Research Article

Design of Bio Gas Generation Plant Based on Food Waste

Rajendra Beedu[Å*] and Pratik Modi[Å]

[Å]Department of Mechanical and Manufacturing Engineering, Manipal Institute of Technology, Manipal University, Manipal, Karnataka, India

Abstract

This paper deals with the design and fabrication of a food waste based biogas generation system. An experimental setup is designed and implemented and the paper illustrates the working principle, chemical analysis, cost effectiveness of biogas plant compared to Liquid Petroleum Gas. Also the paper explains the method of transportation of waste food from different locations to multiple biogas plants.

Keywords: Biogas, Food Waste, Bacteria, Chemical analysis, LPG

1. Introduction

Most of the families in India depend on L P G for cooking and the demand is increasing day by day. We have to spend a large amount of foreign exchange for importing crude oil. Also, in a densely populated nation like India, disposal of waste food, creates the problem of environmental decay and hence needed to be handled properly. Gobar gas plants developed in 80's were not effective because they could be implemented in villages. In addition, gobar gas plants are not effective due to less heat generation (Robert Jon Lichtman, 1983). Biogas plant can be easily implemented in urban or rural areas where waste food with high starch content is available which can be used to produce methane gas and remaining slurry can be used as manure (K. R. Smith, 2001). If 20 % of L P G is replaced by waste food based bio gas plant, it will lead to a saving of substantial amount of foreign exchange and improve the economy of the nation. Also atmospheric degradation can be minimized.

2. Process of Producing Biogas

The process of producing biogas involves anaerobic digestion. In this process, acetic acid forming bacteria (acetogens) and methane forming archea (methanogens) are fed to the digester. The oxygen source in an anaerobic system is derived from the organic material itself. In the presence of specialized methanogens, the intermediates are converted to the 'final' end products of methane, carbon dioxide, and trace levels of hydrogen sulfide. In an anaerobic system, the majority of the chemical energy contained within the starting material is released by methanogenic bacteria as methane. Populations of anaerobic microorganisms typically take a significant period of time to establish themselves to be fully effective.

Therefore, common practice is to introduce anaerobic microorganisms from materials with existing populations, a process known as seeding the digesters, typically accomplished with the addition of sewage sludge or cattle slurry (Dhakal NR, 2003).
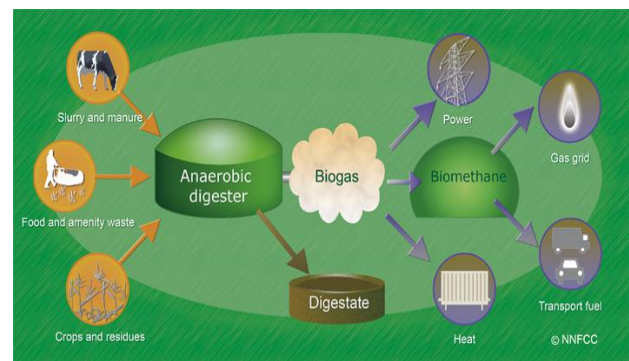

Fig 1 Anaerobic Digestion

3. Design

The dimension of biogas plant depends on the thermal energy to be produced. Since it is intended to replace a part of L P G gas, the energy equivalent for 1 cylinder of LPG is calculated.

Equivalence with LPG
Calorific value of LPG = 50 MJ/kg
One cylinder weighs 14.2 kg
Therefore, net energy in 1 cylinder = 14.2 x 50 MJ
The net energy in 1 cylinder = 710 MJ

The energy available in 1m3 plant in one month.
Biogas contains about 60% methane.
Calorific Value of methane = 55 MJ/kg
Density of Methane at NTP = 0.668 kg/m3

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*Corresponding author: **Rajendra Beedu***

Therefore, Calorific value of methane = 55 x 0.668

$$= 36.74 \text{ MJ/m3}$$

Methane being the only major source of heat,
Calorific value of biogas = 0.6 x 36.74 MJ/m3

$$= 22.044 \text{ MJ/m3}$$

A plant of 1 m3 capacity produces 0.7 m3 of gas per day.
Net energy in 0.7 m3 of biogas = 0.7 x 22 MJ
Net energy in 0.7 m3 of biogas = 15.4 MJ

Assuming that the efficiency of a biogas stove and LPG stove is the same
Energy provided per month = 15.4 x 30
Energy provided per month = 462 MJ

Therefore a biogas plant of 1 m3 capacity is equivalent to 65% of an LPG cylinder per month.

4. Fabrication of biogas plant:

From the literature review, it is found that Arti- Biogas plant system with proper modifications is efficient in producing biogas for cooking purpose.

The design consists of the assembly of two high density polythene (HDPE) tanks of 1 and 0.75 m3 capacity assembled with proper fittings. Smaller tank is the biogas collector which is connected to a burner through a pipe line. The two tanks are fitted with proper sealing. To increase the surface area for the development of biofilms, pebbles of stone is filled at the bottom of lower tank. Also, to provide more surface area plastic mosquito net filled with plastic waste is fitted in the digester in the vertical position as shown in Fig 2. The plant is ready for use.
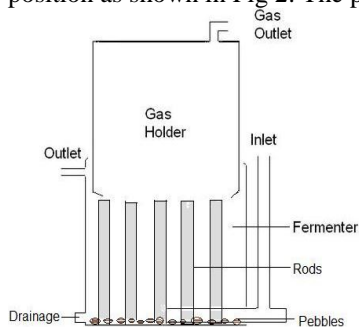

Fig 2 Elevation of Cut section of the plant

5. Working

About 80 kg of wet cow dung was mixed uniformly in batches of 10kg in 15 litres of water to create a consistent mixture. This was poured into the digester tank which was then filled with water till water reached the overflow mark. The gas chamber is mounted on the digester. The tank is left undisturbed for 5 days. The gas burner is ignited and blue flame of methane is observed. Now the digester is ready to receive food waste.

6. Testing

The testing involves the measurement of volume of biogas produced under the following conditions.

a) Varying feed (0.25 to 2.25 kg in 9 days)
b) Feeding constant amount in different intervals of time (1 day to 5 days)
c) Different types of feed (dumped , crushed or blended)
d) Feeding irregular amount with breaks in the supply (0.2 to 2 kg)
e) Regular underfeeding of 0.75 kg/day

The volume is approximately 0.8 x height of gas holder in metres (truncated to lower value in 2nd decimal).

Table 1 Volume of gas due to varying feed

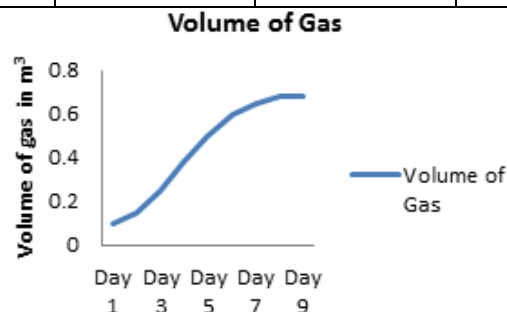| Day	Mass of Feed (kg)	Height of Tank above digester liquid level (m)	Volume of Gas (m^3)
1	0.25	0.13	0.1
2	0.5	0.19	0.15
3	0.75	0.32	0.25
4	1.0	0.48	0.38
5	1.25	0.63	0.5
6	1.5	0.75	0.6
7	1.75	0.82	0.65
8	2.0	0.86	0.68
9	2.25	0.86	0.68

Fig 3 Graph showing change in volume of gas due to varying feed

Table 2 Change in Volume of gas after different periods without feed

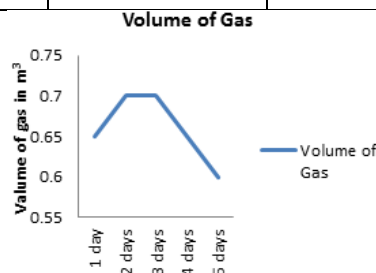| Interval between feeds (days)	Height of Tank above digester liquid level (m)	Volume of Gas (m^3)
1	0.82	0.65
2	0.88	0.7
3	0.88	0.7
4	0.82	0.65
5	0.75	0.6

Fig 4 Change in Volume of gas after different periods without feed.

Table 3: Volume of gas due to different nature of feed

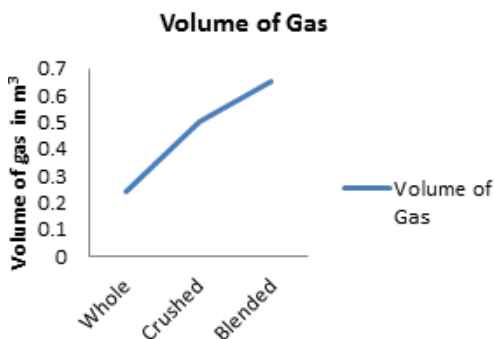| Nature of Feed	Height of Tank above digester liquid level (m)	Volume of Gas (m^3)
Whole	0.30	0.24
Crushed	0.63	0.5
Blended	0.82	0.65

Fig 5 Volume of gas due to different nature of feed.

Table 4 Volume of gas/kg of feed due to irregular feeding

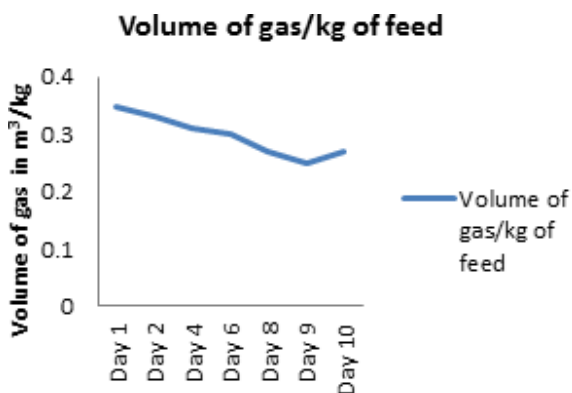| Day	Mass of Feed (kg)	Height of Tank above digester liquid level (m)	Volume of Gas (m^3)	Volume per kg of feed (m^3/kg)
1	2	0.88	0.7	0.35
2	1.2	0.50	0.4	0.33
3	0	0.06	0.05	-
4	0.7	0.28	0.22	0.31
5	0	0.06	0.05	-
6	0.2	0.08	0.06	0.3
7	0	0	0	-
8	2.2	0.76	0.6	0.27
9	1	0.31	0.25	0.25
10	2	0.70	0.55	0.27

Fig 6 Volume of gas/kg of feed due to irregular feeding
Table 5 Effect of regular underfeeding on volume of gas

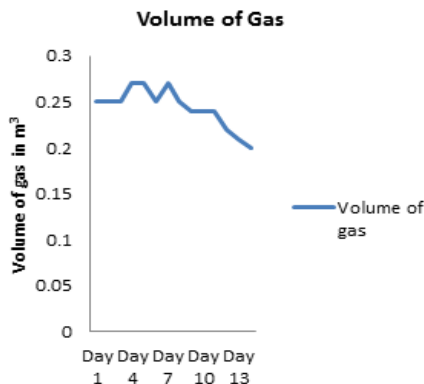| Day	Height of Tank above digester liquid level (m)	Volume of Gas (m^3)
1	0.34	0.25
2	0.34	0.25
3	0.32	0.25
4	0.34	0.27
5	0.34	0.27
6	0.32	0.25
7	0.34	0.27
8	0.32	0.25
9	0.30	0.24
10	0.30	0.24
11	0.30	0.24
12	0.28	0.22
13	0.26	0.21
14	0.25	0.20

Fig 7 Effect of regular underfeeding on volume of gas

Observation

a) In Fig 3 , the increase in gas production per unit mass of feed from the 5th day onwards can be attributed to the effects of a more settled bacteria culture due to increase in feed, the digestion of any undigested waste due to compounding since the reaction takes between 24 and 36 hours to complete and due to improper mixing in the digester.

b) In Fig 4, a significant drop after not feeding for 5 days was observed. This shows that the plant can go without being fed for 3- 4 days without significant loss in performance.

c) In Fig 5, it is clear that feeding the plant with whole food results in large under utilization of the plant as it takes much longer to digest. Hand crushed food works good with foods that can be crushed down to paste by hand but foods like chapattis show a significant drop in volume of gas generated unless they are blended using a blender.

d) In Fig 6, a noticeable dip in the amount of gas generated per unit mass of feed is observed. The bacteria culture is negatively affected due to irregular feed and missed feed.

e) A consistent drop in production is observed from the 8th day of underfeeding (Fig 7). The gas production dropped to a minimum of 0.2 m^3 from the regular 0.25 m^3 in a period of 14 days.

Feasibility study for implementing the project in Manipal Junior College:

Manipal Junior College, Manipal prepares meals for 250 students and regular canteen food is prepared as well. The school buys about 4 cylinders per month which are used only for preparing the mid-day meal.

4 cylinders of LPG = 4 x 710 MJ

= 2840 MJ

Energy required per day = 2840/24 MJ

= 118.33 MJ

Energy obtained per cubic metre of biogas =   22 MJ

Gas requirement to supplement 50% of gas use = 118.33 x 0.5/22 m^3 = 2.7 m^3

Therefore required size of digester = 2.7/0.7 m^3

= 3.85 m^3

Therefore 4 m^3 digester and 3 m^3 gas collector should provide 50% of the energy requirements.

Cost Analysis:

ARTI design:

The ARTI design using HDPE tanks would cost Rs. 4000 x 7 + Rs. 2000 = Rs. 30000 approximately since the cost of HDPE tanks is about Rs. 4000 per m^3.

Cost of 14.2 kg cylinder of HP LPG as on 25th May 2012 is Rs. 450.

Expenditure on LPG per year = 4 x 450 x 10

= Rs. 18,000

Savings up to 50% a year result in saving of Rs. 9000 per year.

Therefore, payback period = 30,000/9,000

= 3.33 years when considering only gas usage.

Cost of liquid fertilizer = Rs. 10 per 30 litres.

Therefore benefit due to fertilizer = 10 x 24 x 10

= Rs. 2400 per year.

Total savings per year = Rs. 9000 + Rs. 2400

= Rs 11,400

Payback period = 30,000/11,400

= 2.6 years

Food Waste Distribution

Instead of considering left out food as wastage, now food waste may be considered as a source of energy. As a result, the food waste gains market and its distribution should be made economical. Manipal food court on an average generates about 800 – 900 kgs of food waste.

Conclusions

Food waste is a very good substitute for L P G gas because India is self-reliant in food production and crude oil is imported.

A regular feeding of biogas plant with proper amount will ensure consistent release of biogas and ensures uninterrupted production of gas.

Even if the plant is not fed for one or two days, (Saturday and Sunday in a school), the efficiency of the plant is not affected.

Crushed and blended food improves the liberation of biogas as digestion becomes easy.

Underfeeding or overfeeding of plant should be avoided. Underfeeding keeps the plant inefficient and overfeeding increases the Ph value of food waste and reduces the development of microbes.

The payback period is small. Hence affordable in schools and small canteens.

The local distribution system in any small location between plants and hotels ensures continuous supply of food waste with an added advantage of reduction in environmental hazards.

Food provided under mid-day meal is simple and mostly rice so a simple single stage digestion process is sufficient and effective.

Schools have ownership and complete stake in the plants hence are more responsible for its working as was seen in household level plants.

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