Electricity production from gelatin wastewater using single-chamber microbial fuel cells

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Abstract. The purpose of this study was to determine the performance of electricity production from gelatin wastewater in a single chamber microbial fuel cells (MFCs). The treatment of MFCs using effective microorganisms (EM4) with concentration 0% (F0), 1.25% (F1), 2.5% (F2), and 5% (F3). Experimental results showed the voltage, current, and resistance in F1 were better than to other treatments. The best treatment of BOD (20.91±0.95 mg/L) and COD (81.64±0.01 mg/L) values with concentration 1.25% EM4 (F1). The higher concentration of EM4 has given lower of TAN values (3.24±0.01 mg/L for F0, 1.69±0.39 mg/L for F1, 0.73±0.44 mg/L for F2, and 0.24±0.11 mg/L for F3). The pH values were not significantly different in all treatment (7.36±0,02 for F0, 7.34±0.02 for F1, 7.55±0.01 for F2, and 7.11±0.01 for F3). The temperature of all the treatment were 25.8°C. The best performance of electricity production was the treatment with concentration 1.25% EM4 (F1) because in all parameters give the best results, except resistance.

Keywords: electricity production, gelatin wastewater, microbial fuel cells

1. Introduction

A heterogeneous mixture of protein derived from the collagen of animals and bone is gelatin. Gelatin commonly used in industries such as food, pharmaceuticals, photography, cosmetics, and wine fining (Maree et al 1990). The gelatin production includes a variety of unit operations such as acidulation, liming, washing, extraction, filtration, deionization, evaporation, sterilization, drying, and blending (Boran and Regenstein 2010). The wastewater of gelatin productions is highly complex of chemical content, such as nitrogen, calcium, and phosphorus. Due to the complexity of gelatin wastewater, it was very difficult to do treatment with conventional methods (Kruthika et al 2013). The problem of gelatin wastewater is very important for the environment, therefore it was necessary to do a good method for breaking down gelatin wastewater, one of which is microbial fuel cells (MFCs).
The MFCs can reduce gelatin wastewater by breaking down some organic components using microorganisms (Maree et al. 1990). The microorganisms can produce fuels, such as ethanol, methane, and hydrogen, from organic matter, and it is well known can produce the electricity even though was very small energy (Lovley 2006). It was reported the effective microorganisms for MFCs were *Escherichia coli*, *Aspergillus niger*, *Saccharomyces cerevisiae* (Rahimnejad et al. 2009), *Lactobacillus bulgaricus* (Arbianti et al. 2013) and others. A great potential microorganism for using MFCs in the anaerobic chamber was *Saccharomyces cerevisiae* (Rahimnejad et al. 2009). Apart from microorganisms, MFCs also required the presence of substrates as nutrient and energy source (Pant et al. 2010). In microbial fuel cells, the fuel source is generally microbially degradable organic matter. It is related to wastewater gelatin from organic matter. Therefore, the attempt was conducted to determine the microbial fuel cells for the treatment of wastewater from gelatin using the effective microorganisms (EM4).

2. Materials and methods

2.1 Microbial fuel cells design

Single-chamber air cathode MFCs consisted of a single cylindrical plastics chamber (25 cm length, 6.5 cm diameter, volume of 830 mL) containing two activated carbon (anode and cathode) each 1 cm for diameter and 3 cm length (Logan et al. 2006a). The activated carbon was coated by filter (filter plastic and wire) to enhance bacterial attachment (figure 1).

![Figure 1. MFCs design.](image_url)

2.2 Materials

The reactor used gelatin wastewater (gelatin wastewater from fish skin), clay, and EM4 (PT. Songgolangit Persada). The content of EM4 was *Lactobacillus casei* and *Saccharomyces cerevisiae*. The treatment of MFCs using Effective Microorganisms 4 (EM4) with concentration 0%, 1.25%, 2.5%, and 5% (table 1). Volume in reactor by 800 mL.

2.3 Electrical analysis

Current, resistance, and voltage were continuously measured by a multimeter (Sanwa CD770) with a data acquisition system every 4 hours to 168 hours or seven days (Logan and Regan 2006b).
| Materials               | Value (%) | F0 | F1 | F2 | F3 |
|------------------------|-----------|----|----|----|----|
| Clay                   |           | 25 | 25 | 25 | 25 |
| Gelatin wastewater ad. |           | ad. 100 | ad. 100 | ad. 100 | ad. 100 |
| Effective microorganisms|           | 0 | 1.25 | 2.5 | 5 |

ad. 100 = additional to 100%

2.4 Chemical analysis
The aqueous solutions were analyzed for chemical oxygen demand (COD), biological oxygen demand (BOD), pH (pH meter HACH HH 11d), total ammonia nitrogen (TAN), and temperature according to the standard methods suggested by American Public Health Association (Kruthika et al 2013). All the reagent from Merck. COD and TAN measured using spectrophotometry Genesys UV-Vis 10S.

3. Results and discussion

3.1 Electricity of MFCs
Current, resistance and voltage values fluctuated due to interactions and competition that occurs in microorganisms (figure 2,3,4). Changes in electrical values associated with electrons that can bind to the TEA (Terminal Electron Acceptor) including oxygen, nitrate, nitrite, and sulfate which diffuse through the cell then the electrons captured by the anode and the proton captured by the cathode which can cause potential differences that produce bio-electricity (Cheng and Logan 2011). The enhancement of the measured electrical value occurs when microorganisms are conducting simple substrate breakdown inside wastewater. Decreasing the value of electricity happens when microorganisms are adapting to break up the substrate the more complex becomes simple (Logan et al 2006). A microorganism can be a substrate for other microorganisms that causes free electrons and H⁺ ions not generated optimally so that electrons flowing to the cathode are reduced and electricity becomes fluctuating (Lovley 2006).

An electrical voltage which is produced by the MFCs system greatly influenced by internal obstacles (Cheng and Logan 2011). The optimum value of the electric voltage generated on MFCs added by EM4 was 405.10±88.95 mV at a concentration of 1.25% EM4, and the lowest value was the concentration of 0% EM4. High substrate concentrations make bacteria more quickly remove oxygen and reduce the mass of oxygen transfer to the anode or some exoelectrogenic ability to produce electricity (Cheng and Logan 2011). The difference in the highest current and resistance values was a concentration of 1.25% EM4. It was closely related to the current and resistance, so the value will be inversely proportional (Huang and Logan 2008). Table 2 showed that the number of microorganisms does not provide significant work on electricity of MFCs, because a microorganisms need optimum space, nutrients, and energy to live and produce electricity (Logan and Regan 2006).
### Table 2. Electrical parameter of MFCs.

| Electrical parameter | F0                  | F1                  | F2                  | F3                  |
|----------------------|---------------------|---------------------|---------------------|---------------------|
| Voltage (mV)         | Higher 198.90±14.31 | 405.10±88.95        | 283.05±28.21        | 228.85±15.34        |
|                      | Lower 4.35±8.43     | 33.80±5.09          | 21.25±23.41         | 9.35±10.96          |
|                      | Average 81.24±51.08 | 254.46±107.65       | 73.77±67.25         | 61.43±53.69         |
| Current (μA)         | Higher 19.15±18.76  | 46.20±22.63         | 24.65±20.44         | 14.00±15.70         |
|                      | Lower 0.65±0.35     | 1.05±0.35           | 1.05±1.34           | 0.77±0.15           |
|                      | Average 5.18±4.43   | 13.63±11.51         | 4.63±4.37           | 3.45±2.61           |
| Resistance (KΩ)      | Higher 112.50±16.42 | 337.50±81.32        | 163.00±31.11        | 99.50±21.92         |
|                      | Lower 1.80±0.22     | 4.00±0.42           | 3.05±0.07           | 2.35±0.35           |
|                      | Average 21.61±24.03 | 113.37±97.38        | 25.88±38.46         | 18.55±23.46         |

#### 3.2 Chemical parameter

TAN value in gelatin waste has decreased after going through a waste treatment process that is integrated with the MFCs system. This value applies that the more EM4 concentrations were added, the lower the TAN value. This is due to the presence of microorganisms such as *L. casei* and *S. cerevisiae* which can break down ammonia in gelatinous wastewater (Rahimnejad *et al* 2009). BOD reduction was only found in the F1 treatment with a value of 20.91±0.95 mg/L. This decrease was influenced by electrical activity and a small EM4 concentration (Pant *et al* 2010). The slow process of COD reduction in gelatin wastewater was suspected because organic and inorganic materials have not been fully able to be degraded well by microorganisms (Rahimnejad *et al* 2009). The COD value only decreased in the F1 treatment, with a value of 81.64±0.01 mg/L. It was allegedly strong because the process of degradation of the substrate had occurred properly so as to produce an electric voltage and current that was stronger than the other treatments (Pant *et al* 2010). pH and temperature values did not provide a significant difference in this study (table 3).

![Figure 2. Voltage of MFCs, (F1), (F2), (F3), (F0).](image-url)
Figure 3. Current of MFCs, (F1), (F2), (F3),(F0).

Figure 4. Resistance of MFCs, (F1), (F2), (F3),(F0).

| Chemical parameter | F0            | F1            | F2            | F3            |
|--------------------|---------------|---------------|---------------|---------------|
| TAN (mg/l)         | 3.24±0.01     | 1.69±0.39     | 0.73±0.44     | 0.24±0.11     |
| BOD (mg/l)         | 102.95±0.09   | 20.91±0.95    | 370.20±83.95  | 540.87±3.94   |
| COD (mg/l)         | 136.05±0.07   | 81.64±0.01    | 593.85±1.77   | 964.05±0.21   |
| pH                 | 7.36±0.02     | 7.35±0.02     | 7.55±0.01     | 7.11±0.01     |
| Temperature (°C)   | 25.80±0.14    | 25.80±0.01    | 25.80±0.01    | 25.80±0.01    |
4. Conclusion
The increase performance in electrical voltage and current, as well as the declining value of COD, BOD, and TAN, showed that the F1 treatment (concentration 1.25 EM4) had a significant influence on the electricity production of MFCs and decreases in gelatinous wastewater.

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