# Biogas Production From Kitchen Waste Generated on DCRUST Campus

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***Abstract:*** A large amount of solid waste is generated in India which is currently 62 million Tonne according to recent data published by *MoEFCC* and the figure is continuously increasing. A large fraction of this waste is organic which is also dumped along with the other waste into landfills without any processing or recovery. The staggering potential environmental problems linked to organic fraction of municipal solid waste which is mostly landfilled have fostered the need for a biological treatment using anaerobic digestion. This is an attractive technology for waste stabilization with potential mass and volume reduction and significantly the generation of valuable by-products such as biogas and compost material. The use of biogas using kitchen waste as feedstock can help solve the problem of energy deficit and at the same time even in *the Environment Impact Survey 2017* published in June 2017 India was placed at 75th rank with renewable energy making up only 15.2 per cent of all energy used.

In this paper a case study has been analyzed for a College campus "D.C.R. University of Science & Technology, Murthal"- Mother Teresa Hostel mess with the possibility of using Kitchen food waste to generate Biogas and observe its efficiency through various parameters. This paper also highlights the social, benefits and economical payback period for set up of a biogas digester at the college level.

## 1. Introduction

India is the second most populous nation on the planet. The Census of 2011 estimates a population of 1.25 billion which is 17.66% of the world population Per capita waste generation ranges between 0.2 kg and 0.6 kg per day in the Indian cities amounting to about 1.15 lakh MT of waste per day and 42 million MT annually. Also, as the city expands, average per capita waste generation increases. The waste generation rates in India are lower than the low-income countries in other parts of the world and much lower compared to developed countries. However, lifestyle changes, especially in the larger cities, are leading to the use of more packaging material and per capita waste generation is increasing by about 1.3 per cent per year. With the urban population growing at 2.7 per cent to 3.5 per cent per annum, the yearly increase in the overall quantity of solid waste in the cities will be more than 5 per cent. *The Energy and Resources Institute (TERI)* has estimated that waste generation will exceed 260 million tonnes per year by 2047—more than five times the present level [1]. The problem of municipal solid waste management Municipal Solid Waste has become a global challenge from a local regional, national environmental and public health issue due to the rapid population, urbanization and industrialization. This is due to the improper management of MSW as reported by several researchers in different cities of developing countries 90% of the MSW generated in India is directly disposed on land in an unsatisfactory manner. Uncollected solid waste can also obstruct storm water runoff, resulting in the forming of stagnant water bodies that become the breeding ground for water borne diseases that include malaria, dengue, filariasis, typhoid, dysentery. Direct dumping of untreated waste in rivers, seas and lakes lead to the bio-accumulation of toxic substances in the food chain through the plants and animals that feed on it [2]. Food waste can be recycled via anaerobic digestion, composting and vermicomposting. Bio methanation systems already exist in India. Biogas is one of the most viable option in controlling the on-going pollution and a large fraction of organic waste and managing the solid waste produced up to a greater extent. Land filling is expensive, requires space and can have negative environmental impact if not well managed due to the production of leachate, methane, carbon dioxide and other nuisances like flies, odour, and vermin like birds and rodents. Leachate could pollute underground water and soil. Methane and carbon dioxide released in landfill sites are greenhouse gases which can lead to global warming. Apart from these general challenges, as stated earlier, the increasing hostel student population (which is currently 2000 of all 7 hostels ) in DCRUST with its corresponding increase in waste generation tends to put pressure on existing waste facilities .A large fraction of this waste is biodegradable material and can be efficiently converted to biogas. By utilising the large fraction of organic fraction of waste to produce biogas we can effectively manage the solid waste problem and set an example in Haryana state. Our experiment can act a pilot project for all the universities and college campuses for making a step count toward sustainable development. The functional plant to be set up further by the university authorities and the subsequent batches in the future can help in utilising this study to achieve the result of our dream project. The current study was done in the DCRUST campus. The food waste was collected from one of the seven hostel of DCRUST campus named Mother Teresa Hostel. The hostel consist of 290 students for which food is prepared daily in the hostel mess thrice a day including breakfast, lunch and dinner respectively.

## 2. METHODOLOGY

### 2.1. Lab Scale Experiments

The Initial lab scale set up include the 4 bottles of small lab scale digester to know the production of gas and gas generation rate with different composition of waste material and the presence/absence of inoculum . The bottles were fitted with a hole mounted cap tightly packed with an air holding polybag to confirm the presence of biogas generation and there rate of production respectively, If there is a production of gas the polybag attached to the bottles will be filled and swollen which confirms the presence of biogas generation and the different amount of puff in the polybag confirmed the generation of highest and lowest amount of gas generated among them respectively. The composite sample of waste was prepared by mixing waste of seven days before each time it was fed into inlet. The spent slurry of Kitchen based two stage Biogas digester is taken which act as inoculum which act a seed material for the digestion and offers methanogen bacteria for the process. Lab scale bottles consist of four categories from which the observations were recorded.

2.2. Experimental Analysis

The major data analysis was based on the set up of a 20 litre bisleri bottle based digester in which a definite amount of feed and inoculum with water was feed twice in an interval of 10 days and the actual potential data of biogas was analysed. A 20 litre bisleri bottle with 2 kg Food waste & inoculum and filled up to 20 litres. The food waste was fed twice within an interval of 10 days from day 1. Hence it was feed on Day 1 & Day 11 of the experiment. The reading of Various parameters namely Gas production, pH, Total solids % & Total solids concentration, Moisture content, Volatile Fatty acids, Gas contents were determined for various intervals and data is prepared and analysed for the final recommendation. The different parameters were checked for the production of biogas and the data was analysed to find out the gas generation potential of DCRUST campus.

2.3. Biogas Production

The amount of gas was measured by water displacement method [3]. A vessel with the pipe hole and graduated cylinder hold was made with the help of thermocol, vessel and m-seal. The amount of water displaced by the gas when it passes through the pipe was measured and the amount of gas generation was obtained. Syringe method [4]. was used for the measurement of amount of methane, carbon dioxide & Trace gases in our gas produced

## 3. RESULTS AND DISCUSSION

3.1. Lab Scale Experiment

The bottle with four different compositions was taken for the assessment of gas production and its rate of generation. The 2nd Bottle with the configuration 50 gm. sample + 1 Litre water Mixed with inoculum (Labelled as M2) recorded the lowest pH and also the Highest amount of gas generation as visually perceived by the puffiness of the polybag being highest among them , The 3rd Bottle with the configuration 50 gm. sample + 2 Litre water Mixed without Inoculum (Labelled as U1) recorded the highest pH but the least amount of gas generation observed by visual comparison

3.2. Final Experiment

The final results for various parameters were recorded from the 20 litre bisleri bottle digester and this leads to the final assessment for the biogas generated from the kitchen waste of Mother Teresa Hostel. The various parameters associated with the biogas production were measured.

3.3 Discussion

From The small bottles experiments (Table 1). we confirmed the formation of biogas from the kitchen waste of Mother Teresa hostel food samples. The inoculum for the catalysis of biogas generation was taken from a biogas plant. The Bottles with the presence of inoculum from the biogas plant started to be filled with gas within 4-5 days of the experiment setup while the bottles without the presence of inoculum started the production of gas after 10 – 12 days of the experiment setup. The different amounts of puffiness around the polybags were observed due to different amount of bio gas generated on the basis of inoculum. The bottle with 1 litre of water (labeled as M2) and food waste sample with inoculum presence shows the presence of fastest and highest gas production among them. Since inoculum contains the methanogenic bacteria which enhanced the activity in this sample and accelerated the amount and rate of gas production, The lowest amount of gas production was visually observed in the 3rd bottle (Labelled as U1) even after the 15th day of the experiment It was confirmed that the inoculum catalyses the process of methanogenesis & gas production. Since the bottle with the 2 litre water & sample with presence of inoculum also shows a noticeable amount of gas production but the large amount of Moisture contents retards the reaction rate and leads to lesser generation of biogas.

The samples without the presence of inoculum show a small amount of gas generation taking a larger time span for the production. Since the raw kitchen waste do not contains methanogeneic bacteria in appropriate amount,Hence the major finding from the small bottles based experiments confirmed the production of biogas from food waste and also that it is affected directly by the moisture content, presence of inoculum and amount of feed to water ratio.

The final experiment of the analysis and production revealed the various aspects of biogas from kitchen waste.

The production of gas in the 20 litre container was 0 ml on Day 1 & Day 2 (Table 2). Gas generation started on the 3rd day in the presence of inoculum with 60 ml on the Day 3, The gas generation rate ranges from 300 to 800 ml per day with a peak reading of 811 ml (Table 2) observed on the 12th day. The gas production continuously increased from the Day 3 to Day 12 (Table 2) except a minute decrease between Day 5 & Day 6, (Chart 1) Since the food waste was added twice during the procedure and after the ambient conditions prevailed from the gas production, the bacteria were in active stage and the second lot of food after 10 days produced gas at a very higher pace with larger gas production. The gas Production decreased on the Day 13 to 589 ml due to decrease in the pH of the digester, a small amount of Lime was added to the digester to stabilize the pH and calibrate the gas production. The production of gas was lesser in our campus compared to other studies on the kitchen waste gas production as there is no use of Non veg in our campus and also the product used in Mess includes Vegetables and Milk products. Ravita D. Prasad et al. [5] also observed in her experiment that the Kitchen waste/Food waste with more Veg proportion produces lesser gas as compared to the Kitchen Waste with higher Proportion of meat and Non-veg products. The reason might me the meat/Non-veg products are simpler in nature and consist of simpler carbon chains while the vegetable substances consist of complex carbon chain molecules which is difficult to breakdown by the bacteria

The pH of the sample was recorded daily as shown in Chart 2 and it was observed that there was a continuous generation of acid in the container during the acidogenesis stage, since the PH on the initial day was 7.4 which reduced to the lowest point 5.2 on the 13th day of experiment that directly resulted in the spot reduction in the gas generation of the digester, lime was then added to stabilize the pH. The generation of acid affects the rate of gas production and also the amount of total solids affects the pH. The food waste put into container was utilized more effectively by the microbes and increase in acidogemesis lowers the pH from 6.1 on 12th day to 5.2 on 13th day which also decreased the gas production on the 13th day by a substantial amount from 811ml to 589 ml on the 13th day. A small amount of lime was added to recalibrate the production process and pH was adjusted to around 7 which increases the gas production rate too.

The generation of volatile Fatty acids affected the pH range which hinders the functioning of methanogenic bacteria. Their readings were recorded daily and the VFA concentrating on first day was 1921 mg/l (Table 2) and it peaked to a level of 5604 mg/L on 12th Day (Chart 3). The amount of food waste to water ratio affects the VFA concentration.

The Total Solids concentration and Moisture content of the sample was measured every 4 consecutive day (Table 3) and the initial concentration of the sample was determined 16.60% that is 332 gm. which dropped due to degradation by microbes and the breakdown of the organic solids into smaller fatty acids and finally into gaseous product by acetogenesis and methanogenesis respectively. The lowest observation of the total solids was 11.04% which constitutes only 220.8 gm. of total solids concentration in the slurry (Chart 4). The production of gas is also affected and decreased due to the decrease of TS and increase in the Moisture content of the container which was 83.40% (Chart 5) on Day 1, The moisture content of the sample did not seen a major change and also the addition of the second slurry after 10th day also substituted the moisture content. Since the amount of water and the total solids combined affected the formation of gas production it was confirmed that a good amount of total organic waste of simpler substance can increase the gas generation rate effectively.

The concentration of Gas observed in the DCRUST campus consisted of around 50-60% of Methane ($CH_4$) and the rest being the $CO_2$ around 40-50% (Table 4). The highest amount of the methane concentration was observed 62% methane on Day 14 which was after the lime stabilization on 13th day when pH was restored and there were optimum amount of methanogenic bacteria in the digester that accelerated the gas production. The lowest amount of gas was observed on Day 11 and Day 20 both consisting 51 % of the total gas generation, this might be due to the reduction of total solids especially organic substances in the digester and also the reduction in the pH that cumulated affected the rate of methanogenic bacteria

## 4. CONCLUSION & RECOMMENDATION

The average rate of gas generation from a 20 litre digester with 2 kg feed is found to be around 0.8 litre per day litre from 20 litre sample and this also can be increased to a certain level by increase the amount of food to water ratio.

2 kg feed = 0.8litre
1 kg feed = 0.4litre
10 kg feed = 4 litre
800 kg feed = 320 litre

Hence around 4 litre of biogas is generated from 20 litre digester from the waste composition of DCRUST hostel.
This leads to a generation of 320 litres of gas generation in the DCRUST hostel from a 800 kg feed daily from a 1000 litre biogas plant that will include slurry preparation from remaining amount of water to obtain better results. The gas can be utilised for cooking purpose of the hostels mess.

### 4.1. Gas Generation Potential

An average of 400 gm. of food waste is generated per person per day which concludes to around 800 kg of waste per day in the hostel mess. Hence the total generation capacity of 320 litre of biogas from a 1000 litre digester, In the 7 Hostel we can produce 320 litre of biogas daily in the DCRUST campus that can eliminate the use of LPG in the hostel up to a great extent. From the previous calculation we know that we can cook food for 60 person from 10 litre of biogas hence.

10 litre biogas = food for 60 person
1 litre of biogas = food for 6 person
320 litre of biogas = 320*6
= 1920 person

Hence on average of 2000 students in the hostel we can produce the food from biogas for more than 1900 students which consist of around 95 % of the total student capacity and can reduce the amount of LPG gas cylinders.

### 4.2. Payback period

An average cost of construction for a 1000 litre Floating type biogas digester made of syntax tank would be 20000 ₹ which can work efficiently for 5-8 years if maintained properly.

A 1000 litre biogas plant can replace an average of LPG cylinders (ISSN No. 2249-3050, Volume 4 No. 2 (2013) Hence the amount of 6 LPG cylinders can be saved per month that will be around 4500 ₹ per annum which will cover the amount of construction in less than 4 years and the payback period is considered after the 4th year of installation with other environmental benefits

4.3. Recommendations

The Design and installation criteria can be considered by my upcoming batch mates as their major project area which will help the university and department to successfully implement the digester along the campus and mark a milestone in the state.
Higher rate of gas generation can be achieved by analysing more various concentrations and increasing the amount of simpler feed such as starch and simple sugars which increases the mthanogenesis process. Since there is no generation of meat of non-veg product in the DCRUST kitchen our biogas generation efficiency is lesser that commonly working Kitchen based plant with mixed veg and non-veg feed. Other waste such as the wooden shavings, leaves etc. can also be utilised unless they harm the rate of production in the digester.
During the winters Solar water can be utilised for the efficient generation of ambient temperature for production of gas. A 200 litre (cost around 20000 ₹) solar water heater can be utilised to heat up the water up to the ambient range.

## 5. CHARTS

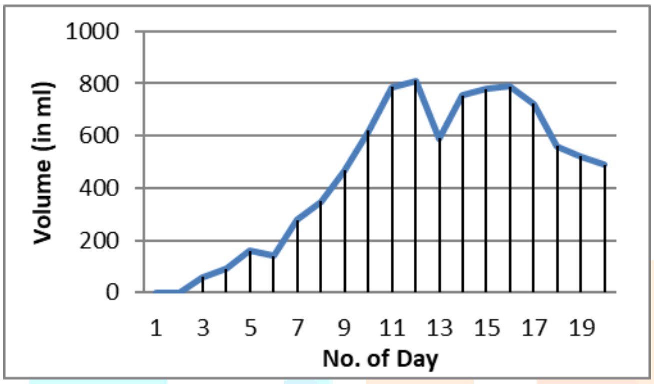


**Chart 1 Variation of Biogas Production during Experiment**

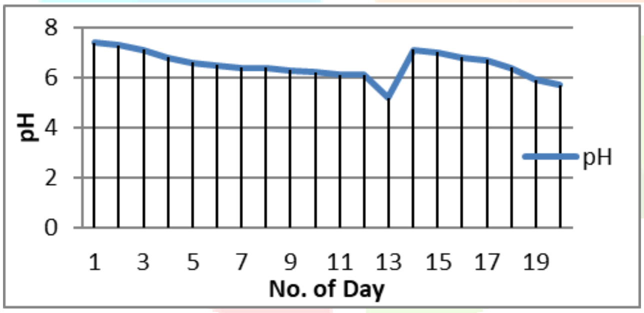


**Chart 2 Variation of pH during Experiment**

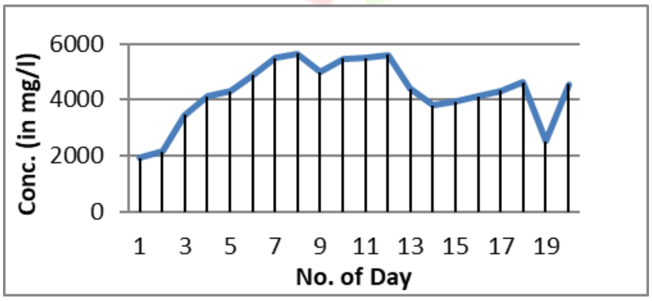


**Chart 3 Variation of VFA during Experiment**

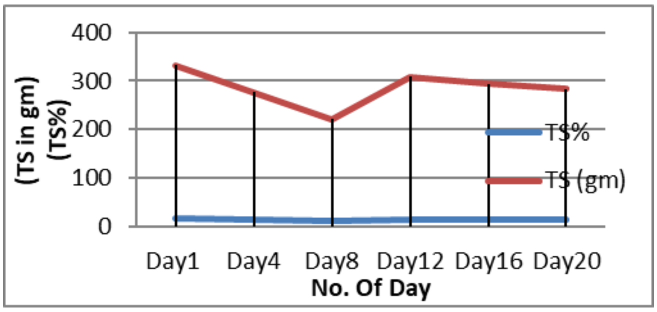


**Chart 4** Variation of **Total Solids % & Total solid Conc. in grams**

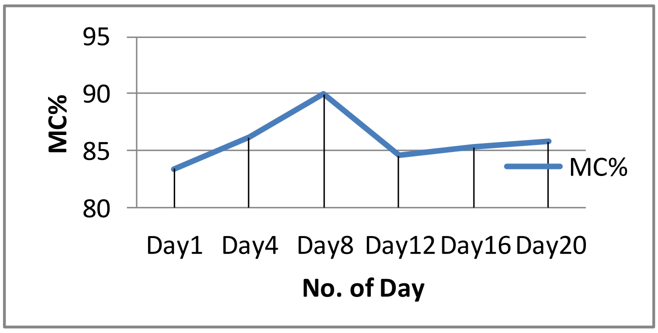


**Chart 5 Variation of Moisture Content during Experiment**

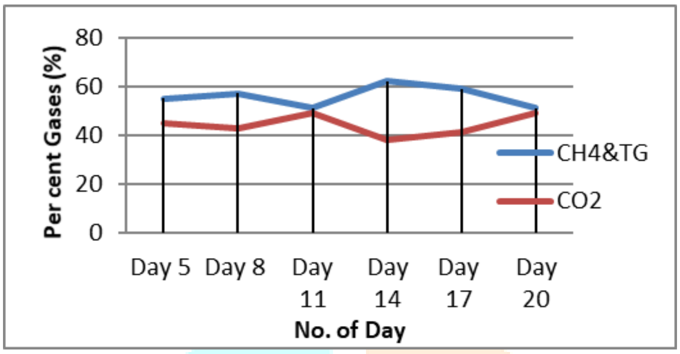


**Chart 6 Variation Of Gaseous concentration**

## 6. TABLES

| S. No | Composition of Bottle | Initial pH |
|---|---|---|
| 1 | 50 gm. sample + 2 Litre water Mixed with Inoculum (Labeled as M1) | 6.1 |
| 2 | 50 gm. sample + 1 Litre water Mixed with inoculum (Labeled as M2) | 5.9 |
| 3 | 50 gm. sample + 2 Litre water Mixed without Inoculum (Labeled as U1) | 6.9 |
| 4 | 50 gm. sample + 1 Litre water Mixed without Inoculum (labeled as U2) | 6.8 |

**Table 1. Composition of lab scale Bottles**

| DAY | Volume(ml) | pH | VFA (mg/l) |
|---|---|---|---|
| Day 1 | 0 | 7.4 | 1921 |
| Day 2 | 0 | 7.3 | 2140 |
| Day 3 | 60 | 7.1 | 3460 |
| Day 4 | 90 | 6.8 | 4121 |
| Day 5 | 160 | 6.6 | 4287 |
| Day 6 | 140 | 6.5 | 4863 |
| Day 7 | 279 | 6.4 | 5478 |
| Day 8 | 349 | 6.4 | 5639 |
| Day 9 | 466 | 6.3 | 4973 |
| Day 10 | 620 | 6.2 | 5457 |
| Day 11 | 786 | 6.1 | 5481 |
| Day 12 | 811 | 6.1 | 5604 |
| Day 13 | 589 | 5.2 | 4397 |

| | | | |
|---|---|---|---|
| Day 14 | 754 | 7.1 | 3806 |
| Day 15 | 780 | 7.0 | 3930 |
| Day 16 | 788 | 6.8 | 4114 |
| Day 17 | 722 | 6.7 | 4320 |
| Day 18 | 561 | 6.4 | 4628 |
| Day 19 | 520 | 5.9 | 4509 |
| Day 20 | 489 | 5.7 | 4547 |

**Table 2 Variation of Gas Volume, pH & VFA**

| Day | MC% | TS % | TS (gm.) |
|---|---|---|---|
| 1 | 83.40 | 16.60 | 332 |
| 4 | 86.18 | 13.82 | 276.4 |
| 8 | 88.96 | 11.04 | 220.8 |
| 12 | 84.55 | 15.45 | 309 |
| 16 | 85.31 | 14.69 | 293.8 |
| 20 | 85.81 | 14.19 | 283.8 |

**Table 3 Moisture content & Total Solids**

| S.No | Methane & TG* (%) | $CO_2$ (%) |
|---|---|---|
| Day 5 | 55% | 45% |
| Day 8 | 57% | 43% |
| Day11 | 51% | 49% |
| Day14 | 62% | 38% |
| Day17 | 59% | 41% |
| Day20 | 51% | 49% |

**Table 4 Gaseous Concentration of Gas Generated****

*TG = Trace Gases ** = approx. value

## 7. FIGURES

**Figure 1 Lab Scale Bottle Sample**

**Figure 2 Experimental Setup**

## 8. REFERENCES

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