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GU JOURNAL OF PHYTOSCIENCES

*GU. J. Phytosci.* 3(1): 47-52 (2023)

# Utilizing Food Waste of Generate Biogas in Urban Areas for Engaging Plastic Biogas Digestion

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**Abstract**

Biogas may be created anaerobically by a consortium of microorganisms digesting biomaterial under regulated circumstances. Methane (50–70%), carbon dioxide (25–50%), nitrogen (0–2%), oxygen (0–0.3%), hydrogen (0–1%), hydrogen sulfide (0–2%), and water (2–7%) are the primary components of biogas. Food waste is being employed as a raw material in the generation of biogas. Anaerobic digestion was maintained in a metal circular digester using a hot water circulation system and an autonomous temperature control system. Over water, biogas was collected in a separate container. Temperature and pH control were measured on a regular basis using a thermocouple probe in the 20°–40°C range and a pH meter, respectively. The data demonstrated that the anaerobic food waste digestion system was extremely sensitive to changes in the microenvironment and substrate loading. The additional substrate was regularly meshed with water to increase surface area and decrease digestion time in a predetermined proportion. Data showed that food waste (bread, curry, rice, etc.) generated about 607 liters (21.428 cu ft) of biogas, which was equivalent to 152 minutes of burning time for 1380/18400 g/liter of substrate fed. The biogas produced gave off a blue flame on burning. Due to its inflammable and odorless nature, this gas can effectively be used for cooking, heating, or lighting. In addition to biogas production, the effluent, or byproduct, of the digester can be used as liquid fertilizer. Based on the data, it is determined that the plastics or related materials used to create the bio-digester model or design are inexpensive and hence may be used economically indoors for burning purposes.

**Keywords:** Biogas; Methane Gas; Food Waste; Urban Areas

## 1. Introduction:

Anaerobic digestion is a natural process that has existed for a long time in the absence of air. A multistep biological process comprising consortia of bacteria converts complex organic material to biogas and nutritious effluent (Tiong *et al.,* 2021). Anaerobic digestion is a potential approach for treating kitchen waste, animal manure, human excreta, agricultural waste, vegetable and fruit waste, bakery trash, and other garbage (Moinuddin, 2011; Suyog, 2011; Mahbub *et al.,* 2021).

Biogas is the primary byproduct of anaerobic digestion and may be used in both rural and urban

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© 2023 (Accepted for publication in November 2022)
Published by Department of Botany, Selection and/or peer-review under supervision of Executive Committee, Ghazi University, DG Khan, 32200 Pakistan

settings. Methane (50–70%), $CO_2$ (25–50%), Nitrogen (0–2%), Oxygen (0–0.3%), Hydrogen (0–1%), Hydrogen Sulfide (0–2%), and water (2–7%) are the primary components of biogas (Javad, 2011; Suyog, 2011; Marquardt *et al.,* 2015). The biogas composition may differ based on the substrate utilized. Biogas is a colorless gas with a blue flame, comparable to liquid petroleum gas. Natural gas contains 85–90% methane, whereas biogas contains 50–70% methane. Biogas weighs 20% less than air. Natural gas has a calorific value of around 896–1069 British Thermal Units per cubic foot, whereas biogas has a calorific value of approximately 550–600 British Thermal Units per cubic foot (Suyog, 2011; Ismat, 2013). Biogas, when purified, is colorless, odorless, and tasteless, with a specific gravity of 0.55, which is lower than that of petrol and LPG. It does not include any hazardous compounds; thus it is safe to use. For full combustion, the stoichiometric ratio of air to biogas by volume ranges from 9.5:1 to 20:1 (Werner, 2010; Liew *et al.,* 2022).

Pakistan is a developing country with a population of 220 million people (Anonymous, 2021) that is suffering greatly from energy difficulties. Over the last 15 years, there has been an 80% growth in energy usage. Pakistan's oil imports have climbed from 34 million tonnes of oil equivalent (TOE) in 1994–95 to 61 million TOE in 2009–2010, supporting annual GDP growth rates of up to 4.5%. Since 2006, it has been more difficult to fulfill energy demand, which has resulted in excessive load shedding, load management, a per capita decline in energy usage, and price increases (Pak Energy Outlook, 2010). According to the National Planning Commission, energy consumption would rise from 30% in 2005 to 62% in 2025 during the following two decades (Anonymous, 2021). Natural gas accounts for 45.4% of Pakistan's energy consumption, followed by oil (34.9%), hydropower (12.3%), coal (6.1%), and nuclear (1.3%) (Pak Energy Outlook, 2010). The first biogas factory in Pakistan was developed in Sindh in 1959 (Sakhawat, 2013). The Government of Pakistan launched a comprehensive biogas project in 1974, as a result of which 4137 biogas plants with capacities ranging from 5 to 15 cubic meters were completed by 1987 (Prakash, 2007; Farooq *et al.,* 2012). The Pakistan Council for Renewable Energy Technologies is the driving force behind the development of biogas technology in Pakistan. Certain municipal waste management programs, which obtain energy from combustion and methane from the metabolism of microorganisms, use food waste but do not directly benefit the individuals who generate the waste; rather, additional costs are incurred in addition to those associated with collection (James, 2011; Liew *et al.,* 2021). The solid waste management of this material by anaerobic digestion appears to be a new treatment that will offer biogas to households and institutions for use in cooking. Waste comprises vegetable and fruit leaves and peels, cooked meals, eggshells, bread, cake, and so on. Food waste has more organic material and nutritional value for microorganisms, resulting in higher methane production by methanogens and, as a result, a reduction in digester capacity. In the current work, a bench-top digester was constructed using food waste as a substrate. A scaled-up design employing plastic materials and procedures has been designed, which may reduce the cost and allow lower to middle-class income groups to experience the convenience of gas. The recommended digester design configuration may not only save money in the beginning, but it may also take up less space than a normal methane digester and be easily erected on the side of a roof. The kitchen is an essential element of the home and the core of food preparation operations. A typical household of 5-6 people produces 1-2 kg of garbage per day (Lohri, 2009).

### *1.1. Objectives:*

- The objectives of the research work to devise the way of production of biogas from kitchen and bakery wastes.

## 2. Materials and Methods:

For the bench-scale biogas production, a 20-liter container was utilized. Kitchen waste was collected from the household. After thorough cleaning, empty paint cans were used as digesters, complete with intake and output valves. The cylinder's intake allowed garbage to be put into it. The digester's maximum loading was to be controlled by the outflow. Any excess loading of new waste from the intake will drive effluent from the outflow. Garden pipes were wrapped around the digester and insulated with jambon of approximately 12 mm thickness to keep the temperature within the cylinder at roughly 37 °C. The food waste (rice, bread, curry waste, etc.) was carefully separated from other materials in the kitchen waste. A hopper was used to put the substrate in the digester. Water was circulated by means of a water pump, which was controlled automatically. The water was heated by an electric water heater. The temperature was controlled by an automatic temperature controller, and the sensing device was a thermocouple probe. It was set in position so that, during water heating, the pump was off, and as soon as it started running to circulate water, the heater went to the off position. Gas was temporarily collected in a small plastic container by the water displacement method. It has a nozzle that utilizes use from time to time. It was also facilitated with a scale.

Inoculum (consortium of anaerobic bacteria) was added along with some substrate as a starter. The specified quantity of substrate (30 g + 400 ml water) was fed daily. The substrate was properly meshed in a grinder in order to increase the surface area and decrease the particle size as well. Biomass properties were evaluated in a lab for total solids, fatty acids, alkalinity, etc. The continuous batch reactor process began in a single stage. Various parameters like pH, temperature, organic loading rate, total biomass fed, total biogas produced, retention time, etc. were observed using standard methods. A plastic material-made design was proposed, along with its potential benefits for effective indoor use at a low cost. It was facilitated with pictures and manufacturing details.

## 3. Results:

The experiment was done with equal amounts of water and substrate infeed, which immediately led to failure since pH lowers rapidly following the synthesis of volatile fatty acids. Normally, carbonates are the principal weak-acid system responsible for keeping the pH around neutral, but volatile fatty acid systems (acetic, propionic, and butyric acids) are the main source of pH drops. The methanogens promptly transformed the H2 and acetic acid into methane under normal, stable functioning conditions. As a result, the volatile fatty acid (VFA) content has stayed low, and the pH has remained consistent. In contrast, when the substrate was overloaded or inhibitory chemicals were present, the activity of the methanogenic and acetogenic bacteria was inhibited, resulting in a buildup of volatile fatty acids, which increased the total acidity in the water, reducing pH. To maintain the pH of the digester containing food waste, more water and substrate were necessary. To keep the pH stable, a little amount of sodium bicarbonate is added. The outcomes are shown below. The pH of the samples appears quite low (5.15) due to the travel time to the lab, during which the contents undergo fermentation activity, resulting in the formation of acids, thus dropping the pH of each solution as mentioned below, but taken at the time of sample preparation is also shown in Table 1.

Table 1: Chemical analysis of food waste

| S. No. | Substrate | pH | | Alkalinity | VFA | A/TIC |
|---|---|---|---|---|---|---|
| | | Initial | Lab | mg/L | | |
| 1 | Food (D4) | 7.5 | 5.15 | 300 | 96 | 0.32 |

The results of anaerobic digestion of food waste are shown in Table 2. It displayed the entire biogas yield as well as the burning duration generated by a typical gas nozzle. The findings indicate that the substrate derived from food is exceptionally capable of manufacturing high-quality methane. Temperature and pH are kept within optimal ranges by using automated temperature control with a digital LCD display and rigorous pH testing twice a day on a regular basis. Although it is essentially constant, it varies somewhat owing to the daily infeed of substrates, but it remains within the prescribed range.

Table 2: Yield obtained from food waste.

| S. No. | Substrate Type | Total Substrate Fed | Total Biogas Produced (Approx) | Daily Biogas (Avg) | Burning Time |
|---|---|---|---|---|---|
| 1 | D4 (Food) | 1380/18400 | 0.6068 Cu. M 21.428 Cu. Ft. (606.8 L) | 0.582 Cu. Ft. (16.5 L) | 151.8 min |

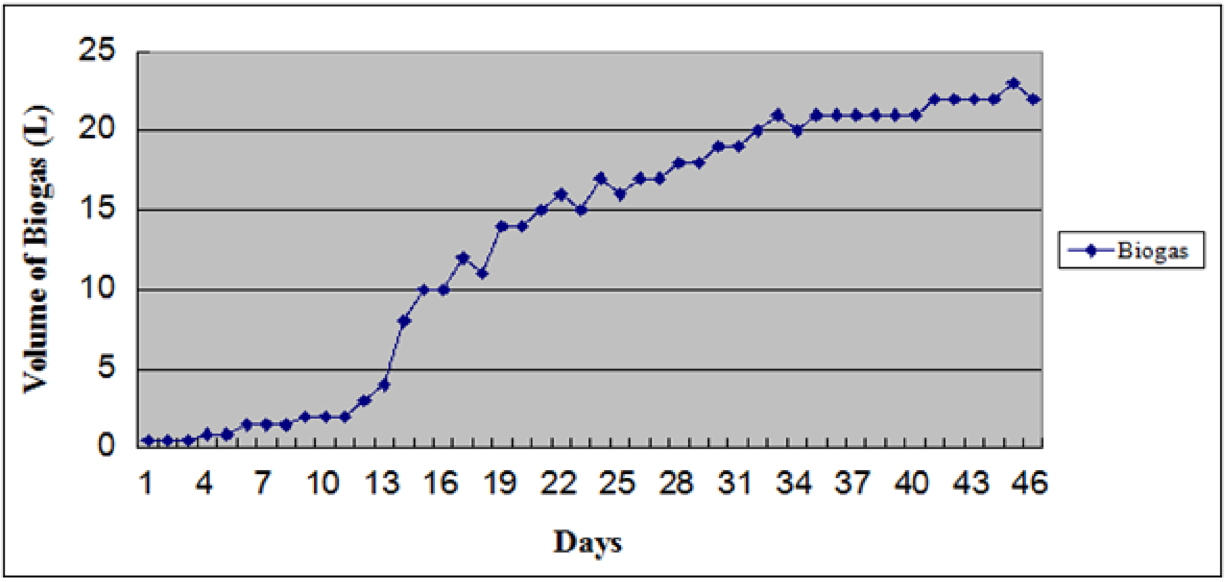


Figure 1: Biogas Productions from Food Waste in Digester

Flammability testing is likely one of the most significant methane gas testing techniques. As seen in the combusted biogas, methane burns in the air with a blue flame. Because of the air-methane combination, the outer flame appeared yellowish under high gas pressure. As the methane concentration of the gas created by the food waste rose, the size of the digester was substantially reduced. However, for the dung, a long retention period as well as a large digestion unit were necessary to create enough gas to meet the needs of an average-sized household. When the system was appropriately stabilized, the gas created from food waste was significantly greater in quantity and produced in much less time. In general, bricks and cement are used to build traditional digesters; however, for processing food waste, specific low-cost plastic materials may be used to make quick designs for operational interior facilities. On average, 1 m3 to 3 m3 of biogas plants are sufficient to maintain a family of five. Food leftovers from meals, such as curry, rice, bread (mainly), and so on, may be fed to the digester. The process was quite sensitive to shock loads and moved rather quickly. A stable system can rapidly progress to the methanogensis stage within a short retention period, which has a significant impact on size reduction and output. It was determined that 1.38 kg of the substrate kitchen trash produced about 606.8 liters (21.428 Cu Ft.) of biogas. It yielded a greater yield, indicating that it is a superior organic material.

### *3.1. Proposed Digester Design for Biogas Production:*

Based on the results of our present experiment, a model for a medium family unit of roughly 5–6 people has been developed, so that it may be adopted by the general population, particularly in metropolitan settings. Because of the scarcity of land in cities as a result of heavy urbanization, the proposed design may successfully meet urban needs. In the traditional manner, the digester was built in the ground, usually outside the home, and gas was piped into the kitchen. The digester appears to be quite expensive to build, requiring extensive drawings, expertise, and work.

#### *3.1.1. Vertical Design for Moderate Biogas Production:*

There seem to be water storage tanks in dwellings. For the stated purpose, either a ready-built drum or one created by hand using fiberglass sheets and rivets can be used. For its construction, it makes use of 3- to 5-mm-thick fiberglass sheets. Two sheets are rounded and laid side by side, with insulating material (jumbolan) of about 12 mm thickness inserted between them. Both are held together with rivets. The top and bottom are attached to L-plates and have a rubber liner to keep the airtight. To support the inlet and output valves, different bore holes may be supplied for the conventional plumbing. The capacity is generally 1500 litres, which may be increased further by stacking particular sheets one on top of the other and securely joining them with rivets. Glue can be used when needed. Furthermore, epoxy is put around the pipes where joints are present to prevent leaking. A separate pipe for gas discharge may be installed. The effluent is an excellent liquid fertilizer that may be utilized immediately or after drying in powder form, which is still another significant advantage of biogas technology.

Table 3: Specification of Vertical Design for Moderate Biogas

| S. No. | Description | Value |
|---|---|---|
| 1. | Total Volume | 1.5 $m^3$ (1500 litres) |
| 2. | Capacity | 1200-1300 litres |
| 3. | Material | Fibre glass |
| 4. | Availability | Readily Available |
| 5. | Approx. Cost | 22000-32000 Rs. |
| 6. | Gas Collection | Separate Container |
| 7. | Daily Input | 1.2-1.4 Kg |
| 8. | Water | 10-12 litres. |
| 9. | Expected Output | 0.6– 0.7 $m^3$ (600-700 litres.) |
| 10. | Burning Time | 2 - 2.25 hours |

The proposed and recommended approach might be employed for a household of six people. It is backed up by a second gas storage tank for short-term storage. The gauge on the storage container is used to measure the pressure.

*3.2. Material Selection:*

Depending on the physical, chemical, and mechanical requirements, numerous materials can be used to create the suggested digesters. Plastic is used because it is cheap, user pleasant, easily available, light in weight, and portable.

*3.2.1. Fiber Glass:*

The proposed digester design is also suitable for use with fiberglass. Fiberglass-reinforced plastics or glass-reinforced plastics are usually referred to as "fibreglass." In fabrication, it is a thermosetting substance that combines polyester or vinyl ester with glass fibres. It has excellent corrosion resistance to a wide range of substances, including UV radiation, smoke, fire retardants, alkalis, and acids, at various temperatures. Such a material is cost-effective, light in weight, resistant to impact, and has good electrical and thermal insulation capabilities. It will have a higher strength-to-weight ratio than other materials and a longer service life with less maintenance.

## 4. Discussion:

The experiment was repeated, and the pH was balanced with more water. pH, alkalinity, and volatile fatty acids are the most important factors in digester inhibition (Abdul, 2014). According to Naila (2011), the methane component of biogas influences flame burning. The effluent has no odour and is a thin liquid that can be used directly in the home garden or container gardening as a liquid fertilizer.

As the gas generated from the food waste was catering increased methane content which, greatly helps in reducing the size of the digester. However, for the dung a long retention time as well as a big digester unit was required to produce enough gas to support average sized family requirement Obileke *et al.,* 2022). Conversely, gas produced from food waste was much more in quantity and produced in less time once the system was properly stabilized. Generally, bricks and cement are utilized to construct the conventional digester whereas, for processing the food waste certain low-cost plastic materials may be utilized to develop as prompt designs to be operative indoor facility. In general, biogas plants of 1 $m^3$ to 3 $m^3$ are sufficient to support the family of 5 persons. In the digester food left over from meals including (Curry, Rice, Bread (mostly) etc.) may be added. The process was very sensitive to shock loadings and quite fast to be proceeded. A stabilized system can lead to methanogenesis stage very quickly within a short retention time which, is a huge benefit in size reduction and having higher production (Cioabla *et al.,* 2022).

## 5. Conclusion:

The biogas generation process was effectively proven utilizing a temperature-controlled system in the mesophyllic range, implying that food waste as a substrate is well suited to the proposed digester design, including the plastic material. The substrate was fed in meshed form into a 20-liter digester over a 46-day retention period. Furthermore, the high-nutrient slurry might be used as fertilizer. This type of energy resource derived from food waste not only works to mitigate the consequences of natural disasters such as erosion, deforestation, desertification, and urbanization.

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