACIDIFICATION: Acid-producing bacteria, involved this step, convert the intermediates of fermenting bacteria into acetic acid, hydrogen and carbon dioxide. These bacteria are anaerobic and can grow under acidic conditions. To produce acetic acid, they need oxygen and carbon. For this, they use dissolved O2 or bounded-oxygen. Hereby, the acid-producing bacteria creates anaerobic condition which is essential for the methane producing microorganisms. Also , they reduce the compounds with low molecular weights into alcohols, organic acids, amino acids, carbon dioxide, hydrogen sulphide and traces of methane. From a chemical point, this process is partially endergonic (i.e. only possible with energy input), since bacteria alone are not capable of sustaining that type of reaction.

METHANOGENESIS: (Methane formation) Methane-producing bacteria, which were involved in the third step, decompose compounds having low molecular weight. They utilize hydrogen, carbon dioxide and acetic acid to form methane and carbon dioxide. Under natural conditions, CH4 producing microorganisms occur to the extent that anaerobic conditions are provided, e.g. under water (for example in marine sediments),and in marshes. They are basically anaerobic and very sensitive to environmental changes, if any occurs. The methanogenic bacteria belongs to the archaebacter genus, i.e. to a group of bacteria with heterogeneous morphology and lot of common biochemical and molecular-biological properties that distinguishes them from other bacterias. The main difference lies in the makeup of the bacteria's cell walls.

Symbiosis of bacteria:

Methane and acid-producing bacteria act in a symbiotical way. Acid producing bacteria create an atmosphere with ideal parameters for methane producing bacteria (anaerobic conditions, compounds with a low molecular weight). On the other hand, methane-producing microorganisms use the intermediates of the acid producing bacteria. Without consuming them, toxic conditions for the acid-producing microorganisms would develop. In real time fermentation processes the metabolic actions of various bacteria acts in a design. No single bacteria is able to produce fermentation products alone as it requires others too.

3.2 FLOW CHART FOR BIODEGRADATION :

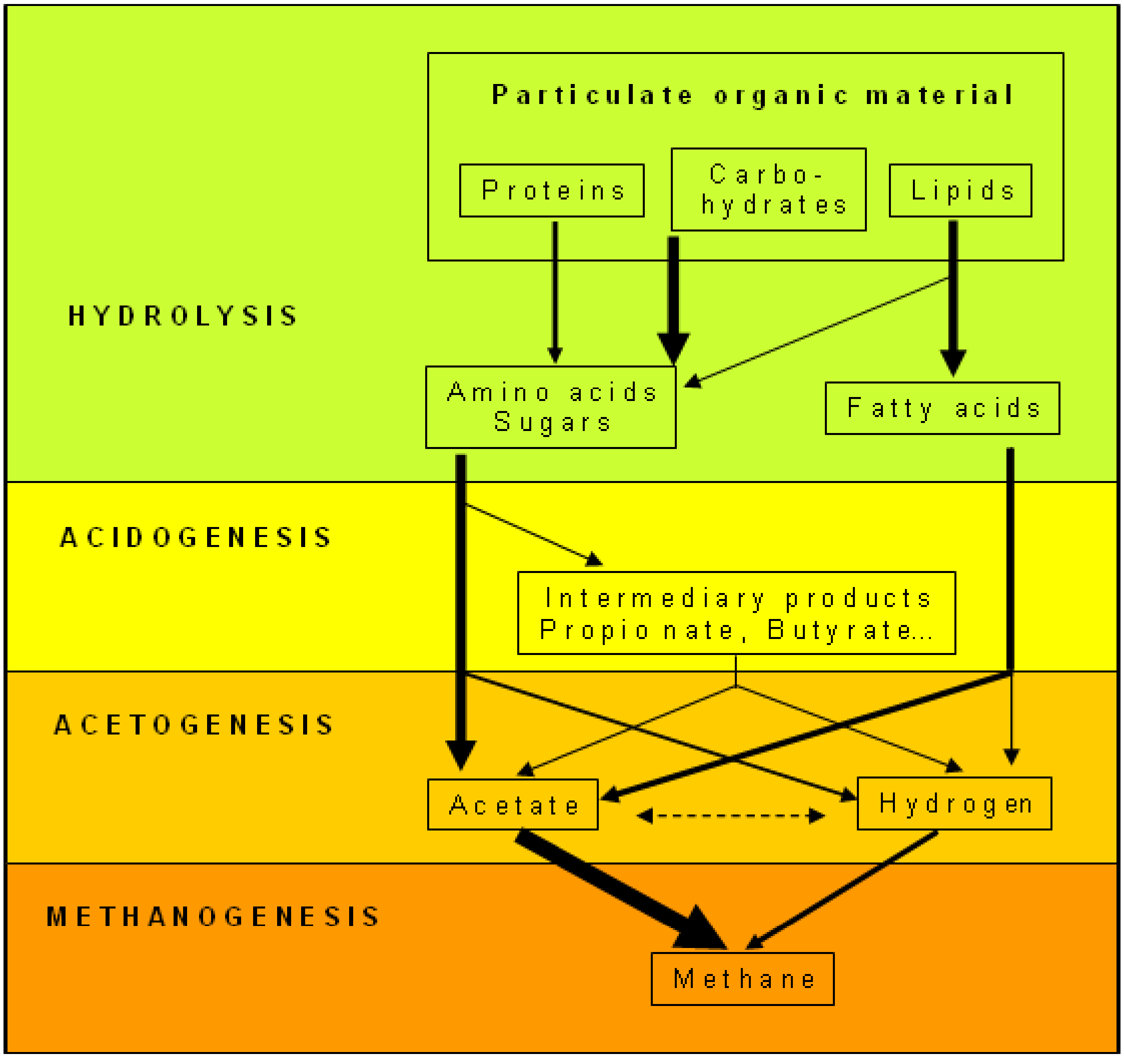

Fig. 1 Flow chart of anaerobic digestion

CHAPTER 4

4.1 LITERATURE REVIEW

ARTI – appropriate rural technology of India, pune (2003) has developed a **compact biogas plant** which uses waste food rather than any cow dung as feedstock, to supply biogas for cooking. The plant is sufficiently compact to be used by urban households, and about 2000 are currently in use – both in urban and rural households in Maharashtra. The design and development of this simple, yet powerful technology for the people, has won ARTI the Ashden Award for sustainable Energy 2006 in the Food Security category. Dr. Anand Karve (ARTI) developed a compact biogas system that uses starchy or sugary feedstock (waste grain flour, spoilt grain, overripe or misshapen fruit, nonedible seeds, fruits and rhizomes, green leaves, kitchen watse, leftover food, etc). Just 2 kg of such feedstock produces about 500 g of methane, and the reaction is completed with 24 hours. The conventional biogas systems, using cattle dung, sewerage, etc. use about 40 kg feedstock to produce the same quantity of methane, and require about 40 days to complete the reaction. Thus, from the point of view of conversion of feedstock into methane, the system developed by Dr. Anand Karve[2][3] is 20 times as efficient as the conventional system, and from the point of view of reaction time, it is 40 times as efficient. Thus, overall, the new system is 800 times as efficient as the conventional biogas system.

Hilkiah Igoni[5] (2008) studied **the Effect of Total Solids Concentration of Municipal Solid Waste on the Biogas Produced in an Anaerobic Continuous Digester**. The total solids (TS) concentration of the waste influences the pH, temperature and effectiveness of the microorganisms in the decomposition process. They investigated various concentrations of the TS of MSW in an anaerobic continuously stirred tank reactor (CSTR) and the corresponding amounts of biogas produced, in order to determine conditions for optimum gas production. The results show that when the percentage total solids (PTS) of municipal sold waste in an anaerobic continuous digestion process increases, there is a corresponding geometric increase for biogas produced. A statistical analysis of the relationship between the volume of biogas produced and the percentage total solids concentration established that the former is a power function of the latter, indicating that at some point in the increase of the TS, no further rise in the volume of the biogas would be obtained.

Kumar et al., (2004) investigated the reactivity of methane. They concluded that it has more than 20 times the global warming potential of carbon dioxide and that the concentration of it in the atmosphere is increasing with one to two per cent per year. The article continues by highlighting that about 3 to 19% of anthropogenic sources of methane originate from landfills.

Shalini Singh[4] et al. (2000) studied **the increased biogas production using microbial stimulants**. They studied the effect of microbial stimulant aquasan and teresan on biogas yield from cattle dung and combined residue of cattle dung and kitchen waste respectively. The result shows that dual addition of aquasan to cattle dung on day 1 and day 15 increased the gas production by 55% over unamended cattle dung and addition of teresan to cattel dung : kitchen waste (1:1) mixed residue 15% increased gas production.

Lissens et al. (2004) completed a study on a biogas operation to increase the total biogas yield from 50% available biogas to 90% using several treatments including: a mesophilic laboratory scale continuously stirred tank reactor, an up flow biofilm reactor, a fiber liquefaction reactor releasing the bacteria *Fibrobacter succinogenes* and a system that adds water during the process. These methods were sufficient in bringing about large increases to the total yield; however, the study was under a very controlled method, which leaves room for error when used under varying conditions. However, Bouallagui et al. (2004) did determine that minor influxes in temperature do not severely impact the anaerobic digestion for biogas production.

As Taleghani and Kia (2005) observed, the resource limitation of fossil fuels and the problems arising from their combustion has led to widespread research on the accessibility of new and renewable energy resources. Solar, wind, thermal and hydro sources, and biogas are all renewable energy resources. But what makes biogas distinct from other renewable energies is its importance in controlling and collecting organic waste material and at the same time producing fertilizer and water for use in agricultural irrigation. Biogas does not have any geographical limitations or requires advanced technology for producing energy, nor is it complex or monopolistic.

Murphy, McKeog, and Kiely (2004) completed a study in Ireland analyzing the usages of biogas and biofuels. This study provides a detailed summary of comparisons with other fuel sources with regards to its effect on the environment, finical dependence, and functioning of the plant. One of the conclusions the study found was a greater economic advantage with utilizing biofuels for transport rather than power production; however, power generation was more permanent and has less maintenance demands.

Thomsen et al. (2004) found that increasing oxygen pressure during wet oxidation on the digested biowaste increased the total amount of methane yield. Specifically, the yield which is normally 50 to 60% increased by 35 to 40% demonstrating the increased ability to retrieve methane to produce economic benefits.

Carrasco et al. (2004) studied the feasibility for dairy cow waste to be used in anaerobic digestive systems. Because the animal's wastes are more reactive than other cow wastes, the study suggests dairy cow wastes should be chosen over other animal wastes .

Jantsch and Mattiasson (2004) discuss how anaerobic digestion is a suitable method for the treatment of wastewater and organic wastes, yielding biogas as a useful by-product. However, due to instabilities in start-up and operation it is often not considered. A common way of preventing instability problems and avoiding acidification in anaerobic digesters is to keep the organic load of the digester far below its maximum capacity. There are a large number of factors which affect biogas production efficiency including: environmental conditions such as pH, temperature, type and quality of substrate; mixing; high organic loading; formation of high volatile fatty acids; and inadequate alkalinity.

Jong Won Kang et al (2010) studied t**he On-site Removal of H2S from Biogas Produced by Food Waste using an Aerobic Sludge Biofilter for Steam Reforming Processing.** They show that A biofilter containing immobilized aerobic sludge was successfully adapted for the removal of H2S and CO2 from the biogas produced using food waste. The biofilter efficiently removed 99% of 1,058 ppmv H2S from biogas produced by food waste treatment system at a retention time of 400 sec. The maximum observed removal rate was 359 g-H2S/m3/h with an average mass loading rate of 14.7 g-H2S/m3/h for the large-scale biofilter. The large-scale biofilter using a mixed culture system showed better H2S removal capability than biofilters using specific bacteria strains. In the kinetic analysis, the maximum H2S removal rate (Vm) and half saturation constant (Ks) were calculated to be 842.6 g-H2S/m3/h and 2.2 mg/L, respectively. Syngas was generated by the catalytic steam reforming of purified biogas, which indicates the possibility of high efficiency electricity generation by SOFCs and methanol manufacturing.

Taleghani and Kia, (2005) outlined the economic, and social benefits of biogas production.

- The economic benefits were as follows:

1. Treatment of solid waste without long-term follow-up costs usually due to soil and water pollution
2. Increased local distribution of fertilizer, chemical herbicides, and pesticide demand
3. Generation of income through compost and energy sales (biogas/electricity/heat) to the public grid
4. Improved soil/agriculture productivity through long-term effects on soil structure and fertility through compost use
5. Reduction of landfill space and consequently land costs

- The social and health effects associated with biogas include:

1. Creation of employment in biogas sector
2. Improvement of the general condition of farmers due to the local availability of soil-improving fertilizer
3. Decreased smell and scavenger rodents and birds.

CHAPTER 5

5.1 OBJECTIVES:

- Optimization of gas production
- Comparison with conventional plants
- Effect of different parameters viz.
  * Temperature
  * PH
  * Total & volatile solid concentration
  * Alkalinity
  * C:N Ratio
- To increase the production by using
  * Additives
  * Nutrients
  * Nitrogen source
- Check optimization of gas production at lab scale and field scale.

5.2 WORK PLAN :

This work is conducted in two phases, 1st at laboratory scale and 2nd at large scale in plastic tank.

Source of kitchen waste:

The waste used in this study is collected from Homi-bhbha hall of residence, NIT Rourkela. Waste contains the cooked rice, vegetables and non-used vegetables waste. This waste is crushed by mixer grinder and slurry was prepared mixing with water.

Lab scale:

In lab scale this experiment was done in 1lit, 2lit & 20lit bottles, digester. Here different concentration & combination of wastes are used. Different parameters of input and effluent like total solid, volatile solid, volatile fatty acid, pH, Temperature, Nitrogen, Carbon, Phosphorous will be measured. After that in 20 lit. plastic container study done to check the gas production.

Large scale:

Here two syntax tanks will be used, one of 1000 lit from digester and other of 750 lit for gas collector.

Here also different parameter will be checked like…

- Total solid – increasing the feeding rate from 100 gm to 5 kg and to check effect on gas production and effluent quality.
- PH – to check change in PH and control of PH
- Temperature effect

Quality and quantity of produced biogas

CHAPTER 6

6.1 PRECAUTIONS WHILE COLLECTING SAMPLE

KITCHEN WASTE:

1. A separate container for coconut shells, egg shells, peels and chicken mutton bones. These will be crushed separately by mixer grinders.
2. Different containers of volumes 5l to collect the wet waste, stale cooked food, waste milk products. The vegetables refuse like peels, rotten potatoes coriander leaves collected in bags.

INSTALLATIONS :

Important aspect in smoother running of plant by avoiding the choking of the plant. This occur due to thick biological waste that not reaches to the microorganisms to digest. The easy answer to this problem is to convert solid wastes into liquid slurry . mixer can be used to convert solid into slurry.

6.2 Analysis of GAS produced in our reactor

<u>Syringe method:</u>

Syringe method was used for the measurement of amount of methane and carbon dioxide in our gas produced

A syringe fitted with flexible tube and dilute sodium hydroxide (NaOH) solution was used for carbon dioxide percentage estimation, since NaOH absorbs CO2 but dose not absorbs methane.

Procedure followed:

(1) Prepare 100 ml of dilute sodium hydroxide solution by dissolving granules of NaOH in about 100 ml of water.

(2) Take 20-30 ml sample of biogas produced during experiment into the syringe (initially fill syringe with H2O to reduce air contamination) and put end of the tube into the NaOH solution, then push out excess gas to get a 10 ml gas sample.

(3) Now take approximately 20 ml of solution and keep the end of the tube submerged in the NaOH solution while shaking syringe for 30 seconds.

(4) Point it downwards and push the excess liquid out, so that syringe plunger level reaches 10 ml. Now read the volume of liquid, which should be 3-4 ml indicating about 30-40% of gas absorbed so we can say the balance of 65-60% is methane.

(5) If the flame does not burn properly and you get over 50% methane (a reading of less than 5 ml of liquid) you must have nitrogen or some other gas present.

COMPOSITION OF BIOGAS OBSERVED AS :

Mehane (50 - 65%)
Carbon dioxide (30 - 40%)
Nitrogen (2 - 3%)
water vapour(0.5%)

CHAPTER 7

7.1 ANALYTICAL METHODS & CALCULATIONS

TOTAL SOLIDS (TS %) - It is the amount of solid present in the sample after the water present in it is evaporised.

The sample, approximately 10 gm is taken and poured in foil plate and dried to a constant weight at about 105 0C in furnace.

TS % = (Final weight/Initial weight) * 100

VOLATILE SOLIDS (VS %) – Dried residue from Total Solid analysis weighed and heated in crucible for 2hrs at 500 0C in furnace. After cooling crucible residue weighed.

VS % = [100-(V3-V1/V2-V1)] * 100

V1= Weight of crucible.

V2= Weight of dry residue & crucible.

V3= Weight of ash & crucible (after cooling)

VOLATILE FATTY ACID (VFA) - Volatile fatty acids (VFA's) are fatty acids with carbon chain of six carbons or fewer. They can be created through fermentation in the intestine. Examples include: acetate , propionate , butyrate. There are many titration method for VFA measurement. I had used two method for VFA measurement.

Method 1

1. Take 100 ml sample in beaker
2. Filter the sample.
3. Check pH of filterate.
4. Take 20 ml of filterate and add 0.1M HCl until pH reaches 4
5. Heat in the hot plate for 3 mins

6. After cooling titrate with 0.01M NaOH to take pH from 4 to 7.

7. Amount of HCl & NaOH recorded

Total VFA content in mg/l acetic acid = (Volume of NaOH titrated) * 87.5

Method 2:

Titration procedure for measurements of VFA and alkalinity according to Kapp :

- Before analysis, the sample needs to be filtered through a 0.45μm membrane filter.
- Filtered sample (20-50ml) is put into a titration vessel, the size of which is determined by the basic requirement to guarantee that the tip of the pH electrode is always below the liquid surface.
- Initial pH is recorded
- The sample is titrated slowly with 0.1N sulphuric acid until pH 5.0 is reached. The added volume A1 [ml] of the titrant is recorded.
- More acid is slowly added until pH 4.3 is reached. The volume A2 [ml] of the added titrant is again recorded.
- The latter step is repeated until pH 4. 0 is reached, and the volume A3 [ml] of added titrant recorded once more.
- A constant mixing of sample and added titrant is required right from the start to minimize exchange with the atmosphere during titration.

❖ Calculation scheme according to Kapp:

$$Alk = A * N * 1000 / SV$$

Alk = Alkalinity [mmol/l], also referred to as TIC (Total Inorganic Carbon).

A = Consumption of Sulphuric acid (H_2SO_4, 0.1N) to titrate from initial pH to pH 4.3 [ml]. A= A1 + A2 [ml].

N = Normality [mmol/l].

SV = Initial sample volume [ml].

$$VFA = (131340 * N * B / 20) - (3.08 * Alk) – 10.9$$

VFA = Volatile fatty acids [mg/l acetic acid equivalents].

N = Normality [mmol/l]

B = Consumption of sulphuric acid (H_2SO_4 , 0.1N) to titrate sample from pH 5.0 to pH 4.0 [ml], due to HCO_3/CO_2 buffer. B = A2 + A3 [ml]

SV = Initial sample volume [ml]

Alk = Alkalinity [mmol/l]

- **A/TIC-ratio**

The A/TIC-method was developed at the Federal Research Institute for Agriculture (FAL) in Braunschweig, Germany. Used as an indicator of the process stability inside the digester, it expresses the ratio between Volatile Fatty Acids and buffer capacity (alkalinity), or in other words the amount of Acids (A) compared to Total Inorganic Carbon (TIC).

$$\frac{A\ [mg/l] = VFA\ [mg/l]}{TIC\ [mg/l] = Alkalinity\ [mg/l]}$$

<u>ORGANIC CONTENT</u> – Organic dry matter weigh the sample and weigh remaining ashes

Organic content = {Mass of TS - Mass of ashes}/Mass of TS

CHAPTER 8

8.1 EXPERIMENT 1.

- A 2 liter bottle
- 50 gm kitchen waste + cow dung
- Rest water (1.5 liter)

Result- Gas production was found but not measured.

8.2 EXPERIMENT 2. Different sets of 1 liter & 2 liters bottles.

3 different sets with different composition are installed as below.

1. 200gm cow dung was mixed with water to make 1lit slurry which is poured in 1lit bottle.
2. 50gm grinded kitchen was mixed with 150gm cow dung and water is added to make 1lit solution which is poured in 1lit bottle.
3. 400gm cow dung was mixed with water to make 2lit slurry which is poured in 2lit bottle.

RESULTS :

In all of the 3 sets gas production occurs and gas burned with **blue flame**. process continues, volatile fatty acids(VFA) are produced which causes the decrease in PH of solution.

8.3 COMPOSITION OF KITCHEN WASTE OF NIT, ROURKELA HOSTELS

Average composition of kitchen waste was analyzed on various occasions. Over 50 % of waste was composed of uncooked vegetable & fruit waste. Eggs, raw meat, the main source of pathogens were relatively low in mass at 1.5% & 1.2% also about 15% of cooked meat was there.

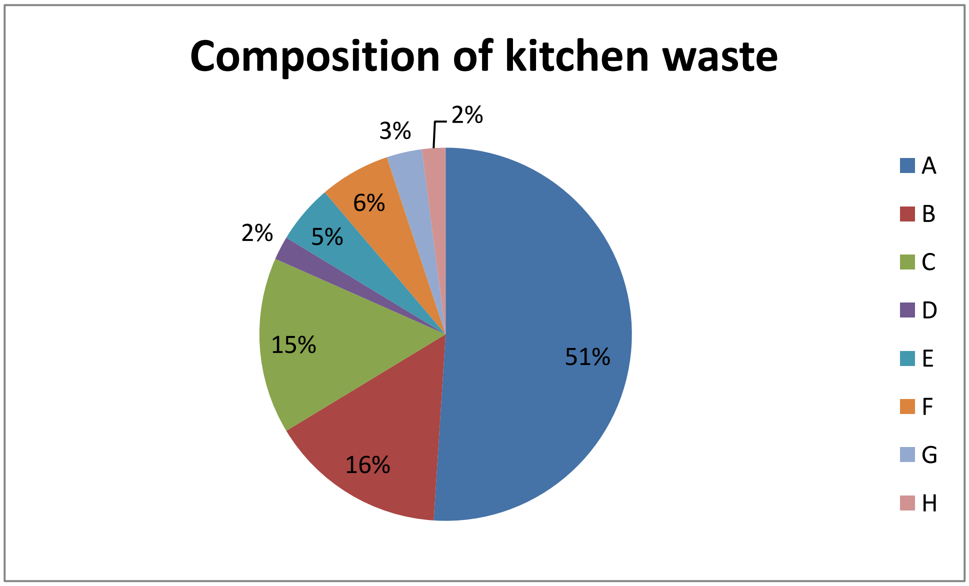

Fig. 2 Composition of kitchen waste

(A) Uncooked fruits & vegetables

(B) Cooked meat

(C) Uncooked meat

(D) Bread

(E) Teabags

(F) Eggs

(G) Cheesse

(H) Paper

8.4 DISCUSSIONS :

From the result it has been seen that in set2 which contain kitchen waste produces more gas, compare to other two set. In set2 with kitchen waste produces average 250.69% more gas than set 1 (with 200gm cow dung) and 67.5% more gas than set 3 (with 400gm cow dung). Means kitchen waste produces more gas than cow dung as kitchen waste contains more nutrient than dung. So use of kitchen waste provide more efficient method of biogas production.

Table 3 : Biogas production in ml

Set no./day	1^{st} day	2^{nd}	3^{rd}	4^{th}	5^{th}	6^{th}	7^{th}	8^{th}	average
1	30	35	20	10	-	40	25	10	23.75
2	80	150	120	50	-	60	90	115	89.37
3	85	75	58	35	-	20	70	100	60.02

From results it has been seen that pH reduces as the process going on as the bacteria produces fatty acids. Here methanogens bacteria which utilize the fatty acids, is slow reaction compare to other so it is rate limiting step in reaction. In set2 which contains kitchen waste pH decreases highly means reaction is fast, means hydrolysis and acidogenesis reaction is fast as organism utilize the waste more speedily than dung. And total solid decreases more in set2.

Table 4 : pH and total solid concentration of setup.

Day	Set 1		Set 2		Set 3	
	PH	TS %	PH	TS %	PH	TS %
1	7.25	8	7.2	6	7.25	8
4	6.7	7.6	5.8	5.4	6.6	7.5
5	6.85	7.6	6.45	5.4	6.9	7.5
8	6.65	7	4.92	4.7	6.5	7

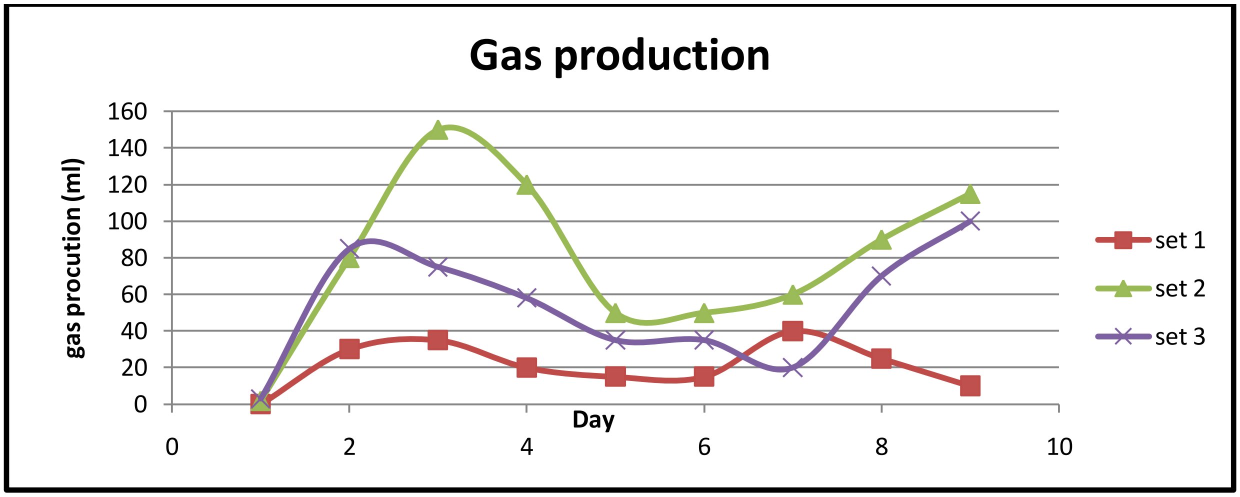

Fig. 3. Gas production V/s day for three sets

Graph Analysis- It can be seen from the graph that gas production increases first upto day 3 but then it starts decreasing as acid concentration increases in the bottles and pH decreases below 7 after 4-5 days water was added to dilute which increases the pH, gas production again starts increasing. Therefore,we can infer that acid concentration greatly affects the biogas production.

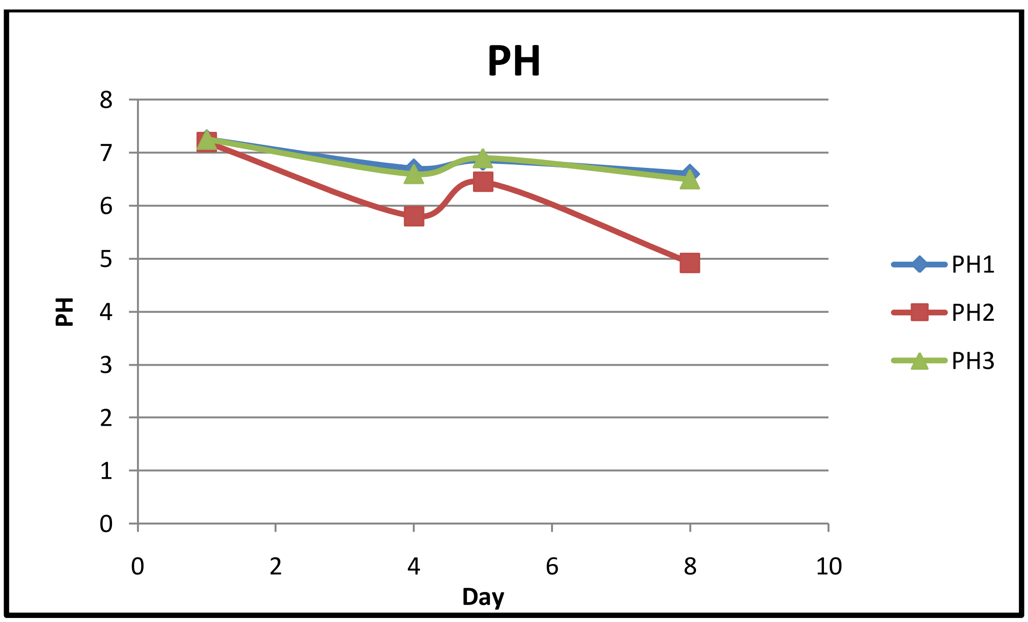

Fig.4 pH V/s day

GRAPH – This graph shows that first the ph is on higher side, as reaction inside the bottles continues it stars decreasing and after day 3 it becomes acidic. Than water added to dilute and thus pH increases.

8.5 PLAN OF BIODIGESTOR

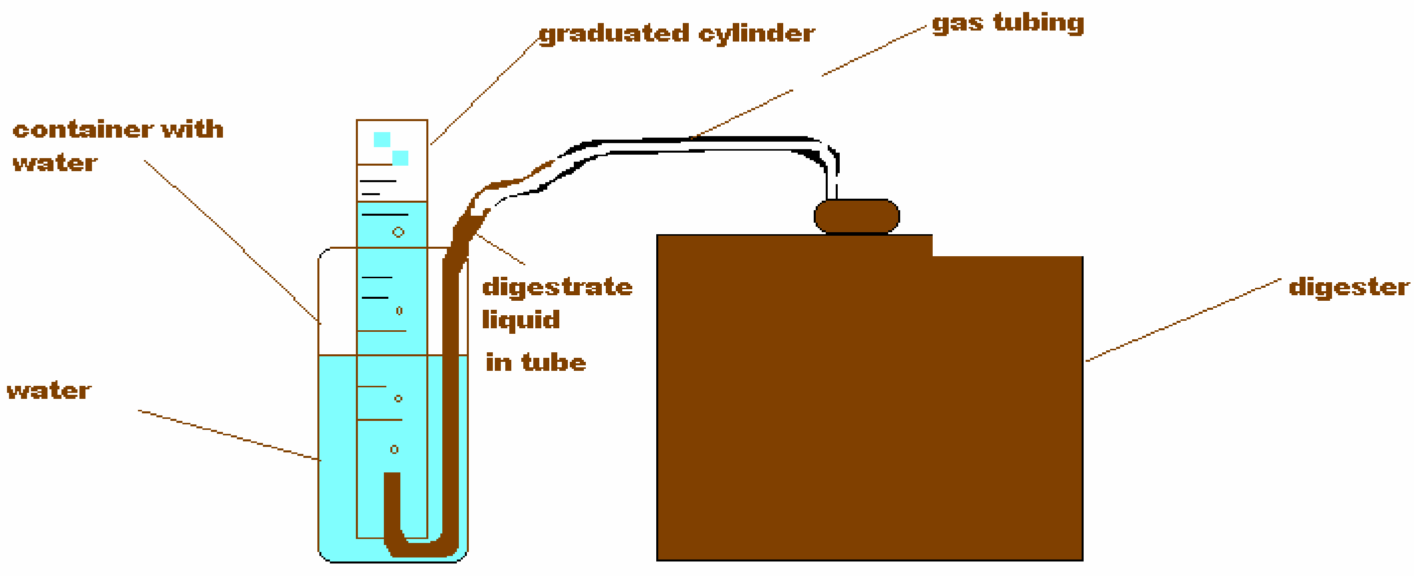

Fig No. 5: Diagram of biodigester

8.6 INSTALATION:

Both the digester was unstalled in environmental lab of biotechnology department. I used the 20 lit. water container as digester. Following were the material used for 20 lit. digester.

TABLE 5: List of materials used In Experiment No. 3

No.	Product Name
1	20 litre container (used for drinking water storage)
2	Solid tape
3	M – seal
4	PVC pipe 0.5’’ (length ~ 1 m)
5	Rubber or plastic cape (to seal container)
6	Funnel (for feed input)
7	Cape 0.5” (to seal effluent pipe)
8	Pipe (for gas output, I was used level pipe) (3-5 m)
9	Bucket (15-20 litter)
10	Bottle – for gas collection (2-10 lit.)

8.7 PROCEDURE AND START UP:

EXPERIMENT 3(N):

Fresh cow dung was collected and mixed with water thoroughly by hand and poured into 20 lit. digester. Content of previous experiment was used as inoculum. As it contains the required microorganism for anaerobic digestion. After the inoculation digester was kept for some days and gas production was checked. After some days kitchen waste was added for checking gas production.

EXPERIMENT 3(O):

This digester contains the following composition.

- 20lit digester.
- Cow dung + inoculum + water added.
- Cow dung – 2.5 lit

- Inoculum - 3.8 lit
- Water – 13.5lit
- PH – 5.02
- NaOH & NaHCO3 added to increase/adjust pH.

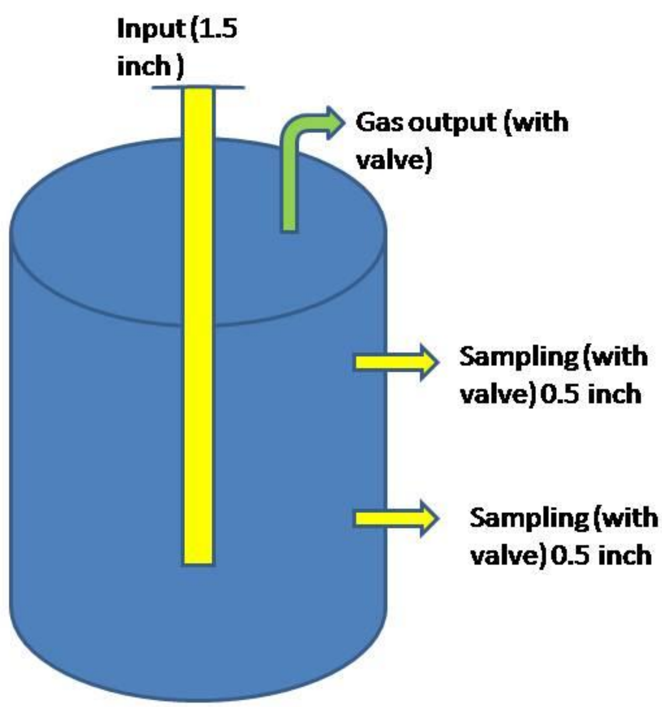

Fig. 6 Layout of experimental setup 3

8.8 RESULTS (for experiment 3)

TABLE 6: daily PH and gas production of digester 3

DAY	**pH (O)**	**pH (N)**	**Gas (O) ml**	**Gas (N) ml**
1	7.5	5.6	-	-
2	7.52	6.82	800	-
3	7.25	6.63	1280	-
4	7.02	6.57	1800	400
5	6.33	6.66	1550	300
6	6.5	6.5	1700	550
7	6.54	6.8	1850	3200
8	6.4	7.03	2000	6500
9	6.9	7.2	1800	6500
10	6.7	7.16	2300	8500
11	6.5	7.2	2200	10400
12	6.51	7.51	2000	12850
13	6.74	7.34	1500	12600
14	6.52	7.3	900	7600
15	6.6	7.26	3750	8500
16	6.7	7.52	4250	9000
17	6.87	7.36	3300	8000
18	6.35	7.8	5300	7600
19	6.52	7.28	7500	9400
20	6.69	7.16	7400	10650
21	6.74	7.4	7250	11500
22	6.49	7.24	7000	11500
23	6.78	7.16	6800	10900

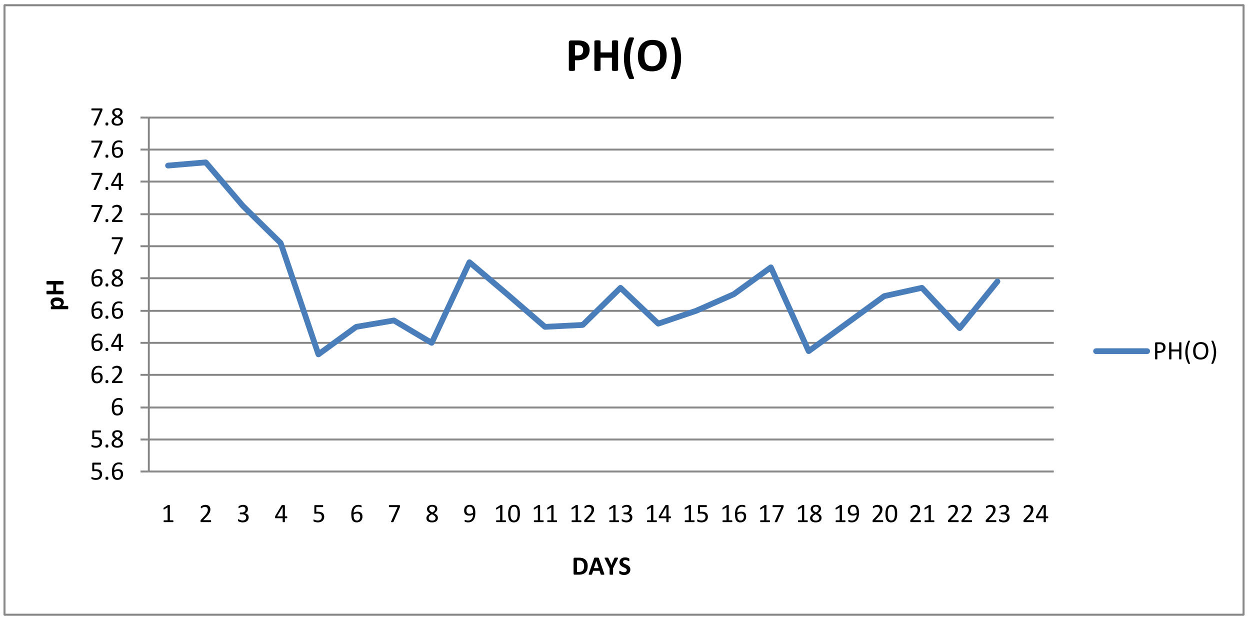

Fig. 7 Daily pH change of digester 3(O)

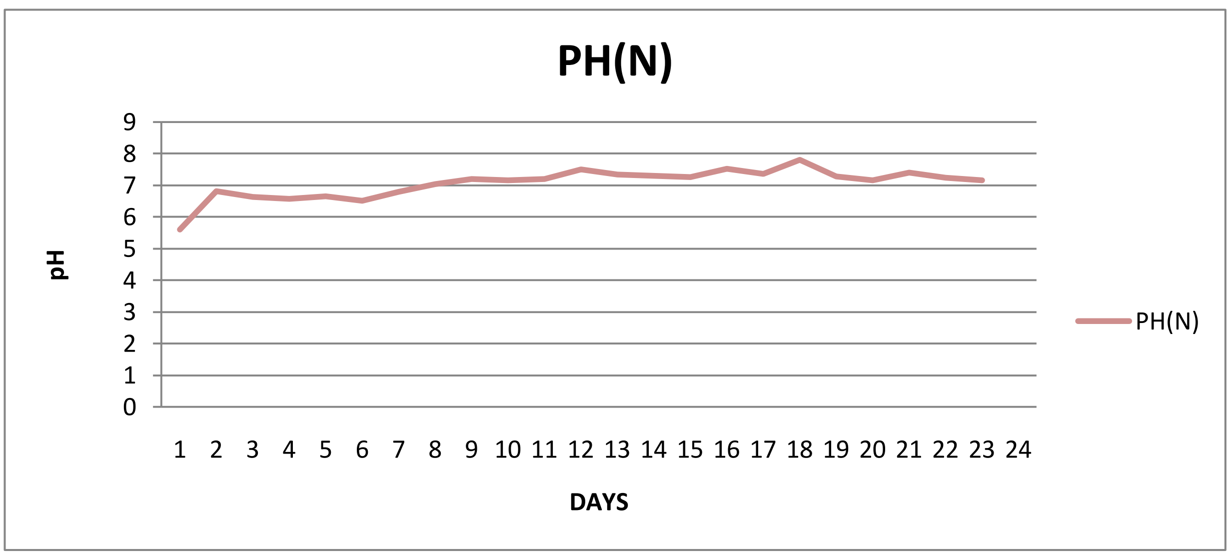

Fig. 8 Daily pH change of digester 3(N)

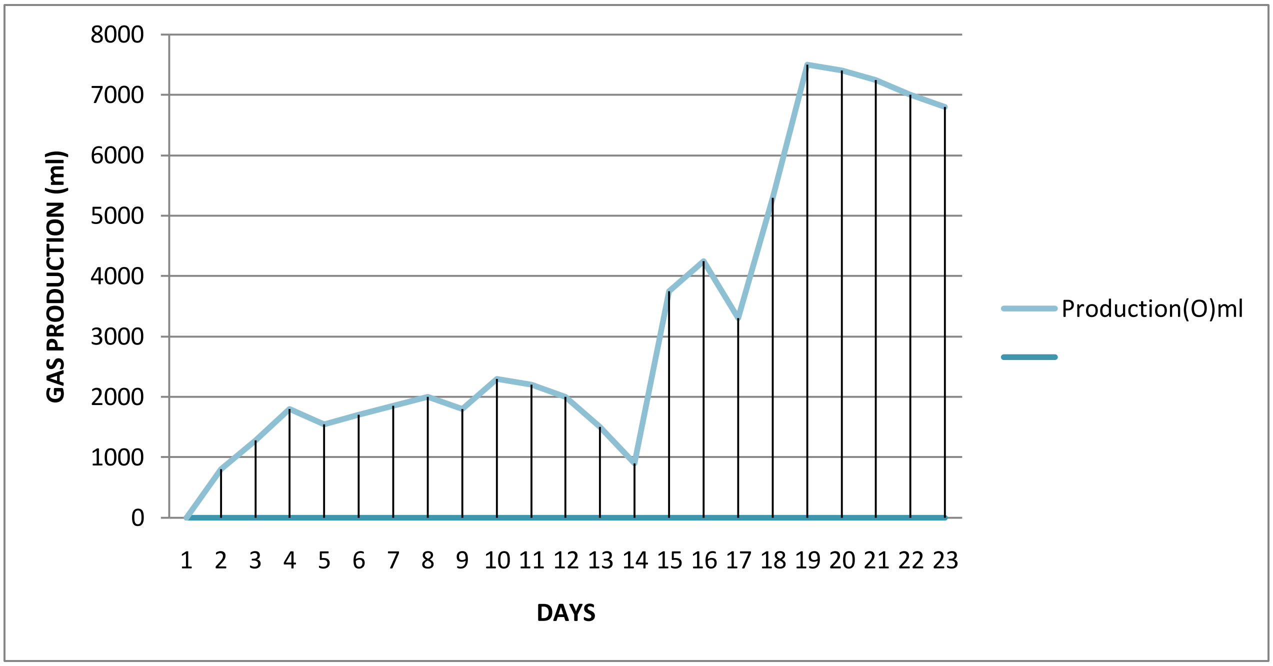

Fig. 9 Daily gas production of digester 3(O)

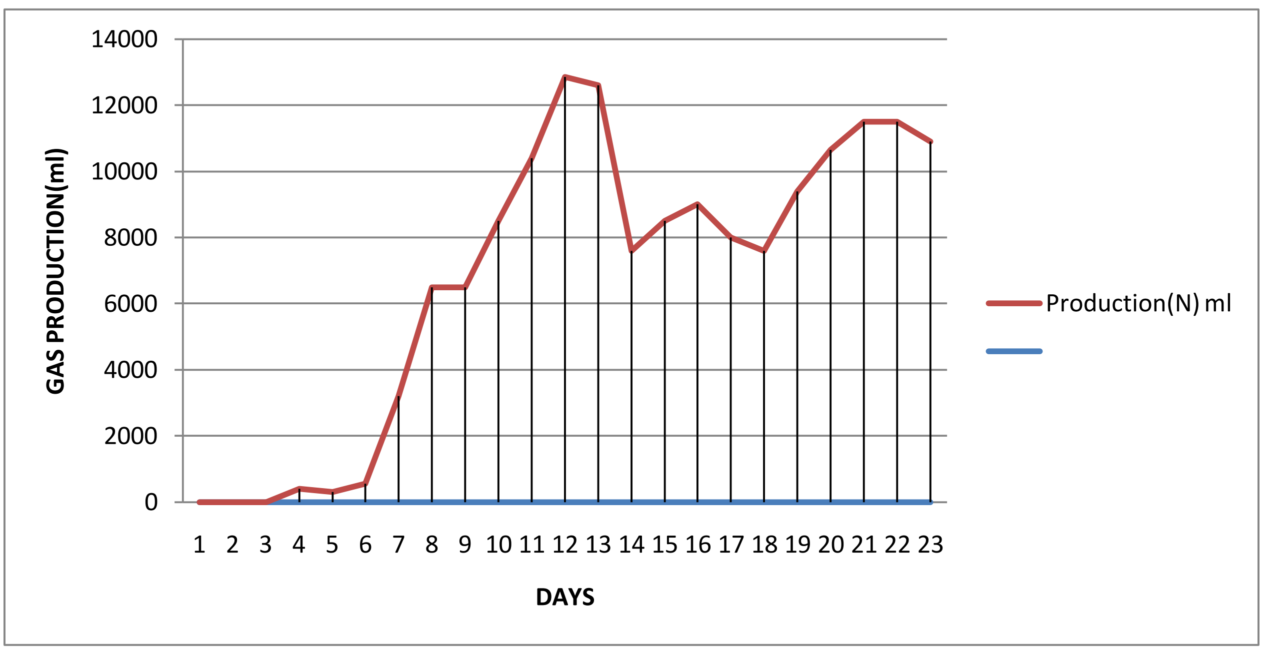

Fig. 10 Daily gas production of digester 3(N)

TABLE 7: DAILY VFA AND GAS PRODUCION

DAYS	VFA(O) mg/l	VFA(N) mg/l	Gas (O) ml	Gas (N) ml
1	1968.75	3762.5	-	-
2	1837.5	6562.5	800	-
3	1750	5337.5	1280	-
4	2012.5	3937.5	1800	400
5	2187.5	6125	1550	300
6	2800	6387.5	1700	550
7	2537.5	5687.5	1850	3200
8	2231.25	4287.5	2000	6500
9	2187.5	5512.5	1800	6500
10	2275	4375	2300	8500
11	3675	5162	2200	10400
12	2450	6300	2000	12850
13	2370	6562.5	1500	12600
14	2281	6743	900	7600
15	2685	5612	3750	8500
16	2194	5783	4250	9000
17	2300	5907	3300	8000
18	2350	4956	5300	7600
19	2012.5	4112.5	7500	9400
20	2080	3953	7400	10650
21	2199	3200	7250	11500
22	2208	3200	7000	11500
23	2259	2500	6800	10900

TABLE 8: DAILY A/TIC RATIO

DAYS	A/TIC (O)	A/TIC(N)	Kitchen Waste (O) gm	Kitchen Waste (N) gm
1	0.45	0.94	-	-
2	0.45	0.845	20	-
3	0.471	0.88	-	-
4	0.52	0.874	20	-
5	0.65	0.853	-	-
6	0.524	0.892	20	20
7	0.55	0.817	-	-
8	0.646	0.75	20	20
9	0.586	0.64	-	-
10	0.662	0.520	20	20
11	0.61	0.456	-	-
12	0.563	0.49	-	-
13	0.834	0.315	-	-
14	0.743	0.284	30	30
15	0.668	0.339	-	-
16	0.597	0.295	20	20
17	0.72	0.38	-	-
18	0.687	0.343	30	30
19	0.767	0.386	-	-
20	0.73	0.334	30	30
21	0.67	0.343	-	-
22	0.63	0.369	30	30
23	0.625	0.333	-	-

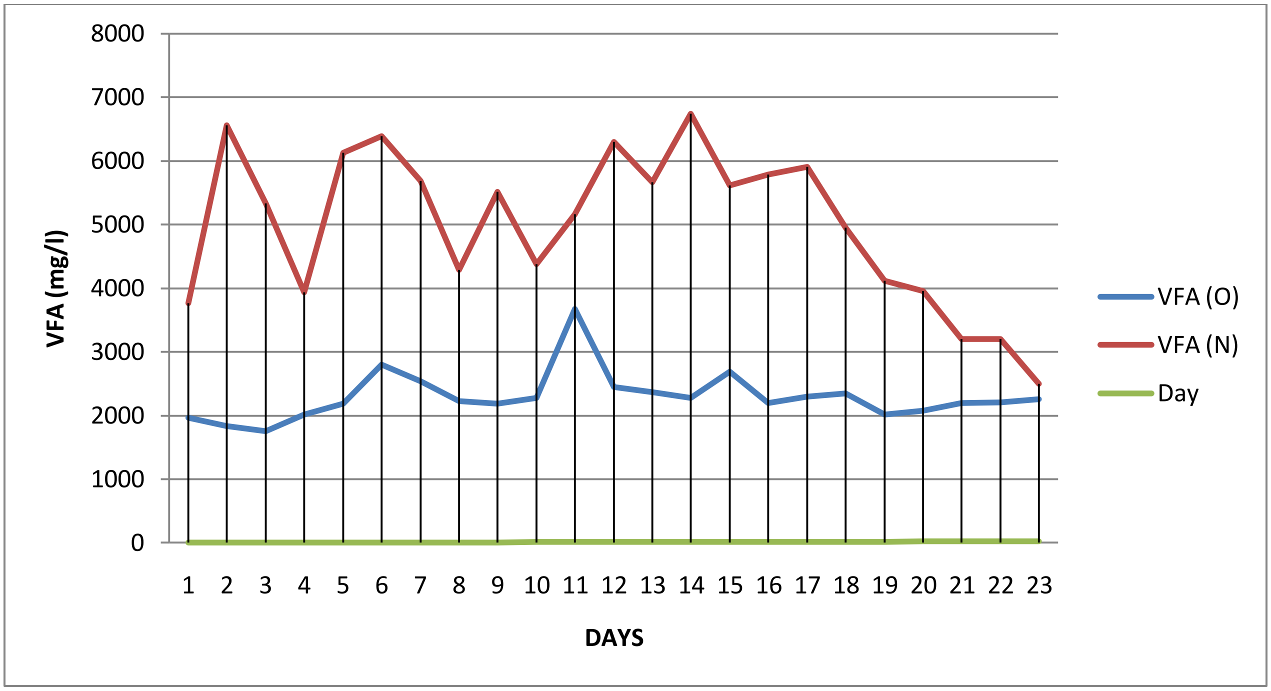

Fig.11 DAILY VFA CHANGE

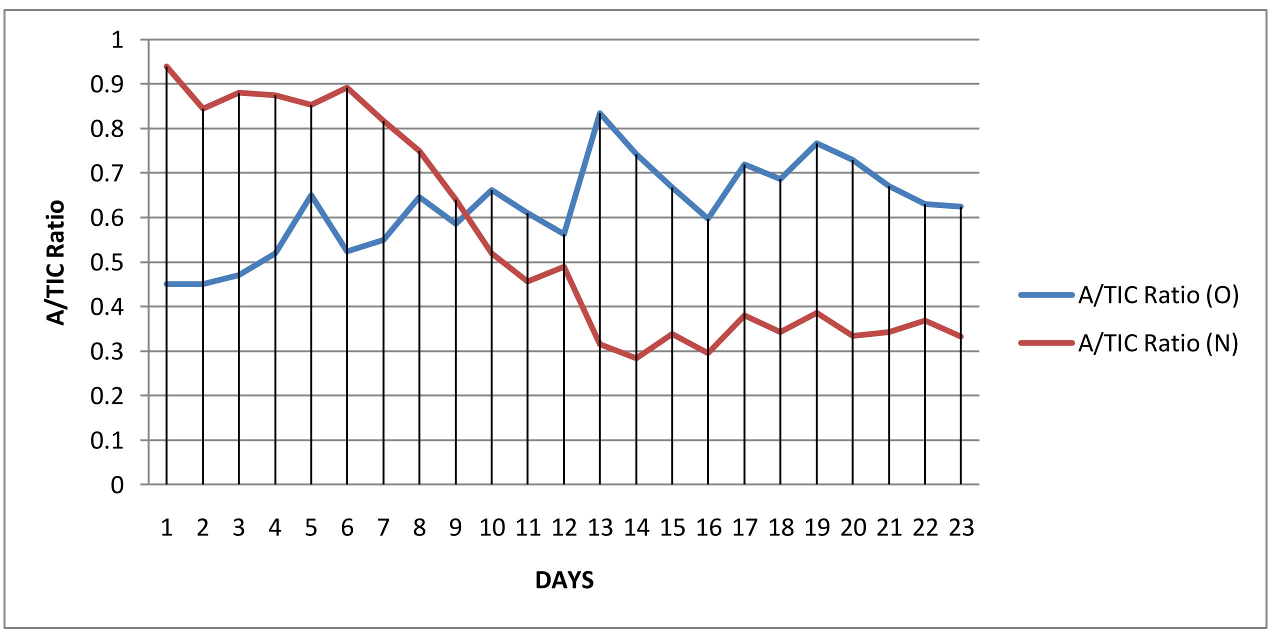

Fig.12 A/TIC ratio v/s day

CHAPTER 9

9.1 CASE STUDY

From my experiment I am able to produce around 10 lit of biogas daily in a 20 lit reactor (digester).

According to our purpose of our project we were trying to design reactors of 1000 lit for each and every hostel of NIT, Rourkela. (at the backyard of the mess, using kitchen waste directly as a feedstock)

Hence I can conclude that we can produce 650 lit of biogas daily in 1000 lit reactor, under ideal conditions (like maintaining pH , VFA , Alkalinity, etc.).

Table 9: LPG consumption at targeted hostels

SL No.	HOSTEL NAME	CONSUMPTION OF LPG (per month)
1	M S SWAMINATHAN HALL OF RESIDENCE	1412.4 kg
2	DHIRUBHAI AMBANI HALL OF RESIDENCE + Extension	3547.5 kg
3	HOMI BAHBHA HALL OF RESIDENCE	2038 kg

9.2 <u>ANALYSIS 1</u> **:**

Calorific value of Biogas = 6 kWh/m^3

Calorific value of LPG = 26.1 kWh/m^3

Let us assume we need to boil water sample of 100 gm

We have Energy required to boil 100 gm water = 259.59 kJ

Hence, we need Biogas to boil 100 gm water = 12.018 lit

And, we need LPG to boil 100 gm water = 2.76 lit.

Therefore, amount of water which can be boiled using this much Biogas = 5.408 lit/day Now, amount of LPG required to boil 5.408 lit of water per day = 149.26 lit So. We can save up to 10 cylinders of LPG per day.

9.3 <u>ANALYSIS 2 :</u>

Let us use the Biogas produced in our plant for Breakfast & evening snacks (1 hr in morning and 1 hr in the evening)

650 lit if used for 2 hrs gives = $66.46 * 10^3$ J /day

Let V be the amount of LPG used to produce same amount of energy

Hence, we get ,V = 2827.56 lit i.e. Mass (m) of LPG = 6.079 kg

Therefore per month consumption of LPG = 182.38 kg which is equivalent to 12.84 cylinders

<u>Result</u> :- We can save abound 13 cylinders of LPG if Biogas from 1000 lit tank is used for 2 hours daily.

9.4 ANALYSIS 3 :

Comparision of my biogas digester with conventional

Biogas systems are those that take organic material (feedstock) into an air-tight tank, where bacteria break down the material and release biogas, a mixture of mainly methane with some carbon dioxide. The biogas can be burned as a fuel, for cooking or other purposes, and the solid residue can be used as organic compost. Through this compact system, it has been demonstrated that by using feedstock having high calorific and nutritive value to microbes, the efficiency of methane generation can be increased by several orders of magnitude. It is an extremely user friendly system.

TABLE 10: COMARISION OF CONVENTIONAL BIOGAS AND KITCHEN WASTE BIOGAS SYSTEM

Comparison with Conventional Bio-Gas Plants	**Conventional Bio-gas Systems**	**Kitchen Waste Bio-gas System**
Amount of feedstock	40kg + 40ltr water	1.5-2 kg + water
Nature of feedstock	Cow-Dung	Starchy & sugary material
Amount and nature of slurry to be disposed	80ltr, sludge	12ltr, watery
Reaction time for full utilization of feedstock	40 days	52 hours
Standard size to be installed	4,000 lit	1,000 lit

In a kitchen waste biogas system, a feed of kitchen waste sample produces methane, and the reaction is completed in 52 hours. Conventional bio-gas systems use cattle dung and 40kg feedstock is required to produce same quantity of methane.

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