

Experimental Analysis of Biogas from Kitchen Wastes

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ABSTRACT: In today's world, there is a vast growth in pollution because of wastes from many sources. When these wastes are disposed or buried underground, they affect the groundwater, increase soil pollution and also there are many indirect effects. The concept of the 'four R's', which stands for Reduce, Reuse, Recycle, and Renewable energy, has generally been accepted as a useful principle for waste handling. The emission of Carbon dioxide and other greenhouse gases (GHG) has also become an important issue. When we consider the fuels used today, they are in a destroying path which may lead to complete scarcity in the near future. In our project, we focus on utilizing kitchen wastes for useful gas production called biogas. So biogas can be used as an alternate fuel in the engines which cause no harmful emissions as today's fuel does. There are many sources available for gas production but we prefer kitchen wastes because the reaction time is faster and easily available.

In our institute we have two hostels and all having their own individual mess, where daily a large amount of kitchen waste is obtained which can be utilized for better purposes. Biogas production requires anaerobic digestion. Project was to create an Organic Processing Facility to create biogas which will be more cost effective, eco-friendly, cut down on landfill waste, generate a high-quality renewable fuel, and reduce carbon dioxide & methane emissions. Overall by creating biogas reactors on campus in the backyard of our hostels will be beneficial. Kitchen (food waste) was collected as feedstock for our reactor which works as anaerobic digester system to produce biogas energy. The anaerobic digestion of kitchen waste produces biogas, a valuable energy resource. Anaerobic digestion is a microbial process for production of biogas, which consists of primarily methane (CH₄) & carbon dioxide (CO₂).

KEYWORDS: Carbon dioxide, Greenhouse gases, methane, Anaerobic digester,

I. INTRODUCTION

A. General

About 90% of the emitted methane derives from biogenic sources, i.e. from the decomposition of biomass. The remainder is of fossil origin (e.g. petrochemical processes). In the northern hemisphere, the present tropospheric methane concentration amounts to about 1.65 ppm. Substrate and material balance of biogas production In principle, all organic materials can ferment or be digested. However, only homogenous and liquid substrates can be considered for simple biogas plants: faces and urine from cattle, pigs and possibly from poultry and the wastewater from toilets. When the plant is filled, the excrement has to be diluted with about the same quantity of liquid; if possible, the urine should be used. Waste and wastewater from food-processing industries are only suitable for simple plants if they are homogenous and in liquid form

B. biogas from different sources:

Biogas can be obtained from different sources such as the production of biogas from different wastes and they are as follows:

1. Sewage Sludge
2. Municipal solid wastes
3. Kitchen wastes (Vegetable peels, waste food materials)

4. Agricultural wastes (Husk, grass, weeds etc.)
5. Industrial wastes (Saw dust, wastes from food processing industries)
6. Animal By-Products
7. Poultry wastes

C. Main characteristics of biogas in India

1. Household biogas plants mainly based on cattle manure for cooking and lighting
2. Biogas plants based on cattle manure, slaughterhouse and vegetable market wastes for heat, electricity or motive power
3. Biogas from urban and industrial wastes and effluents
4. Co-digestion of farm / agricultural residues with urban and industrial wastes

II. FLOATING-DRUM PLANTS

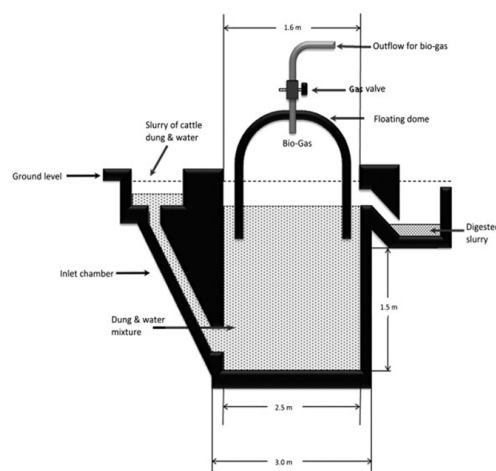


Fig:2.1 Floating-Drum Plants

The fixed-dome plant consists of a digester with a fixed, non-movable gas holder, which sits on top of the digester. When gas production starts, the slurry is displaced into the compensation tank. Gas pressure increases with the volume of gas stored and the height difference between the slurry level in the digester and the slurry level in the compensation tank.

III. DESIGN OF EXPERIMENTAL SETUP

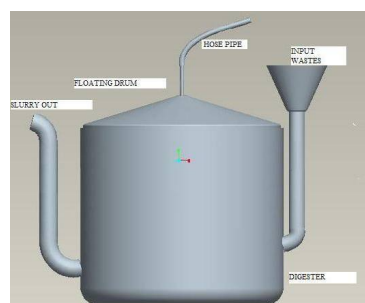


Fig:3.1 Design of our digester

Sl.No	Materials	Specifications		
		Capacity (lit)	Height (m)	Diameter (m)
1	Digester	1000	1.2	1.2
2	Floating Drum	500	0.6	1.1
3	PVC Pipes	-	0.9	0.1
4	Hoses	-	-	0.015

Table 3.1 Specification of our digester



Fig:3.2 Experimental Setup

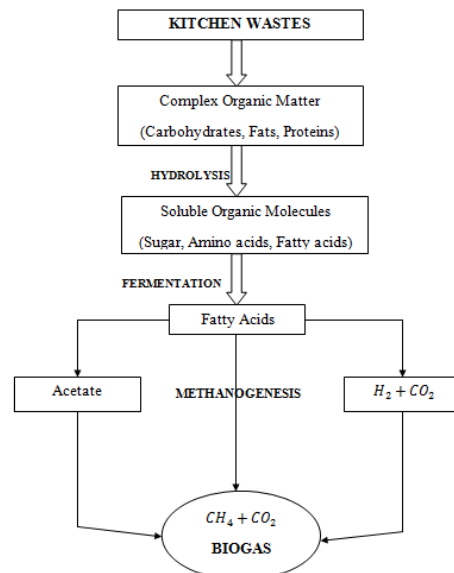


Fig:3.3 Project Flow chart

IV. EXPERIMENTAL ANALYSIS

From the above digesters, we contributed to the selection of Floating drum digester since its efficiency and lifetime is more. Further we analysed initially with cow dung wastes for bacteria formation to initiate the production of biogas and the various analysis were made both on cow dung and kitchen wastes.

At the initial stage, 300 litres of cow dung is mixed with 600 litres of water in 1:2 ratio in the 1000 litres capacity digester and is closed at the top using floating drum and some weights are kept on the drum to increase the pressure in the gas.		
Day Analysis	Cow Dung	Kitchen wastes
Day 1	It is mixed with water in 1:2 proportion by using a partition for cow dung and water in the digester	-
From day 1 for an average of 13-15 days, CO ₂ is let out to atmosphere through the out flow gas valve until biogas odour is formed.		
Day 15	Biogas is formed with little CO ₂ and testing is made by identifying the blue flame.	-
Day 16	-	Boiled rice mixed with steamed rice water in 1: 2 ratio is added
Day 17	-	Bluish flame is produced in a single burner which is burnt for 1 ¹ / ₄ hours. The same day boiled rice mixed with steamed water is added.
Day 18	-	Bluish flame produced for 1 ¹ / ₂ hours.

Table 4.1 Experimental analysis of gas produced/ day

V. CASE STUDY

According to our purpose of our project we were trying to design reactors of 1000 lit for each and every hostel of SMVEC, Madagadipet. (at the backyard of the mess, using kitchen waste directly as a feedstock), Hence I can conclude that we can produce 650 lit of biogas daily in 1000 lit reactor, under ideal conditions (like maintaining pH, Alkalinity, etc.)

Sl.No	Hostel name	Consumption of LPG (per month)
1	SMVEC Boys and Girls Hostel	1710 kg
2	SMVMCH Boys and Girls Hostel	2850 kg

Table 5.1 Consumption of LPG

Analysis 1:

Calorific value of Biogas = 6 kWh/m³

Calorific value of LPG = 26.1 kWh/m³

Let us assume we need to boil water sample of 100 gm. We have Energy required to boil 100 gm.

Water = 30.146 kJ and for 1kg = 301.46 kJ.

Hence, we need Biogas to boil 100 gm. water = 12.018 lit, for 1 kg = 120.18 lit and we need LPG to boil 100 gm. water = 2.76 lit, for 1 kg = 27.6 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 month.

Analysis 2:

Let us use the Biogas produced in our plant for Breakfast & evening snacks (1 hr in morning and 1 hr. in the evening) 650 lit if used for 2 hrs. Gives = 66.46 * 103 J /day, Let V be the amount of LPG used to produce same amount of energy Hence, we get, V = 2827.56 lit i.e. Mass (m) of LPG = 6.079 kg

Therefore per month consumption of LPG = 182.38 kg which is equivalent to 12.84 cylinders

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

Calculation: Analysis 1

Energy required to boil 100 gm.

$$\begin{aligned} \text{Water} &= mcp \Delta t \\ &= 0.1 \times 4.187 \times (100-28) \\ &= 30.146 \text{ kJ} \end{aligned}$$

Since we produce 650 litre of biogas every day,

$$\begin{aligned} \text{Amount of water that can be boiled} &= 650/120.18 \\ &= 5.408 \text{ lit/day} \end{aligned}$$

$$\begin{aligned} \text{Therefore amount of LPG req. for same} &= 27.6 \times 5.408 \\ &= 149.26 \text{ litre} \end{aligned}$$

We know that, $m = \rho \times v$, where for biogas

$$\rho = 0.66 \text{ kg/m}^3, v = 0.650 \text{ m}^3$$

$$\text{Therefore "m" per day} = 0.66 \times 0.650 = 0.429 \text{ kg}$$

$$\begin{aligned} \text{Similarly for LPG, } \rho &= 2.155 \text{ kg/m}^3, v = 0.150 \text{ m}^3 \text{ and} \\ m &= 0.323 \text{ kg} \end{aligned}$$

VI. COMPARISON OF OUR BIOGAS DIGESTER WITH CONVENTIONAL

Biogas systems are those that take organic material (feedstock) into an air-tight tank, where bacteria break down the material and release biogas, a mixture of mainly methane with some carbon dioxide. The biogas can be burned as a fuel, for cooking or other purposes, and the solid residue can be used as organic compost. Through this compact system, it has been demonstrated that by using feedstock having high calorific and nutritive value to microbes, the efficiency of methane generation can be increased by several orders of magnitude. It is an extremely user friendly system.

Comparison with Conventional Bio-Gas Plants	Conventional Bio-gas Systems	Kitchen Waste Bio-Gas System
Amount of feedstock	40 kg + 40 ltr water	1.5-2 kg + water
Nature of feedstock	Cow-Dung	Starchy & sugary material
Amount and nature of slurry to be disposed	80 ltr, sludge	12 ltr, watery
Reaction time for full utilization of feedstock	40 days	52 hours
Standard size to be installed	4,000 lit	1,000 lit

Table 6.1 Comparison with Bio gas plants

VII. RESULTS AND DISCUSSIONS

Wastes	Day 1-14	Day 15	Day 16	Day 17	Day 18	Day 19	Day 20	Day 21	Day 22	Day 23
Cow Dung (kg.)	300	-	-	-	-	-	-	-	-	-
Kitchen waste(gm.)	-	1000	1000	1250	1250	1500	1500	1750	1750	2000
Gas burnt/day (hours)	1.00	1.05	1.15	1.20	1.30	1.40	1.50	2.00	2.05	2.15

Table 7.1: Comparison Of feed given to the digester

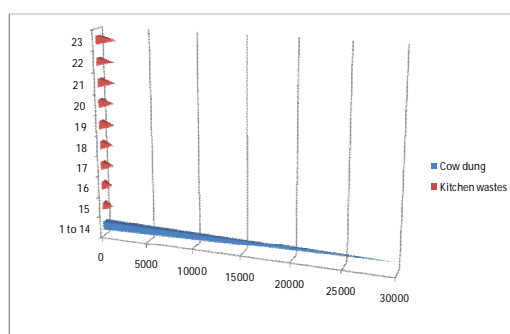


Fig. 7.1 Feed input to the digester

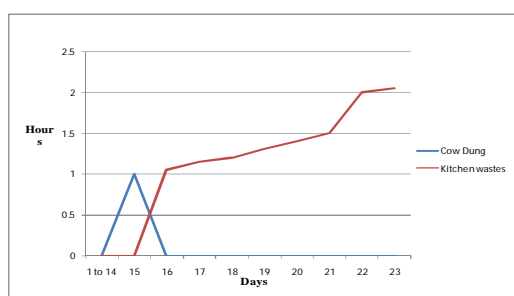


Fig 7.2 Gas production/day

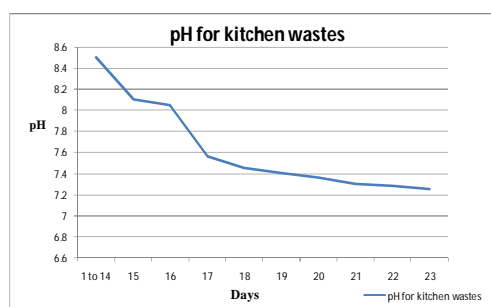


Fig 7.3 pH range/day

VIII. CONCLUSION

The increasing cost of conventional fuel in urban areas necessitates the exploration of other energy sources. Animal and plant wastes are abundant especially in rural areas. Biogas can be produced from food wastes/refuse and peelings as a substitute for fossil fuels. The generation of biogas from food waste/refuse or peelings produces an energy resource. The process also creates an excellent residue that retains the fertilizer value of the original waste products. The search for alternative source of energy such as biogas should be intensified so that ecological disasters like deforestation, desertification, and erosion can be arrested.

IX. FUTURE SCOPE

BIOGAS-FUELED ENGINES

Gas demand

If the output of a biogas system is to be used for fuelling engines, the plant must produce at least 10 m³ biogas per day. For example, to generate 1 kWh electricity with a generator, about 1 m³ biogas is required. Small-scale systems are therefore unsuitable as energy suppliers for engines.

Types of engines

The following types of engines are, in principle, well-suited for operating on biogas:

- Four-stroke diesel engines
- Four-stroke spark-ignition engines
- Converting diesel engines
- Converting spark-ignition engines

1. Four-stroke diesel engines

A diesel engine draws air and compresses it at a ratio of 17:1 under a pressure of approximately 30-40 bar and a temperature of about 700°C. The injected fuel charge ignites itself. Power output is controlled by varying the injected amount of fuel, i.e. the air intake remains constant (so-called mixture control).

2. Four-stroke spark-ignition engines

A spark-ignition engine (gasoline engine) draws a mixture of fuel (gasoline or gas) and the required amount of combustion air. The charge is ignited by a spark plug at a comparably low compression ratio of between 8:1 and 12:1. Power control is affected by varying the mixture intake via a throttle (so-called charge control). Four-stroke diesel and spark-ignition engines are available in standard versions with power ratings ranging from 1 kW to more than 100 kW. Less suitable for biogas fuelling are:

1. loop-scavenging 2-stroke engines in which lubrication is achieved by adding oil to the liquid fuel, and
2. Large, slow-running (less than 1000 r.p.m) engines that are not built in large series, since they are accordingly expensive and require complicated control equipment.
3. Biogas engines are generally suitable for powering vehicles like tractors and light-duty trucks (pickups, vans). The fuel is contained in 200-bar steel cylinders (e.g. welding-gas cylinders).

The technical, safety and energetic cost of gas compression, storage and filling is substantial enough to hinder large-scale application.

3. Converting diesel engines:

Diesel engines are designed for continuous operation (10000 or more operating hours). Basically, they are well-suited for conversion to biogas utilization according to either of two methods:

In the dual fuel approach the diesel engine remains extensively unmodified, except for the addition of a gas/air mixing chamber on the air-intake manifold (the air filter can be used as a mixing chamber). The injected diesel fuel still ignites itself, while the amount injected is automatically reduced by the speed governor, depending on how much biogas is injected into the mixing chamber. The biogas supply is controlled by hand. The maximum biogas intake must be kept below the point at which the engine begins to stutter. If that happens, the governor gets too much biogas and has turned down the diesel intake to an extent that ignition is no longer steady. Normally, 15-20% diesel is sufficient.

As much as 80% of the diesel fuel can thus be replaced by biogas. Any lower share of biogas can also be used, since the governor automatically compensates with more diesel.

As a rule, dual-fuel diesels perform just as well as comparable engines operating on pure diesel. As in normal diesel operation, the speed is controlled by an accelerator lever, and load control is normally affected by hand, i.e. by adjusting the biogas valve (keeping in mind the maximum acceptable biogas intake level). In case of frequent power changes at steady speed, the biogas intake should be somewhat reduced to let the governor decrease the diesel intake without transgressing the minimum diesel intake. Thus, the speed is kept constant, even in case of power fluctuations. Important: No diesel engine should be subjected to air-side control. While special T-pieces or mixing chambers with a volume of 50 to 100% of the engine cylinder volume can serve as the diesel / biogas mixing chamber, a proper mixing chamber offers the advantage of more thorough mixing.

To sum up, conversion according to the dual-fuel method is:

1. A quick & easy do-it-yourself technique;
2. Able to accommodate an unsteady supply of biogas;
3. Well-suited for steady operation, since a single manual adjustment will suffice and requires a minimum share of diesel to ensure ignition

4. Conversion to Spark Ignition (Otto cycle) involves the following permanent modifications at the engine:

- Removing the fuel-injection pump and nozzle
- Adding an ignition distributor and an ignition coil with power supply (battery or dynamo)
- installing spark plugs in place of the injection nozzles
- Adding a gas mixing valve or carburettor
- Adding a throttle control device
- Reducing the compression ratio (ratio of the maximum to the minimum volume of the space enclosed by the piston) to $E=11-12$
- Observing the fact that, as a rule, engines with a pre-combustion or swirl chamber are not suitable for such conversion.

Converting a diesel engine to a biogas-fuelled spark-ignition engine is expensive and complicated so that only pre-converted engines of that type should be procured.

5 Converting spark-ignition engines:

Converting a spark-ignition engine for biogas fuelling requires replacement of the gasoline carburettor with a mixing valve (pressure-controlled venturi type or with throttle). The spark ignition principle is retained, but should be advanced as necessary to account for slower combustion (approx. $5^{\circ}-10^{\circ}$ crankshaft angle) and to avoid overheating of the exhaust valve while precluding loss of energy due to still-combustible exhaust gases. The engine speed should be limited to 3000 rpm for the same reason. As in the case of diesel-engine conversion, a simple mixing chamber should normally suffice for continuous operation at a steady speed. In addition, however, the mixing chamber should be equipped with a hand operated air-side control valve for use in adjusting the air/fuel ratio (optimal "actual air volume/stoichiometric air volume" = 1.1). Converting a spark-ignition engine results in a loss of performance amounting to as much as 30%. While partial compensation can be achieved by raising the compression ratio to $E=11-12$, such a measure also increases the mechanical and thermal load on the engine. Spark ignition engines that are not explicitly marketed as suitable for running on gas or unleaded gasoline may suffer added wear & tear due to the absence of lead lubrication. The speed control of converted spark-ignition engines is affected by way of a hand-operated throttle. Automatic speed control for different load conditions requires the addition of an electronic control device for the throttle.

The conversion of spark-ignition engines is evaluated as follows:

- Gasoline engines are readily available in the form of vehicle motors, but their useful life amounts to a mere 3000-4000 operating hours.
- The conversion effort essentially consists of adding a (well-turned) gas mixer

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