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# An Investigation into Generation of Biogas from Restaurant Waste

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### ABSTRACT

This is the study to evaluate the performance of new design of biogas unit and to enhance the biogas production by using different parameters. The raw material to be fed in digester will be the food waste which gets generated everyday from restaurant full of crowd in the locality. With this unit, biogas equivalent to two kg of LPG can be generated from the feeding of approximately 15 kg of food waste every day. This is the only design available which allows the user to choose how much biogas pressure he wants. Biogas thus produced can be checked for quality by different inoculums and additives. Thus the cost of disposing the food waste can be saved and the energy can also be recreated and reutilized for restaurant benefits. Hence the atmospheric contamination automatically gets prevented.

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### Introduction

The food waste includes uneaten food and food preparation leftovers from residences, commercial installations such as institutional sources like school cafeteria, restaurants and industrial sources like factory lunchrooms. Food waste is a growing issue, and the disposal of it is debatable, given increased food expenditures and the resources required. Food waste from restaurant is potential to be used for an energy source because of its high organic content. Energy from food waste can be achieved by anaerobic digestion to produce biogas. The food waste is, for the most part, disposed of in landfill. In light of rapidly rising costs associated with energy supply and waste disposal and increasing public concerns with environmental quality deprivation, conversion of food wastes to energy is becoming a more economically possible practice. Food wastes can be highly variable depending on their sources. Typical food waste composition consist Lipids, Proteins Polysaccharides (cellulose, starch, hemicellulose) Lignin Minerals mm (phosphorous, metals) and some contaminants like heavy metals, pesticides and insecticides. A Swiss restaurant recycles organic waste into biogas. Compared to the former incineration costs, the restaurants now pay 60% less for the disposal of organic waste. The biogas vehicles save each about 10,000 liters of diesel annually. Some characteristics of food wastes that have been reported in the literature are shown in following Table 1. It indicates moisture content of 74–90%, volatile solids to total solids ratio (VS/TS) of 80–97%, and carbon to nitrogen ratio (C/N) of 14.7–36.4.<sup>[1]</sup>

Food waste defined as uneaten portion of meals, leftover and trimmings from food preparation from restaurants, kitchens and cafeterias. Improper disposal of food waste causes odour and potential vermin and scavengers' infestification. Generally, it was disposed off together with other MSW in landfill. With capacity of landfill gradually filling up and fewer landfills being commission, it is critical to look for alternative disposal method.

One possible method is composting. Composting is an aerobic process and it produces humus that can be used as fertilizers or soil conditional, Incineration is another approach but it is not feasible because the moisture contents of food waste is very high. The composition of food waste are consists of meat, bones, fats and oils, greens and fruits, carbohydrates and moisture. The high moisture content is feasible for composting and anaerobic degradation. The Anaerobic Digestion process could be applied to the kitchen wastes and it could increase the methane recovery rate of yield biogas.<sup>[2]</sup>

Table 1: Characteristics of food wastes

Source	Characteristics		
	MC (%)	VS/TS (%)	C/N
Dining hall	84	96	14.7
Cafeteria	80	94	18.3
Municipal source	90	80	NA*
Fruit & vegetable	74	89	36.4
Household	93	94	NA*
Juice centre	90	97	NA*

\*NA-Not Available

Due to increasing needs for renewable energy generation and diversion of organic residuals from landfills to reduce the greenhouse gas emissions and other environmental impacts, treatment of food waste using anaerobic digestion technologies has become a more attractive method for food waste management. Biogas can principally be used like other fuel gas. For domestic purposes it is most suitable for cooking, heating water and lighting. The utilization of biogas as a fuel helps to replace fossil fuels, which the use of fossil fuels raise environmental concerns. Nowadays, the gas demand is market-

driven. There is a need to improve and also increase the efficiency of biogas production.

The following are some approximate quantities of gas for these different uses from which typical features of biogas can be understood.

**Table 2: General features of biogas**

Energy content	6.0 to 6.5 kWh/m <sup>3</sup>
Fuel equivalent	0.60 to 0.65L oil/ m <sup>3</sup>
Explosion limit	6 to 12% biogas in air
Ignition temperature	650-750°C
Critical pressure	75 to 89 bar
Theoretical air demand	5.7 m <sup>3</sup> air/ m <sup>3</sup> burning
Critical temperature	-82.5 °C
Normal density	1.2kg/ m <sup>3</sup>
Smell	Bad eggs

Domestic cooking: 2m<sup>3</sup> per day for a family of five or six people.

Water heating: 3m<sup>3</sup> per day for a 100-litre tank or 0.6m<sup>3</sup> for a tub bath and 0.35m<sup>3</sup> for a shower bath.

Lighting: 0.1-150m<sup>3</sup> per hour per light.

The gas demand can be defined on the basis of energy consumed previously.

For example,

1kg firewood corresponds to 200l biogas, 1kg dried cow dung corresponds to 100l biogas and 1kg charcoal corresponds to 500l biogas.

The gas demand can also be defined using the daily cooking times.

The gas consumption per person and meal lies between 150 and 300l biogas.

For one litre water to be cooked 30-40l biogas are required, for 1/2kg rice 120-140l and for 1/2kg vegetables 160-190l. The critical temperature of methane is around -82.5°C; even with very high pressure it is not possible to liquefy methane at higher temperature, which is probably the most important bottleneck of biogas utilization. As a consequence, biogas cannot be stored over long periods at reasonable costs, but has to be used immediately or within a few hours.

## Literature review

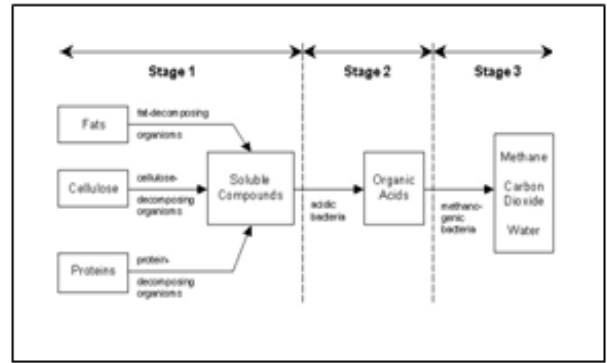
### A. Anaerobic Digester

It is a controlled biological degradation process and allows for efficient capturing and utilization of biogas for energy generation. The product from anaerobic digesters contains many nutrients and can thus be used as plant fertilizer and soil improvement.<sup>[3]</sup>

Anaerobic digestion provides the possibility and solution to major global concerns such as alternative energy production, proper management of mankind, and animal, agricultural, municipal and industrial waste, controlling environmental pollution, reusing of nutrients back to soil.<sup>[4]</sup> The gas produced through anaerobic fermentation of organic wastes is referred to as biogas. Biogas consists of approximately 60 % methane, 40 % carbon dioxide, and some impurities, such as hydrogen sulphide, ammonia and hydrogen chloride.

The low heating value of biogas is approximately 23 MJ/m approximately half the value of LPG. Since impurities such as hydrogen sulphide harm the catalysts used in fuel cell power units, they need to be removed in advance. Although LPG contains sulphur compounds as an odorant, biogas contains sulphur compounds several hundred times greater than that of

LPG.<sup>[5]</sup>



**Figure 1: Anaerobic digestion**

### B. Biogas Digester

According to gas storage the design of biogas digester may vary accordingly to suit the requirements of the owner. This can be divided into three groups, such as: bag digester, fixed-digester, and floating gas holder.

Frequent problems with fixed dome digester are the gas-tightness of the brickwork gas holder (a small crack in the upper brickwork can cause heavy losses of biogas); Gas pressure fluctuates substantially depending on the volume of the stored gas; Even though the underground construction buffers temperature increase, digester temperatures are generally low.

The floating gas holder digester makes use of a floating tank for gas storage. This can be further subdivided into Top Floating Gas Holder Digester and Separate Floating Gas Holder Digester. In former type gas storage is directly installed on top of the digester. This is usually employed for small size digester and in later there are two tanks involved: one is the fermentation tank and the other is the storage tanks, this is applied for medium to large size digester.<sup>[6]</sup>

#### Why Top Floating Gas Holder Digester? :

Similar to floating covers; however, they are designed to accommodate gas storage as well as digester drawdown. The gas holder cover, which floats on digester gas rather than on the liquid surface, is equipped with a skirt that extends below the liquid surface to contain gas. A concrete ballast ring below the skirt stabilizes the cover and helps control gas pressure.<sup>[7]</sup>

### C. Methods to increase biogas production

The biogas production can be increased, when the mixture kitchen waste and activated sludge like municipal solid waste is used. However, the highest value of methane production was for the combination of 75% kitchen waste and 25% activated sludge. For the rate of biogas production the situation was the same and the best result was for above combination. The anaerobic co-digestion of kitchen waste and activated sludge are demonstrated to be an attractive method for environmental protection and energy savings, but it is clear that with applying better equipment and adjustment of conditions able to give more reasonable results.<sup>[8]</sup>

Some results showed that for the volume reduction ranged from 32.7% to 43.7%, the production of biogas ranged from 0.55 to 1.29 ml biogas/kg food waste. The addition of grease had retarded the anaerobic process whereas the addition of chicken manure had increased the production rate. Temperature is an important factor, a higher temperature will increase the degradation rate and hence gas production rate.<sup>[9]</sup>

This suggests that improving the initial pH at the point of charging could further enhance the rate of biogas production.

When cow liquor waste was inoculated the rate of biogas production was enhanced. Further work on the optimal blending ratio of cow liquor waste with carbonated soft drink can be done to achieve the right pH for anaerobic digestion. Improving the initial pH at the point of charging could further enhance the rate of biogas production.<sup>[13]</sup>

**D. Comparison with LPG**

Calorific value of Biogas = 6 kWh/m<sup>3</sup>

Calorific value of LPG = 26.1 kWh/m<sup>3</sup>

Let us consider we need to boil water sample of 100 gm

We have Energy required to boil 100 gm water = 259.59 kJ

Hence, we need Biogas to boil 100 gm water = 12.018 lit

And, we need LPG to boil 100 gm water = 2.76 lit.

Therefore, amount of water which can be boiled using this much Biogas = 5.408 lit/day.

Now, amount of LPG required to boil 5.408 lit of water per day = 149.26 lit So,

We can save up to 10 cylinders of LPG per day.

We can save around 13 cylinders of LPG if Biogas from 1000 lit tank is used for 2 hours daily.

In a kitchen waste biogas system, a sample feed of kitchen waste produces methane, and the reaction is completed in 52 hours. Conventional bio-gas systems use cow dung and 40kg feedstock is required to produce same quantity of methane.<sup>[10]</sup>

It has to be noted that 2m<sup>3</sup> of biogas is equivalent to 1kg of LPG in energy content (thermal). To compare biogas to LPG, it is done in terms of the energy content (Heat).

Assuming standard conditions, that is, 1 kWh = 3.6MJ; biogas density = 0.8kg/m<sup>3</sup>. The calorific value of biogas is 6kwh/m<sup>3</sup>. Using these figures, the caloric value of biogas is 27MJ/kg. We can therefore conclude that 1kg = 46.6MJ (LPG) and 1kg= 27MJ (biogas).<sup>[11]</sup>

**Methodology Proposed**

**A. New Design of Unit**

As Floating Gas Holder Digester is the best suitable option for restaurant waste digestion and with some improvement in the gas holder and the digester design can be proved much efficient. This unit is available in three sizes depending upon the weight of feed. Unit of 1 cubic meter (CUM) is suitable for 6 to 7 kg of feed, unit of 2 CUM is suitable for 10 kg of feed and unit of 4 CUM is suitable for 15 kg of feed. Feed more than above mentioned limit will cause acidification and odor problems. Hence 4 CUM per day capacity unit is suitable.

Salient features of new design (Figure 2) are discussed below. In this new unit the gas holder contains pockets where concrete blocks can be placed. Because of this provision enough weight can be added as per application requirement which allows the user to choose how much biogas pressure he wants. This can be mass produced its existing capacity is 50 plants per day of 4 CUM per day capacity. Because of unique stackable design all components can be easily transported at very modest cost. Roof top installation of this unit is possible. It also requires small space, only 7 feet diameter for a plant of 4 CUM/day. Concrete weights can be put in pockets which will provide adequate pressure at burners. Additional pockets if gas is to be carried for long distance. Concrete weight in pockets increases gas pressure. Weight can be added as desired. Gasholder and digester both are made up of high density plastic so it is light in weight as compared to conventional unit, thus the overall weight of the system gets reduced and indeed results in durability<sup>[12]</sup>.



**Figure 2: CAD model of unit**

**B. Composition and handling of Food waste**

For 15kg of food waste collected to check out the composition following data accumulated.

**Table 3: Composition of Food waste**

Content	% of total weight
Uncooked fruit and	22
Cooked fruit and	18
Uncooked meat	5
Cooked meat	15
Rice and other remains	25
Gravy	13
Tea bags	2

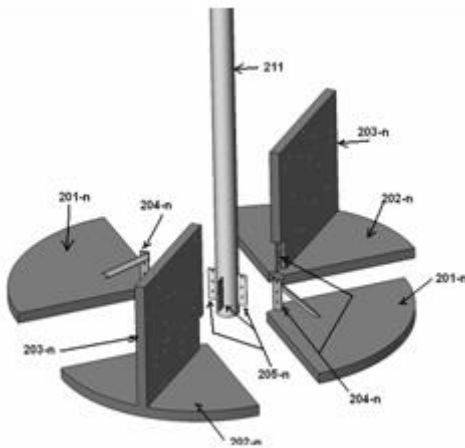
The biogas formation process does not start immediate after feeding, it is required to produce the bacteria by keeping the mixture of cow dung (approximately 40) and slurry from any other running biogas plant (approximately 20 kg) in new installed unit. It will generally take 3 weeks to produce the bacteria which will cause the fermentation of food waste. The food waste before feeding is moisturized by mixing with some quantity of water this is also done to make sure that it will not get stuck in the feeding line. Mixing, within the digester, improves the contact between the micro-organisms and substrate and improves the bacterial population its ability to obtain nutrients. Furthermore it prevents the formation of scum and the development of temperature distinguishes inside the digester. Mixing can be done by the recirculation of digester residue and biogas inside the digester to keep the material moving to ensure a sufficient homogeneity.<sup>[14]</sup> Centrally guided system (Figure 3) is there for proper mixing of slurry in digester indeed for efficient performance of the system. It is having baffle plates fastened at the end of guiding rod so that the slurry inside the digester can be stirred properly from the top of unit.

**C. Biogas production enhancing methods**

The general conditions and parameters which affect the anaerobic biological process are temperature, pH-value and alkalinity, mixing/stirring, biochemical composition of organic matter and inhibitors.

The most suitable values are between 20 and 40 °C (mesophilic optimal range) and between 50 and 65 °C (thermophilic optimal range). As well as the biogas production the pH value is a parameter that indicates digester instabilities

In a one-step anaerobic treatment process, the pH is typically maintained at 6.8 to 7.8. The alkalinity describes a measure of the buffering capacity of the system.



**Figure 3: Centrally guided system**

The measurement of alkalinity allows declarations of how sensitive the AD process is to disturbances. Mixing the feedstock allows also minimizing the retention time and this can increase the performance. Organic waste as substrate for biogas plants may consist of many different types of material. These types can be classified into three groups: fats (68 to 73 % methane content), proteins (70 to 75 % methane content), carbohydrates (50 % methane content) which contain in all organic matter. The most common inhibitors are formed during degradation of the substrate, such as organic acids, ammonia and sulphide. Further it can be also enhanced by adding the inoculums like municipal solid waste, horse dung, chicken manure, carbonated soft drink, industrial waste etc. All above additives can be verified for quality of biogas.

#### **Expected Outcome**

##### **A. Saving potential**

Once the bacteria gets generated the time require to generate biogas is 24 to 48 hours where as for biogas produced from cow dung usually takes 40 days. Improvements in the conventional design the proposed plant can save around 2 kg of LPG (Rs. 120/-) per day OR 20 kg of firewood.

For hotels and restaurants it will save additional cost of waste disposal which they are paying. This is also approved waste treatment methodology for pollutions control boards.

##### **B. Payback Period**

Initial Investment=Rs.30000/-

Cost Saved per day=Rs.120/-

Thus, Cost Saved per month=Rs.120 x 30

Days=Rs.3600/-

Time to recover the investment

= Initial Investment / Cost Saved per month

= 30000/3600

= 8.33 Months ≈ 9Months

Considering the maintenance and the subsidy, it can be concluded that the Payback Period of the proposed system is almost one year (12 Months).

#### **Conclusion**

It will have low payback period of one year only so this can be proved economical for restaurant owner. Its shorter waste

processing period in comparison to 4–8 weeks in other biogas systems will be beneficial. The discharge system is zero waste as the slurry coming out can be used as fertilizer for any small size farm. Its low water requirement is another advantage. Biogas of higher calorific value can be produced. Due to effective stirring system there will be no chances of scum formation. Various matters can be used as inoculums to enhance the biogas quality and quantity. The HDP material eases the handling and this indeed results in low maintenance.

#### **References**

- [1]Rao M.S., Singh S.P., 2004.Bioenergy conversion studies of organic fraction of MSW: kinetic studies and gas yield-organic loading relationships for process optimization. *Bioresour, Technol.* 95 (2), 173–185.
- [2]Cheng, Y.H., Sang, S.X., Huang, H.Z., Liu, X.J. & Ouyang, J.B. 2007.Variation of Coenzyme F420 activity and methane yield in landfill simulation of organic waste.*Journal of China University of Mining & Technology*, 17(3): 0403-0408.
- [3]Cho J K, Park S C, Chang H N. Biochemical methane potential and solid state anaerobic digestion of Korean food wastes. *Bioresour Technol*, 1995; 52(3): 245–253.
- 4]U.Marchaim. Biogas processes for sustainable development. MIGAL Galilee Technological Centre Kiryat Shmona, Israel, 2002, Available online: [www.fao.org](http://www.fao.org)
- [5]Kokan Kubota Kenichi, Kuroda Koji Akiyama. Present Status and Future Prospects of Biogas Powered Fuel Cell Power Units. Korea
- [6]V.V.N.Kishore, D.C.Pant. Anaerobic Digesters in India TERI University and the Energy and Resources Institute, Delhi.
- [7]Anaerobic Digester Covers ENVE737 Anaerobic Biotechnology for Bio-energy Production.
- [8]Amirhossein Malakahmad, Noor Ezlin Ahmad Basri. Anaerobic Codigestion of Kitchen waste and Sewage Sludge for Producing Biogas., Sharom Md Zain University Kebangsaan Malaysia, 43600 UKM, Bangi, Selangor, Malaysia.
- [9] K.H. Chua, C. H. Yip, W. L. S. Nie. A Case Study on the Anaerobic Treatment of Food Waste and Gas Formation. Universiti Tenaga Nasional, Malaysia.
- [10]Vij, Suyog, 2011, Biogas production from kitchen waste & to test the Quality and Quantity of biogas produced from kitchen waste under suitable conditions. B.Tech thesis.
- [11] P.A. Scherer, state of the art for the digestion of solid waste: environmental aspects, principles and variants ", *Waste Management journal* 6, [12]Promoters and Researchers in Nonconventional Energy (PRINCE) Design.
- [13]Sunil Dhingra. Tata Energy Research Institutes's enhanced acidification and methanation process, a tool to generate wealth from waste.
- [14] Henning Hahn, Uwe Hoffstede. Biogasmax a driving force, assessment report on operational experience. Fraunhofer IWES, November 2010.