

Research Article

Biogas Recovery from Different Composition of Food Waste Using Anaerobic Digestion Technique

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Abstract: Nowadays, extensive studies in anaerobic digestion have been carried out for recovering resources from waste. In this study, food waste is used as anaerobic digestion substrates because of the abundant availability of waste. Improper waste disposal technique has contributed to environmental problems. At the same time, despite being dependent on fossil fuels as an energy source. Biogas, which is produced through the anaerobic digestion process can be used as a renewable energy source. Therefore, this study was carried out to investigate biogas recovery through the anaerobic digestion technique. The biogas recovery was performed using an anaerobic batch digester at mesophilic ($35^{\circ}\text{C} \pm 1$) condition and pH was controlled at 6.8 to 7.2 for 10 days Food waste was segregated into different compositions namely carbohydrates rich-food waste, fiber rich-food waste, and protein rich-food waste. Sludge collected from the pond was used as the inoculum to boost up the anaerobic digestion process. The results showed carbohydrate-rich food waste recover the highest biogas with $66\text{mL} \pm (0.01)$ in 3 days of digestion, followed by protein-rich food waste $40\text{ mL} \pm (0.05)$ (Day 5) and fiber-rich food waste $27\text{ mL} \pm (0.02)$ (Day 6), respectively. The difference in values could be due to higher volatile solid content in carbohydrate-rich food waste (98.9%) compared to protein-rich food waste (94.4%) and fiber-rich food waste (82.9%), respectively. Moreover, this study also provides information on a new strategy used in recovering biogas.

Keywords: Biogas recovery; Carbohydrate-rich food waste; Protein-rich food waste; Fiber-rich food waste; Anaerobic digestion.



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1. INTRODUCTION

Food waste (FW) is produced every day with a growing pattern across the globe as a result of rapid population growth, economic development, and urbanization. Most of the food that is wasted comes from many sources, including fish, shellfish, vegetables, fruits, meat, dairy products, and grains. Home, cafeterias, canteens, restaurants, residential neighbourhoods, and the food industry are all places where FW is produced. Even though food waste has a high potential for composting and is biodegradable, the majority of it is disposed of in landfills. According to a report, Malaysians throw away 16,688 tonnes of food per day, enough to provide 2.2 million people with one meal a day, that ends up in landfills (Hashim et al., 2021). Organic matter in the landfill does not have access to oxygen decomposes anaerobically and releases the greenhouse gases like methane and carbon dioxide. The emission of greenhouse gases contributes to global warming and has a negative

environmental impact. When FW is improperly disposed of by landfilling and deposited outdoors, it can also cause several sanitation issues, including fouling odour, groundwater contamination, leachate generation, and possibly harmful gas releases (Xu et al., 2018).

Apart from environmental issues, researchers are motivated to find alternative green energy sources to overcome the problem of depletion of fossil fuel supplies and increasing crude oil prices globally (Chhandama et al., 2022). These problems of insufficient energy supply and the growing concern for environmental issues could be simultaneously handled by biogas production from anaerobic digestion of FW. Anaerobic digestion is an environmentally friendly process for turning liquid or solid organic wastes into biogas, which can then be converted into useful resources (heat and/or electricity) (Zhang et al., 2017). The term "biogas" often refers to a gas created when organic matter, such as dead plants, animal waste, and kitchen trash, undergoes a biological breakdown in the absence of oxygen (Firmo et al., 2022). Typically, biogas has about 55 – 65% methane, 30 – 35% carbon dioxide, and traces of nitrogen, hydrogen, and other impurities. Biogas can be used as a renewable energy source for any heating purpose, such as cooking, and electricity, and when compressed like natural gas can be used as vehicle fuel to power motor vehicles (Kabeyi & Olanrewaju, 2022).

Due to the huge potential of anaerobic digestion of FW to generate biogas, this study was conducted to evaluate biogas production from some common FW taken from the cafeteria at UiTM Sabah Branch, Kota Kinabalu Campus. The digestion was carried out in batch-type anaerobic digesters for 10 days of the retention period to study the potential of biogas recovery from different compositions of FW and to optimize the time of digestion through an anaerobic digestion technique.

2. PROBLEM STATEMENT

FW is a major issue that has an impact on society, the economy, and the environment globally. FW that is not disposed of properly contributes to greenhouse gas emissions, occupies a large area of landfill space, and wastes resources. Higher education institutes are one of the major generators of food waste. It was reported that 33% of total waste in higher education institutes consisted of food waste whereas the waste generated at a university mostly is disposed of at landfills (Torrijos et al., 2021). At UiTM Kota Kinabalu Campus, with the number of students of around 5000 in a semester, it is expected that a significant amount of FW is produced every day.

Therefore, careful management of FW generated on campus is essential to reduce the need for landfill space and leachate generation as well as to cut greenhouse gas emissions. Biogas recovery from FW gives a long-term and environmentally friendly solution for controlling FW, especially at the campus level, by converting organic waste into biogas, which can be used as an energy source.

3. OBJECTIVES

1. To study the potential of biogas recovery from different compositions of food waste.
2. To optimize the time digestion for biogas recovery through an anaerobic batch digestion technique.

4. METHODOLOGY

4.1 Sample collection and preparation

FW composition was collected from Manukan cafe located in UiTM Kota Kinabalu Campus. All the FW was segregated into carbohydrate-rich food waste (CRFW), protein-rich food waste (PRFW), and fiber-rich food waste (FRFW). FW samples were grounded to small sizes of about 3-5 mm to facilitate digestion efficiency. While inoculum used was the sludge obtained from the pond at UiTM Kota Kinabalu Campus and it was put in an incubator at a temperature 35°C (± 1). This step was done to make sure the sludge was in the best condition before the AD process was performed. Table 1 shows the physical properties of FW.

Table 1. Physical properties of FW

Parameters	CRFW	PRFW	FRFW
Total Solid (TS)(%)	38.90 $\pm$ 0.10	34.16 $\pm$ 0.12	15.10 $\pm$ 0.09
Volatile Solid (VS)(%)	98.90 $\pm$ 0.05	94.40 $\pm$ 0.10	82.90 $\pm$ 0.08
pH	3.88 $\pm$ 0.08	3.75 $\pm$ 0.08	3.45 $\pm$ 0.03

4.2 Operation startup for AD (FW composition and Inoculum)

The experimental work was performed using a Duran Bottle with a working volume of 400 mL. The schematic diagram of AD can be referred to in Figure 1. Digestion tests were performed in a water bath and the temperature was set up at mesophilic conditions 35°C (± 1). The substrates to inoculum ratio was fixed at 2.0:1.0. The Duran bottle was charged with different types of FW (CRFW, PRFW, and FRFW) and pH was controlled at pH 6.8 to 7.2 by using 1.0 M HCl and 1.0 M NaOH. The digestion time for each digester was set up for 10 days which is suggested by a previous study by Selaman et al., 2019. During the experiment, the gas was released once a day. Determination of gas recovery was done by using the water displacement technique (Figure 2). The volume of gas recovery was calculated using Equation 1. The procedure was repeated using PRFW and FRFW.

$$\text{Volume of gas recovery (mL)} = \text{Volume of distilled water displaced (mL)} \quad (\text{Eq. 1})$$

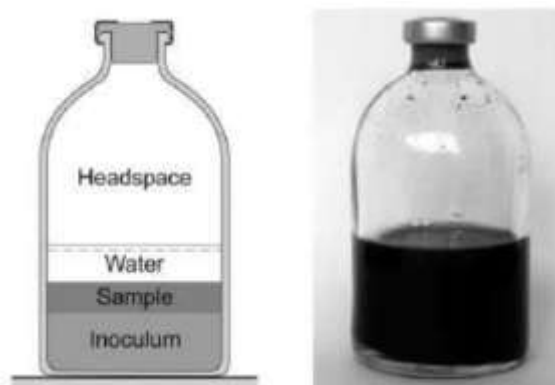


Figure 1. AD in batch reactor



Figure 2. Determination of gas volume by water displacement technique

5. RESULTS & DISCUSSION

The biogas recovery from different compositions of FW (CRFW, PRFW, and FRFW) was studied at 10 days of digestion time. The result obtained from the analysis is shown in Figure 3. The highest biogas recovery and optimum day of AD for CRFW was 66 ml in day 3, followed by PRFW; 40 ml (Day 5), and FRFW 27 ml (Day 6), respectively. The difference in value could be due to the volatile solid (VS) content in each composition (Table 1).

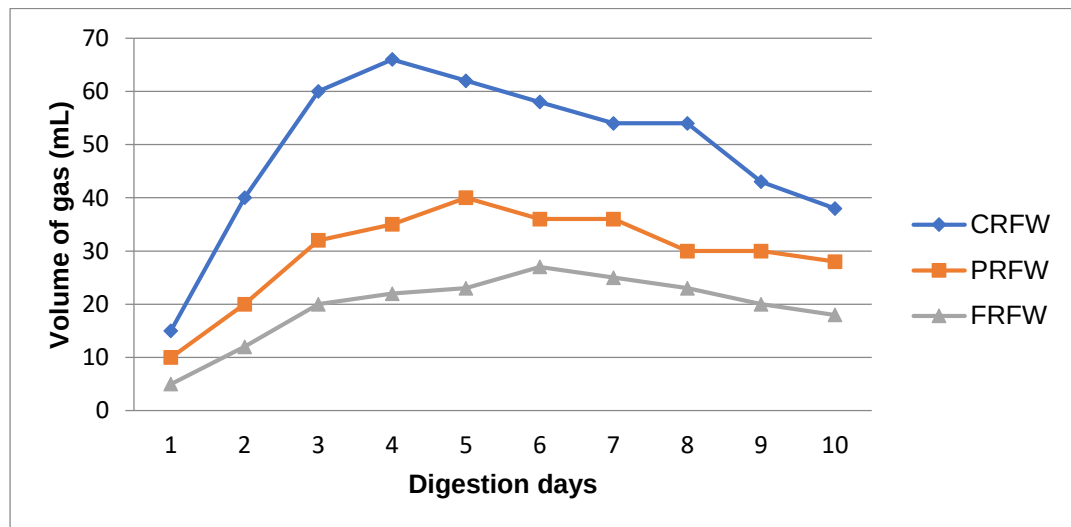


Figure 3. Biogas recovery in 10 days of AD

Table 2 shows the amount of biogas expressed in different units. In general, these findings suggested, all the FW compositions can be used in the recovery the biogas. Moreover, it can recover about 60% of methane (CH_4) gas which is primarily used as fuel.

Table 2. Biogas recovery in different unit

Biogas Recovery (Unit)	CRFW	PRFW	FRFW
10g of sample/ mL	66	40	27
1 Kg of sample/ L	0.066	0.040	0.027
Food waste produced Kg/ day	1122462	680280	459.189
17007 tonnes = 17007 x 10 ³ Kg			
Biomethane (CH ₄), 60% Kg/day	673477.20	408168	275.5134

1g= 1ml

1 Kg= 1L

6. CONCLUSION

These findings suggested that CRFW can produce the highest value of biogas recovery with a value of 66 mL compared to PRFW (40 mL) and FRFW (27 mL), respectively. It was also found that the optimum day of AD is Day 3 for CRFW, Day 5 for PRFW, and Day 6 for FRFW. AD can be used in the recovery of biogas with a composition of 60% methane, which reduces the biogas release to open surroundings. Overall, AD to generate biogas can be used as an alternative technique in the disposal of FW.

7. BENEFIT OF PRODUCT/IMPACT/NOVELTY

Methane production via AD of organic wastes would benefit society by providing clean fuel. In this research, diverting waste and using it for fuel is a legitimate climate solution. These would reduce environmental impacts and, at the same time, replace fossil fuel-derived energy. Moreover, utilizing the anaerobic digestion of food waste to harness biomethane recovery as an energy source offers a multitude of advantageous outcomes. The process of diverting organic waste from landfills, such as food waste, mitigates methane emissions and contributes to waste reduction while providing a renewable and sustainable energy source. This ecologically conscious strategy diminishes dependence on limited fossil fuel resources, decreases greenhouse gas release, and improves energy generation at the local level, strengthening energy security. By transforming food waste into a valuable resource, biomethane recovery stimulates economic growth through job creation, corresponds with circular economy principles, and supports climate goals, marking a vital step towards a cleaner, more resilient, and sustainable energy future.

8. COMMERCIALIZATION

Based on the results, it can be concluded that AD offers significant biogas emission benefit as compared to its fossil counterpart. This benefit can be even more when the unsustainable handling of FW in the current situation is considered (Khan et al., 2021). Moreover, it offers high-value-added products, mainly biogas and biomethane, to produce heat and energy needed in food processing and digestate that could be used as organic fertilizer or soil conditioner for agronomic purposes (Zhu et al., 2023). The commercialization and utilization of biomethane potential recovery signify a notable progression in waste management, renewable energy, and sustainable resource management. On a global scale, nations are increasingly pursuing renewable and sustainable energy alternatives, with biogas recovery emerging as a significant market opportunity and environmental benefit.

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