# Experimental Study on the Influence of pH and Temperature in a Mini Mesophilic Anaerobic Digester for Sustainable Energy Production

N. Mahalakshmi

*Department of Physics, Meenakshi Sundararajan Engineering College, Affiliated to Anna University, Kodambakkam, Chennai- 600042, Tamil Nadu, India.*

***Abstract*—Biogas is a renewable source of energy, playing a vital role in the development of sustainable energy production, waste management, reduction of environmental pollution, and efficient use of resources. In this study, a mini mesophilic anaerobic digester was designed and analyzed in order to determine the influence of pH values and temperature on the production of biogas. Organic food waste was used as the substrate in the experiment, collected from households as waste. The experiment was carried out using a 100-Litre biogas digester, operating in the mesophilic range (30-40°C) for a period of 10 days. The pH values of the substrate were measured on a daily basis, as were the temperatures, while the evaluation of the produced biogas was carried out using a water boiling test, with the heat energy released during combustion calculated using the concept of the change in enthalpy. The findings show that the maximum amount of biogas was produced when the pH values were near neutral, i.e., around 7, with the temperature ranging from 33-34°C. The study shows that the pH values and temperatures have a significant influence on the efficiency of the production of biogas.**

***Index Terms*—Food waste, pH; sustainable energy, Biogas, Mesophilic digestion, methane.**

## I. INTRODUCTION

Waste disposal for biodegradable and non-biodegradable waste has been one of the challenging issues confronting the developed and developing nations [1]. These wastes, when improperly managed, contribute to unhygienic environmental conditions that have the potential of breeding pathogenic microorganisms that could result in adverse health implications to humans; thus, rendering the environment unpleasant and unattractive. However, these wastes can be managed appreciably by converting them into biogas, an environmentally friendly form of renewable energy [2]. Anaerobic digestion is the biodegradation of organic matter through the activity of some micro-organisms in the absence of air to produce flammable gas like methane, for heating and drying purposes. The underlying theory and technology of this anaerobic digestion have been used by humans for centuries. It is one of the useful tools that is applied in generating renewable energy in the form of heat. Current research is directed not only to the yield of the process but also toward the optimization of the digestion conditions [3]. Biogas is a mixture of gases that is composed chiefly of methane, $CH_4$: 40 – 70% by volume, and $CO_2$: 30 – 60% by volume; generated as a result of biodegradation of organic material under anaerobic condition by the action of bacteria. Other gases are also generated but mostly in insignificant quantities. These are ammonia ($NH_3$), hydrogen sulphide ($H_2S$), oxygen ($O_2$) and carbon monoxide (CO) [4]. The set-up or unit that is used in the production of biogas is a bio-digester and in its operation, the parameters that are of interest to researchers are the type and amount of biomass used as feedstock, size of digester, pH, pressure, retention time and temperature of the reaction mixture [5,6]. With the growing demand for sustainable energy sources, biogas has emerged as an important renewable energy option. Biogas is produced through anaerobic digestion, a biological process in which microorganisms break down organic matter in the absence of oxygen. This process converts organic waste such as food waste, agricultural residues, and animal manure into a combustible gas mixture primarily composed of methane and carbon dioxide. Biogas production provides several advantages, including waste reduction, renewable energy generation, and nutrient recycling for agricultural use. However, the efficiency of biogas production depends on several operational parameters, particularly pH and temperature, which directly influence microbial activity within the digester. Mesophilic digestion, typically carried out between 30 °C and 40 °C, is widely used because it provides stable microbial activity and efficient biogas generation. Maintaining the optimal pH range (6.5–8.0) is also essential for methanogenic bacteria responsible for methane production. The objective of this study is to design a mini mesophilic anaerobic digester and analyze the effect of pH and temperature on biogas production using food waste as the substrate.

## II. MATERIALS AND METHODOLOGY

### 2.1 Biogas Digester Setup

A 100-litre plastic cane was used as a digester for the biogas experiment. Using a soldering iron, two holes were created through which two PVC pipes were fixed into the digester. One of the pipes which run vertically into the tank serves as the inlet of feedstock into the digester for feeding organic waste. The other one which serves as the outlet of the slurry was fixed two inches from the bottom of the tank. A gas tube was then connected to the digester to serve as a pathway for biogas into the gas collector gas outlet connected to a tire tube used as a gas storage unit. A valve was used to control the flow of gas in and out of the gas tube as described elsewhere [7]. All perforations were sealed with fine granules of earth and adhesive. Figure 1 is the pictorial view of the built digesters in operation. The system was designed to operate under mesophilic conditions suitable for microbial digestion.


Figure1: Pictorial representation of the biodigester set

### 2.2 Waste Collection and Pretreatment

Five kilograms of cow dung were mixed with water in the ratio of 1:1 to form a slurry. Solid matter such as stones and sticks was removed to obtain a homogenous mixture. This feedstock was then fed into the digester through the inlet pipe with a funnel fitted to the top. During the experiment, the digester was stirred with a paddle stirrer at certain time intervals. Between the hours of 8:00 am and 9:00 am in the mornings and then 3:00 pm and 4:00 pm in the afternoons, about 20 ml of the feedstock was collected and the pH meter was then inserted into this feedstock and the reading taken while the ambient temperature was also read by using a digital thermometer. This procedure was carried out for 10 days. The substrate used in this study consisted of household organic waste, including:

- Food waste
- Fruit waste
- Vegetable waste

The collected waste was chopped and ground into smaller particles to increase the surface area available for microbial activity. Smaller particle sizes enhance biodegradability and improve biogas production.

### 2.3 Experimental Procedure

Before starting the experiment, the leftover digestate in the digester from the residues was flushed out through the outlet to make the system ready for fresh inoculation. The physicochemical parameters of the substrate, such as pH and temperature, were measured and recorded for the substrate that was prepared for the experiment shown in figure 2. The substrate was then added to the 100 L capacity biogas digester for the digestion process. The digestion process was carried out for a period of 10 days under controlled conditions, and fresh substrate was added on a daily basis while maintaining a ratio of 1:1 for the substrate. The anaerobic digestion process is carried out by microbes, and the microbes produce biogas from the substrate. The digestate from the biogas plant was taken out first through outlet before feeding. pH value and the temperature of the substrate (organic waste) are then measured using pH meter and thermometer before adding it to the digester. The substrate is then fed into 100 L biogas digester through an inlet for a period of 10 days. The pH and Temperature of the substrate readings on the equipment were taken and entered in tables .1 and 2. The accepted results were used in the construction of the graphs that follows. Figures 3 and 4 show the pH and temperature of the substrate on each day, respectively. After adding the substrate to the digester, then the bacteria start breaking down the organic components in the absence of oxygen and turn them into biogas.

Figure 2. Pictorial representation of substrate pH measurement

Table 1: Represents the details of pH values of substrate

| Day | Measured PH values of the substrate |
|---|---|
| Day 1 | 7.4 |
| Day 2 | 7.1 |
| Day 3 | 7.4 |
| Day 4 | 7.4 |
| Day 5 | 7.0 |
| Day 6 | 7.3 |
| Day 7 | 7.2 |
| Day 8 | 6.9 |
| Day 9 | 7.0 |
| Day 10 | 7.1 |

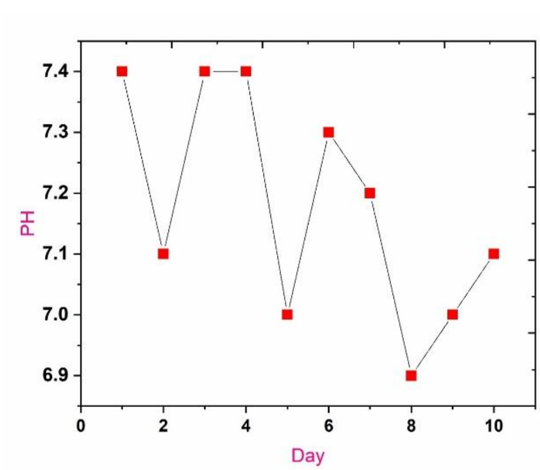


Figure 3: Graph Represents the day wise pH values of the substrate

Table 2: Represents the details of temperature values of substrate

| Day | Measured Temperature values of the substrate in °C |
|---|---|
| Day 1 | 30.5 |
| Day 2 | 32.5 |
| Day 3 | 33 |
| Day 4 | 30 |
| Day 5 | 34 |
| Day 6 | 34 |
| Day 7 | 34 |
| Day 8 | 32 |
| Day 9 | 33.5 |
| Day 10 | 32 |

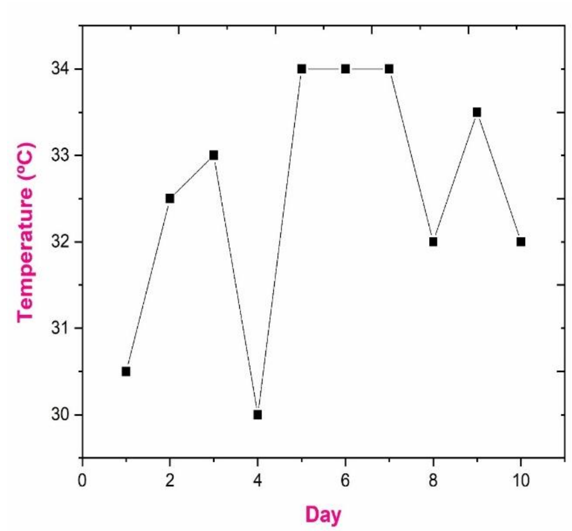


Figure 4: Graph Represents the Temperature values of the substrate

The gas produced from the biogas was, used to determine water boiling test. For this experiment, 1 litre of water was taken in a container, and its initial temperature at the starting time was noted. The water was then boiled using the gas produced from the biogas plant until we run out of gas and its final temperature was noted using thermometer, which is shown in table 3. The same procedure and experiment have been carried out for a period of 10days.

- 1 litre of water was placed in a container.
- The initial temperature was recorded.
- The water was heated using the produced biogas until the gas supply ended.
- The final temperature and time were recorded.

This experiment was repeated daily for 10 days.

Figure 5: The pictorial representations of biogas and Boiling temperature measurement

Table 3: Represents the details of water boiling test under biogas

| Day | Amount of Water in litres | Initial temperature in °C | Final temperature in °C |
|---|---|---|---|
| Day 1 | 1 Litre | 31.8 | 65 |
| Day 2 | 1 Litre | 32.5 | 66.7 |
| Day 3 | 1 Litre | 32.1 | 77.6 |
| Day 4 | 1 litre | 35.8 | 65.4 |
| Day 5 | 1 Litre | 31.6 | 95.5 |
| Day 6 | 1 Litre | 32.6 | 83.6 |
| Day 7 | 1 litre | 32.8 | 76.7 |
| Day 8 | 1 litre | 31.5 | 94.1 |
| Day 9 | 1 litre | 34.8 | 93.3 |
| Day 10 | 1 litre | 33.7 | 81.9 |

The above table. 3 represents the details of water boiling test. This table clearly shows that lowest temperature of 65°C was observed on day 1, whereas highest temperature of water was observed on day 5, followed by day 8 with a temperature of 94.1°C. The obtained data were used to determine the enthalpy change during the combustion on each day. i.e., the amount of heat energy fully released by the biogas when it is burned, which has been produced from the substrate of the corresponding day, this calculation was used to determine on which day the biogas is producing more yield when it is burned. Since it is combustion of methane, which produces heat energy [8]. The amount of energy released during the combustion of the biogas was calculated by finding the change in enthalpy using the formula in equation (1):

$$Q = m \times C \times \Delta T \ (1)$$

Enthalpy changes during combustion

Where, $Q$ = heat energy released in the process

$m$ = mass of water in grams

$C$ = specific heat capacity of water

$\Delta T$ = temperature change

This calculation helped in finding the amount of energy produced on a daily basis from the biogas produced.

Table 4: Represents the enthalpy produced on each day

| Day | Enthalpy of biogas in |
|---|---|
| Day 1 | 138.776 |
| Day 2 | 142.956 |
| sDay 3 | 190.190 |
| Day 4 | 139.548 |
| Day 5 | 267.102 |
| Day 6 | 213.180 |
| Day 7 | 183.502 |
| Day 8 | 261.668 |
| Day 9 | 244.530 |
| Day 10 | 201.476 |

The above (table:3) shows the enthalpy change during combustion of biogas on each day. The above table shows that the lowest enthalpy of bigas was observed on day 1 and the highest enthalpy was observed on day 5. The enthalpy of biogas was an amount heat energy released during the combustion. A plotted graph of the enthalpy of the biogas was shown in figure 6. The pH value and temperature value of the substrate are the deciding factors for the heat of combustion of biogas so that the comparison graph was plotted and shown in figure 7.

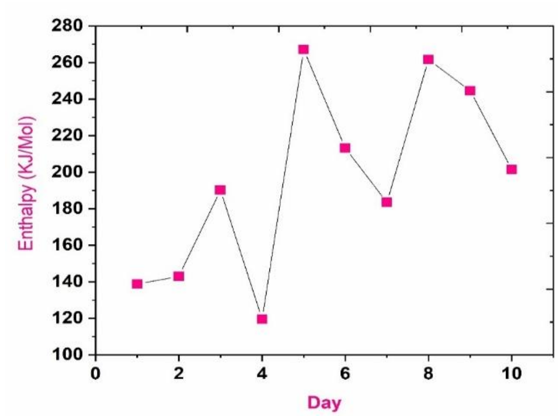


Figure 6: Graph Represents the Enthalpy values of the gas

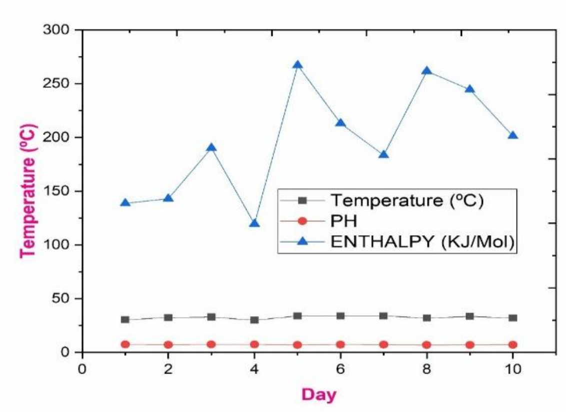


Figure 7: Graph Represents comparison of pH, Temperature and Enthalpy values

## III. RESULT AND DISCUSSION

3.1 Study on the Effect of pH of the substrate:

The result shows that highest energy content of biogas was observed in the substrate having pH of 7.0 on day 5, followed by the substrate having 6.9 pH. According to the results, we can notice that the production of biogas, under the pH of 7.0 was maximal. The lowest energy of biogas was observed in pH having 7.4 on day 4. Even though day 3 and day 4 are having same pH but the heat energy content produced from biogas on day 3 was little higher compared with day 4. This is because of the variation of the substrate temperature. Thus, the result showed that pH and temperature of the substrate are the two main parameters of the anaerobic digestion process that has a significant effect on the digestion process and biogas production. Thus, the results showed that pH 7 made favourable condition for bacterial growth in the digester and produced better biogas yield compared to the others. This indicates that pH which tends towards neutral possesses the potential to produce better biogas yield. In this result we can also notice that lowest biogas yield was observed in the substrate having 7.4 pH, which clearly states that increase and decrease in the pH will have an impact on the production of biogas, thus resulting in the reduction of biogas production. A higher and lower pH in the digester inhibits the activity of microorganisms involved in the digestion process, particularly methanogenic bacteria [9]. The result shows that the pH of the substrate has a significant effect on biogas production because, it affects the activity of bacteria to destroy organic matter into biogas [10].

3.2 Study on the effect of temperature of the substrate:

Temperature of substrate is a significant parameter inside the reactor, which has a direct effect on the microbial performance. The rate of decomposition and gas production is sensitive to temperature. The optimum temperature range of a substrate is 30-40°C [11]. The objective of this study is to define the optimal temperature that presents a better performance in terms of biogas production. According to the results, the biogas production has been showing a maximal production rate, registered for the substrate having a temperature of 34°C on $5^{th}$ day. According to the results, the energy content rate was high at the temperature of 34°C, On the other hand, it was necessary to know that energy content of biogas production was less at the substrate having a temperature of 30°C on $4^{th}$ day, which is very close to start of the required optimum temperature for the biogas production. The less bigas production may be due to the annihilation of microorganism metabolism due to low temperature [12]. This is because the rate of decomposition and biogas production is sensitive to temperature and the methanogens become inactive in extremely low and high temperature.

3.3. Suggestions to Improve Biogas Production

pH Control

- Lime can be added to increase pH when acidity is high.
- Hydrochloric acid can be used to reduce pH when alkalinity increases.

Temperature Control

- Digesters can be buried underground to maintain temperature stability.
- Insulating materials such as straw, leaves, or sawdust can be used in cold climates.

Maintaining pH near neutral and temperature above 30°C ensures optimal digestion.

## IV. CONCLUSION

A mini mesophilic anaerobic digester was successfully designed and evaluated using household food waste as the substrate. The results demonstrated that both pH and temperature strongly influence biogas production. Maximum energy production was observed when the substrate pH was approximately 7.0 and the temperature was around 33–34°C. These conditions favour the growth of methanogenic microorganisms responsible for methane generation. The study highlights the importance of maintaining optimal environmental conditions within the digester to enhance biogas yield and improve renewable energy production from organic waste.

## REFERENCES


[1] C. P. Ukpaka, J. Ben-Iwo, and J. J. Fakrogha, "Examination of temperature and pH in anaerobic digester process," *Journal of Scientific and Engineering Research*, vol. 5, no. 3, pp. 384–393, 2018.

[2] V. A. Ezekoye, B. A. Ezekoye, and P. O. Offor, "Effect of retention time on biogas production from poultry droppings and cassava peels," *Nigerian Journal of Biotechnology*, vol. 22, pp. 53–59, 2011.

[3] Anukam, A. Mohammadi, M. Naqvi, and K. Granström, "A review of the chemistry of anaerobic digestion: Methods of accelerating and optimising process efficiency," Dept. Eng. and Chemical Sciences, Karlstad Univ., Sweden, pp. 3–6, 2019.

[4] Kavuma, "Variation of methane and carbon dioxide yield in a biogas plant," M.S. thesis, Dept. Energy Technology, Royal Institute of Technology, Stockholm, Sweden, 2013.

[5] S. Mirmohamadsadeghi, K. Tabatabaei, and M. Aghbashlo, "Biogas production from food wastes: A review on recent developments and future perspectives," *Bioresource Technology Reports*, pp. 4–10, 2019.

[6] International Renewable Energy Agency (IRENA), *Measuring small-scale biogas capacity and production*. Abu Dhabi, UAE: IRENA, 2016.

[7] S. Charu, "Factors affecting biogas yield: Six factors."

[8] Raja and S. Wazir, "Biogas production: The fundamental processes."

[9] Hajji, M. Rhachi, M. Garoum, and N. Laaroussi, "The effects of pH, temperature and agitation on biogas production under mesophilic regime," 2016.

[10] R. D. Prasad, "Empirical study on factors affecting biogas production," 2012.

[11] P. Dobre, N. Farcaş, and F. Matei, "Main factors affecting biogas production—An overview," 2014.