

# Investigation of Biogas Generation from Food Waste

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**ABSTRACT:** A biogas plant is an anaerobic digester that converts various waste materials viz. food waste, animal waste into biogas. Biogas is an example of a clean and easily controlled source of renewable energy from organic waste materials and its production does not require much labor input. Moreover, Biogas is a sustainable substitute for firewood or fossil fuels which are slowly depleting and hence becoming more expensive. Biogas can be produced by anaerobic digestion of biodegradable materials by micro-organisms in the absence of oxygen. Since biogas is a mixture of mainly methane (also known as marsh gas or natural gas, CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>), it is a renewable fuel produced from waste treatment. Production of biogas from food waste is 10 times faster than the production of biogas from cow dung. In this study, the food waste from the canteen of Budge Budge Institute of Technology has been decomposed to form Biogas. Presently the food waste is being collected by some outside agency and the fate of the waste is not known. Hence this study focuses on the design of a prototype biogas plant which will demonstrate the feasibility of conversion of this waste food into biogas. This study contemplates the proper management of the food waste generated daily from the canteen and conversion of the same to biogas which may be used for cooking to reduce the LPG consumption in the college canteen. Due to the presence of anaerobic bacteria decomposition of food waste-cow dung mix will take place under two phases of reaction. In the first phase, acidification will occur, where pH level may fall due to acid formation. To maintain the pH in the alkaline level (which is a pre-requisite for methanogenesis), NaOH has been added in requisite dose. Hence in the second phase at higher pH (above 7) and higher temperature (above 40°C), methane (CH<sub>4</sub>) formation has occurred.

**KEYWORDS:** Biogas, Anaerobic Digestion, Downward displacement of water, Food waste, Methane production.

## I. INTRODUCTION

The worldwide scarcity of petroleum and coal and the problem of their combustion have led to research to improve the accessibility of new sources of energy, like renewable energy resources. Among all renewable energy resources like solar energy, wind energy, hydel energy, biogas, etc., biogas is unique because it uses, controls and collects organic wastes and at the same time, it helps in agricultural irrigation by producing fertilizer. Biogas can be used anywhere and its production does not require any advanced technology and moreover, it is very easy to use and apply [1].

The efficiency of methane production can be increased and size of reactor and cost of biogas production can be reduced by using food waste which is an organic material having high calorific value and nutritive value to microbes [2]. Poor management of food wastes like uncontrolled dumping leads to pollution of surface and groundwater through leachate and provides a breeding ground for flies, mosquitoes, rats and other disease-bearing vectors. It also produces methane which is a major greenhouse gas contributing to global warming [3].

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, the 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 a case by case basis [4].

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## II. RELATED WORK

**ARTI** – Appropriate Rural Technology of India, Pune (2003) has developed a compact biogas plant which uses the waste food rather than any cow dung as feedstock, to supply biogas for cooking. The biogas 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. Dr. Anand Karve (ARTI) developed a compact biogas system that uses starchy or sugary feedstock (waste grain flour, spoilt grain, overripe or misshapen fruit, non-edible seeds, fruits and rhizomes, green leaves, kitchen waste, leftover food, etc.). Just 2 kg of such feedstock produces about 500g 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 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 [5].

**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 [6].

**Taleghani and Kia, (2005)** [7] 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.

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**Hilkihigoni (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 [8].

### III. METHODOLOGY

Three setups were done to study the production of biogas and methane production. In setups 1 and 2, only the biogas produced was measured but in setup, the methane produced was measured. The methodology followed is as follows:

1. Construction of Bio-digester: The Bio-digester of 2L capacity was constructed with a 2L water bottle. It was painted black to absorb light in order to increase the temperature of the reactor content.
2. Collection of food waste from the college canteen: About 30 gm of the food waste along with vegetable trimmings were collected and mixed with 30 gm of cow dung and placed in the reactor. About 1.5L of water was added to make the ratio of the feed to water 1:1 and the food waste-cow dung slurry was prepared. The slurry was kept in the digester for a considerable amount of time for digestion. The parameters like pH, Temperature were monitored at regular intervals of time and if required pH was increased to the desired level by mixing sodium hydroxide (NaOH) in adequate amounts.
3. Process taking place in the digester: Due to the presence of anaerobic bacteria decomposition of food waste- cow dung mix will take place under two phases of reaction. In the first phase, acidification will occur, where pH level may fall due to acid formation. To maintain the pH in the alkaline level (which is a pre-requisite for methanogenesis), NaOH may be added in requisite dose. Hence in the second phase at higher pH (above 7) and higher temperature (above 40°C), methane (CH<sub>4</sub>) formation will occur.
4. The gas was collected in a measuring cylinder (water displacement method) in setup 1 and 2. And the gas was collected in a measuring cylinder (NaOH solution displacement method) in setup 3. From setup 3, the amount of methane gas produced could be estimated as the NaOH solution will absorb the other constituents of biogas like carbon dioxide, etc.
5. The digester was fed daily with 6 gm of food waste.

### IV. RESULTS AND DISCUSSION

#### 1. Characterization of Food Waste and Cow Dung Slurry

The food waste and cow dung slurry have been characterized in terms of Total Solids, Volatile Solids, Fixed Solids, COD, BOD and Alkalinity both before and after digestion and the results have been shown in Table 1.

**Table 1: Characterization of Food Waste and Cow Dung Slurry**

Parameters	Before Digestion	After Digestion	Reference [9]
Total Solids (in %)	22.96	12.55	Standard Method 2540B
Volatile Solids (in %)	13.6	6.4	Standard Method 2540E
Fixed Solids (in %)	9.36	6.15	Standard Method 2540E
COD (in mg/L)	2500	500	Standard Method 5220
BOD (in mg/L)	180	75	Standard Method 5210
Alkalinity (in mg/L)	430	198	Standard Method 2320

#### 2. Biogas production from the three Setups

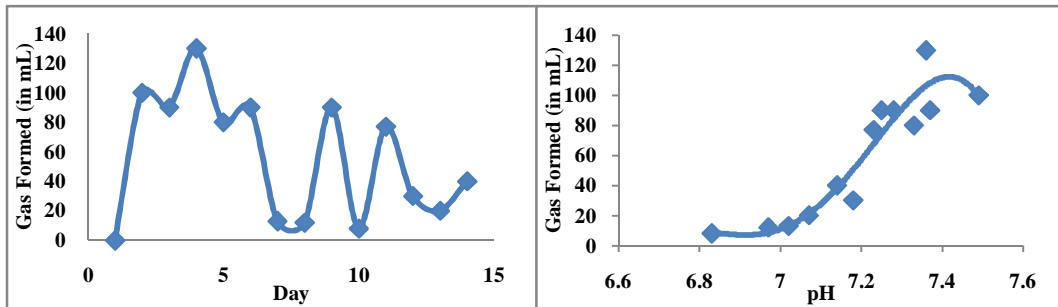
The amount of gas produced in each day and the variation of the pH level of the slurry in Set up 1 are shown in Fig 1 and Fig 2.

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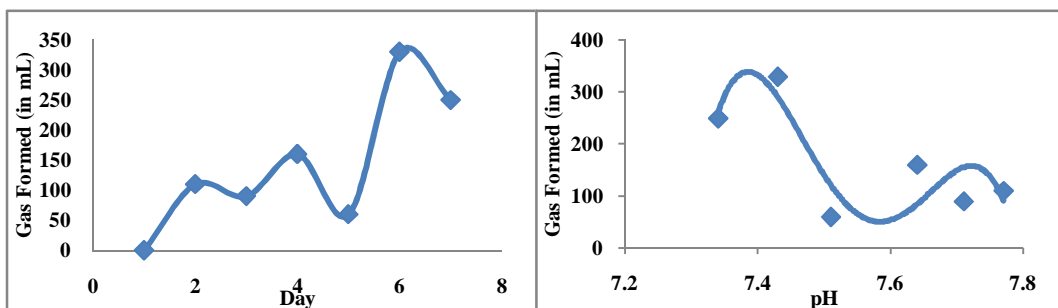


**Fig1: Day vs Gas Formed Graph for Setup 1**

**Fig 2: pH vs Gas Formed Graph for Setup 1**

It can be seen from Fig 1 that gas production increases first upto day 4 but then it decreases a little on day 5 and day 6 but on day 7 and day 8 the gas production has decreased drastically as acid concentration has increased in the bottles and pH has decreased. Then 0.1 (N) NaOH solution was added to increase the pH and gas production again increased on day 9 but again there was a drastic fall in gas production on day 10 due to a sharp decrease in pH value. Again NaOH solution was added to increase the pH value which in turn improved the gas production. Therefore, we can infer that pH value plays a pivotal role in the biogas production and along with maintenance of high temperature; the pH value also had to be properly adjusted to a range above 7 i.e. in the alkaline region. Fig 2 emphasizes the fact that gas production is a function of the pH value of the food waste slurry. Maximum gas production was witnessed at a pH value of 7.36. But as anaerobic digestion process is followed, the formation of acetic acid, carbon dioxide, methane etc. all contribute to the lowering of the pH value, so a proper monitoring of the pH value is required which has to be done on regular basis. In this study 0.1 (N) NaOH solution has been added to counteract the lowering of pH value.

The amount of gas produced in each day and the variation of the pH level of the slurry in Set up 2 are shown in Fig 3 and Fig 4.



**Fig 3: Day vs Gas Formed Graph for Setup 2**

**Fig 4: pH vs Gas Formed Graph for Setup 2**

It can be seen from the Fig 3 that gas production has been more or less on the higher side as the pH value has been maintained above 7.3 which confirm the observation from the previous Setup. Fig 4 establishes the fact that maximum gas production was witnessed at pH 7.43. In this Setup 2, from the very beginning, the pH value has been regularly monitored and kept above 7.3 by the addition of 0.1 (N) NaOH solutions.

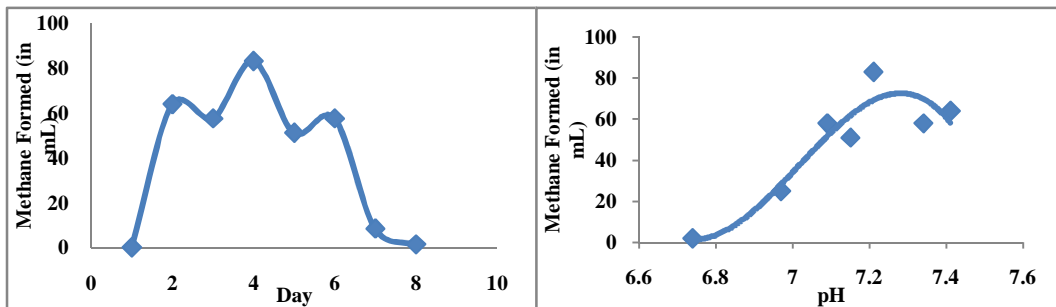
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The amount of methane gas produced in each day and the variation of the pH level of the slurry in Set up 3 are shown in Fig 5 and Fig 6.



**Fig 5: Day vs Methane Formed Graph for Setup 3    Fig 6: pH vs Methane Formed Graph for Setup 3**

In Set up 3, the gas has been collected by downward displacement of NaOH solution to directly measure the amount of methane formed. Bio gas generally contains methane and carbon dioxide with trace amounts of ammonia and hydrogen sulfide. Here the carbon dioxide will get absorbed by the NaOH solution leaving only the methane gas. From Fig 5, it is seen that the gas formation followed a similar trend as it had in the previous set ups. Here also pH value has been an important factor. From Fig 6, the methane formation with respect to pH value had shown a similar trend as the previous set ups.

### V. CONCLUSION

The economic benefit of using biogas in terms of replacement with LPG is shown in Table 2.

**Table 2: Probable Replacement of LPG Cylinder by the Biogas Generated from Canteen Food Waste (Daily Production being 100 Kg)**

Specifications	Value	Unit
Production of biogas from 1kg of food waste	0.5 [10]	m <sup>3</sup>
Calorific value of biogas	20 [11]	MJ/ m <sup>3</sup>
Calorific value of 1kg food waste	20x0.5	MJ
Calorific value of 100kg of food waste	1000	MJ
Calorific value of LPG	49 [12]	MJ/Kg
1 LPG cylinder contain	19.2	Kg
Calorific value of 1 LPG cylinder	940.8	MJ
Number of cylinder equivalent to biogas produced from 100kg food waste	1.06 say 1	Cylinder/day

On an average production of food waste from college canteen is 100Kg/day and requirement of LPG cylinder is 6 nos./day.

The amount of biogas produced daily is equivalent to 1 LPG cylinder.

The cost of 1 no 19.2Kg LPG cylinder is Rs. 1050.00.

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The cost of saving per year is Rs. 3,78,000.00

The cost of 2 Nos of 50m<sup>3</sup> Bio-digester to cater 100Kg food waste daily (including equivalent O&M charges) = Rs. 10,00,000.00

So, the payback period is 2.65 years say 3 years

In general, every home household waste mainly consists of kitchen waste, which can be used to produce biogas and that can be a substitute for natural gas. Instead of throwing the garbage, every home can collect them, produce their very own biogas and use it for their cooking and heating purposes. This may reduce the transportation and other costs associated with the garbage collection and removal.

This economic gain can be channelized in sectors enhancing sustainable development where implementation of a biogas plant in every city of India and also at the household level can be achieved. In addition to this, the landfill sites at every municipality can be used for developing research centers for studying the aspects of biogas production and also building biogas plants. Even the effluent slurry from an anaerobic digester can be used as natural fertilizers.

Since the dumping of garbage on landfills produces mainly methane and carbon dioxide which are the major greenhouse gases and can increase the global temperature leading to global warming, the use of the household waste for biogas production can mitigate the emission of greenhouse gases, which leads to "GO GREEN".

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