Performance Analysis of Anaerobic Digestion to extract Biogas from Kitchen Waste

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Abstract—In day to day life, large amount of food waste is unutilized and disposed as wastage in many places such as restaurants, hostels, food courts, cafeteria, marriage functions etc., which is used for generation of biogas. Biogas production requires anaerobic digestion for which biogas reactors are required. In this project food waste was collected from different places as feedstock for the reactor. The anaerobic digestion of food waste produces biogas, a valuable energy resource. Anaerobic digestion is a microbial process for production of biogas, which consists of Primarily methane (CH4) & carbon dioxide (CO2).

The main objective of this work is to utilize food wastage for generation of biogas. This work was carried out in a reactor comprising of a plastic water tank with a crusher, gas purifier and gas collector using different source of food waste available in SNS COLLEGE OF ENGINEERING hostel mess and canteen.

Biogas can be used as energy source and also for numerous purposes. But, any possible applications require knowledge & information about the composition and quantity of constituents in the biogas production. It was realized through the observation and experimental test that by using 5 liter of source material with 5 different compositions of food waste and cow dung such as 100:0, 75:25, 50:50, 25:75, 0:100 for 15 days. It was inferred from the experimental observation to produce 3100ml of biogas in the 75:25 ratios. It was found that 75:25 ratio of food waste and cow dung is the best composition, based on this a test ring was fabricated and experiment was conducted in 120 liter digester and the biogas produced was analyzed.

Index Terms— Anaerobic Digestion, Bacteria, Digester, Gasification, Gasifier, Metabolism, Biogas, Critical Pressure, Enzyme hydrolysis, Acid Formation, Methane Formation, Fuel Properties.

1 INTRODUCTION

Due to scarcity of petroleum and coal it threatens supply of fuel throughout the world also problem of their combustion leads 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 characteristics 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 require 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 eco-friendly substitute for energy.

In 2003, **Dr. AnandKarve[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..

Anaerobic digestion is a 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. 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

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

Biogas technology is concerned to microorganism. These are living creatures which are microscopic in size and are in visible to unaided eyes. They are called bacteria, fungi, virus etc. Bacteria can be dividing into two major groups based on their oxygen requirement. Those which grow in the presence of oxygen are called aerobic while the other grow in the absence of gaseous oxygen are called anaerobic. When organic matter undergoes fermentation (process of chemical

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change in organic matter brought about by living organisms) through anaerobic digestion, gas is generated. This gas is known as Biogas. Biogas is generated through Fermentation or bio digestion of various waste is by a variety of anaerobic and facultative- organisms. Facultative bacteria are capable of growing both in presence and absence of air or oxygen.

1.1 Anaerobic Digestion

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Aerobic and anaerobic fermentation can be used to decompose organic matter. Normally the aerobic fermentation produces Co_2, NH_3 and small amount of the other gases along with the decomposed mess and evolution of heat. Anaerobic fermentation produces CO_2, CH_4, H_2 and trace of other gases along with the decomposed mass. Aerobic fermentation is used when the main aim is to render the material hygienic and to recover the plant nutrients for the reuse in the fields. The residue is rich in C_2, N_2, P, K and other nutrients. In biogas plants the main aim is to produce the Methane and hence the anaerobic digestion is used. Here the complex organic molecules broke down to sugar, alcohols, pesticides and amino acids producing bacteria. The overview of anaerobic Digester system is shown in Fig 1.

The Anaerobic Digester system is give below:

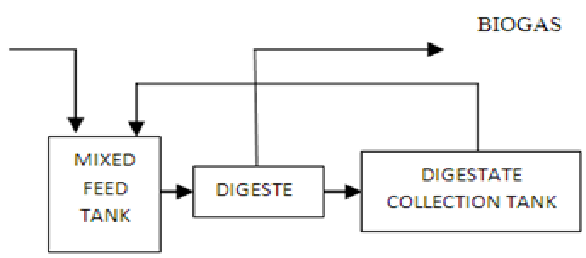

Fig 1.1 The Anaerobic Digester process

This Anaerobic digestion is broadly classified into three phases:

- **Enzymatic Hydrolysis:** Where the fats, starches and proteins contained in the cellulosic bio mass are broken down into simple compounds.
- **Acid Formation:** where the microorganisms of facultative and anaerobic group collectively called acid farmers, hydrolysis and ferments are broken to simple compounds into simple acids and volatile solids.
- **Methane Formation:** Where the organic acids as formed above are converted into Methane (CH_4) and CO_2 by the bacteria which are strictly anaerobes. These bacteria are called methane fermenters. For efficient digestion these acid formers and methane fermenters must remain in the state of dynamic equilibrium. This equilibrium is very critical factor which decide the efficiency of generation. The methane formers are very sensitive to pH changes. A pH value from 6.5 - 8 is the best for the formation and normal gas production [10].

1.2 Bacteria Involved

There are numerous types of microorganisms that are found to produce methane during anaerobic condition. Strictly anaerobic bacteria are the most common class of bacteria that produced methane, mesophilically or thermophilically within pH 4–7. However, a few facultative bacteria have been identified as methane producers when the hydrogenase enzyme was found in these bacteria. Even though the production rate of methane was lower than in strictly anaerobic bacteria, the issue of sensitivity to oxygen did not raised here. Recently, methane production was found to be possible by aerobic bacteria.

To date, most of the research on methane production involved anaerobic bacteria due to its high production rate and the ability to use a wide range of carbohydrates. Clostridium sp. is a typical acid and methane producer which ferments carbohydrate to acetate, butyrate, carbon dioxide and organic solvent. Clostridium butyricum [11], Clostridium acetobutyricum [12], Clostridium beijerinckii [12], C. thermolacticum [13], C. saccharoper butylacetonicum [14], Clostridium tyrobutyricum [15], C. thermocellum [16] and Clostridium paraputrificum [17] are examples of anaerobic and spore forming methane producer.

1.3 Sources of Waste

The waste used in this study was the peelings and food refuse from SNS College of Engineering canteen and Hostel mess. In SNS College of Engineering there are around two hostel mess and two canteens from which plenty of food wastes (approximately 1000kg/ week) are available. The waste foods available in SNS College of engineering are as shown in Fig 1.2. The sources of waste are from mess, canteen of SNS College of engineering.

❖ **Fig 1.2 Sources of Waste**

The plastic buckets are used to collect the waste from the SNSCE hostel mess and canteens.

1.3. A Carbohydrate Waste

Food wastes from the institutions and contain high levels of carbohydrate and protein. Currently, food wastes from the institutions are mostly treated anaerobic ally. However, lactic acid, bio compost and energy from food wastes would be a value added strategy for treatment of food wastes. The organic constituent especially carbohydrate in food wastes could be a potential substrate for anaerobic Biogas production. The specific

Methane production potential of food wastes was found to be higher than sewage sludge. However, Methane production potential increased as sewage sludge composition was increased up to 13–19% of volatile solids. The maximum specific Methane production potential of 122.9ml H2/g carbohydrate-COD was found at 87:13 (food waste: sewage sludge). A comparative study was carried out by Pan et al. [18] on Biogas production at mesophilic and thermophilic conditions. The Biogas yield from the thermophilicacidogenic culture was higher than that from the mesophilic culture at all tested food to microorganism ratio.

Continuous Biogas fermentation in a leaching bed reactor was carried out by Han and Shin [19]. At an optimized dilution factor (D), from the reduced COD of the food wastes was converted to Biogas, volatile fatty acids, ethanol and carbon dioxide. It was suggested that control of D gave environmental conditions favourable for Biogas production. Further, the efficiency was improved by enhanced degradation of slowly degradable matters. It delayed the shift of the predominant metabolic flow from Methane and acid forming pathway to solvent forming pathway. Potential of Methane production from highly concentrated, carbohydrate-rich wastewaters was reviewed by Van Ginkel et al. [20]. The biogas produced using wastewater from apple processing and potato processing industries contained 60% Biogas with no methane generation.

When additional nutrients were added to the wastewaters, it showed an increase of Methane production. The overall Methane production was 0.9 L-H2/L medium for apple processing waster and 2.1 L-H2/L medium for potato processing wastewater. Rice slurry is another potential starch-based waste from industry as rice is the most common dietary food. Rice contains carbohydrate, protein, lipid and water.

2 Study on Biogas Plant

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. AnandKarve (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 waste, 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 of feedstock to produce the same quantity of methane, and it require about 40 days completing 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.

HilkiahIgoni [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 solid 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 cattle 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 *Fibrobactersuccinogenes*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 bio waste 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 Bio filter for Steam Reforming Processing.** They show that a bio filter containing immobilized aerobic sludge was successfully adapted for the removal of H2S and CO2 from the biogas produced using food waste. The bio filter 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 bio filter. The large-scale bio filter using a mixed culture system showed better H2S removal capability than bio filters 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.

3 Description of Parts

3.1 Crusher

Crusher is a manual machine used to reduce the size, or change the form of waste food like semi solid, so they can be more easily disposed of or recycled, or to reduce the size of a solid mix of raw materials, so that pieces of different composition can be differentiated. Crusher is made by stainless steel by the attachment of bevel gears and blade.

3.2 Digester

A digester is a huge vessel where chemical or biological reactions are carried out. Anaerobic digestion is a series of processes in which microorganisms break down biodegradable material in the absence of oxygen. It is used for industrial or domestic purposes to manage waste and/or to release energy. The digestion process begins with bacterialhydrolysis of the input materials to break down insoluble organic polymers, such as carbohydrates, and make them available for other bacteria. Acidogenic bacteria then convert the sugars and amino acids into carbon dioxide, hydrogen, ammonia, and organic acids. Acetogenic bacteria then convert these resulting organic acids into acetic acid, along with additional ammonia, hydrogen, and carbon dioxide. Finally, methanogens convert these products to methane and carbon dioxide. The digester is made up of fiber material.

3.3 Valves

A valve is a device that regulates, directs or controls the flow of a fluid (gases, liquids, fluidized solids, or slurries) by opening, closing, or partially obstructing various passageways. In an open valve, fluid flows in a direction from higher pressure to lower pressure. The ball screw valve is made by plastic material.

3.4 Gas Purifier

The gas produced from digester consists of carbon dioxide, hydrogen sulphide and methane. The removal of both H2S and CO2 can be done by passing it through water. This simple process is used to produce a pure methane gas.

3.5 Pressure Gauge

Many techniques have been developed for the measurement of pressure and vacuum. Instruments used to measure pressure are called pressure gauges or vacuum gauges. The pressure gauge is a device used to measure the pressure inside the digester.

3.6 Flow Pipes

The pipe lines are made up of PVC (polyvinyl chloride). It's used to flow the waste crushed food into the digester and also to flow the gas from digester to gas purifier.

3.7 Bevel Gears

Bevel gears are gears where the axes of the two shafts intersect and the tooth-bearing faces of the gears themselves are conically shaped. Bevel gears are most often mounted on shafts that are 90 degrees apart, but can be designed to work at other angles as well. The pitch surface of bevel gears is a cone. The bevel gears made by cast iron.

4 Problems with Landfills

The waste generated by this increasing urbanization of humans and industries will have to be sorted and processed. The most common waste management solution is land filling. The main problem with this is that landfills around the world are running out of space. The last landfill in the greater New York City area closed in 2001 and now 12,500 tons of garbage is transported daily outside the state by truck, barge, and train [1]. London currently sends 20 million tons of annual waste to 18 different landfills that are running out of space [2]. Montreal, Canada, has a contract to send 1.3 million tons of waste each year to a landfill located 40 km away with permits that extend only to 2012 [3]. In 2006, nearly a million tons of the waste generated in Toronto, Canada, was trucked to landfills across the U.S. border into Michigan. As a solution, the City of Toronto has purchased a landfill site that is over 200 km away from the downtown area that opened January, 2011 [4]. Mexico City produces 12,500 tons of trash per day and sends it to a sprawling, polluted landfill that is running out of space [5]. As of 2011, two thirds of China's cities are overrun with garbage and millions of tonnes of waste are sent to non-sanitary landfills with one quarter of cities having no place to dispose of trash [6]. There is no simple solution to this waste problem. This is a pressing global issue that requires design and consumption paradigm shifts as well as new waste management solutions.

5 Fabrication Procedure and Experimental Setup

Step 1: Manually operated crusher is fabricated with the arrangements of bevel gears and blade.
Step 2: Two fiber tanks for digester (120 liters) and gas purifier (50 liters) tanks are purchased.
Step 3: The inlet and outlet ports are drilled as per the requirement.
Step 4: Then the crusher, digester and gas purifier are assembled by using PVC pipes and gate valves.
Step 5: The pressure gauge is fitted in the purifier tank to measure the presence of methane gas.
Step 6: Finally all the air leakages are arrested by using M.C. seals and plaster of Paris

FIG 6.1 BIOGAS PLANT

6 CONCLUSION

From SNS college hostel mess and canteen 1 ton of food waste per week is unutilized which is used in this project to create biogas, Fixed drum type model is used in this project.

From the lab scale experiment 75:25 Ratio of food waste and cow dung will provide more efficient gas. From this experiment it is able to produce around 3100ml of biogas daily in a 5 liter reactor (digester). The same composition is implemented in the 120 liter digester and the gas produced in measured. The gas produced in this plant can be measured, analyzed & utilized for Diesel Engine in upcoming days.

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