Microbial fuel cells constructed from the integration of anaerobic and aerobic sanitary landfill site systems

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Abstract. The world's main source of energy now is fossil fuels but the demand for power is increasing. In addition, the burning of fossil fuels produces harmful greenhouse gases and has a significant impact on the environment. The fuel cell system in this study is based on the aerobic and anaerobic integration system are used in most waste disposal methods in Malaysia. It is a system of electrochemistry results from the oxidation of organic matter that transfers electrons to carbon graphite. This research is to study the effectiveness of the method generating electricity from micro-fuel cells produced from leachate wastewater and it is also conducted to identify microbial activity using a double chamber system. The food waste obtain is divided into double chambers which is aerobic and anaerobic. Digital readings using a multimeter are performed for ten to thirteen days continuously to obtain the highest reading results for voltage and electric current. The measurement of the highest reading result on the 11th day recorded a reading as high as 146.8 mV at 2000 mV while the current reached 28 µA at 2000 µA. This study has proven that there is the production of electrical sources from the activity of organisms present in food waste using microbial fuel cell systems. The result show that food waste and cattle manure produce the highest voltage and current. This has provided an opportunity to explore alternative ways of generating electricity according to the environment and conditions of each region.

Keywords: Microbial fuel cell, aerobic landfill, anaerobic landfill, semi-aerobic landfill.

Track Name: Advanced Technology and Renewable Energy

1. Introduction

Microbial fuel cells convert chemical energy produced by the oxidation of organic or inorganic compounds by a sequential reaction in which electrons are transferred to terminal electron receivers to generate electrical current with the help of microbes. Fuel cells are used to produce electrical electrochemistry from many different chemicals such as hydrogen gas and methanol through the oxidation of fuel at the anode and chemical reduction at the cathode. Microbial fuel cells are unique because they do not require the use of a metal catalyst at the anode. Instead, they use microorganisms that oxidize organic matter and transfer electrons to the anode. The use of microbial fuel cells as an alternative source for power generation is considered a reliable, clean, efficient process, which use renewable methods and does not produce toxic by-products. Thus, recently studies on microbial fuel
cells have demonstrated powerful technologies for the recovery and in-situ conversion of chemical energy into electrical energy \([1]\).

High energy resource requirements in future are driving more research on new and more environmental approach technologies. Until now, fossil fuels have met most of the overall energy needs. This has resulted in a reduction in fossil fuel resources and leads to ecological imbalances. In addition, the burning of fossil fuels produces a lot of carbon dioxide, which is a major dangerous greenhouse gas and has shown alarming effects on the environment. According to some studies, excessive consumption of fossil fuels will lead to two unavoidable issues namely depletion of fossil fuel resources and global environmental problems \([2]\).

Developed and developing countries face challenges in providing energy and addressing the environmental problems generated by the use of fossil fuel technology. Methods for obtaining energy sources from biomass such as ethanol, methane, and hydrogen have been created using environmental friendly technologies and some of these technologies have been applied practically. It is also very important to study new technologies that can generate energy in various forms according to the environment and conditions in each region. Apart from the above technologies, biofuel cells use microorganisms and enzymes, which can produce renewable electrical energy from organic matter contained in food waste are beginning to attract attention as a way to obtain sustainable energy \([3]\). It has not been practically used but if more studies are done to identify this new method thus without any problem electrical by-products can be obtained directly from this micro fuel cell method. Previous studies have been conducted and have shown success in research of microbial fuel cells constructed using graphite felt as the anode and platinum coated as the cathode \([4]\). Another study showed that fuel cell installations in food processing plants could potentially generate 330 kW per day of power at 7,500 kg of waste material based on 30% efficiency \([1]\). Yet the two studies have one thing in common which is to have a space where it puts the anode and cathode together.

To achieve the goals of this research, a specific objective has been outlined, the first is to compare the electric current from the fuel cell generated from the leachate water of food waste by anaerobic and aerobic integration methods. The second is to determine the electrical voltage of the fuel cell resulting from the leachable water of food waste by anaerobic and aerobic integration methods.

2. Materials and Methods

2.1 Preparation of food waste and cattle manure

The sampling location for this research is located at the Faculty of Science and Technology Cafe, UKM Bangi. As in Figure 3.1, the experiment was started by collecting food waste that is already available in the waste bin and a total of five kilograms of food waste for each method is required to ensure that this research study runs smoothly. Then the sample were separated from any plastic so as not to affect the parameters when analysed later. Food waste were blended so that it becomes perfectly blended and more easily digested by bacteria and microorganisms where it will speed up the process of electricity generation by micro fuel cells. Cattle manure in this study was taken from a cattle farm near UKM Bangi.

2.2 Microbial fuel cell

There are two types of methods that were used in this study, namely semi aerobic method and full aerobic method. The semi aerobic method is a condition where there are two chamber that will form the circuit namely the anode space and the cathode space. The anode space was represented by an anaerobic chamber where no air will penetrate this area while the study is in progress. While the cathode space was represented by a semi aerobic chamber which is the area where air entered and reacted with food waste and cattle manure.

The cathode space was also replaced with a full aerobic chamber to test the efficient rate of a circuit. A full aerobic chamber is an area where each space in the container representing the cathode will be filled with air so that all food waste can react when air enters the cathode space.
Food waste were placed into both chambers representing the cathode chamber and the anode chamber as shown in Figure 1. The anode space, which is the anaerobic chamber, were closed so that no oxygen can penetrate the area. While for aerobic chamber there are two types of methods that were used, namely semi aerobic and full aerobic. The full aerobic method where airways were channelled all the way to the bottom of the surface of the chamber. While for the semi-aerobic method, the air was only channelled at the top. This is done to see the rate of oxygen efficiency if it is fully channelled or will not directly affect the rate of voltage and current generation.

![Figure 1. Microbial fuel cell diagram model represents for integration of aerobic and anaerobic landfill design.](image)

3. Results and Discussion

Figure 2 has shown the voltage flow of semi aerobic method which uses food waste generates a voltage of 59.70 mV as the highest total voltage but the voltage generation for this method is faster yet cannot generate more voltage compared to aerobic chamber (101.2 mV) which uses food waste. This is because in a microbial fuel cell, electrons released by bacteria from substrate oxidation in the anode space are transferred to the cathode space through a conductive material. In the cathode space electrons are combined with oxygen and protons are dispersed through the proton exchange membrane or in this study the salt bridge is replaced as a channel. Microbial fuel cells require the constant release of electrons at the anode and the use of electrons at the cathode. The metabolic energy gain achieved for bacteria is directly related to the difference between the anode potential and the redox potential of the substrate. Electrode oxidation organisms use electrons from the cathode to reduce material in the cathode space. In the aerobic chamber, microorganisms can reduce oxygen to water. In an anaerobic environment, nitrate or sulfate can be reduced to nitrite, nitrogen, or sulfur ions. Another bacterial reducing potential is the conversion of carbon dioxide into methane or acetate [5]. The advantage of using this anaerobic and chemical conversion method is that it demonstrates high efficiency, stability and elimination of voltage inhibition that may occur to methanogen [6]. In terms of nutrient degradation and utilization it is clear that fuel cells can use the nutrients in the annolite efficiently and this was done in a short study period.
Figure 2. Voltage comparison between semi aerobics and aerobics microbial fuel cell for food waste.

Figure 3. Current comparison between semi aerobics and aerobics microbial fuel cell for food waste.

Figure 3 shows the current flow graph of the semi aerobic method against the flow of the aerobic method. The flow of the aerobic method is almost similar to the flow of the semi aerobic method but has a different current value because at first it is the same at a current value and then both flows ascending for the second and third day, however decreased on the fourth and fifth day but the flow of semi aerobic method increased drastically until it reached the highest value on the sixth day which is 16.00 µA. The current flow of the full aerobic method increased from the sixth day and reached the highest current value on the eleventh day at a value of 27.00 µA which is consistent with the value of voltage generation 101.2 mV in Figure 2. However, after the current reached its peak value, it decreased drastically and finally recorded a value of 0.00 µA on the thirteenth day. The flow rate for both current and voltage has an internal resistance for the fuel cell but if the current flow increases the rate of voltage generation will
be higher. The decrease in electron emission is due to a decrease in the microbial population when nutrients are depleted and ultimately results in lower current generation.

4. Conclusion
In this study food waste as a substrate, contains organic matter available for energy generation from microbial activity. Graphite carbon rods as electrodes and salt bridges as membranes are used to produce more microbial fuel cells generating more voltage and electric current. Using a salt bridge instead of a proton exchange membrane is more economical because it is cost effective and readily available. Microbial fuel cells that integrate anaerobic and aerobic landfill models produce more voltage and electric current compared to the coupling of anaerobic and semi-aerobic landfill models. Limitation of micro fuel cells is that they cannot operate at very low temperatures due to the fact that microbial reactions are slow at low temperatures. Optimal designs for micro fuel cells are still under research, and different materials for electrodes as well as more selective membranes for proton exchange are still being developed to improve fuel cell performance. The use of two types of methods, namely semi aerobic and full aerobic, can clearly show that oxygen plays an important role in ensuring that microbes can generate electricity.

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