# Anaerobic Co-Digestion of Bread Waste and Sewage Sludge for Methane Production

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**Abstract** The purpose of this study is to develop a lab-scale model for energy self-sufficiency via the promotion of the generation of sustainable renewable energy from bread waste and sewage sludge to biogas. Most of the garbage consisting of bread and sewage sludge is typically disposed of in landfills, which can result in substantial health and environmental problems due to the release of gaseous substances. As a result of this, the research endeavors to make use of sewage sludge and bread wastes as substrates to produce methane. A pH meter and a drying oven were used, respectively, to analyze each substrate's pH level as well as its dry weight, total solids, and volatile solids content. A methane gas detector was used on each sample to check for the presence of methane. The recorded pH is within the optimal range as it is between 6.9 and 7.2 for the substrates, bread waste, and sewage sludge as well as both ratios of the mixtures before and after the anaerobic co-digestion process. Following three to four days of cultivation using the streaking and spread culture method on nutrient agar, the microorganisms Saccharomyces cerevisiae and Pseudomonas aeruginosa were isolated from the bread waste and sewage sludge, respectively. The methane gas detector registered a value of 9999 ppm, which is 20% LEL.

**Keywords:** Sewage sludge, bread waste, methane, gas detector

## 1. INTRODUCTION

The presence of greenhouse gas emissions contributes significantly to global warming, primarily due to human activities over the last 150 years. Carbon dioxide is the most critical greenhouse gas produced by human activity, with food waste accounting for over 11% of total greenhouse gas emissions [1]. This leads to severe issues such as air and water pollution and climate change. For instance, approximately 2.5 kilograms of greenhouse gases are emitted for every kilogram of food waste disposed of in landfills [1].

In Malaysia, food waste is a persistent issue, with the residential sector responsible for 44.5% of the daily 16,667.5 tonnes of waste [2]. By 2030, Malaysia aims to achieve carbon

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neutrality by 2050 and reduce the greenhouse gas intensity of its GDP by 45% [2]. To achieve this, waste elimination at every level is crucial.

This study aims to develop a lab-scale model for energy self-sufficiency by promoting the generation of sustainable renewable energy from bread waste and sewage sludge to biogas. The research addresses the challenge of waste disposal in landfills, which poses health and environmental risks due to the release of gaseous substances. By using sewage sludge and bread waste as substrates for methane production, the study contributes to reducing landfill waste and generating green energy. The manuscript is structured as follows: the methodology section details the experimental setup and procedures, the results section presents the findings, and the discussion section interprets the results in the context of existing literature.

## 2. LITERATURE REVIEW

Anaerobic digestion (AD) is a well-established technology for converting organic waste into biogas, which consists mainly of methane and carbon dioxide. The process involves the breakdown of organic matter by microorganisms in the absence of oxygen. AD has been widely studied for its potential to manage waste and produce renewable energy [3].

Several studies have explored the co-digestion of different organic wastes to enhance biogas production. For instance, the co-digestion of food waste with sewage sludge has been shown to improve methane yields due to the complementary characteristics of the substrates [3]. The addition of bread waste, which is rich in carbohydrates, can further enhance biogas production by providing readily available organic matter for microbial degradation [3].

Recent advancements in AD technology include the optimization of process parameters such as temperature, pH, and substrate composition to maximize biogas yields [3]. The use of pre-treatment methods, such as thermal and mechanical treatments, has also been investigated to improve the biodegradability of complex organic matter [3].

## 3. METHODOLOGY

### 3.1 Research design and approach

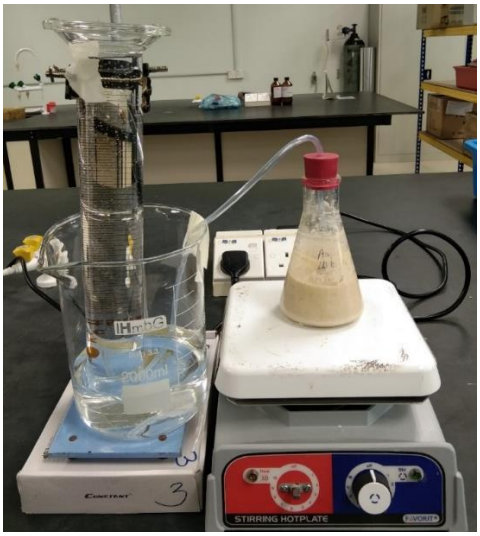


**Fig. 1**: Experimental setup

Two conical flasks, each with a volume of 250ml, labeled as A and B. Conical flask A, which was initially empty, was filled with a mixture of bread scraps, sewage sludge, and water in the proportions of 1:2 (50:100) and 2:1 (100:50). To break down the mixture into smaller particles, a hand mixer was used prior to conducting the experiment. After adding the feedstocks, conical flask A was purged with pure nitrogen for five minutes. The purpose of nitrogen flushing was to create an anaerobic environment before starting the reaction.

The gas collection apparatus consisted of two 250ml conical flasks where the reaction occurred, two 500ml measuring cylinders filled with water and inverted into two 2L beakers partially filled with water. To collect the gas produced during the reaction, one end of a tube was connected to the reaction flask, and the other end was attached to an inverted measuring cylinder for gas collection. As gas was generated, it displaced the water in the measuring cylinder, allowing the estimation of the gas volume based on the displaced water volume.

Using the collected gas volume and applying gas laws, the total number of moles of gas could be determined. Simultaneously, the water level inside the measuring cylinder would adjust to maintain a constant pressure inside and outside the cylinder. Consequently, the pressure of the gas inside the measuring cylinder could be calculated by considering the atmospheric pressure outside the cylinder. Following the digestion process, a methane gas detector was employed to detect methane in the experiment [4].

### 3.2 Sampling strategy and data collection methods

Bread waste was collected by using expired bread from a nearby university mart or obtained from students. Sewage sludge was gathered from the wastewater plant in UMK Jeli.

Bread that had been discarded was visually identified based on its external appearance, which involved observing visible mold or patches of different colors on the loaf. Sewage sludge was distinguished through the process conducted at the wastewater plant.

Each sample was assigned a unique ID and labeled with the corresponding time, date, and location. Fresh bread waste was collected right before laboratory work and did not require storage. Samples needed to be confirmed in advance, preferably a week to several days, to ensure that suitable sludge could be collected at a specific time and location. Prior to analysis, the samples were stored on ice at a temperature of 4°C [5].

## 4. RESULTS

### 4.1 Substrate Characterization

Characteristics of BW, SS, and the mixture of the sample with the ratio of 1:2 and 2:1 are shown in Table 1. All experimental setups utilize 150g of material, with another 15g used for volatile solids (VS) and total solids (TS).

**Table 1**:Characteristics of bread waste (BW), sewage sludge (SS) and the mixture with ratio of 1:2 and 2:1

| Parameters | Bread Waste (BW) | Sewage Sludge (SS) | Before Digestion | | After Digestion | |
|---|---|---|---|---|---|---|
| | | | Mixture 1:2 | Mixture 2:1 | Mixture 1:2 | Mixture 2:1 |
| **Dry weight (g)** | 150 | 150 | 150 | 150 | 150 | 150 |
| **Weight of dish (g)** | 0.619 | 0.621 | 0.623 | 0.626 | 0.593 | 0.597 |
| **Weight of dish + total solids (g)** | 14.381 | 14.379 | 14.377 | 14.374 | 14.407 | 14.403 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **pH** | 7.0 | 7.2 | 6.9 | 7.1 | 7.0 | 7.2 |
| **% TS** | 27.18 | 29.03 | 28.57 | 43.90 | 26.36 | 33.01 |
| **TS (g)** | 0.2718 | 0.2903 | 0.2857 | 0.4390 | 0.2636 | 0.3301 |
| **% VS** | 25.57 | 29.02 | 28.11 | 43.75 | 26.35 | 32.88 |
| **VS (g)** | 0.2557 | 0.2902 | 0.2811 | 0.4375 | 0.2635 | 0.3288 |

### 4.2 Microbial Identification

The bread and sewage sludge samples were inoculated on nutrient agar and left for a week before the identification.

**Table 2:** Microbial Identification of Bread Waste and Sewage Sludge on Nutrient Agar

| **Categories** | **Bread Waste** | **Sewage Sludge** |
|---|---|---|
| **Technique** | Streak plate | Spread plate |
| **Colony** | Flat and cream in colour | White cream in colour |
| **Shape** | Spherical | Rod-shaped |
| **Motility** | Motile | Motile |
| **Organism** | *Saccharomyces Cerevisiae* | *Pseudomonas Aeruginosa* |

### 4.3 Methane Gas Analysis

The methane gas concentration and its lower explosive limit (LEL) was recorded using a methane gas detector; HABOTEST Smart Gas Leak Detector.

**Table 3:** The Concentration and Lower Explosive Limit (LEL) of the mixture of BW and SS with ratio 1:2 and 2:1

| **Categories** | **Concentration (ppm)** | **LEL (%)** |
|---|---|---|
| **Mixture 1:2** | 9999 | 20.00 |
| **Mixture 2:1** | 9999 | 20.00 |

## 5. DISCUSSION

### 5.1 Substrate Characterization

The pH levels in bread waste (BW) and sewage sludge (SS) were measured at 7.0 and 7.2, respectively. The 1:2 and 2:1 ratio mixtures had pH values of 6.9 and 7.1, respectively, before digestion, which fell within the normal range for anaerobic digestion (AD) between 6.8 and 7.4 [6]. The substrate pH was initially neutral before digestion. During anaerobic digestion, acids were produced, leading to an increase in pH. Methane-producing bacteria utilized

volatile acids to generate alkalinity, which raised and stabilized the pH. However, volatile fatty acids caused a decrease in pH, resulting in reduced biogas and methane production. Acidic mixtures slowed down the fermentation process. As gas production ceased, free fatty acids accumulated rapidly, potentially explaining the acidic pH observed in all industrial effluent after digestion [7].

The total solids (TS) content present in solid waste can significantly impact the efficiency of anaerobic digestion, particularly in the production of biogas and methane. When comparing the total solids content of sewage sludge (0.2718 g or 27.18%) to bread waste (0.2903 g or 29.03%), the latter had a higher value. A 1:2 mixture had a total solids weight of 0.2857 g (28.57%) before digestion, while the 2:1 ratio mixture weighed 0.4390 g (43.90%). The concentration of total solids (TS) affects the effectiveness of microorganisms involved in the decomposition process. The digestion process resulted in a decrease in total soluble solids (TS) content, likely due to microbial activity and the structural diversity of bacteria [8].

The amount of organic matter that can be converted into biogas during heating is measured in terms of volatile solids (VS). Bread waste contained 0.2557 g (25.57%) of volatile solids, while sewage sludge contained 0.2902 g (29.02%). In the pre-digested state, the 1:2 mixture had a total of 0.2811 g (28.11%) volatile solids, which decreased to 0.2635 g (26.35%) after anaerobic digestion. The volatile solids in the 2:1 mixture initially measured 0.4375 g (43.75%) but were reduced to 0.3288 g (32.88%) after digestion. The decrease in volatile solids is attributed to the breakdown of organic matter by methane-forming bacteria during the methanogenesis process [9].

### 5.2 Microbial Identification

Both the streaking culture method and the spread plate method were employed, with the former used for bread waste samples and the latter for sewage sludge samples.

After three days of incubation on nutrient agar, both plates exhibited signs of active growth. The culture grown on the bread waste displayed a flat, cream-colored colony, while the culture grown on the sewage sludge plate formed an opaque, creamy white colony spread.

The fungus isolated from stale bread exhibited a spherical shape and motility characteristic of Saccharomyces cerevisiae under microscopic examination. The rod-shaped colony with motility observed under the sewage sludge plate confirmed the presence of Pseudomonas aeruginosa bacteria [10].

### 5.3 Methane Gas Analysis

For methane gas analysis, a methane gas detector called HABOTEST High Accuracy Sensor HT601B Portable Gas Leak Detector was utilized. It featured a 16-inch bendable probe, an HD/LCD screen, an audible and visual alarm, and a high-precision sensor. Both mixtures showed a similar concentration of 9999 ppm and 20% LEL (Lower Explosive Limit), which was the maximum amount detectable by the installed detector. Comparing the two systems, the presence of 20% LEL indicated that the produced gas comprised >99% methane and 1% air. Typically, these alerts range from a low of 10% to a high of 20%. 1% is equivalent to 500 ppm methane [11].

## 6. CONCLUSION

Temperature, pH, total solids, and volatile solids all influenced the microbial biogas generation process. These factors played a crucial role in regulating the quality and quantity

of biogas produced. The utilisation of food waste for biogas production represents a significant advancement in harnessing one of the world's most abundant and underutilized renewable energy resources. The project successfully achieved its objectives, which involved exploring the potential of bread waste and sewage sludge as substrates for methane generation, aiming to establish a renewable energy system independent of external resources. The concept of anaerobic co-digestion of bread waste and sewage sludge for biogas production not only offers sustainable energy possibilities but also presents an effective waste management solution. However, in order to realize its positive impact on economic growth, energy security, and air quality, the various stakeholders must possess a clear and shared vision while fostering strong collaborative abilities [12].

## ACKNOWLEDGEMENT

This work was supported by Research Grant R/JUST/A1300/00457A /005/2023/01210 from Malaysia-Jordan Matching Research Grant Scheme UMK.

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