
Research Article

Analysis of bioelectric potential of cabbage waste (*Brassica oleraceae* var. *capitata*) using microbial fuel cells

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Abstract

Vegetable waste, one of which is cabbage waste, has long been recognized as a cause of a significant environmental problems in traditional markets and must be addressed. However, cabbage waste can be used as an alternative energy source through the Microbial Fuel Cell process. The purpose of this study was to determine the potential of cabbage waste as a producer of bioelectricity and the storage time of cabbage waste that produces the largest bioelectricity using Microbial Fuel Cells. This research was conducted in February 2022 at Laboratory of Microbiology and Botany, Universitas Siliwangi. The study employed a completely randomized design (CRD), with treatment consisting of a control group (without storage), five storage treatments, namely: treatment 1 (2 days storage), treatment 2 (4 days storage), treatment 3 (6 days storage), treatment 4 (eight days storage), and treatment 5 (10 days storage). All treatments were repeated 4 times. A digital multimeter is used to determine the resulting electric current. The results indicated that the highest average total electric current generated was 0.022 mA from the 4 days storage treatment. The lowest average total electric current generated was 0.010 mA from the 10th days storage. These data indicate that the treatment of storage time of up to 4 days can increase the amount of electric current generated, then it decreases with increasing length of storage. It is influenced by several variables, including the growth phase of the bacterium, the availability of organic molecules, and the population of bacterium.

Introduction

In human life, most of the amount of waste comes from economic activities namely trading activities. This certainly causes many problems, because the increase in the volume of waste has a value comparable to the increase in

human consumption (Nagong, 2020). In Indonesia, the total volume of waste generated is around 60-70%, including wet waste with a moisture content of 65-75%. Most of the waste comes from traditional markets and settlements (Ayuningtyas et al., 2020). Tasikmalaya

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City produces waste in various forms and characteristics, one of which is vegetable waste which contributes to the total waste accumulation of Tasikmalaya which is 106,688.51 tons per year in 2020 (Sistem Informasi Pengelolaan Sampah Nasional, 2020). Waste management in Tasikmalaya City remains traditional, is generally carried out by collection, transportation, and disposal (Haerani et al., 2019).

Cabbage is one sort of the most common types of vegetable waste found in traditional market (*Brassica oleracea* var. *capitata*). Cabbage and mustard typically account for the largest proportion of market vegetable waste. Cabbage contains carbohydrates, sugars, dietary fiber, fat, protein, thiamine (vitamin B1), riboflavin (vitamin B2), niacin (vitamin B3), pantothenic acid (vitamin B3), vitamin B6, folate (vitamin B9), vitamin C, calcium, iron, magnesium, phosphorus (Agustina, 2016; Utama & Mulyanto, 2009). Cabbage vegetable waste contains 64 mg calcium, 1.7 mg iron, 0.7 g protein, and a water content of around 65-80% (Sutrisno, 2010). Water and nutrients can be used as a medium or food supply for microorganism growth and metabolic reaction acceleration (Anisah & Rahayu, 2015; Asgar & Musaddad, 2006).

One of the uses of cabbage waste is an organic substrate in Microbial Fuel Cells (MFCs). Microbial Fuel Cells (MFCs) are anaerobic bioreactors that convert chemical energy contained in organic materials into electrical energy through catalytic reactions involving microorganisms (Angenent et al., 2004). Various examples of bacteria that have been used for MFC, namely *Rhodospirillum rubrum*, *Geobacter sulfurreducens*, *Aeromonas hydrophila*, *Escherichia coli*, *Shewanella putrefaciens*, *Pseudomonas aeruginosa*, *Erwinia solvens*, *Desulfovibrio desulfuricans*, *Clostridium butyricum*, and *Enterococcus faecillus*. In addition, there are also yeast strains such as *Saccharomyces cerevisiae* and *Hansenula* sp. (Darmawan et al., 2018; Franks & Nevin, 2010; Kurnianingsih et al., 2017; Rabaey & Verstraete, 2005). At the same time, various genera of bacteria such as *Enterobacter*, *Streptococcus*, and *Bacillus* were discovered in cabbage trash. This waste also

serves as a habitat for bacteria such as *Lactobacillus plantarum*, employed to synthesize MFCs (Aliya et al., 2016; Sayuti et al., 2016).

MFCs-generated electricity can be employed as an alternative energy source in Indonesia, which until now the source of electrical energy in Indonesia is still dominated by fossil fuels, particularly from coal (50%), natural gas (29%), fuel oil (7%), and renewable energy (14%) (Siswanto, 2019).

The availability of fossil as an energy source will dwindle while the need for electrical energy will continue to increase each year, it is an integral part of human civilization in various fields (Fadillah et al., 2015; Parinduri & Parinduri, 2020).

This study aims to ascertain the potential of cabbage waste as a source of bioelectricity via Microbial Fuel Cells. Cabbage waste used is a mixture of cabbage waste with water in a ratio of 1:1, and the amount of generated electrical current is determined by the storage duration and the storage time is varied to see how much electric current is generated.

Materials and methods

This research was conducted at the Microbiology and Botanical Laboratory, Universitas Siliwangi from November to May 2022.

Preparation of cabbage waste

The source of cabbage waste is the traditional market of Cikurubuk Tasikmalaya. Cabbage waste to be used is mixed with water in a ratio of 1:1. A total of 100 grams of cabbage waste were cut using a knife and then blended after adding 100 mL of water. After blending, the cabbage waste was incubated at 37°C for 2, 4, 6, 8, and 10 days.

Preparing nutritious broth media (NB)

Into a 500 mL Erlenmeyer, 25 grams of Nutrient Broth were added and 192 mL of distilled water was added and then cooked on a portable stove while stirring until homogeneous. Erlenmeyer flask containing NB media was covered with aluminum foil and plastic wrap then sterilized for 15 minutes at 121°C in an autoclave. The NB medium was then divided into 24 test

tubes of 8 mL each using a measuring tube which was carried out in a laminar chamber and using a flame from Bunsen so that the media was not contaminated.

Bacteria *Lactobacillus plantarum* Inoculation

Lactobacillus plantarum isolate from slanted nutrient agar media was taken using a loop needle into 24 test tubes containing Nutrient Broth medium. *Lactobacillus plantarum* on Nutrient Agar Slants media was taken using a ose needle. Inoculation is done by inserting the ose needle carrying bacteria isolate into a test tube containing Nutrient Broth media then pulling it out in a zigzag pattern. All test tubes had been inoculated with *Lactobacillus plantarum* were incubated at 37°C in an incubator.

The Microbial fuel cell manufacturing process

Preparing the electrode

Carbon rods are utilized as electrodes in the anode and cathode chambers. Before usage, the two carbon rods were immersed in a 1N HCl solution for one day and then rinsed with distilled water. They were then immersed in a 1N NaOH solution and washed for one day with distilled water. After soaking the two carbon rods for 30 minutes in distilled water, each replicate was immersed in a buffer solution.

Preparing the salt bridge

The salt bridge that will be used is a dagger rope which is boiled in 200 mL of 1 M NaCl solution for 30 minutes in a 250 mL Erlenmeyer flask. As much as 29.25 grams NaCl

powder was added to distilled water until the volume reached 1000 mL in a 1000 mL beaker glass then homogenized on a portable stove.

Preparing the electrolyte solution

Electrolyte solution was prepared by dissolving 7.9 grams of KMnO_4 powder in 500 mL of distilled water in a 500 mL Erlenmeyer flask and centrifuged until homogeneous.

Developing microbial fuel cells reactor

MFCs contain two different types of chambers: anode chambers and cathode chambers. Using plastic jars of 130 mL capacity, two divisions are constructed. On both sides of the jars, holes were drilled with a soldering screwdriver and connected to a salt bridge in the form of a dagger rope shielded by an acrylic tube. The tube and jar are enclosed in electrical insulation and tube insulation. 100 mL of cabbage waste and 8 mL of *Lactobacillus plantarum* bacteria were put to the anode chamber for each treatment. Although the anode chamber jars were hermetically sealed, the lids were perforated to accommodate the carbon rods and alligator clamp wires. The anode and cathode chambers are correspondingly filled with carbon rods. Chamber of cathode containing 100 mL and 0.1 M KMnO_4 The lid of the cathode chamber jar was conditioned aerobically and punctured with many holes. The carbon rod is then bored with a second hole to accommodate the alligator clamp cable. Attaching a multimeter to one of the other ends of the two alligator clips allowed for the measurement of the amount of current produced by the MFCs in each treatment.

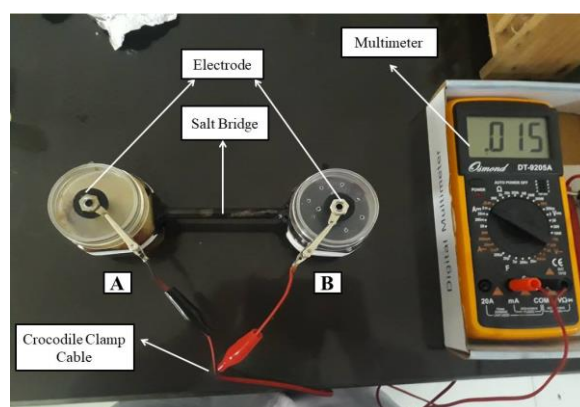


Figure 1. MFC two chamber construction (A) Anode compartment (B) Cathode compartment

Results and discussion

Current measurement the effects of storage time variation

A multimeter measures the electrical energy in the form of an electric current created

by the MFCs reactor. Data on electricity production from each result of length of storage for cabbage waste in this study can be seen in Table 1.

Table 1. Production of electricity as a function of length of storage

Treatment	Replication				Average Total Electric Current (mA)
	1 (mA)	2 (mA)	3 (mA)	4 (mA)	
0 day	0,010	0,013	0,015	0,017	0,014
2 day	0,018	0,016	0,019	0,022	0,019
4 day	0,024	0,020	0,020	0,022	0,022
6 day	0,009	0,014	0,015	0,012	0,013
8 day	0,014	0,017	0,012	0,011	0,014
10 day	0,015	0,006	0,004	0,013	0,010

According to Table 1, cabbage waste can generate energy when used as an organic substrate for Microbial Fuel Cells. It can be determined by measuring the quantity of electric current with a multimeter. The highest average total electric current was detected from the four day of storage, at 0.022 mA. While the lowest average of total electric current was 0.010 mA from the ten day of storage. Meanwhile, the

average total electric current produced from days 0 storage (control) and 8 days storage is 0.014 mA.

Figure 2 illustrates the average total electric current generated by the Microbial Fuel Cells reactor using organic substrate in the form of cabbage waste between treatments 2 days, 4 days, 6 days, 8 days, and 10 days.

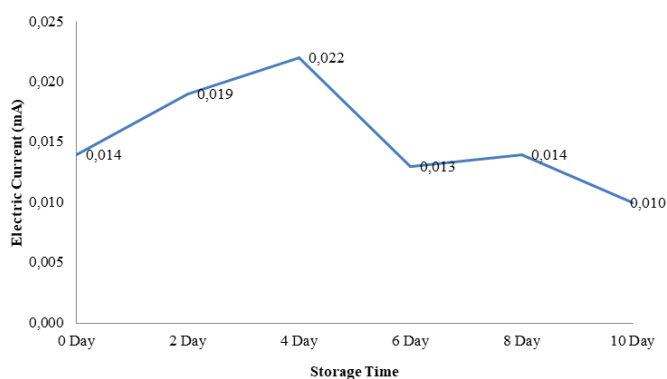


Figure 2. Average Total Electric Current Curve

The electric current generated by each treatment is depicted in figure 2 as a storage time of up to ten days. According to Figure 2, a specific storage time treatment can increase the electric current produced, but the electrical energy has decreased with the increasing length of storage. The measurement results indicate that there is a match with the bacterial growth phase, which is composed of a lag phase, an exponential phase, a stationary

phase, and a death phase (Nurhajati et al., 2016). The control group generated an electric current of 0.014 mA. In the control treatment, *Lactobacillus plantarum* was in the lag phase, which is the phase where the bacteria adapt to their environment. On the fourth day storage treatment, *Lactobacillus plantarum* bacteria raise the electric current to 0.22 mA. In this treatment, the bacteria entered the fourth day of incubation and their growth entered an

exponential phase, which is a phase in which the number of bacteria increases exponentially. Due to their ability to divide into two cells through binary fission, the bacterial population is growing. The electric currents produced on the sixth and eighth days were identical, 0.013 mA and 0.014 mA, respectively. The bacteria then entered a phase in which their growth rate was equal to their mortality rate, resulting in a constant number of cells (Darmawan et al., 2018). This occurs because the nutrients required by bacteria begin to diminish, resulting in suboptimal bacterial cell division and a drop in the pace of bacterial growth. In the ten day storage treatment, the electric current produced dropped to only 0.010 mA, indicated that the bacteria had entered the death phase since the substrate no longer suitable for the nutritional needs of the bacteria (Darmawan et al., 2018).

The electrical energy produced decreases and increases directly related to the number of electrons and protons released by bacteria. Ac-

cording to Liu et al., (2005), if no organic substrate remains, the electricity output will diminish due to a lack of molecules to oxidize. Microorganisms will produce protons and electrons when they degrade nutrients in cabbage waste. When the number of bacteria increase, nutrients are exhausted faster, and microorganisms stop growing and eventually die. Additionally, this also decreases the number of protons and electrons transported to the electrodes (Arbianti et al., 2013). Thus, the electrical energy provided by Microbial Fuel Cells is related to bacterial metabolism. The electron transfer efficiency from the bacterial cell to the electrode is proportional to the number of bacteria connected to the electrode surface (Lee et al., 2010).

The Chemical reactions that take place in microbial fuel cells

Figure 3 illustrates the design drawing for the Double Chamber Microbial Fuel Cells used in this study.

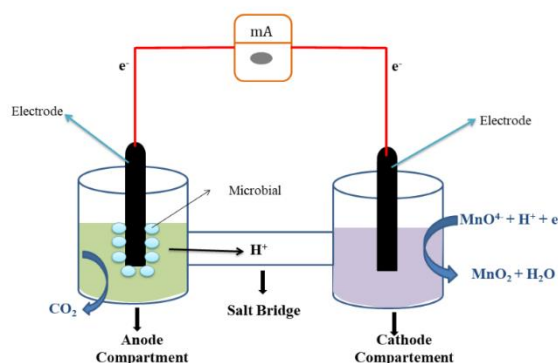
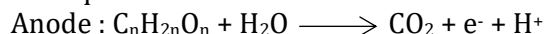


Figure 3. Design sketch of Double Chamber Microbial Fuel Cells

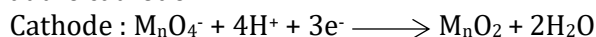
In the anode and cathode chambers, chemical processes occur. Organic waste in cabbage waste and microorganisms in the form of *Lactobacillus plantarum* are stored in the anode compartment. Cabbage waste contains a variety of nutrients, one of which is carbohydrate-based. Microorganisms degrade carbohydrate compounds into simple sugar molecules such as glucose, sucrose, etc. The anode's electrode surface promotes microbial adhesion and organic oxidation, generating electrons. Rod carbon was employed as the electrode in this study because of its high conductivity. Micro-

bial Fuel Cells convert chemical energy to electricity by utilizing the catabolic action of living cells, specifically bacteria (biocatalysts). When bacteria oxidize substances, they collect electrons and transport them to a series of respiratory enzymes that store energy in cells in the form of adenosine triphosphate (ATP). The electrons are transferred to electron acceptors such as iron, nitrate, sulphate, or oxygen. Microbes decompose organic substrates in the anode chamber, producing electrons (e^-) and protons (H^+) that are transported to the cathode (Bajracharya et al., 2016; Das & Mangwani,

2010; Scott et al., 2012). At the anode, the reaction equation is as follows.



A salt bridge made of NaCl solution connects the anode and cathode chamber. Protons generated during oxidation travel through the proton exchange membrane to the cathode compartment, where they mix with oxygen to create water (Sekrecka-Belniak & Toczyłowska-Maminska, 2018). The cathode chamber is filled with $KMnO_4$ (potassium permanganate) solution to measure the electrical power. Permanganate has a high redox potential, which may affect the amount of electrical energy generated by Microbial Fuel Cells. The higher the potential difference between the anode and cathode, the greater the amount of electrical power produced. Mn^{7+} is reduced to Mn^{4+} using protons and electrons from the anode compartment (Guerrero-R et al., 2010). The following equation describes the reaction at the cathode.



Bacteria are able to transform organic chemicals into carbon dioxide, water, and energy via chemical reactions at the anode and cathode. Microorganisms need this energy to grow and metabolize. Through the metabolic processes of microorganisms, organic substances can be transformed to electrical energy via Microbial Fuel Cells technology.

Conclusion

Cabbage waste has the potential to generate renewable energy via Microbial Fuel Cells. Cabbage waste can be utilized as a substrate for bacteria to generate electricity. The cabbage waste can be utilized as an organic substrate in Microbial Fuel Cells and as a nutrition for microorganisms in order to produce electrical energy. During the storage of cabbage waste, the total electric current produce does not necessarily grow in proportion to the duration of the storage time. The highest average total electric current generated was 0.022 mA from the four day storage treatment and 0.010 mA from the ten day storage treatment.

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Author's declaration

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

VM was designed in this study and responsible to the manuscript. EN (Graduate Student) carried out laboratory work and analysed data. DH advised about the laboratory technique and conducted manuscript proofreading before submission. All authors read and approved the final version of the manuscript.

References

- Agustina, N. (2016). Pemanfaatan *Brassica oleracea* menjadi pupuk cair organik dengan cara fermentasi (variabel rasio bahan baku dan lama waktu fermentasi). *Jurnal Inovasi Proses*, 1(2), 80–85.
- Aliya, H., Maslakah, N., Nurampi, T., Buana, A. P., & Hasri, Y. N. (2016). Pemanfaatan asam laktat hasil fermentasi limbah kubis sebagai pengawet anggur dan stroberi. *Bioedukasi: Jurnal Pendidikan Biologi*, 9(1), 23–28. [CrossRef](#)
- Angenent, L. T., Karim, K., Al-Dahhan, M. H., Wrenn, B. A., & Domínguez-Espinosa, R. (2004). Production of bioenergy and biochemicals from industrial and agricultural wastewater. *Trends in Biotechnology*, 22(9), 477–485. [CrossRef](#)
- Anisah, & Rahayu, T. (2015). Media alternatif untuk pertumbuhan bakteri menggunakan sumber karbohidrat yang berbeda. In A. Saputra (Ed.), *Seminar Nasional XII Pendidikan Biologi FKIP UNS: Biologi, Sains, Lingkungan, dan Pembelajarannya* (pp. 855–860). Indonesia: Universitas Sebelas Maret. [Direct Link](#).
- Arbianti, R., Utami, T. S., Hermansyah, H., Novitasari, D., Kristin, E., & Trisnawati, I. (2013). Performance optimization of microbial fuel cell (MFC) using *Lactobacillus bulgaricus*. *MAKARA Journal of Technology Series*, 17(1), 32–38. [CrossRef](#)
- Asgar, A., & Musaddad, D. (2006). Optimalisasi cara, suhu, dan lama blansing sebelum pengeringan kubis. *Jurnal Hortikultura*, 16(4), 83054. [CrossRef](#)

- Ayuningtyas, G., Dwi Pratiwi, R., & Yulianti, A. (2020). Pemilahan sampah metode 3R sebagai upaya peningkatan kesehatan lingkungan di Cluster Casablanca Bukit Dago. *Jurnal Abdi Masyarakat*, 1(1), 86–92.
- Bajracharya, S., Sharma, M., Mohanakrishna, G., Dominguez Benetton, X., Strik, D. P. B. T. B., Sarma, P. M., & Pant, D. (2016). An overview on emerging bioelectrochemical systems (bess): technology for sustainable electricity, waste remediation, resource recovery, chemical production and beyond. *Renewable Energy*, 98, 153–170. [CrossRef](#)
- Darmawan, M. D., Hawa, L. C., & Argo, B. D. (2018). Performance of microbial fuel cell double chamber using mozzarella cheese whey substrate. *IOP Conference Series: Earth and Environmental Science*, 131(1), 1–6. [CrossRef](#)
- Das, S., & Mangwani, N. (2010). Recent developments in microbial fuel cells : a review. *Journal of Scientific & Industrial Research*, 69, 727–731.
- Fadillah, M., Sukma, D., & Nurhalim. (2015). Analisis prakiraan kebutuhan energi listrik tahun 2015–2024 wilayah PLN kota Pekanbaru dengan metode gabungan. *Jurnal Online Mahasiswa Bidang Sains dan Teknologi*, 2(2), 1–10.
- Franks, A. E., & Nevin, K. P. (2010). Microbial fuel cells, a current review. *Energies*, 3, 899–919. [CrossRef](#)
- Guerrero-R, N., Rodriguez-, J. A., Garza-Garc, Y., Rios-Gonza, L. J., Sosa-Santi, G. J., Garza-Rodr, I. M. de la, Martinez-A, S. Y., Rodriguez-, M. M., & Rodriguez-, J. (2010). Comparative study of three cathodic electron acceptors on the performance of mediatorless microbial fuel cell. *International Journal of Electrical and Power Engineering*, 4(1), 27–31. [CrossRef](#)
- Haerani, D., Syafrudin, & Sasongko, S. (2019). Pengelolaan Sampah Di Kota Tasikmalaya. In A. Saputra (Ed.), *Proceeding Biology Education Conference: Biology, Science, Environment, and Learning* (pp. 266–274). Indonesia: Universitas Sebelas Maret. [Direct Link](#).
- Kurnianingsih, I., Rosini, R., & Ismayati, N. (2017). Upaya peningkatan kemampuan literasi digital bagi tenaga perpustakaan sekolah dan guru di wilayah Jakarta Pusat melalui pelatihan literasi informasi. *Jurnal Pengabdian Kepada Masyarakat*, 3(1), 61. [CrossRef](#)
- Lee, S. W., Jeon, B. Y., & Park, D. H. (2010). Effect of bacterial cell size on electricity generation in a single-compartmented microbial fuel cell. *Biotechnology Letters*, 32(4), 483–487. [CrossRef](#)
- Liu, H., Cheng, S., & Logan, B. E. (2005). Production of electricity from acetate or butyrate using a single-chamber microbial fuel cell. *Environmental Science and Technology*, 39(2), 658–662. [CrossRef](#)
- Nagong, A. (2020). Studi tentang pengelolaan sampah oleh dinas lingkungan hidup kota Samarinda Berdasarkan peraturan daerah kota Samarinda Nomor 02 Tahun 2011 tentang pengelolaan sampah. *Jurnal Administrative Reform*, 8(2), 105. [CrossRef](#)
- Nurhajati, T., Soepranianondo, K., & Lokapirnasari, W. P. (2016). Uji aktivitas pertumbuhan *Enterobacter cloacae* selulolitik aerob rumen-1 isolat asal limbah cairan rumen sapi peranakan ongole. *Jurnal Veteriner*, 17(3), 383–388. [CrossRef](#)
- Parinduri, L., & Parinduri, T. (2020). Konversi biomassa sebagai sumber energi terbarukan. *Journal of Electrical Technology*, 5(2), 88–92.
- Rabaey, K., & Verstraete, W. (2005). Microbial fuel cells: Novel biotechnology for energy generation. *Trends in Biotechnology*, 23(6), 291–298. [CrossRef](#)
- Rusad, R. E., & Santosa, S. (2016). Pemanfaatan limbah sayur kubis (*Brassica oleracea*) dan buah pepaya (*Carica papaya*) sebagai pakan cacing tanah *Lumbricus rubellus*. *Jurnal Biologi*, 1, 8–15.
- Sayuti, I., Yustina, & Hardianti, N. (2016). Identifikasi bakteri pada sampah organik pasar kota Pekanbaru dan potensinya sebagai rancangan lembar kerja siswa (LKS) biologi sma. *Jurnal Biogenesis*, 13(1), 51–60.
- Scott, K., Yu, E. H., Ghangrekar, M. M., Erable, B., & Duteanu, N. M. (2012). Biological and microbial fuel cells. *Comprehensive Renewable Energy*, 4, 277–300. [CrossRef](#)
- Sekrecka-Belniak, A., & Toczyłowska-Maminska, R. (2018). Fungi-based microbial fuel cells. *Energies*, 11, 1–18. [CrossRef](#)
- Sistem Informasi Pengelolaan Sampah Nasional. (2020). *Data pengelolaan sampah dan RTH*. SIPSN. [Direct Link](#).
- Siswanto, D. (2019). *Indonesia energy outlook*. DEN. [Direct Link](#).
- Sutrisno, J. (2010). Pembuatan biogas dari bahan sampah sayuran (kubis, kangkung, dan bayam). *Jurnal Teknik Universitas PGRI Adi Buana*, 8(1), 100–112. [CrossRef](#)
- Utama, C., & Mulyanto, A. (2009). Potensi limbah pasar sayur menjadi starter fermentasi. *Jurnal Kesehatan*, 2(1), 6–13.