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Electricity Generation through Microbial Fuel Cells Utilizing Leftover Rice as Food Waste

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ABSTRACT

Organic food waste management has been a major issue for the environment, as it poses a significant threat to human health and the ecosystem. Converting this waste into a valuable resource is crucial for sustainable development. In this project, we aim to develop a microbial fuel cell (MFC) using leftover rice as a substrate, which can generate electricity through the electrochemical reactions of microorganisms. The main objectives of this study are to investigate the performance of MFCs under two different conditions: with and without a mediator and catalyst. The experimental results showed that both designs of MFCs achieved optimized outputs, with a minimum of 5V voltage output. This demonstrates the potential of MFCs as a promising alternative renewable energy source. MFCs can be utilized as a sustainable energy source, particularly for rural areas, where access to electricity is limited. Furthermore, large-scale operation of MFCs can significantly reduce food waste, which has a significant impact on health and the environment. By converting food waste into electricity, this technology can help mitigate the negative effects of waste accumulation and contribute to the transition towards a circular economy.

1. Introduction

Organic wastes that are mismanaged have always been detrimental to the environment and harmful towards human's health [1-3]. Therefore, modern societies would make use of such waste to produce electricity. The most popular process to convert organic substances to electricity is biomass. It generates large amount of power, but with low efficiency. However, there is another method of converting organic substance to electricity. This method is called microbial fuel cell and is rather underrated. Microbial fuel cells have been identified as a promising alternative source of power generation due to its clean, efficient, and reliable process that does not generate any toxic by-products, as supported by previous research [4].

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Microbial fuel cells (MFCs) are a technology that utilizes the metabolism of microorganisms to convert it to electrical energy. The MFC consists of several main components: the anode electrode, cathode electrode, separator, and substrate. MFCs have a similar design to batteries, with two electrodes, a separator or barrier, and electrolytes [5]. In MFCs, the substrate is in the anode compartment while the cathode compartment is filled with air or water if oxygen is present. The two compartments are separated by a membrane barrier that should be permeable to protons. Electrons can travel between compartments, but only through an external circuit where each end is connected to the corresponding electrode.

The MFC for this project will focus on using leftover rice as substrate. Other variables that affect the power output will also be considered to ensure maximum power output is generated as possible with limited resources.

As mentioned earlier, improper treatment or handling of organic waste can cause harm to both people and the environment. Food waste is a prime example of organic waste that is difficult to eliminate completely. Additionally, households require electricity to carry out their daily activities. To address this issue of mismanaged organic waste and generating power for residential, commercial, or industrial use, renewable energy plants are available. Biomass is a renewable energy source that can produce a significant amount of power, but its combustion process leads to considerable heat loss and low efficiency [6]. Moreover, the installation cost is high, and it can only be used as a power plant for more than one household [7]. However, there is an eco-friendly alternative energy source that can compensate for this heat loss, namely the microbial fuel cell (MFC), which has a significantly higher efficiency compared to biomass [8]. Although it may produce less power than biomass, the installation cost of MFC is much cheaper, and it can be installed in each house independently. The materials required to build MFCs are often either unavailable or very expensive [9]. Nevertheless, various methods and materials can be used as substitutes to address these issues [10]. MFCs can utilize organic waste such as leftover food as substrate or fuel to generate power [11].

Despite the promising potential of microbial fuel cells, there are still several challenges that need to be addressed. One of the major issues is the low power output of MFCs, which limits their practical application. While MFCs have been shown to produce electricity, the amount generated is typically lower than what is required for practical applications. Additionally, MFCs are often sensitive to variations in temperature and pH, which can affect the performance of the microorganisms involved in the process. Furthermore, there is still a lack of understanding of the microbial community involved in MFCs, and the factors that influence their activity and efficiency. Therefore, there is a need for further research to optimize the performance of MFCs and to identify the most effective ways to scale up this technology for practical applications.

The objective of this project is to design and build a Microbial Fuel Cell (MFC) that can generate electricity using leftover rice as a substrate. The MFC will be constructed using simple and easily accessible materials for its components. The project aims to investigate the performance of the MFC daily by measuring the electrical output generated by the device over a period. The project will also analyze the effectiveness of using leftover rice as a substrate for electricity generation and evaluate the potential for scaling up the technology for larger-scale applications in the future.

2. Literature Review

Ever since human population has risen drastically since the last century, the demand for electricity is also at all-time high. Alongside that, waste produced is also high and can lead to harming the environment. To counter these two problems, MFC is one of many methods to the solution. Its key aspect is to handle the organic waste by human, specifically food waste, while at the same time generate electricity. Aside that, MFC can also filter the fuel or substrate and produce water. This chapter provides detailed research on MFC designs, food wastes as potential substrates, and electrodes material selection.

Several MFCs have been applied previously by various parties. However, MFCs were only applied for practical experiment instead of residential or commercial use. There were not many MFCs sold as a complete set in the market due to more research needed to be conduct. With detailed research on specific MFC designs, substrates, electrodes, and separator, an efficient eco-friendly renewable energy source can be installed in a residential premise if planned carefully as well.

2.1 Microbial Fuel Cell Designs

To optimize the efficiency of MFC, a thorough inspection on which design to use is important. As time passes on, MFC has been developed into several new designs. These newer designs have their own additional uses and flaws. Nonetheless, they stem from the original MFC design. The MFC designs mentioned are standard MFC, Microbial Electrolysis Cell (MEC), Microbial Desalination Cell (MDC), and Microbial Electrosynthesis Cell [12].

MFC is a one of many renewable energy sources that can be further explored for suitable and efficient applications. It is mostly self-sustainable and friendly towards the environments. The process involves respiration of microbes in a chamber filled with substrates that will eventually produce electricity [13]. To simplify, it converts chemical energy to electrical energy. Normally, there would be two chambers in MFC, anode chamber and cathode chamber and commonly known as double chamber MFC. The schematic of MFC can be referred in Figure 1.

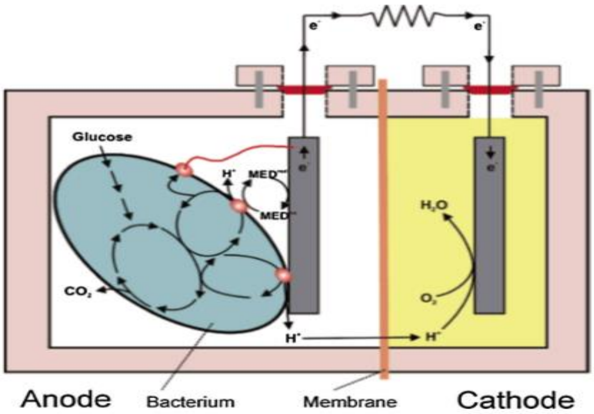


Fig. 1. Double/dual chamber MFC [14]

The anode chamber is sealed airtight to prevent external oxygen from entering. Both chambers are separated by a membrane that is only permeable to protons. Electrons will travel through closed circuits connected externally. In anode chamber, microbes or bacteria will consume substrates and water to produce hydrogen ion and electrons. As for the cathode chamber, it will receive the hydrogen ions and electrons only to react with oxygen. The product in this chamber would be water [15]. Electrons travelled between both chambers and passing through load will produce current. The chemical reactions involved in anode chamber, cathode chamber, or overall can be seen in Eq. (1), Eq. (2) and Eq. (3) [5].

$$\text{Anode reaction: } C2H4O2 + 2H2O > 2CO2 + 8H+ + 8e\text{-} \tag{1}$$

$$\text{Cathode reaction: } 2O2 + 8H+ + 8e\text{-} > 4H2O \qquad (2)$$

$$\text{Overall cell reaction: } (CH2O)n + nH2O > nCO2 + 4nH+ + 4ne\text{-} \qquad (3)$$

The MFC can generally be seen as a battery. It consists of two electrodes and electrolyte, which can commonly be found in most batteries [5]. In some cases, MFC can also be designed with only one chamber, or commonly known as single chamber MFC. This MFC does not require the separator or a membrane. It does, however, still require two electrodes. This design is used because membranes in MFC may result in protons to gather in anode chamber. This will reduce the pH value of substrates and lead in deterioration of microbe's performances [16]. Figure 2 shows the diagram of a single chamber MFC. In contrast to MFC, MEC require external energy to activate it and does not produce electrical energy. The power input is relatively small, around (>1.2V), but the product of MEC is high concentration of hydrogen gas. Installation of MEC is usually combined with other renewable energy sources to achieve self-sustainability. Such devices may be solar power, thermoelectric-power, or MFC itself [17]. The design of MEC is close to that of MFC, only that instead of load at the external circuit, it is connected with external sources.

The MEC is also separated into two designs, single-chambered MEC and two chambered MEC. Both designs, however, end up with the same products and requirements. As with MFC, single-chambered MEC also does not have separator as to prevent accumulation of protons in anode chamber. Disturbances in pH value of both chambers may affect MEC performances.

Since the final product of MEC would be huge amount of hydrogen gas with small amount of power used [17].

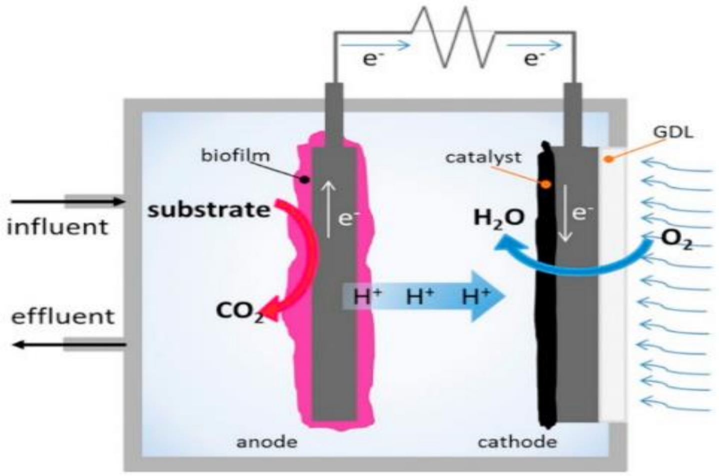


Fig. 2. Air cathode single chamber membrane-less MFC [16]

2.1 Food Waste

Food waste is the unwanted byproduct or leftover after humans consuming sustenance. These organic substances are an ethical issue and may endanger the social, economy, and environment if not managed properly. The mismanagement of food waste is one of the causes of food shortages. Although foods produced are sufficient in feed 7 billion people in the world, but 1.3 billion metric tons of food are lost waste or lost [9,18]. In a world filled with individualists and materialists, they neglect the need to counter food waste problems. Some people prioritize their own happiness over the needs of others. However, not all food wastes are overlooked in terms of mishandling. The ones that do caught the attention of most communities are utilized to transform into more useful route.

Such routes include reduce and recycling food wastes. In reducing, with minimal amount of breakfast, lunch, and dinner consumed, less food wastes are generated. In recycling, food wastes can be used to convert into useful substances such as manure for horticulture [19] or convert into electrical energy.

Due to excessive food waste production, most of them are reused and recycled. One of many ways in recycling food waste is by utilizing these food wastes by converting into electrical energy. The process to convert these organic substances to electrical energy, however, pose difficulties since it composed of variety contents, has high moisture contents, and has low calorific value [20] as can be seen in Figure 3. From Figure 3, there are many ways to convert food waste to other form of energy or useful substances. The useful products that can be converted from food wastes are biodiesel, biogas, ethanol, butanol, and many more [21]. Although the 80-85% of solid wastes volume are reduced and produced electricity, toxic air emissions containing dioxins from incineration are unfavorable in some countries [20]. The incineration of organic substances to generate electricity is called biomass.

Anaerobic digestion (AD) is another way in converting food wastes to other energy. Usually, this method focuses in producing biogas, such as methane and carbon dioxide, and prevent emission to the atmosphere [22]. As time passes on, it is further developed to produce electricity and treat wastewater. This is called microbial fuel cell technology, where it involves anaerobic digestion process. The difference between anaerobic digestion and microbial fuel cell is that AD requires two weeks at most to produce biogas which can later be combusted to produce electricity, while MFC converts food waste to electrical energy directly after two days [23].

Diverse type of foods gives of different power output when converting them into electrical energy. Since food wastes are usually a mixture of different type of foods, it is hard to achieve a consistent result.

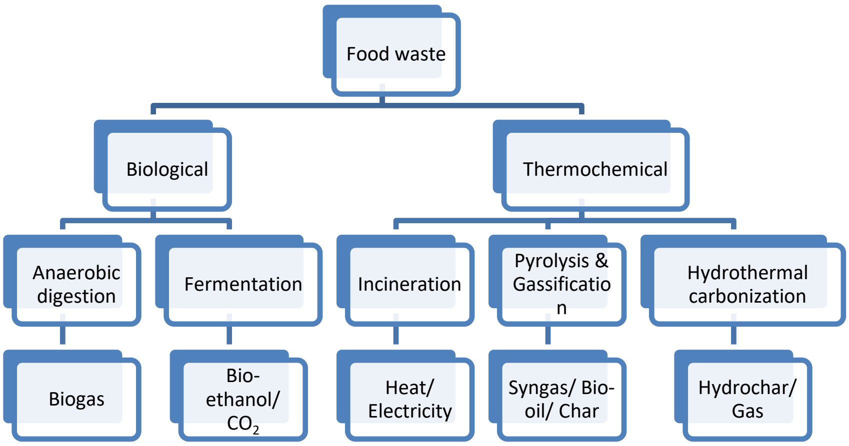


Fig. 3. Food waste to other energy technology

2.3 Electrodes

Current flows in a circuit if the loop is closed. The circuit's pathway is usually made of conductive materials. Some devices consist of a close circuit with halfway made of conductive materials, while the rest is non-conductive. These devices are batteries and fuel cell. The junction where the conductive and non-conductive materials met in these close circuits are called electrodes. Electrodes are conductive, though they do not have to be metallic. Some conductive electrodes are carbonaceous-based materials. Electrodes in a circuit consist of two types, anode and cathode.

Anode accepts electrons and leads them flowing to cathode through external circuit, or load. Cathode release electrons for any positive ions inside cathode chamber to form bond with it.

As the name implies, microbial fuel cell is another fuel cell technology. This means that electrodes exist in its design. There have been several materials used as electrode in microbial fuel cell. Selection of materials are based on several characteristics. The characteristics mentioned are conductivity towards electricity, corrosive resistance, great mechanical strength, large surface area, biocompatibility, friendly towards environment, and low cost [12]. Figure 4 shows the materials that can be used as electrodes in MFC. The materials selected must also be assigned accordingly whether they are anode or cathode.

The materials mostly used as electrodes in microbial fuel cell are carbon materials. Such materials include graphite fiber brush, carbon cloth, graphite rod, carbon paper, reticulated vitreous carbon (RVC), and carbon felt [14]. The materials mentioned comes in all shapes and sizes, though regardless of materials, the larger surface area produces more power output. In other cases, metallic-based materials are also used as electrodes for microbial fuel cell. The popular metallic-based materials used are zinc as cathode and copperas anode. These materials are chosen instead of graphite, iron, and carbon due to it being cheap and high electricity conductivity [24]. However, copper and nickel ions in anode chamber can be poisonous to the bacteria and may result in reduced performance [12].

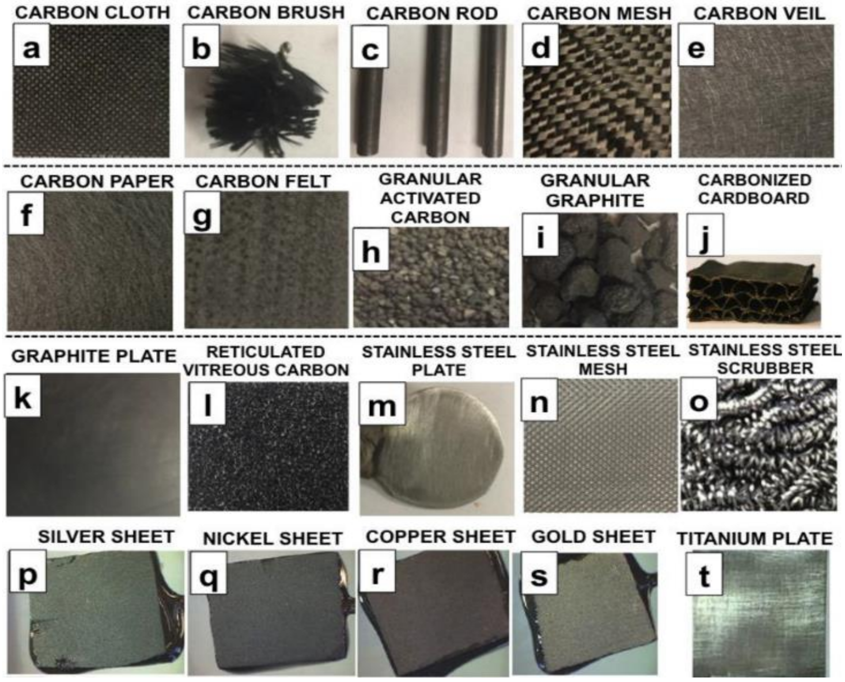


Fig. 4. Materials suitable to be used as MFC’s electrodes [12]

2.4 Separators

Batteries and fuel cells are technologies that produce electricity through the use of electrochemical reactions. As mentioned before, electrodes are the terminals that connects chemicals that consist in anode and cathode chamber with external electrical circuit. The component that separates anode and cathode is called separator. Most batteries use separators that soaked with electrolytes. Different batteries use different separators and electrolytes. These separators exist to prevent short circuits within batteries or fuel cell and is seen as safety measure [25].

Microbial fuel cell also requires separator for protons to permeate from anode to cathode compartment. These separators are separated into three categories, which are salt bridge, ion exchange membranes (IEM), and size-selective separators. The first two separators are commonly used in MFC, with IEM being difficult to acquire but more effective.

IEM is further divided into two, which are cation/proton exchange membrane (CEM/PEM) and anode exchange membrane (AEM). CEMs is rather popular among MFCs design since it has low internal resistance and high cation conductivity. Anions are impossible, or at least very difficult to permeate through this separator. Common among CEMs are Nafion, Ultrex, Zirfon and Hyflon. These substances, however, are very difficult to obtain [14].

Other than IEMs, salt-bridge is far simpler to apply it in MFC. It is very cheap, or one can just mixed it with common ingredients to make it. The ingredients to salt-bridge are salt, agar ($C_{14}H_{24}O_9$), and water. Salt comes in many types such as sodium chloride (NaCl), potassium chloride (KCl), sodium nitrate (NaNO3), potassium nitrate (KNO3), and others [26].

2.5 Present Challenges and Future Perspectives of MFC

Despite the potential advantages of MFCs, such as their low cost and ability to treat wastewater, there are still some challenges that need to be addressed before they can be widely implemented as viable technology.

One of the challenges of MFCs is their low power output, which limits their applications to low-power devices. Additionally, the efficiency of MFCs is currently limited by the slow growth rate of the microorganisms and the low current densities that can be generated. Scaling up the technology to commercial levels is also challenging due to the need for a continuous supply of organic matter for the microorganisms to metabolize, and the need for effective materials and designs for the anode and cathode to optimize energy generation.

In terms of future perspectives, MFCs have the potential to become an important source of renewable energy and provide a sustainable solution for wastewater treatment. Further research is needed to improve the performance of MFCs by identifying and optimizing the microbial communities, improving the materials and design of the electrodes, and developing new approaches for generating higher current densities. In addition, MFCs can be integrated with other technologies, such as membrane bioreactors and microbial electrolysis cells, to enhance their performance and expand their range of applications.

Overall, while there are still challenges to be addressed, the potential benefits of MFCs make them an exciting area of research for sustainable energy and environmental engineering.

3. Methodology

Microbial fuel cells come in all design, component materials, and types of fuel used. This gives multiple choices for constructing MFC in terms of design and materials. The research done in this chapter is to ensure what designs and materials to use to construct a microbial fuel cell with higher performance. There are lots of selection to do so. However, the simulation and calculation for microbial fuel cells before application is limited. This setback results in inaccurate assumption in determining the power generated by MFC. Not to mention, type of microbes exist in anode chamber is beyond control for this project. Furthermore, not all effective materials in MFC performance are available. Nonetheless, with correct design and material selection included with boost converter as external circuit, the predicted result will show promising output.

Many variables can affect the output of MFC. These variables are also taken into consideration in constructing it. With mindful and focused preparation, the power generated by MFC will be more efficient. The variables in MFC that affect power generated can be referred to Table 1, along with details and other information.

Table 1
The factors affecting MFC output

Variables	Details	References
Materials of electrodes (anode and cathode)	• Different anode and cathode materials have different power output. • Important characteristics include electrical conductivity, resistance to corrosion, high mechanical strength, developed surface area, biocompatibility, environmentally friendly, and low cost. • Carbonaceous-based and metallic based materials are most common in MFC since both comply to characteristics above. • Experiments conducted by Prasad & Tripathi (2018) indicates that copper anode and zinc cathode were chosen as best electrode materials and cheaper too compared to graphite, iron and carbon.	[12,24]
Surface area of electrodes (anode and cathode)	• Electrodes with larger surface area can increase the output power generated. • MFC produce low power. This is principal problem of MFC. It can be solved by increasing surface area of electrodes.	[4]
Types of substrates	• Substrates acts as a fuel for MFC. Different substrates give different results in terms of power output. • MFC was originally used to remove impurities and pollutants from waste streams before released to the environment. • Research done by Sarma, Tamuly, & Kakati (2021) indicates that MFC using various solid and liquid substrates have performed roughly similar as it is difficult to compare. However, most MFCs use liquid substrates due to easy handling, storage, and accessibility of wastewater in industrial and commercial level.	[27]
Substance of separator	• In ion exchange membrane (IEM), there are cation exchange membrane (CEM) and anion exchange membrane (AEM). CEM is mostly notes as proton exchange membrane (PEM). • Membrane is the separator between anode chamber and cathode chamber. It allows protons to travel between chambers. • The separators are divided into three categories: salt bridge, size-selective separators and (IEM). • Examples of CEM includes Nafion, Ultrex, Zirfon and Hyflon. • AEM is used to counter the limitations of CEM. It utilizes carbonate and phosphate pH buffer to improve proton transfer. • Bipolar membrane (BPM) is combination of both CEM and AEM. Metallic materials such as stainless steel and graphite is used for bipolar plate membrane. • Salt bridge is another separator that can be used in MFC. It is much cheaper and more available compared to CEMs. • Salt bridge can be made of water, Agar, and salt. Most notably salt used is Sodium Chloride (NaCl).	[14,26]
Surface area of separator	• Surface area of separator is also proportional to the power output of MFC. Larger surface area of separator means more protons transferred from anode chamber to cathode chamber. • PEM's (example of separator) surface area plays an important role in electricity generation. Reports indicate that power output is reduced when PEM surface area is smaller than the area of electrodes due to the internal resistance.	[27]

3.1 MFC design

Basically, MFC consist of several developed designs that not only produce electricity, but other products such as hydrogen gas or desalinated water as well. However, some design may require electricity instead of generating it. In this proposed project, a conventional MFC design is chosen to produce electricity and water. The project design with a dual/double chambered MFC as in Figure 1 where anode and cathode consist of their own compartment. Both compartments were separated by a separator and connected through external electrical circuit. The space available in each compartment is planned to be able to store 1500 ml of substrate. The compartment is made of plastic because there are no stronger or robust materials available.

3.2 Electrodes

In MFC, electrodes used is either in metallic-based or carbonaceous-based materials. If the electrodes are made of metallic-based materials, the anode and cathode must be made of different types, depending on if the material is electron acceptor or electron donor. Furthermore, metallic-based materials can corrode easily, and its ion will harm the microbes in anode chamber. For this project, the electrodes used are carbonaceous-based material. To be more specific, they are graphite plates, instead of the previously planned carbon cloth. This is because carbon cloth is extremely expensive compared to graphite plates. The graphite plates are good conductor and resist to corrosion. Both anode and cathode electrodes will use the same material, which is graphite plate. The size of graphite plate is 10cm x 10cm x 0.25cm. This gives the total surface area of graphite plate exposed to surroundings about 210cm^2.

3.3 Substrates (Anode Chamber)

The project is aimed to use food waste as MFC's substrate. In general, food waste is a mixture of all sorts of unwanted or leftover food. This means that in case two identical MFCs are experimented with food waste as substrate, the results may be arbitrary even if the mixture of all sorts of food waste may result in higher performance. Therefore, this project is aimed to focus on one type of food waste, which is rice. In Malaysia, rice is the staple or most common food among the locals. They can hold their edibility in two days at maximum and starts to decompose after that. In MFC, the leftover rice will be mixed with moderate amount of water to ensure electrons flow more easily. Plus, potassium ferricyanide ($C_6N_6FeK_3$) as in Figure 5 will be added as mediator for better performance. The volume of rice in anode chamber used is around 660 g. Besides that, 1700 ml of pool water is also added to ensure there are presence of active bacteria.

Fig. 5. Potassium ferricyanide

3.3 Cathode Chamber and Separator

Whereas for cathode chamber, there is limited of choices as to what substance is to use in cathode chamber. Most MFC uses either air or water for the reaction at cathode chamber. For this project, water will be used in cathode chamber with the volume being around 2200 ml. Potassium permanganate ($KMnO_4$) as can be seen in Figure 6 will be mixed among the water to oxidize it and act as catalyst.

The separator used for protons to permeate from anode chamber to cathode chamber in this project will be a specific membrane. Since cation exchange membranes (CEM) such as Nafion, Ultrex, Zirfon and Hyflon are too costly and unavailable in market, another type of separator should be chosen. Bipolar membranes (BPM) are also difficult to acquire due to its price and effectiveness. This microbial fuel cell project will use a salt bridge as the membrane that separates anode chamber and cathode chamber. The salt bridge used is made by cooking, instead of purchasing directly. This is because there are no ready to use salt bridge available in market. The ingredients used are 200 ml of water, 8g of agar, and 30g salt. They are cooked and stirred at high temperature, stored in a cylindrical PVC pipe, and freeze it to turn it solid.

Fig. 6. Potassium permanganate

3.4 External circuit

Lastly, for the external circuit initial design was implying a boost converter as its external load. However, due to unavailability of function generator to generate 10V at frequency of 50kHz, and the MFC's unexpected high results, the external circuit is replaced with basic yellow LED and a 220Ω resistor.

4. Results

The MFC project undergoes two different experiments, where the first experiment includes the mediator potassium ferricyanide, and the catalyst potassium permanganate. The voltage and current is observed daily. For the second experiment, both mediator and catalyst are absent, and the data are collected at random intervals, at least twice a day. The boost converter circuit will not be used due to real voltage being higher than expected voltage from previous studies. It is expected that the MFC will generate at an average of 0.1V, but during practical experiment the voltage is much higher.

4.1 MFC- First Run

In this MFC project's trial run as can be seen in Figure 7, the content of both anodic and cathodic chambers consists of the addition of 45g of potassium ferricyanide in anodic chamber and 45g of potassium permanganate in cathode chamber. These substances will only act as catalyst, not increase of total power produced. The data are collected daily on this run as depicted in Table 2. Thus, after completely observing the data of MFC after five days, it can be summarized that the power generated by it initially started strong, only to gradually decreasing until it eventually reaches 0 W as can be seen in Figure 8 until Figure 10. This is due to the nutrients in anodic chamber continue to deplete as bacteria needs to oxidize to survive.

Between day 1 and day 2, the power generated increased because bacteria reproduce in the anodic chamber as there are still plenty of nutrients. Increase number of bacteria will lead to more power generated, assuming the nutrients are infinite. However, as more bacteria reproduced, the rate of nutrients consumed by these microbes steadily increase as well.

Fig. 7. MFC project first run

Table 2
The compilation of MFC outputs trial run

Day	Voltage, V	Current, mA	Power, W
1	2.31	10.61	0.0245
2	6.19	27.88	0.1726
3	5.33	24.37	0.13
4	3.57	16.03	0.0572
5	1.36	6.2	0.0084

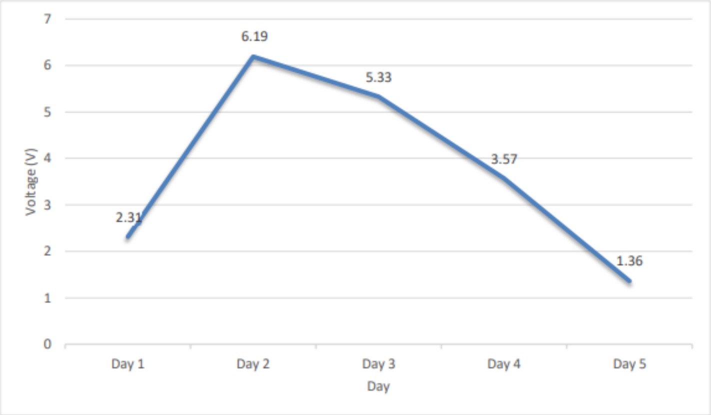


Fig. 8. Graph of voltage vs days passed

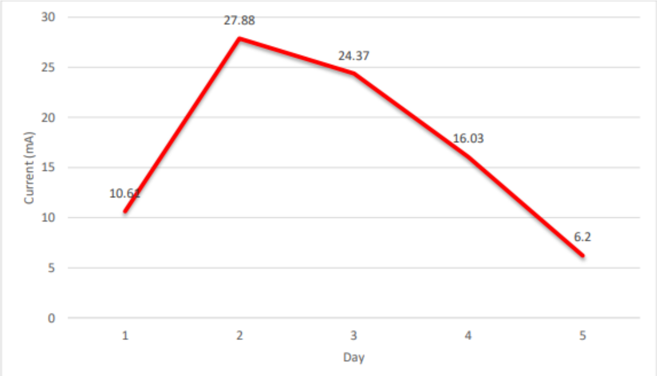


Fig. 9. Graph of current vs days passed

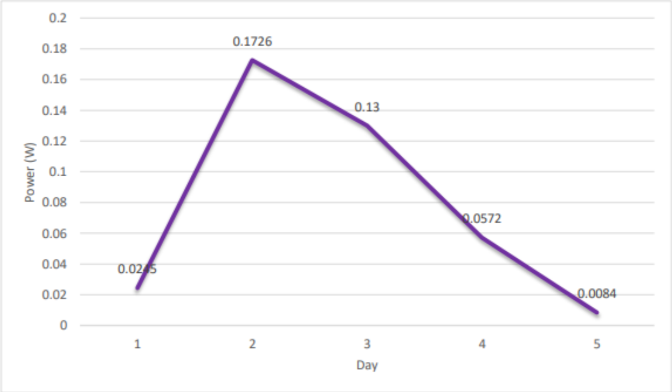


Fig. 10. Graph of power vs days passed

4.2 MFC- Second Run

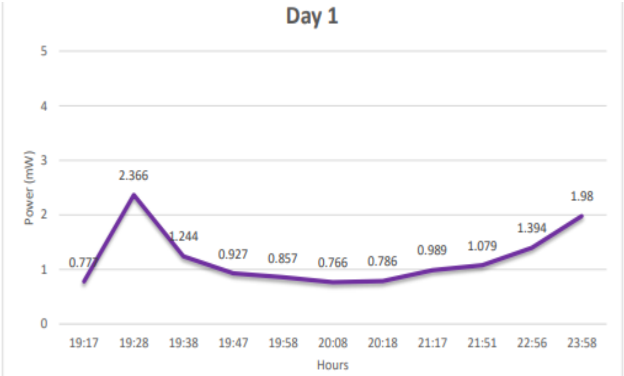
After the initial first run is completed, a second project was conducted as can be seen in Figure 11. This time, the project will run at the same condition as before, except that it will exclude the catalyst and mediator in both chambers. Besides that, the data recorded will be at random intervals, with at least two or three times a day as shown in Table 3 and its corresponding graph in Figure 12. The purpose of changing the time intervals of recording data is to extract a more precise and accurate one than before. Mediator and catalyst are both removed to observe whether there are any behavioral changes to the microbes.

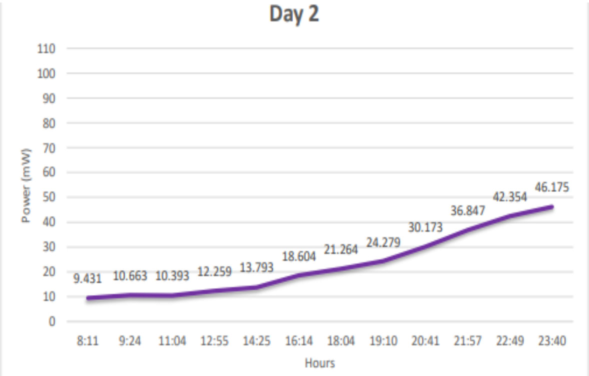
Fig. 11. MFC setup second run

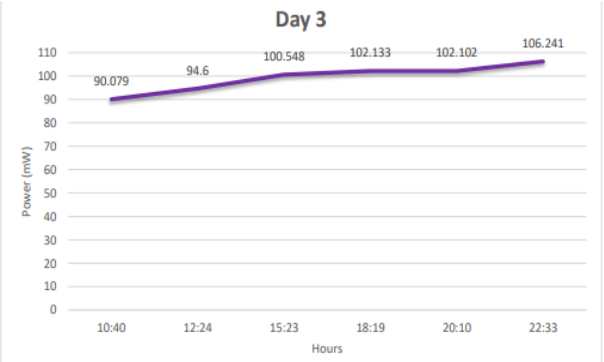
Table 3
The compilation of MFC outputs test run

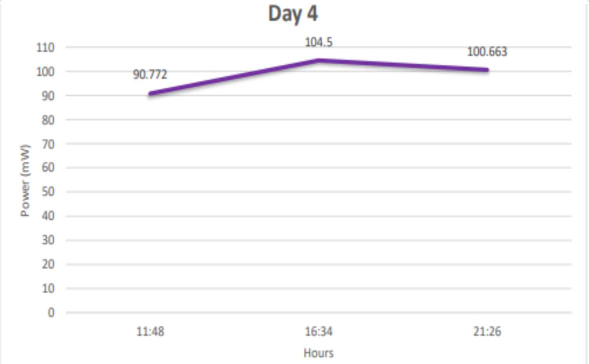
DAY 1			
HOURS	VOLTAGE, V	CURRENT, mA	POWER, mW
19:17	0.415	1.873	0.777
19:28	0.721	3.282	2.366
19:38	0.523	2.378	1.244
19:47	0.451	2.056	0.927
19:58	0.435	1.969	0.857
20:08	0.413	1.855	0.766
20:18	0.416	1.89	0.786
21 :17	0.466	2. 123	0.989
21:51	0.487	2.215	1.079
22:56	0.555	2.511	1.394
23:58	0.675	3.07	1.98
DAY 2			
HOURS	VOLTAGE, V	CURRENT, mA	POWER, mW
8:11	1.441	6.545	9.431
9:24	1.53	6.963	10.663
1 1:04	1.512	6.874	10.393
12:55	1.642	7.466	12.259
14:25	1.742	7.918	13.793
16:14	2.02	9.21	18.604
18:04	2.163	9.831	21.264
19:10	2.307	10.524	24.279
20:4 1	2.576	11.713	30.173
21:57	2.846	12.947	36.847
22:49	3.051	13.882	42.354
23:40	3.19	14.475	46.175
DAY 3			
HOURS	VOLTAGE, V	CURRENT, mA	POWER, mW
10:40	4.451	20.238	90.079
12:24	4.563	20.732	94.6
15:23	4.702	21.384	100.548
18:19	4.74	21.547	102.133
20:10	4.739	21.545	102.102
22:33	4.832	21.981	106.241
DAY 4			
HOURS	VOLTAGE, V	CURRENT, mA	POWER, mW
11:48	4.468	20.316	90.772

16:34	4.794	21.798	104.5
21 :26	4.703	21.404	100.663
DAY 5			
HOURS	VOLTAGE, V	CURRENT, mA	POWER, mW
13:34	4.521	20.622	93.232
18:51	4.506	20.508	92.409
DAY 6			
HOURS	VOLTAGE, V	CURRENT, mA	POWER, mW
8:23	4.323	19.672	85.042
9:52	4.297	19.538	83.955
10:54	4.203	19. 121	80.366
12:33	4.156	18.89 1	78.51 1
13:40	4.074	18.52	75.45
15:04	3.933	17.912	70.448
17:58	3.821	17.372	66.378
19:23	3.671	16.694	61.284
20:20	3.602	16.388	59.03
21 :53	3.577	16.27	58.198
22:47	3.48	15.827	55.078
23:49	3.413	15.563	53.117
DAY 7			
HOURS	VOLTAGE, V	CURRENT, mA	POWER, mW
8:50	2.721	12.39	33.713
9:43	2.81	12.778	35.906
11:34	2.736	12.454	34.074
12:56	2.786	12.683	35.335
14:12	2.707	12.307	33.315
15:15	2.69	12.249	32.95
16:39	2.612	11.88	31.031
18:02	2.537	11.541	29.28
20:3 1	2.441	11.098	27.09
21:55	2.391	10.892	26.043
23:29	2.31	10.548	24.366









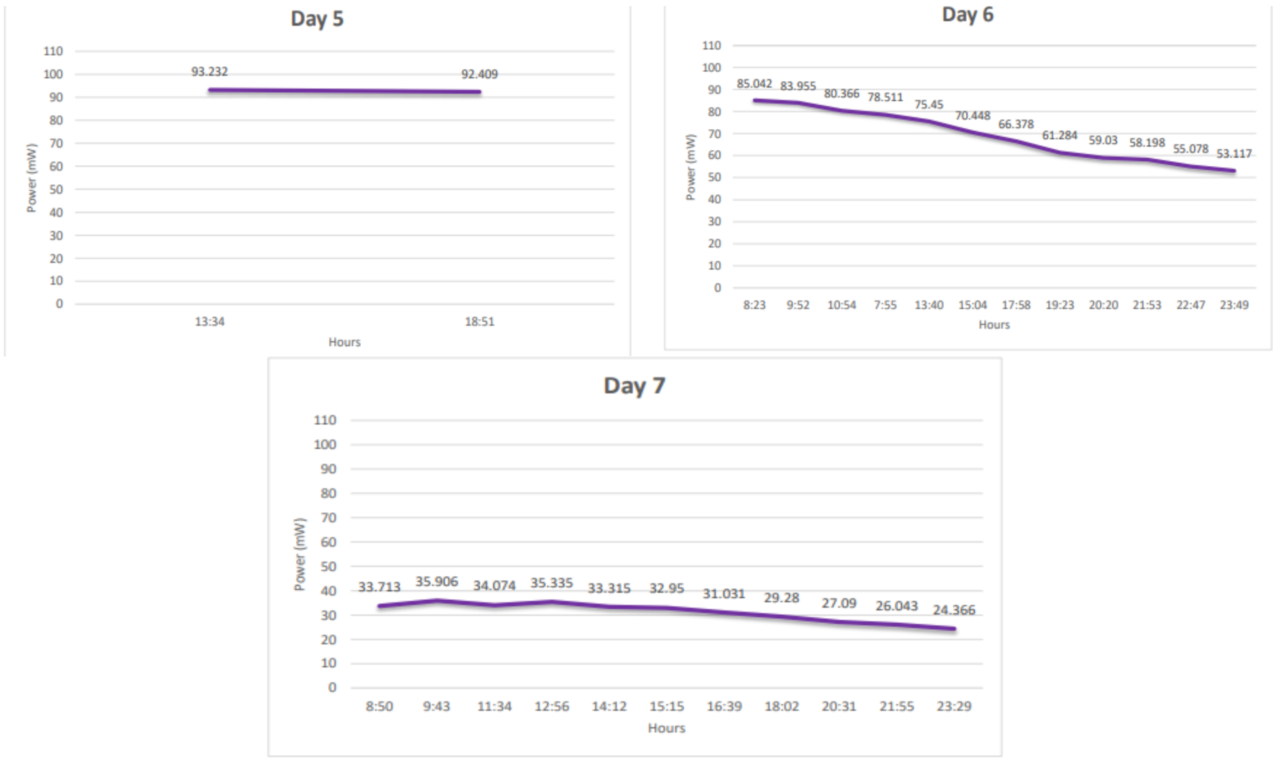


Fig. 12. Graph of power generated vs time passed for 7 days

After conducting the second project run for one week, the power generated by MFC is initially low. In due time, it slowly rises until its peak at day 3. The power generated then will remain constant for 2 more days, only to later decrease in power. In day 6, the power generated is already reduced and gradually decreasing. It can be predicted that power generated will be 0W after a week.

At the start of project run, there is a small spike in power generated. This is due to oxygen demand increase between the moment anodic chamber is sealed, and external circuit is connected. The power generated slowly increased due to increase number of bacteria as the microbes continue to oxidize. The power generated is then remained constant for some time due to inactive reproduction of bacteria. The steady decrease of power generated indicates that nutrients in food waste are low and will run out after a week.

From both set of results obtained in MFC trial and test run, there are differences in power generated when including mediator and catalyst. As can be seen in first project run, including mediator and catalyst in MFC can increase power generated up to 172.6mW. However, the project only lasted for five days since the nutrients in rice are quickly consumed. In the second project run, its highest power generated around 106.241mW is not as impressive as previous run, but the MFC lasted for one week, and maybe more. This is because the microbes oxidize at much slower rate than previous MFC run conducted. Regardless of both projects run, the power generated by MFC is rather high than previously predicted power generated, which is around 0.1V.

The results of this study demonstrate the potential of microbial fuel cells (MFCs) as an eco-friendly alternative energy source for the efficient conversion of organic waste into electrical energy. The use of MFCs can provide a sustainable solution to the problem of mismanaged organic waste and generate power for residential, commercial, or industrial use.

The literature suggests that MFCs can utilize a wide range of organic substrates, such as wastewater, agricultural waste, and food waste, for the generation of electrical energy [28]. One advantage of MFCs over other bioenergy technologies is their ability to operate continuously, as long as the organic substrate is supplied to the anode compartment [29]. Moreover, MFCs have been shown to have a higher energy conversion efficiency compared to other bioenergy technologies, such as anaerobic digestion and composting [30].

Although MFC technology is still in its infancy, there has been significant progress in recent years in terms of improving its efficiency, scalability, and cost-effectiveness [31]. For example, researchers have developed novel electrode materials, improved cathode design, and optimized reactor configurations to enhance the performance of MFCs [32]. Additionally, the use of synthetic microbial communities, or microbial consortia, has been proposed as a strategy to improve the stability and performance of MFCs [33].

Despite the promising potential of MFCs, there are still several challenges that need to be addressed before their widespread adoption. These challenges include improving the durability and stability of MFCs, optimizing the electrode and reactor design, and reducing the cost of production [28]. However, with continued research and development, microbial fuel cells have the potential to become a game-changing technology in the field of renewable energy.

5. Conclusions

In conclusion, this project successfully demonstrated the potential of microbial fuel cells as a sustainable and efficient technology for converting organic waste into electrical energy. The utilization of food waste as a substrate has shown promising results in terms of generating both electricity and water. The construction and operation of the MFC were found to be simple and user-friendly, with moderate efficiency despite limited resources for assembly. The eco-friendly nature of this technology, as well as its renewable energy source, make it an attractive alternative for small-scale applications.

Although the power generated by the MFC may not be enough to power large electrical appliances, it can still be used to power small electronic devices or stored in batteries for later use. The research also highlights the need for further development and optimization of MFCs to address the current limitations and challenges associated with this technology.

As per the existing literature, microbial fuel cells have shown significant potential for wastewater treatment, biogas upgrading, and bioenergy recovery. Future research should focus on developing more efficient electrode materials and enhancing the performance of MFCs to make them more practical for larger-scale applications. Overall, microbial fuel cells have proven to be a promising technology in the field of sustainable energy and have the potential to play a significant role in achieving a more sustainable future.

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