# Investigation of Enhancement of Biogas Generation from Canteen Waste

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**Abstract -** *Methane (CH4) is highly flammable and when mixed with air it forms a mixture which can easily be ignited. The garbage generated in Mumbai city is dumped in the open which possess not only health hazards but the methane generated has been a source of major fires in the last few years resulting in large parts of the city being covered by the resulting smoke. In our study the research work was conducted to investigate the prospect of college canteen waste for biogas production and ultimate protection of environment from the bad effect of methane gas that would be produced by uncontrolled anaerobic digestion. The objective was to study the mechanisms to increase the Biogas generation which would maximize the yield of conversion of the kitchen waste into Biogas. Earlier studies of production of biogas from kitchen waste with various concentration of NaOH additive showed that the maximum gas production was observed with 1.5% NaOH concentration at a loading rate of 200gm/lit[1]. In our study we have compared the effects of other additive namely $Na_2CO_3$, $CH_3COONa$ as well as NaOH on biogas production. Also previous studies have used cow dung manure as the bacterial seed. We have studied the effect of using compost from an already operational biogas plant as the bacterial seed on the biogas yield.*

***Key Words***: Biogas, garbage, Canteen waste, anaerobic digestion, methane gas etc.

## 1. INTRODUCTION

Mumbai generates around 9,400 tonnes of trash that it sends daily to its dumping grounds. Of this 73% comprises food, vegetable and fruit waste, says the Brihanmumbai Municipal Corporation (BMC)'s latest Environment Status Report (ESR).

Waste management experts said if Mumbai recycles this waste, it can reduce the amount of garbage transported to its overburdened landfills by 93%. “Not more than 7% of non-recyclable and inert waste requires to be dumped at landfills in Mumbai because they can be treated at source,” said Satish Sinha, waste management expert, who was part of the committee that drafted the Municipal Solid Waste Management Rules, 2016.

Despite the high proportion of recyclable components in its garbage, Mumbai segregates only 8% for recycling and only 5% is composted by private agencies such as housing societies, restaurants and produce markets.

The dumping of garbage poses health hazards because it is a breeding ground for mosquitoes, flies, and rodents, which are carriers for disease-causing pathogens. It also aggravates air pollution, ground water pollution and soil pollution affecting the fragile ecosystem. Also, it emits unpleasant odour & methane which is a major greenhouse gas contributing to global warming.

A fire broke out at the Deonar dumping ground on Monday afternoon, March 27, 2018, leading to toxic fumes emanating from the garbage dump. Eight fire engines and seven water tankers were sent to the spot to bring the fire under control. The dumping ground was caught in a massive fire earlier too on two occasions - once on January 27 and again on March 20 in 2016 that had led to a large portion of the city covered in toxic plumes.

In 2016, the smoke from Deonar, Asia's oldest and largest garbage dump was visible from space, according to NASA images that were released days after the fire that was visible from across Mumbai.

In both instances when the fire broke out at the Deonar dumping ground in 2016, the fire brigade took over a week to douse the fire. As a result of which residents living across Central Mumbai were exposed to the thick plumes of smoke for days. In February, schools around the dumping yard were shut for days due to the air pollution [2]. These kinds of problems could be reduced to a great extent if the solid wastes generated could be reduced at source.

In 2003, Dr. Anand Karve [3][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.

Large scale producers of biodegradable wastes such as restaurants, canteen, housing societies can biodegrade the wastes and in turn produce biogas which would help to reduce non-renewable LPG consumption as well as generate high quality manure that can be sold [5]. The objective of this study is to design an anaerobic biogas digester utilizing canteen kitchen waste of A. C. Patil College of Engineering that could be converted into biogas and to study the mechanisms to increase the Biogas generation which would maximise the yield of conversion of the kitchen waste into Biogas.

## 2. Materials and methods

### 2.1. Waste collection and processing

Waste collection - Kitchen waste (KW) was collected from the college canteen to be introduced in digester to produce biogas through anaerobic digestion. Kitchen waste consisted of waste vegetables, fruits and leftover food mainly consisting of starchy material. After removing the bones, plastic bags, metals and inorganic residues, wastes were cut into small size in order to reduce the size to get efficient biogas production. Then these wastes were mashed into paste by using hopper. Compost was collected from BARC, township biogas plant, Mumbai.

### 2.2. Experimental set-up

A simple lab-scale experiment was fabricated using four digesters. Each digester was made of glass. The volume of each digester was 2 L and working volume was 1 L. In this study the volume of produced gas was measured by water displacement method considering the volume of the generated gas equal to that of expelled water in the water collector. Each digester was connected to water chamber (measuring cylinder) by a plastic pipe which was used to pass the produced gas into the measuring cylinder. One end of the plastic pipe was inserted just at the top of the digester and the other was inserted just at the bottom of the measuring cylinder. The plastic pipe end inside the digester was made completely airtight by using M-seal and Teflon tape.

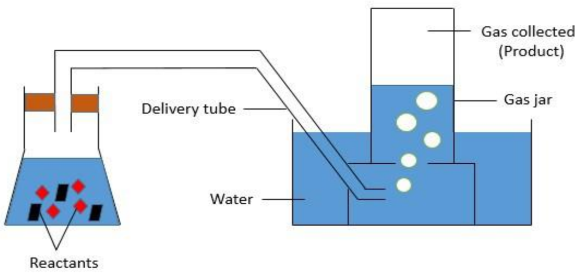


**Fig-1: Schematic diagram of the lab-scale experimental set-up**

Lab scale experiment - Lab-scale experiments were operated in batch mode. Firstly, four digesters were prepared; D-1, D-2, D-3 and D-4 (Set 1). The digesters were run at room temperature 37°C (summer season, April 10, 2018). The substrate composition of the digesters is given in the Table 1.

**Table-1: Composition of batch digester at room temperature of 37°C**

| Sr. No. | No. of digesters (D) | Organic biomass KW (gm) | Bacterial seed Compost (gm) | 100 ml of 1.5% Additive |
|---|---|---|---|---|
| 1 | D-1 | 200 | 50 | - |
| 2 | D-2 | 200 | 50 | $Na_2(COOCH_3)_2$ |
| 3 | D-3 | 200 | 50 | $Na_2CO_3$ |
| 4 | D-4 | 200 | 50 | NaOH |

Further, based on the results of the above experimental setup four more digesters were prepared A1, A2, A3, A4 (Set 2) to study the effect of pH on Biogas production by mixing KW, Compost and various volumes of 1.5% NaOH at room temperature, 28$^0$C (Rainy season, 3 July, 2018). The substrate composition of the digesters is given in the Table 2.

**Table-2: Composition of batch digester at room temperature of 28°C**

| Sr. No. | No. of digest er (D) | KW + Comp. + NaOH | KW (gm) | Compost (gm) | 1.5% of NaOH (ml) | pH |
|---|---|---|---|---|---|---|
| 1 | A1 | 4:1:0.2 | 200 | 50 | 10 | 6 |
| 2 | A2 | 4:1:0.5 | 200 | 50 | 25 | 7 |
| 3 | A3 | 4:1:1.5 | 200 | 50 | 75 | 9 |
| 4 | A4 | 4:1:2 | 200 | 50 | 100 | 10 |

From the results of the above set up, various volumes of 1.5 % NaOH was injected in each digester A1, A2, A3, A4 on Day 4 to make the volume of NaOH to 100 ml. The volume composition of NaOH in these digesters is given in Table 3.

**Table-3: Composition of batch digester showing different volumes of NaOH injected on Day 4**

| Sr. No. | No. of digester (D) | Initial Volume of NaOH (ml) added | Volume of NaOH (ml) injected | pH |
|---|---|---|---|---|
| 1 | A1 | 10 | 90 | 10 |
| 2 | A2 | 25 | 75 | 10 |
| 3 | A3 | 75 | 25 | 10 |
| 4 | A4 | 100 | - | 7 |

### 2.3 Biogas plant in our college

a) Substrate inlet -This consists of a receptacle for the raw organic waste and pipe of 110 mm diameter leading to the digester. The connection between the inlet pipe and the digester was made air tight.

b) Digester - A 1000 lit black plastic water tank was taken as a reservoir for the organic waste in which the substrate is acted on by anaerobic microorganisms to produce biogas.

c) Gas Storage/ Reservoir - A 750 lit black plastic water tank was taken as a reservoir for the storage of biogas. This tank was inverted into the digester satisfying the floating drum design.

d) Exhaust outlet - A 63 mm size outlet pipe was connected towards the top of the digester to facilitate outflow of exhausted slurry.

e) Crusher/ Mixer - Important aspect in smoother running of plant by avoiding the choking of the plant. This occurs due to thick biological waste that does not reach 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.

f) Biogas stove - This is a modified burner suitable for combusting biogas for cooking.


**Fig-2: Biogas plant from canteen kitchen waste in A. C. Patil College of Engineering, Kharghar, Navi Mumbai**

## 3. Result and discussion

### 3.1 Comparisons of biogas production from KW, compost and various additives at room temperature, 37$^0$C (summer season, May 2018)

Earlier research of anaerobic digestion of kitchen waste under mesophilic condition (37$^0$C) at the same loading rate (200gm/lit) using cow manure as microbial seed produced total of around 1350 ml of biogas at the end of 10 days. In our studies we observed that use of compost from an existing kitchen waste biogas digester as a microbial seed enhanced the biogas production by two factors. This is probably because cow dung manure have microbial flora suitable for the diet of the cow, whereas compost from existing kitchen waste biogas digester has microbial flora suitable to kitchen waste digestion.

Literature survey of production of biogas from kitchen waste with various concentration of NaOH additive showed that the maximum gas production was observed with 1.5% NaOH concentration at a loading rate of 200 gm/lit [1].

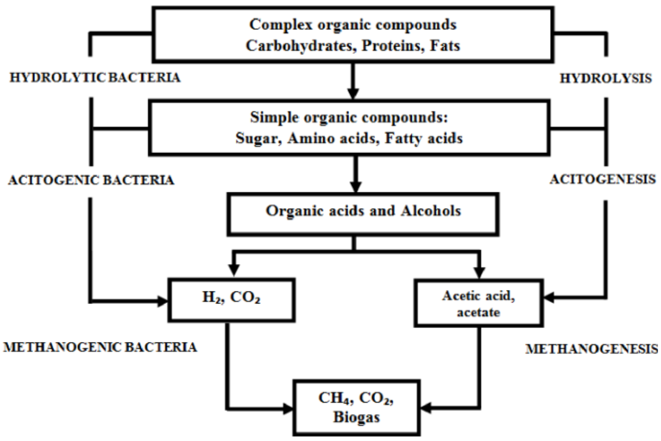


**Fig-3: Digestion of kitchen waste**

The last stage of digestion of kitchen waste, that is conversion of acetic acid/acetate to methane is a slow reaction compared to others, so it is a rate limiting step in the reaction. Addition of NaOH upto a desirable concentration enhances methane gas production.

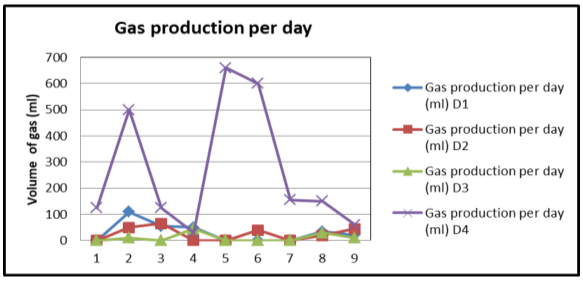


**Fig- 4: Comparison of Daily Biogas production with various additives**

Our study with different additives yielding alkaline environment, seems to suggest that it is not just alkaline environment but presence of NaOH which is favorable for the growth of methanogenic microorganisms.

Also a separate study with higher concentrations of NaOH resulting in pH around 12 did not yield any biogas formation at all, suggesting that too high pH was detrimental to the growth of the microorganisms. We can therefore safely conclude that although NaOH enhances methane formation, its concentration must be limited to creating pH of around 10.

### 3.2 Comparisons of biogas production from KW, compost and various volumes of 1.5% NaOH at room temperature 28$^0$C (rainy season)

Our studies from Set 1 showed that the best results for biogas production was obtained when an aliquot of 100 ml of 1.5 % NaOH was added to the Kitchen waste ( organic loading rate of 200gm/lit). In Set 2, further studies were conducted by varying the volumes of 1.5% NaOH added to the kitchen waste with the same loading rate.

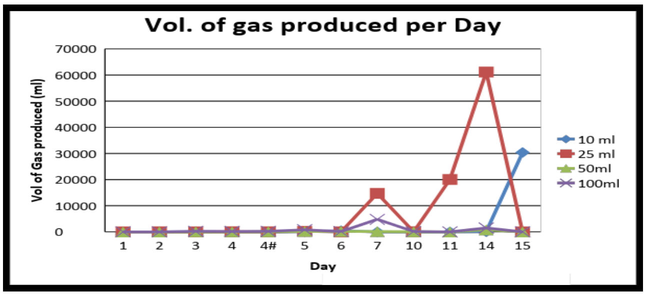


**Fig -5: Daily biogas production of various digesters with various pH # after addition of aliquots of NaOH as per Table No.3**

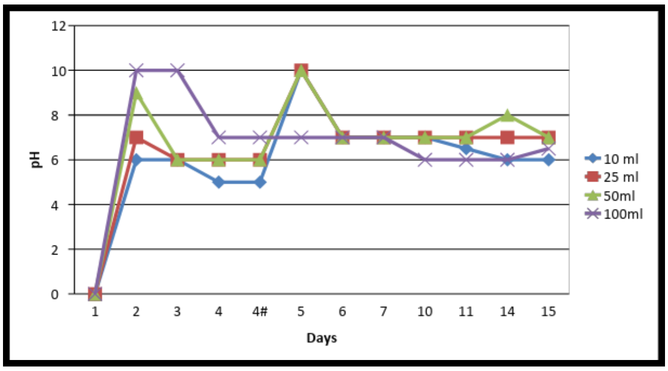


**Fig-6: pH Vs. Day**

From Fig.4 it is very clear that addition of initial lower volumes of NaOH increase Biogas production by 4 to 12 times. An initial lower volume of NaOH encourages the growth of the acid forming microorganisms. Since the 4 stages in methane formation are interconnected, a higher yield of acetic acid/ acetate would result in higher yield of methane formation.

In digesters A1 and A2 it is seen that the pH immediately after injecting 1.5 % NaOH in the digesters (to make the total volume 100 ml) was 10 but it fell rapidly to a pH 6-7 the next day suggesting earlier acetogenesis reaction. However since methane forming bacteria seem to flourish in alkaline medium, the addition of NaOH encouraged the growth of methanogenic bacteria which thereafter broke down the acid/ acetate to methane. Hence the gas productions in these digesters increased rapidly subsequent to the addition of NaOH.

### 3.3 Characterization of kitchen waste and digested slurry

The kitchen waste and digested slurry have been characterized in terms of Total Solids, Volatile Solids and Fixed Solids before and after digestion and the results have been shown in Table no.4

**Table-4: Characterization of kitchen waste and digested slurry**

| Sr. No. | Parameters | Before digestion | After digestion |
|---|---|---|---|
| 1 | Total Solids (%) | 74.52 | 8 |
| 2 | Volatile Solids (%) | 18.73 | 1.7 |
| 3 | Fixed Solids (%) | 55.79 | 7.3 |

At the end of 15$^{th}$ day, Total Solids and Volatile Solid reduction by a factor of 10 was observed.

## 4. CONCLUSION

The study conclusively proves that the yield of biogas increases by a few factors on using bacterial seed from an already existing biogas plant and initial pH of around 7 that should be increased to 10 on the fourth day. Conversion of organic solid waste into biogas and compost is an effective method of reducing total volume of municipal organic solid waste. In addition the process will yield biogas which would reduce the demand for LPG thereby saving fossil fuel also the slurry produced can be used as good fertilizer.

## ACKNOWLEDGEMENT

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