

Sodium percarbonate addition as electrolyte and buffer to produce electricity economically using industrial-tempeh-wastewater based microbial fuel cell

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Abstract. Microbial Fuel Cell (MFC) is an energy conversion system used by bacteria to generate electricity from organic wastes. Currently, MFC electricity is still small, so it complemented by electrolytes. Previous research shows the addition of potassium persulfate can increase electric voltage 10-fold, but this is less economical so it is necessary to find alternative electrolyte. Sodium percarbonate is a cheap electrolyte which has buffering ability. Therefore, a performance study of single-chamber-MFC using sodium percarbonate electrolyte and or without buffer was conducted by measuring electricity production and tempe wastewater treatment quality (BOD and COD). This result was compared with the results of MFC with potassium persulfate with and without a buffer in the same procedure. In MFC containing sodium percarbonate, charge reversal occurred, with average power 0.04 mW/m², only 1.25% average power of MFC containing potassium persulfate. These results increased by buffer addition. Other results show that MFC containing sodium percarbonate will degrade more than 40% COD, greater than MFC with potassium persulfate, but still not efficient because Coloumb Efficiency was only in the range of 10⁻⁶ %. Nevertheless, this system can produce 63% BOD₅ reduction when a buffer was not added.

1. Introduction

Indonesia's energy consumption is increasing from year to year but, until 2015, only 88.30% of the regions in Indonesia can enjoy the power grid [1]. Electrical energy supply system that can be a solution is an energy conversion system that utilizes renewable resources, such as solar, wind, water, biomass and so on, but efforts need to be made to reduce investment costs by exploring the possibility of power plant mass production. The reduction of investment costs will have a direct impact on production costs [2].

Microbial Fuel Cell (MFC) is an energy conversion system used by bacteria to generate electricity from organic wastes [3]. MFC provides new opportunities for sustainable energy production from biodegradable fuels and can reduce substrate compounds [4]. The principle of the MFC system is that bacteria in the vessel produce electrons then transfer to the anode and conduct to the cathode connected by the conductivity device to produce a power that can run a machinery [5]. When bacteria degrade the substrate, electricity will be produced from MFC, so bacterial growth will be directly proportional to the increase in electricity production. Exclusively for waste substrates, bacterial growth will increase when electricity is produced and a decrease in COD (Chemical Oxygen Demand) [6].



The problem of MFC is the resulting voltage is still very small, so it cannot be applied immediately. To handle this, earlier researchers added electrolytes, such as potassium permanganate [7] and potassium persulfate [8], into the MFC compartment to speed up the electron transfer process that occurs in the anode. A study conducted by Citrasari [9] found that addition of potassium persulfate in MFC was able to increase the electrical voltage 10-fold. However, potassium persulfate price is still expensive, preventing it from being applied on a large scale. Therefore, we use cheap electrolyte, namely sodium percarbonate ($2\text{Na}_2\text{CO}_3 \cdot 3\text{H}_2\text{O}_2$) or washing soda which has natural buffering ability due to bicarbonate ion (HCO_3^-). Power density produced by MFC with sodium percarbonate electrolyte is 9.6 W/m³ so it is worth paired with other electrolytic power density [10].

In this research, we will examine the effect of electrolyte addition by sodium percarbonate compared with potassium persulfate addition on MFC performance, which includes electricity production and COD/BOD₅ reduction. This research purpose is to produce an MFC system without buffer, low capital cost, and can be applied to turn on home appliances.

2. Methods

2.1. Microbial Fuel Cell (MFC) Preparation

MFC preparation comprises of electrode preparation and reactor preparation. The electrodes used in this MFC study include anodes and cathodes made of graphite. This electrode was immersed in 0.1 M HCl for 1 day then rinsed and immersed again with NaOH with the same concentration and immersion duration before used. Preparation of the MFC reactor involves preparing a tubular acrylic-based reactor. The anode that used is elongated cylindrical and installed at one end of the bioreactor, while the cathode is a square-shaped water-cathode. The reactor used is a batch reactor which the top can be opened and then locked with a bolt.

2.2. Substrate Mixture Preparation

The substrate mixture used in this study consisted of incubated liquid tempeh wastewater with/without buffers, electrolytes, and Gram-negative isolates. The prepared electrolytes were sodium percarbonate ($2\text{Na}_2\text{CO}_3 \cdot 3\text{H}_2\text{O}_2$) and potassium persulfate ($\text{K}_2\text{S}_2\text{O}_8$), each 0.03 M content with 225 mL volume. The buffer used was PBS (Phosphate Buffer Solution) 0.1 M pH 7 of 50 mL. The substrate used in this research was the residue of soybean cooking water in tempeh-making process in industrial tempeh manufacture, which the tempeh boiling ratio is 2:3 (w gr/v mL water) [11]. This wastewater is grown in mixed culture by incubating in a closed container for 3 days. 1 mL of this wastewater was then incubated in MacConkey agar for an inverted petri dish position for 24 h at 30°C to obtain Gram-negative isolates. Subsequently, the isolate was incubated in 50 mL of Luria Bertani (LB) medium for 24 hours and 1 mL of isolate was added to the substrate by separation using centrifugation at 400 rpm for 20 min. There are 4 mixture variants for this research which can be seen in table 1.

Table 1. 500 mL substrate mixture variant.

	225 mL sodium percarbonate 0,03 M	225 mL potassium persulfate 0,03 M
225 mL tempeh wastewater + 50 mL buffer	Sodium Percarbonate Buffer (SPB)	Potassium Persulfate Buffer (PPB)
275 mL tempeh wastewater	Sodium Percarbonate (SP)	Potassium Persulfate (PP)

2.3. MFC Experiment

MFC voltage measurements are performed using a digital multimeter connected directly to the CPU/PC. Multimeter used in this study is APPA 109N with data logger feature which is set to record data every 10 seconds. The multimeter is connected to the electrode with the power cable and then given the resistance to make the system into closed circuit with 820-ohm resistor. The experiment was carried out with the reactor condition being turned upside down. The results obtained are electric

voltage data (V) in mV which is then converted to power density ($P = V.I/A$) in mW. A is the surface area of the anode with unit m^2 . I is the electric current obtained from the equation $I = V/R$.

2.4. COD, Coulomb Efficiency (EC), and BOD₅ Analysis

Measurement of COD and BOD₅ were performed on wastewater mixtures in MFC before and after MFC was operated. COD measurements were performed using the spectrophotometric method with 2 mL sample reacted with Reagan HACH Cat. 2125925. Coulomb Efficiency (CE) calculated by using COD removal and current generated by MFC.

3. Result and discussion

3.1. Power Output of Electrolyte Mixture Variation

Overall, the average power density generated by wastewater (WW) + potassium persulfate buffer (PPB) is 15 times the average electrical density. This increase in electricity production is due to the buffer reducing the ohmic resistance [12] and facilitating ion transfer through the anode biofilm [13]. Buffers also inhibit the decrease in pH and increase the conductivity of solutions that affect the production of electricity and wastewater treatment efficiency [14].

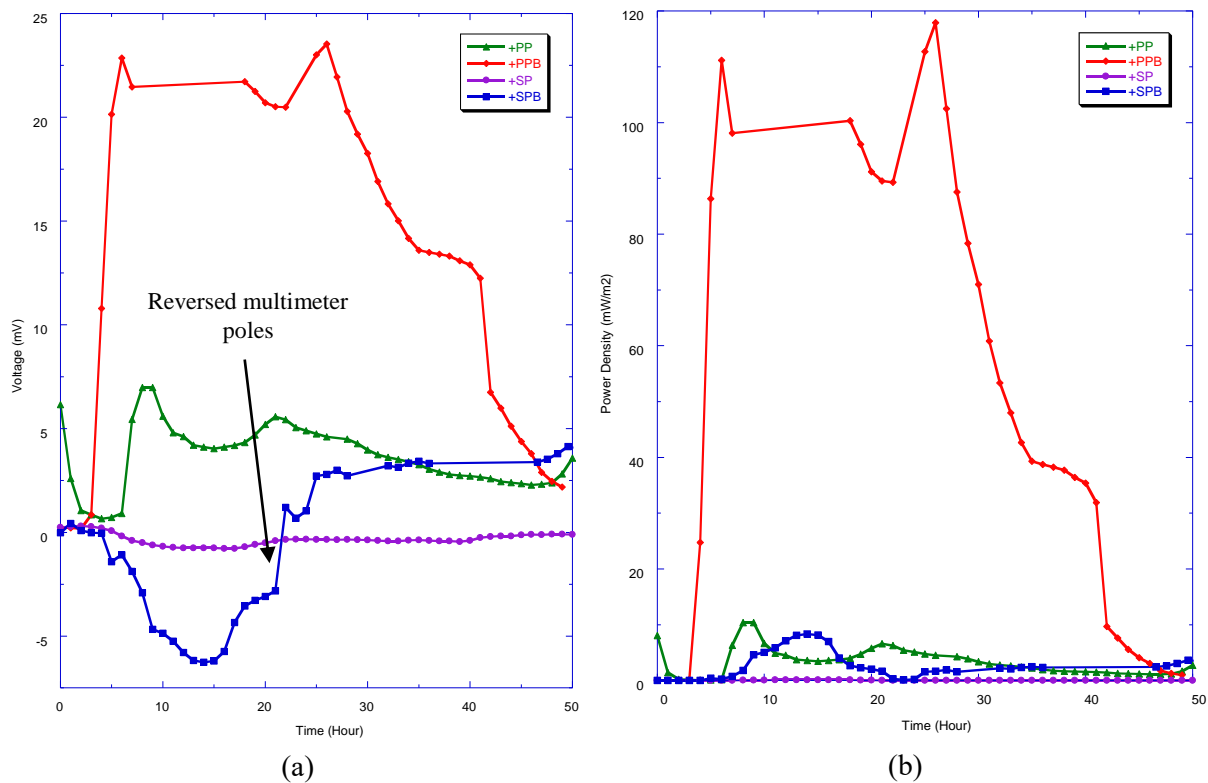


Figure 1. Profile of (a) electric voltage and (b) power density for each variation

The interesting thing to be gained from this research is the charge reversal on MFC using Sodium Percarbonate (SP), which is confirmed by reversing polar at the end of multimeter at 22 hours in MFC WW + Sodium Percarbonate Buffer (SPB) (figure 1(a)). This phenomenon has occurred in stacked MFC [15] One of the things that might explain the phenomenon of charge reversal in this research is the basic environment of wastewater due to pKa sodium percarbonate value is 10.3 (Sigma-Aldrich). This makes oxygen easy to dissolve, making oxygen in MFC is overflow where oxygen come from the decomposition of hydrogen peroxide by mixed culture bacteria [16] and diffusion from the environment. This condition encourages bacteria to stick to the surface of the MFC lid to absorb

oxygen that can produce larger ATPs [17]. The remaining oxygen will tend to do a reduction reaction because of the broadness of the anode surface contact with the wastewater.

The results showed very high average electrical density difference between MFC added by potassium persulfate (PP) (3.32 mW/m^2) with MFC added by SP electrolyte (0.04 mW/m^2). This occurs because the resistance of the flow of protons and electrons due to the oxygen present in MFC tends to be used for aerobic bacteria internal respiration and the presence of electrolyte resistance. This can be handled with the addition of a buffer that shows an increase in electrical density as much as 70-fold in SP electrolyte (0.04 mW/m^2 to 2.87 mW/m^2).

3.2. COD and BOD₅ Removal Measurement

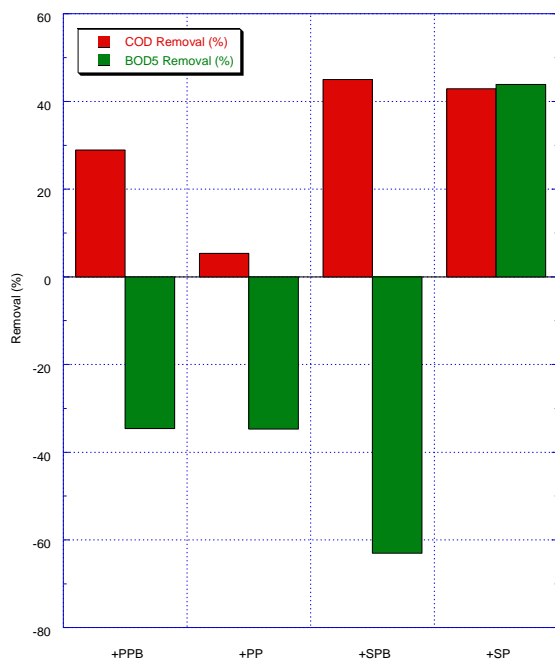


Figure 2. MFC's COD & BOD₅ removal measurement with different wastewater mixtures.

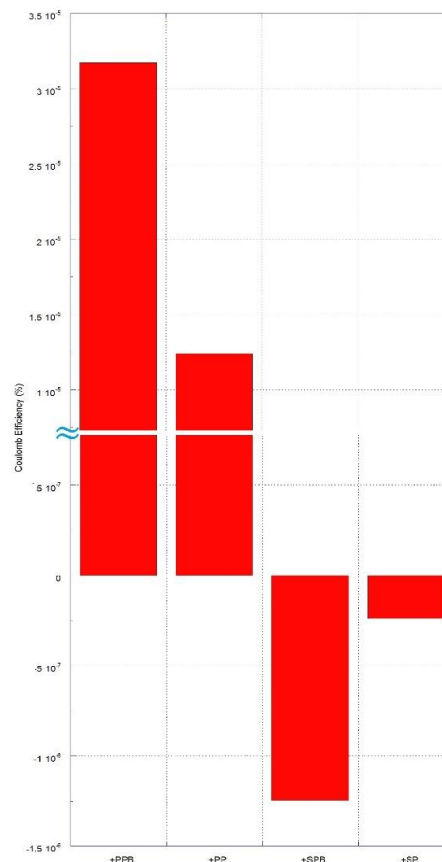


Figure 3. MFC's Coulomb Efficiency analysis measurement with different wastewater mixtures

From the measurement of the COD removal (figure 2), it was found that there was a decrease of COD of 28.9% in MFC added with PPB electrolyte, which was better than COD removal in MFC added with PP electrolyte. This is due to an increase in the conductivity of the solution [14] which is an important factor in improving the performance of wastewater treatment by MFC [18]. However, this is still low compared to MFC added with SP electrolyte, which exceeded 40% removal. This was because increasing the pH of waste after added sodium percarbonate (SP) makes aerobic bacteria grow more so that the conversion of nutrients in wastewater is greater.

The results of the BOD₅ measurements indicate an increase in oxygen in MFC in 3 of the 4 variations of this study, which indicates that bacteria are still actively growing. In the MFC added with sodium percarbonate there was a decrease in BOD₅ by 43.87% but increased by 63.05% when the

buffer was performed. In the WW+SP variant, the basic wastewater environment making almost all mixed culture in wastewater respire aerobically so oxygen in wastewater decreased. This distinct with MFC WW+SPB which the pH was close to 7 (neutral), making a small proportion of mixed culture bacteria which still performs anaerobic respiration and H_2O_2 decomposition, resulting in the greater rate of decomposition and rate of oxygen diffusion to MFC compared to the growth rate of aerobic bacteria.

3.3. Coulomb Efficiency Analysis

Results of Coulomb Efficiency analysis (figure 3) show that MFC system with mixed waste with PP electrolyte is the most efficient variant compared to MFC system with SP electrolyte which has negative value due to the charge reversal phenomenon. The efficiency of Coulomb in MFC with SP electrolyte is very low, only within the range of 10^{-6} %. This shows the tendency of mixed culture bacteria not to release electrons and protons outside the cell and the ineffective hydrogen peroxide electrolyte which has been decomposed by the enzyme catalase in mixed culture bacteria [16].

4. Conclusion

The use of sodium percarbonate in single chamber MFC generates charge reversal electricity with average of power density is 0.04 mW/m^2 , only 1.25% of MFC with an addition of potassium persulfate so it is necessary to add buffers to increase the electrical output. COD removal results showed that MFC with sodium percarbonate addition is a better wastewater treatment system than MFC with potassium persulfate addition, although the conversion of nutrients to electricity production is still not efficient. The BOD₅ removal analysis showed that MFC added by sodium percarbonate without buffer was able to reduce the BOD pollutant present in the wastewater. Thus, single chamber MFC with sodium percarbonate addition without buffer would be better applied as an economical natural waste treatment system without electricity production. Therefore, the use of sodium percarbonate as an MFC electrolyte needs to be further investigated, especially its optimum concentration.

5. Acknowledgments

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6. References

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