Electricity Production from Tofu Whey using Double Chamber Microbial Fuel Cell: Effect of Sodium Acetate

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Abstract

This study was aimed at evaluating the effect of sodium acetate on the performance of aerated double chamber microbial fuel cells from tofu whey. Six different mass of sodium acetate was soluted in the anode chamber (0, 1, 2, 3, 4, and 5 gr). The value of open circuit voltage (OCV) was taken to analyze the performance. A double chamber microbial fuel cell (MFC) was developed to produce electricity from tofu whey and studied for 1680 hours (70 days). Anode and cathode were made by uncoated graphite rod. After 1680 hours, the electricity production characteristics were obtained. The results show that the highest OCV (274 mV) was reached by adding 5 gr of sodium acetate in the anode chamber. Furthermore, adding 5 gr sodium acetate in the anode chamber could provide more stable OCV then other (0, 1, 2, 3, and 4 gr sodium acetate). From the study can be concluded that adding the sodium acetate in the anode chamber can provide stable and higher OCV.

Keywords: electricity production, microbial fuel cell, tofu whey, sodium acetate

Abstrak

Penelitian ini bertujuan untuk mengevaluasi pengaruh natrium asetat terhadap kinerja sel bahan bakar mikroba bilik ganda aerasi dari bubuk tahu. Enam massa natrium asetat yang berbeda dilarutkan dalam ruang anoda (0, 1, 2, 3, 4, dan 5 gr). Nilai tegangan rangkaian terbuka (OCV) diambil untuk menganalisis unjuk kerja. Sebuah sel bahan bakar mikroba ruang ganda (MFC) dikembangkan untuk menghasilkan listrik dari bubuk tahu dan dipelajari selama 1,680 jam (70 hari). Anoda dan katoda dibuat dengan batang grafit yang tidak dilapisi. Setelah 1680 jam, karakteristik produksi listrik diperoleh. Hasil penelitian menunjukkan bahwa OCV tertinggi (274 mV) dicapai dengan penambahan 5 gr natrium asetat pada ruang anoda. Selanjutnya, menambahkan 5 gr natrium asetat dalam ruang anoda dapat memberikan OCV yang lebih stabil daripada yang lain (0, 1, 2, 3, dan 4 gr natrium asetat). Dari penelitian tersebut dapat disimpulkan bahwa penambahan natrium asetat pada ruang anoda dapat memberikan OCV yang stabil dan lebih tinggi.

Kata kunci: *produksi listrik, sel bahan bakar mikroba, bubuk tahu, natrium asetat*

1. Introduction

Food wastes are the largest component in municipal waste of urban area [4] and it has the potential to produce energy. Most food wastes, generated from communities, restaurants, food productions, and food factories, and end up in the landfill or some in the river without any sustainable treatment. In fact, food waste and food production waste can be used as a useful source of energy [5]. Nevertheless, the waste characteristics influence the selection of technology and waste management including how to convert the waste into a valuable form of energy [9]. Considering Indonesia as the developing country and the 4th most populous country in the world, understanding of a proper technology to manage the food wastes is essentially needed. Furthermore, one of the most food production industry in Indonesia is tofu production. Unfortunately, the waste produced by the production is not treated properly and contaminate the water.

One type of food production waste is in liquid form, often called the leachate or whey. It is addressed by a complex structure and a high pollutant [4]. Food leachate is formed from the hydrolysis or acidogenic stage of the anaerobic process of microorganisms that are rich of volatile fatty acids [10]. Moreover, leachate can be obtained from food waste that contains many organic elements [3] such as NH_4^+-N, heavy metals, organic and inorganic chlorine, salt, etc. Heavy pollutants from leachate can also contaminate water sources [8]. It adversely affects the health of the ecosystem.

A microbial fuel cell (MFC) is a bioelectrochemical system that can convert chemical energy to electrical energy contained in an organic substrate directly [6] and it can be used as a solution to treat leachate or whey. MFC is one of the electrochemical technology to treat leachate and can produce clean energy [8]. It is effective to generate energy and decreases organic matter in leachate [1]. In the common principle of MFC, microbes play an important role as the oxidizing agent from the substrate in the anode side. Microbes oxidize the substrate which produces proton and electron. Here, the electron is produced from microorganisms in the anode side which is then passed into the cathode through an external circuit. After that, electrical energy is resulted and finally water is produced as the waste product. Since the waste product is harmless, MFC is an environmentally friendly method to produce power and a viable alternative for leachate/whey treatment.

In principle, food production waste leachate can be used as a substrate to produce electricity using MFC. One of the food production waste products is tofu whey. Using aerated double chamber MFC, it could produce more electricity than using non-aerated one from acidogenic food waste leachate [8]. It was also reported by previous study by Greenman that aerated MFC could produce more electricity than non-aerated MFC by using landfill leachate substrate [2]. Furthermore, adding the anolyte with the salt solution can generate higher electricity production [5]. One salt solution as a good electrolyte is sodium acetate. The electrolyte can facilitate the electron transfer that produced by microorganism to the electrode in the anode chamber. Even, MFC was not only producing electricity but also could neutralize the acidity (pH number) of the substrate from acidic to alkaline conditions (pH 4-9) [5].

The objective of this study was to evaluate the effect of sodium acetate addition to the performance of aerated double chamber microbial fuel cells from tofu whey. The value of open circuit voltage (OCV) was taken to analyze the MFC performance.

2. Materials and Methods

The tofu whey was collected fresh from the home industry tofu production in Yogyakarta, Indonesia. The six laboratory-scale acrylic double chamber MFCs were used in this study. The anode and cathode chamber was designed with capacity of 128 ml and 64 ml working volume respectively. They were separated by a proton exchange membrane (PEM) of Nafion 212. The anode and cathode were constructed from graphite rod (effective area = 13 cm^2). The electrodes were uncoated with any catalyst, thus cost of this MFC configuration was much cheaper than the MFC with the coated electrode. The electrodes were submerged into the anode and cathode chambers. The electrodes were connected by a copper wire. The air pump was used to supply the dissolved air which contained oxygen in the cathode chamber. The configuration of the aerated MFC is shown in Fig.1.

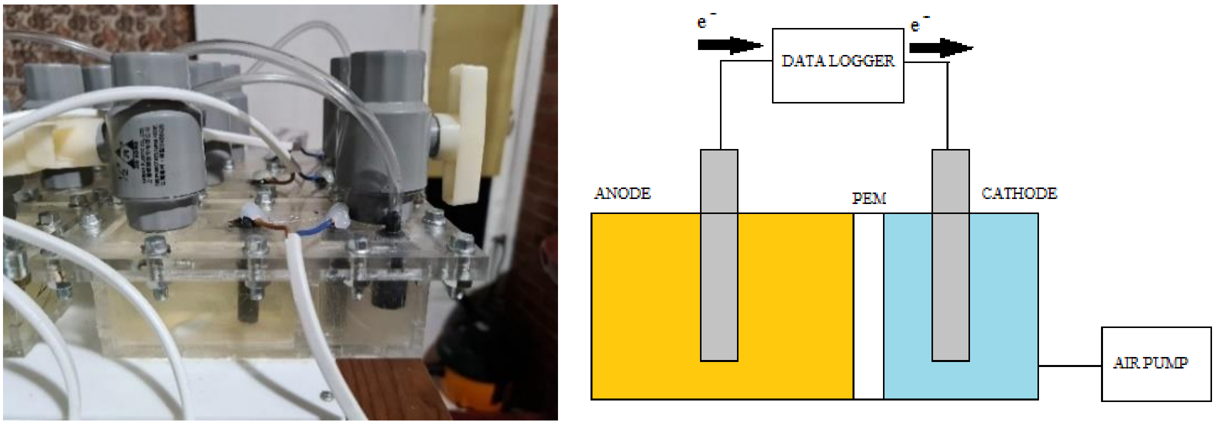

Fig.1. Schematic of aerated double chamber microbial fuel cell.

The anode chamber was fed with 128 ml tofu whey (as a substrate) and maintained to be in anaerobic condition. Sodium acetate (CH_3COONa) was added to the anode chamber with six different masses that were 0 gr, 1 gr, 2 gr, 3 gr, 4 gr, and 5 gr. A 24 g/L of sodium acetate solution was used as an electrolyte in the 64 ml of cathode chamber and maintained to be in aerobic condition. Those microbial fuel cells were operated within 1680 hours (70 days). The result of open circuit voltage (OCV) was recorded every 1 hour. A data logger (Omega OM-SQ2020) was used to record OCV.

3. Results and Discussion

The electricity from tofu whey was resulted during the experimental period. Six MFCs were operated continuously for 1680 hours (70 days) at open circuit conditions. Fig.2 shows OCV of six MFCs with different mass addition of sodium acetate in anode chamber during the experiment. Close observation of the figure indicates that the maximum OCVs (under no-load condition) from six different mass sodium acetate additions are obtained at the different hour of operation (time). The maximum OCV was reached by MFC with 5 gr addition of sodium acetate, it was 274 mV and obtained after 1436 hours (± 59 days) of operation. Then, it was followed by 3, 4, 2, 0, and 1 gr sodium acetate additions that were 245, 197, 163, 145, and 118 mV respectively. They were obtained after 1106, 1658, 374, 1069, and 634 respectively. It is also presented that the maximum microbial growth occurs at those hours for each MFC.

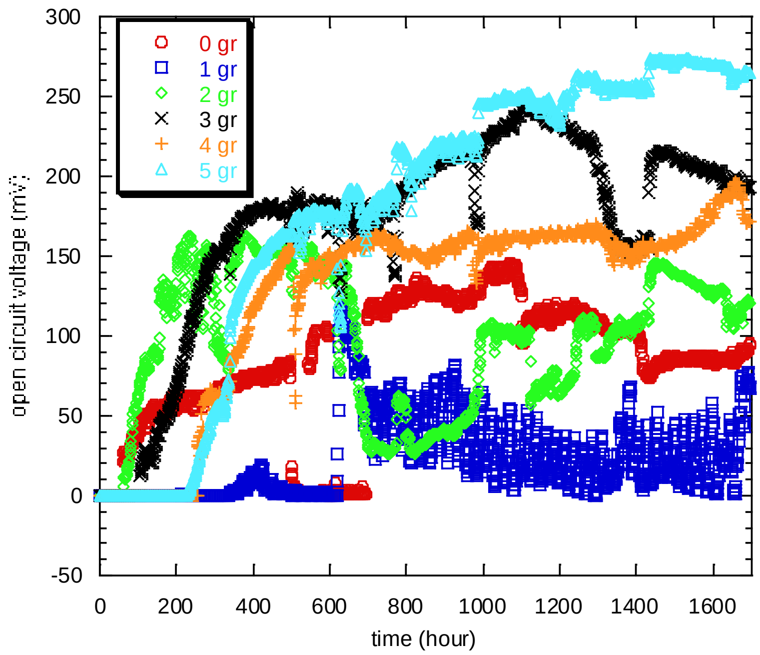

Fig.2. Open circuit voltage of MFCs during operation by different sodium acetate addition.

As we can see from Fig.2, each MFC has different OCV curve. The increase OCV of MFCs with 2, 3, 4, and 5 gr sodium acetate addition is sharper than the MFCs with 0 and 1 gr sodium acetate addition. It indicated that the addition of sodium acetate in the anode chamber can provide faster output voltage increase. The electrolyte from sodium acetate solution in the anode chamber transferred the electron from the bacteria to the anode that did not stick on the anode. The OCV of MFC with 0 gr sodium acetate addition increased faster than the other but after 82 hours of operation, it was overtaken by the MFC with 2 gr sodium acetate addition. The OCV generated by the MFC with 2 gr addition sodium acetate sharply increased and reached the maximum OCV 163 mV at 374 hours of operation. After reaching the maximum OCV, it fluctuated until the end of the operation. Then, the OCV from MFC with 3 gr sodium acetate addition sharply increased before 400 hours operation and then gradually increased to the maximum OCV 245 mV at 1106 hours operation. After reached the maximum OCV, it slightly decreased to the end of the operation and had some fluctuation. Next was the output OCV by the MFC with 4 gr sodium acetate addition. The OCV generated by this MFC sharply increased after 254 hours operation until before 500 hours operation and gradually increased to the maximum OCV 197 mV at 1658 hours operation. Then, the performance declined until the end of the operation.

The highest OCV was generated by the MFC with 5 gr sodium acetate addition. The OCV generated by this MFC started at 230 hours operation and suddenly inclined before 500 hours operation. And then it gradually inclined and reached the maximum OCV 274 mV at 1532 hours of operation. As we can see from Fig.2, the OCV generated by this MFC has more stable increase than the other. It indicates that the addition of sodium acetate in the anode chamber of double chamber microbial fuel cell can generate higher and more stable OCV. From this study, the maximum OCV generated by non-addition and 5 gr addition of sodium acetate was 145 mV and 274 mV respectively. It shows that the addition of 5 gr sodium acetate in the anode chamber can generate almost two times of maximum OCV. After the OCV reached maximum voltage for all MFC, the performance declined. This phenomenon also points out the decrease of nutrient concentration in the feed and also shows the indication that the bacteria start to collapse (die) due to the exhaustion of nutrients.

4. Conclusion

Electricity generation from tofu whey was obtained using six double chamber microbial fuel cells. 0, 1, 2, 3, 4, and 5gr sodium acetate was added in the anode chamber for each MFC. The highest maximum OCV was generated by the MFC with 5gr sodium acetate addition, it was 274 mV, almost two times than non-addtion of sodium acetate. And also, it generated stable amount of OCV. This study proved that the addition of sodium acetate in the anode chamber increases the output OCV and generates stable output OCV of double chamber microbial fuel cell.

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