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Effective Treatment and Utilization of Food Waste & Degradable Waste to Produce Biogas

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Abstract—
In our homes daily a large amount of kitchen waste is obtained which can be utilized for better purposes. Biogas production requires anaerobic digestion. The overall goal was to use the food waste to produce a useable energy source in the form of methane gas and to serve as an educational example for the community. We developed methods to produce, filter, collect, and store biogas and used the gas as a cooking fuel instead of a heat source for the greenhouse. Overall, by creating a biogas reactors in the backyard of our homes will be beneficial. Kitchen (food waste) was collected from home 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). The continuously fed digester requires addition of sodium hydroxide (NaOH) to maintain the alkalinity and pH to 7. For this reactor we have introduced the shredder where the larger sized food waste is converted into smaller substances which increases the speed of digestion in the digester. A temperature maintaining instrument is used for biogas production at 37°-55°C so as to increase the speed of digestion in the digester.

Index Terms— Biogas, Anaerobic digestion, Digester, Heating coils, PH

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.

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. 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 diseases 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 odors & methane which is a major greenhouse gas contributing to global warming.

Today, there are several different techniques for producing biogas and several models and designs of biogas machines and plants now exist. Nevertheless, the concept remains simple and the same. The heart of any biogas system or production arrangement is known as a bio digester.

The methane gas that is produced usually rises and builds up at the top of the digester. A gas pipe is attached to the top of the digester to carry the produced gas back into the house (usually the kitchen) where it is used as fuel for cooking and heating.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 equipment's to produce gas in small places like backyard, among others.

2 BIOGAS

2.1 Biogas

BIOGAS is Produced through the bio-degradation of organic material under anaerobic conditions. Natural generation of biogas is an important part of bio-geographical carbon Cycle. It Can be used in both rural and urban areas.

Table -1: composition 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
Normal Density	1.2 kg/m3
Smell	Rotten vegetable

2.2 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.

3 Literature Review

- **[1]Ravi P. Agrahari** (2014): here biogas technology provides an alternative source of energy mainly from organic wastes. Using local resources, viz. Cattle waste, kitchen waste and other organic wastes, energy and manure are derived. It is produced when bacteria degrade organic matter in the absence of air
- **[2]P. Singanand Kumar** (2015): the anaerobic digestion of kitchen 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). Mixture of vegetable wastes was an-aerobically digested in 2 L capacity lab scale batch reactors. Biogas can be used as energy source and for numerous purposes
- **[3]Rajan Sharma** (2011): Lignocellulose wastes, inexpensive and potential sources of bioenergy were explored for delignification and production of biogas. Wheat straw was subjected to chemical and biological treatment methods for removal of lignin, facilitating bio-methanation. Pre-treatment produced remarkable results with an enhanced amount of methane.
- **[3]N. Stalin, et al**(2007): According to him three stage methane fermentation system was developed to digest animal manure effectively. The digester having an effective volume of 200 liter is constructed with central tube filled with burnt bricks. The burnt brick in the central portion of the digester increase the microbial concentration by immobilizing the bacteria on the surface of the burnt brick. The size of brick materials is not more than 3 to 5 mm size

4 Principles of Biogas Production

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 and 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

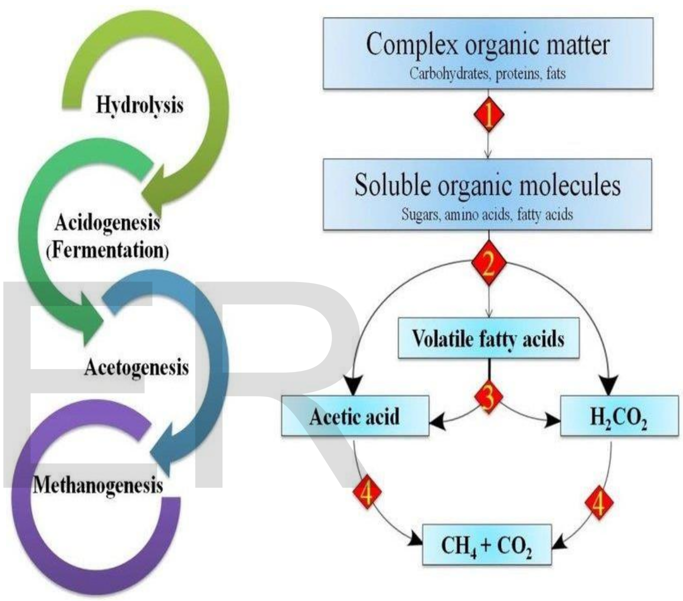
The digestion process occurring in presence of oxygen is called **Aerobic digestion** and produces mixtures of gases having carbon dioxide (CO2) which is responsible for global warming.

The digestion process occurring in the absence of oxygen is called **Anaerobic digestion** which generates mixtures of gases. The gas produced which is mainly methane which when burned at normal room temperature and presents a viable environmentally friendly energy source to replace fossil fuels (non-renewable).

5. ANAEROBIC DIGESTION

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

<u>FLOW CHART FOR ANAEROBIC DIGESTION</u>:



Flow chart of Anaerobic Respiration

5.1 Benefits Of Biogas Technology

1. Production of Energy.
2. Transformation of organic wastes to very high-quality fertilizer.
3. Improvement of hygienic conditions.
4. Environmental ecofriendly as it protects soil, water, air etc.

6 WORKING PRINCIPAL

The working principle provides us the functionality of the developed model. The developed model produces the biogas i.e. methane by utilizing the food waste from our houses. This process does not take many days to produce the methane gas. The design incorporates the mixer blades that is present inside the mixer container were the motor is mounted in vertical position and the blades are mounted on the motor shaft. Hinged support is given to put the mixed content in to the digester. The digester stores the mixed content and anaerobic reaction takes place here. Mica strip heaters are used to heat the content present in coil. Thermostat is used to maintain the temperature. In the digester anaerobic reaction takes place.

Steps involved

- First the food waste that is being collected from the house and is put into the mixer along with water where the quantity of water added is double the quantity of food waste added. The mixer containing the blades chop the solid content and coverts into simpler compounds it results into slurry, mixer blades usually runs through dc motor.

- In the digester the mica strip heaters are provided to heat around 36ºC to 55ºC the slurry content so that it enhances the rate of reaction. Thermostat is used to maintain the temperature. Here anaerobic reaction takes place in a distinct manner.

The anaerobic digestion process undergoes three distinct processes of microorganism activities.

- The fermentative bacteria fermented and hydrolyzed the complex organic materials, carbohydrates protein and lipid into fatty acid, alcohol, carbon dioxide, hydrogen, ammonia and sulfides.
- The acetogenic bacteria consume the primary products and produce hydrogen, carbon dioxide and acetic acid.
- Methane gas ($CH4$) produced in the digester is been collected through the outlet valve and is been stored in the rubber tube.

7. PROJECT OBJECTIVE

1. To produce biogas effectively within a short time as compared to existing biogas.
2. Produce a small biogas plant for household level within less cost.
3. Check optimization of gas production at the field. Also, to be available within budget and come in easy manner to operate.

8. METHODS AND CALCULATIONS

The related parameters used in calculation part are defined as:

W = Weight of the kitchen waste available per day (kg/day)

G = Gas production rate (m^3/kg)

V_S = Active slurry volume in the digester (m^3)

S_D = Slurry displacement volume (m^3)

D = Diameter of the digester (m)

H = height of the digester (m)

h = slurry displacement in the inlet and outlet tanks (m)

l, b =length and breadth of the inlet and outlet tank (m)

Calculations w.r.t digester

1) Gas production rate (G)

From the literature survey it is found that one kilogram of kitchen waste, if well digested, yields 0.3m3 of biogas. The gas production rate (G) for the available kitchen waste, working with 5kg/day was found to be given by:

G = W X 0.3

= 5 X 0.3

=1.5m^3/day

2) Active slurry volume

The active slurry volume of the digester is directly related to the hydraulic retention time (HRT). This is the theoretical time that a particle or volume of liquid waste added to a digester would remain in the digester. It is calculated as the volume of the digester divided by the volume of slurry added per day and is expressed as days.

Active slurry is therefore given by:

Vs = HRT X 2 X W/1000, for kitchen waste, HRT = 3 days

= 3 X 2 X (5/1000)

= 0.03m^3

3) Volume of the digester

Vs = l x w x h

= 350 x 450 x 350

= 55.125000cm^3

4) Volume of slurry displacement inside the digester

The selection of a suitable value of d depends upon gas usage pattern. Since cooking at house is usually done three times a day, 50% of the gas to be produced in a day will be made available for one cooking span. The total cooking time is about 0.5 hours, the variable gas storage volume (SD) is obtained from the equation:

0.5/24G + SD = 50/1 00G. By simplification,

SD = 50/1 00G – 0.5/24G

SD = 0.71875m3

9. EXPERIMENTS & ANALYSIS

Fresh wastes such as leftover food, peeled vegetables, fruits, other kitchen wastes are added into the digester.

9.1 Experiment 1

The heater coils were switched OFF during this process to check the biogas production in a digester. It was observed that it took 58 hours for the wastesto completely undergo reactions and ready to dump.

Digester contents are as follows:

- 20 litres digester.
- Fruits and vegetable wastes.
- Food leftover.
- Water – 10 litres.

PH was measured using litmus paper after adding water and mixing thoroughly.

Gas produced was measured using inverted container technique, an inverted container filled with water. We collected gas inside a tyre tube and connected to inverted container. The gas forces out of the tyre tube.

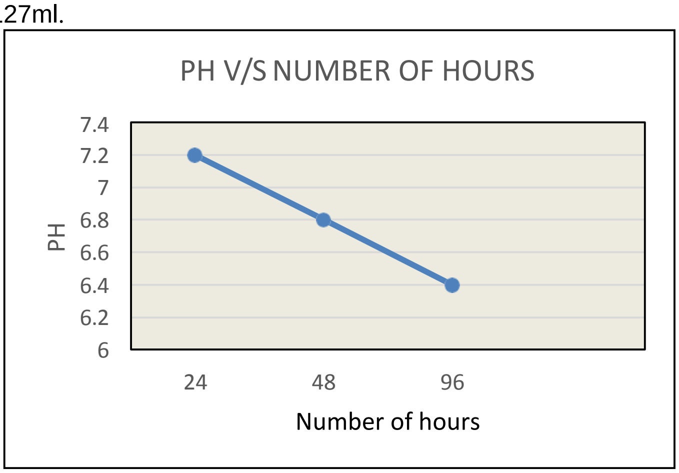
Results:

It is been observed that it took only 96 hours to produce the biogas.

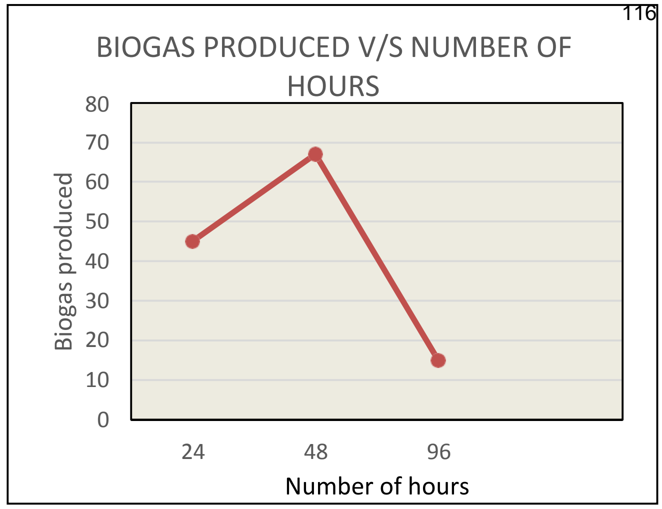
No/. Of Hrs. Waste Kept in Digester	PH	Biogas Produced(ML)
24	7.12	45
72	6.8	67
96	6.4	15

- Initial PH value was 7.2
- Finally measured PH after 96 hours was 6.4

In this stage volume of biogas produced was found to be 127ml.



PH v/s Number of Hours



Biogas produced v/s number of hours

9.2 Experiment 2:

We conducted the same experiment and same amount of food waste and 3 litres of water is been added into the digester. The food waste also includes Chicken bones, Fish scalps, along with the previously included wastes. These wastes were mixed using a mixer blade setup at an inlet of the digester, so the waste was thoroughly mixed and water to be added to the digester. Wastes occupied the digester container evenly and need not to be mixed any further. The setup was closed to undergo the anaerobic digestion and after every 10 hours the PH and the biogas production rate is been determined. PH is determined through litmus paper and biogas production rate is determined through inverted tyre and tube method.

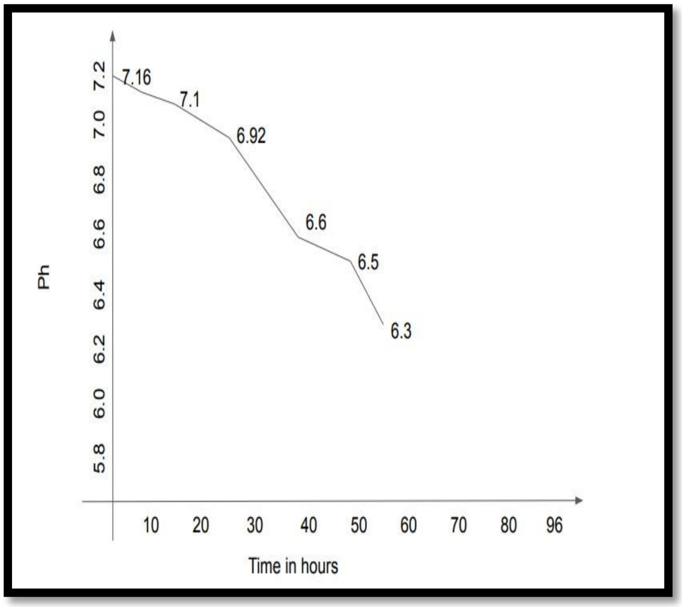
Results:

It is been observed that it took only 58 hours to produce the biogas and even the amount of biogas produced has been increased.

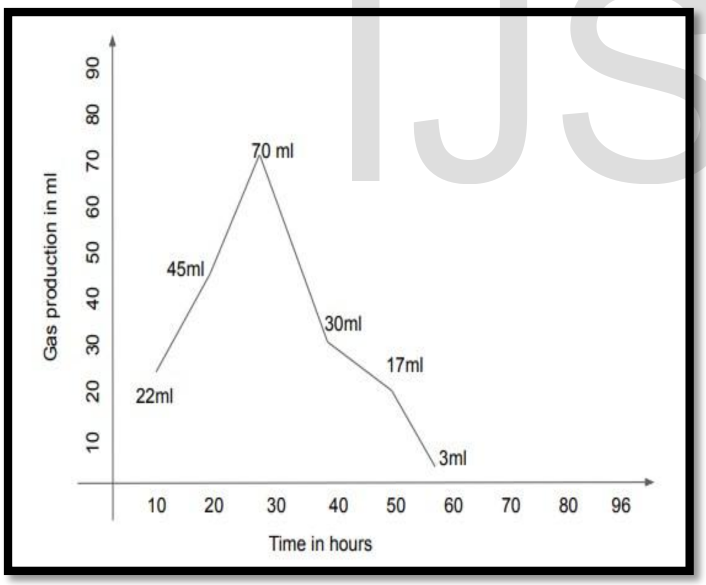
- Initial PH value: 7.2
- Final PH value: 6.3

Time (Hours)	PH	Biogas Produced
0	7.2	-
10	7.16	22
20	7.1	45
30	6.92	70
40	6.6	30
50	6.5	17
58	6.3	3
TOTAL		187 ML

In this stage volume of biogas produced was found to be 187ml.



PH v/s Time in Hours



Graph 9.4: Gas produced v/s Time in hours

9.3 Analysis

Comparison of same setup when heater turned OFF v/s heater turned ON when the waste is mixed well.

In a kitchen waste biogas system, a feed of kitchen waste sample produces methane, and the reaction is completed within 58 hours. Conventional biogas systems without heating.

Parameters	Experiment 1	Experiment 2
Amount of Feedback Stock	1.75kg waste +10L water	3.2kg Waste + 3L Water
Amount of Slurry	12 Litres	6 Litres
Production time for Biogas	96 Hours	58 Hours
Power Cost For Heater Coil	NIL	$0.15 RS per Month
Standard Size To be installed	2000-3000 Litres	1000 Litres

Comparison of Experiment 1 & Experiment 2

10. CONCLUSION

- The project developed helps in various urban areas to . manage wastes produced in the kitchen.
- It helps citizens to understand the importance of waste management, greater production of biogas and amount of capital spending for gas cylinders can be saved.
- The project is economical, cost effective and environmental friendly and also pollution free.
- Even sludge waste remained after gas production can be used as manure for the plants and trees in the locality
- The developed model is simple, efficient, requires less time and cost effective compared to existing machines.

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