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The Effect of Adding Activated Sludge and Types of Series Circuit Systems Microbial Fuel Cell (MFC) Using Chinese Food Restaurant Wastewater

Danang Jaya[a*†], Tunjung Wahyu Widayati, Singgih Adi Nugroho and Firda Ellysa

Department of Chemical Engineering, Faculty of Industrial Engineering, Universitas Pembangunan Nasional Veteran Yogyakarta, Depok, Sleman 55283, Yogyakarta, Indonesia

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ABSTRACT: Electricity consumption expands every year. However, in Indonesia, electricity is still highly dependent on conventional energy sources such as coal. Microbial fuel cell (MFC) is one of the alternative inventions that consist of tools series which converts chemical energy into electrical energy in the presence of microbial metabolism. In addition, to producing electrical energy, it may also help to solve environmental issues by dealing with waste. This research purposed to investigate the potential of Chinese food restaurant waste as the substrate to generate electricity in the microbial fuel cell. The research was done in three stages: wastewater preparation, assembly of MFC tools in various circuits, and running MFC processes. Results showed that the best electrical average (1.02 V) was found in the treatment system without active sludge. The best circuit was in the system in 4 series, which obtained an average voltage of 3.71 V and a power density of 61.87 mW/m^2. In addition, with the addition of active sludge, biological oxygen demand (BOD) of the wastewater could be lowered up to 29.27%, and chemical oxygen demand (COD) up to 51.58%. Total suspended solid (TSS) could be decreased up to 49% on the sample without sludge addition.

Keyword: MFC; Active sludge, wastewater, electricity, renewable energy

1. Introduction

The population in Indonesia has already reached 270.2 million people, and it continues to grow every year. Indonesia's population growth rate every year from 2010 to 2020 was 1.25% on average (BPS, 2021). Because of Indonesia's high population growth rate year after year, electricity consumption is also increasing. Non-renewable energy sources such as coal are still frequently used for electricity production. It will be resulted in Indonesia experiencing a power problem in the future. As a result, Indonesia must change to new and renewable energy sources. Furthermore, population expansion led to an increase in the number of Chinese Food restaurants, which risen the amount of produced waste. Chinese food restaurant waste has a high level of pollutants due to its use. The characteristics of Chinese food restaurant liquid waste have a pH range of 6-8 with BOD and COD levels of 58-1,430 mg/L and 292-3,390 mg/L. It also has an oil and fat content of 120-712 mg/L and is suspended at 13-246 mg/L (DLH, 2019). If sewage treatment is allowed continuously, it is not appropriate. If wastewater is released into the environment, excessive growth of microorganisms will occur, resulting in a decline of quality (pollution).

Liquid waste treatment technology is the key to preserving the environment. The liquid waste treatment technology that is built must be able to be operated and maintained by the eligible parties. The developed wastewater treatment technology is generally divided into three treatment methods, namely physical treatment, chemical treatment, and biological treatment. For biological wastewater treatment, it is used to reduce dissolved components, especially organic compounds to a safe limit for the environment by utilizing microorganisms and/or plants (Ibrahim 2005). In the biological treatment of liquid waste, it can be done by adding activated sludge. The method that can be used for processing liquid waste into energy is a biofuel cell. One of the types of biofuel cells is Microbial Fuel Cells.

Research related to Microbial Fuel Cell (MFC) from various types of raw materials and various factors has been carried out by previous researchers. Several factors were accomplished by previous researchers to optimize MFC. In the results of the research, Putra et al (2018) examined one of the MFC factors, namely the type of electrode where the MFC system with Cu and Zn electrodes resulted in the production of greater electrical energy than other electrodes plates. The maximum power value that can be generated from the MFC system for two measurements is 1.26 mW using Cu and Zn electrode plates. Then other factors such as research conducted by Apriyani (2013) concluded that fishery wastewater can be used to generate

[*] Corresponding Author: +6281904025253
Email: danangjay@upnyk.ac.id

electricity through one vessel MFC technology. A load of liquid waste (total nitrogen, BOD, COD, and ammonia) in one vessel MFC with the addition of activated sludge experienced a greater decrease than the treatment without activated sludge for 6 days of observation. The treatment of wastewater without activated sludge has a higher average electrical value than the average electric value of liquid waste with the addition of activated sludge for 120 hours. The highest value of liquid waste electricity occurred at 119 hours, namely in liquid waste without activated sludge 144.9 mV and in liquid waste with the addition of activated sludge 87.6 mV. In addition, in increasing the electricity of the MFC, another very influential factor is the type of circuit used. Research by Novarina (2018) concluded that there is a big difference in the Electromotive Force (EMF) generated between the MFC circuit designs of series, parallel, mixed type 1, and type 17 mixed type 2 with a ratio of 3: 1: 1.5: 2 where the maximum EMF is obtained in a series circuit of 3.29 V. Knowing the best type of electrode is used by analyzing the results of the electricity produced with the MFC system through various series variations.

This research purposed to investigate the potency of Chinese food restaurant waste as the substrate to generate electricity of microbial fuel cell. This research is utilizing active sludge coupled with microbial fuel cell (MFC) technology to treat the waste. Active sludge is often used in the treatment of waste from anaerobic reactors (Ningtyas, 2015). The purpose of using processes with active sludge is to reduce BOD levels, nitrification, and denitrification (Ibrahim et al, 2017). In addition, this research is also to study the effect of various variations of series circuits. The various process variables studied were intended to determine the optimum process conditions to obtain maximum electrical results.

2. Material and Methods

2.1. Materials

The waste substrate was collected from Chinese food waste at Condong Catur, Sleman, Yogyakarta, Indonesia. Active sludge was obtained from a wastewater treatment company (IPAL) in Bantul, Yogyakarta, Indonesia. Other materials used were KCl Powder 0.1 mole, aquadest, gelatin.

2.2. Tools

The main equipment used was a dual glass chamber MFC reactor, consisting of an anode and a cathode chamber separated by a salt bridge. Other equipment was a digital multimeter, Zn electrode, Cu electrode, Cover/Bulkhead, Cable, U Pipe, Glass baker, Measuring Glass, stirrer.

2.3. Procedure

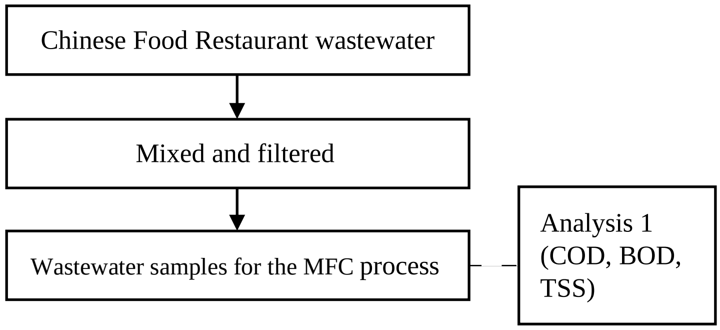


Figure 1. Wastewater Preparation

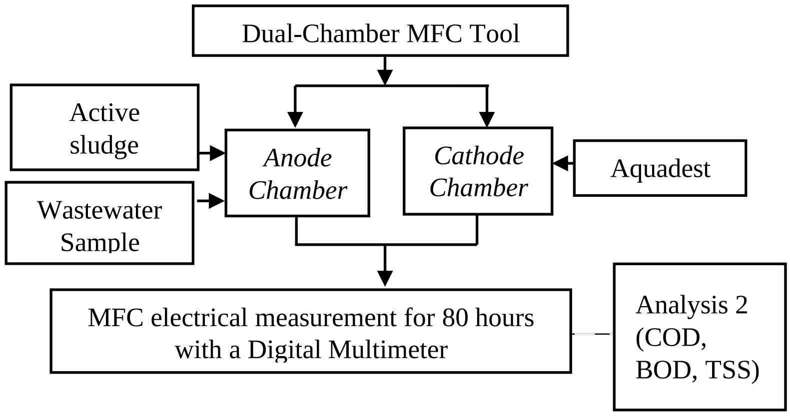


Figure 2. The process with activated sludge

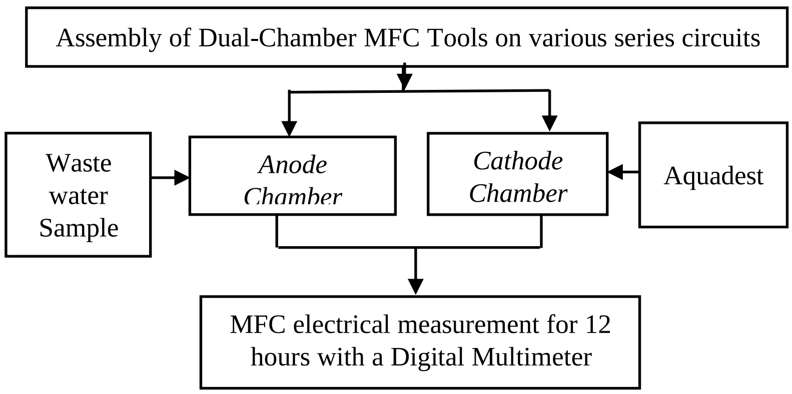


Figure 3. The process on various series circuits

2.3.1. Wastewater Preparation

Chinese food restaurant wastewater samples were put into bottles that had been sterilized using 70% alcohol. The samples were then filtered and analyzed 1 to obtain chemical oxygen demand (COD), biological oxygen demand (BOD), and total suspended solid (TSS).

2.3.2. MFC Tool Assembly

The dual-chamber MFC system was assembled concerning by previously (Novarina,2018), which has been modified. In addition, the use of zinc electrodes as anode and copper as chatode refers to research (Jaya et al, 2021). Then both chambers were connected by salt bridges (U pipes filled with gelatine mixture with KCl powder 0.1 mol). Active sludge and wastewater samples were filled simultaneously into the anode chamber and the active sludge was varied (without active sludge, and with active sludge). The ratio of active sludge and wastewater was 1:7. At the same time, aquadest was inserted into the cathode chamber. After that, the assembly of the MFC system series was carried out.

2.3.3. MFC running process

The process with active sludge was carried out for 80 hours by measuring the electricity generated from MFC every 4 hours using a digital multimeter. After the process was completed, the wastewater was analyzed 2 to obtain the level of BOD, COD, and TSS. In addition, the MFC process on various series circuits was carried out for 12 hours every 1-hour using a digital multimeter.

2.3.4 Analysis

Analysis includes chemical oxygen demand (SNI 6989.2-2019), biological oxygen demand (SNI 6989.72-2009), and total suspended solid (in House Methode) that are tested in Balai Besar Teknik Kesehatan Lingkungan dan Pengendalian Penyakit (BBTKLPP) Yogyakarta.

2.4. Calculation of Power Density

Power density can be calculated using equation (1) as follows:

$$\boldsymbol{Pd} = \frac{(\boldsymbol{I} \: \boldsymbol{x} \: \boldsymbol{V})}{\boldsymbol{A}} \qquad (1)$$

- Pd is Power Density (W/m^2)
- I is Current (A)
- V is Voltage (V)
- A is Anode Surface Area (m^2)

3. Result and Discussion

3.1. Effect of Active Sludge on MFC System Electrical

Electric generation from MFC was taken every 4 hours for 80 hours. From Figure 4, it shows that the initial voltage of the sample without sludge was recorded at 0.94 V, while the initial voltage of the sample with the addition of sludge was recorded at 0.97 V. The difference in electricity occurred due to the number of free electrons captured by the anode in the MFC with the addition of active sludge. It led to an increase in the number of electrons produced due to the degradation of organic compounds by active sludge.

The average voltage value on an active sludge system was recorded at 0.99, while the sample without active sludge was recorded at 1.02 V. Currently, microorganisms have adapted to the MFC system to increase microbial growth, and electricity also increased. Nevertheless, at above 40 hours, the generated electricity decreased. It could be due to reduced nutrients in the system. According to research by Hou et al (2015), it also can cause most of the oxygen aerated in the aeration tank can not be consumed by activated sludge, but it is released to air due to the mass transfer limitations, causing a vast waste of energy in activated sludge processes.

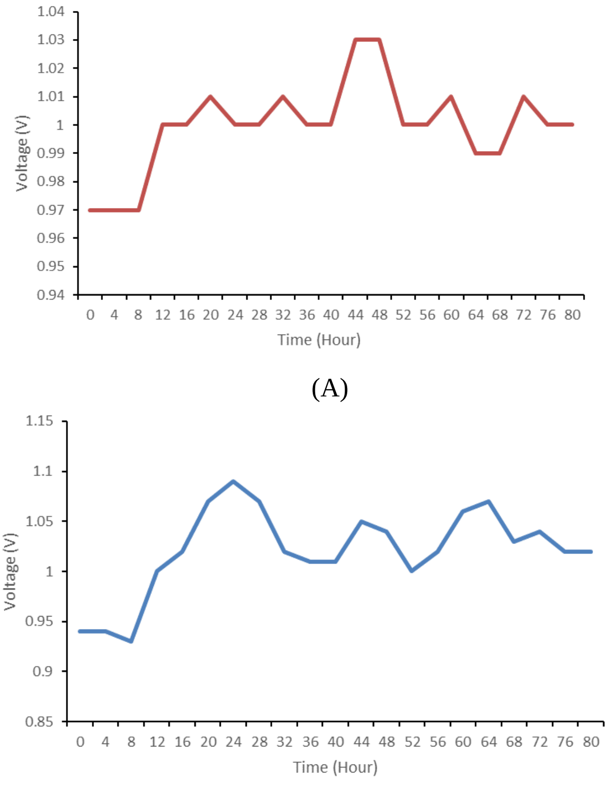
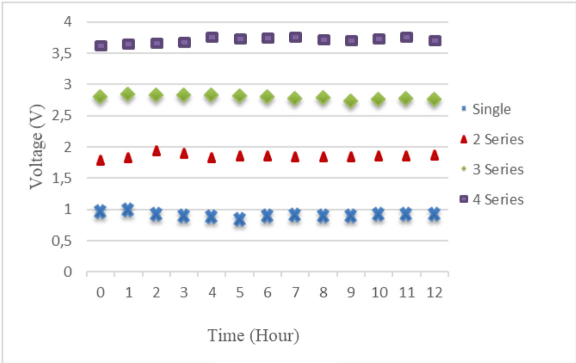


Figure 4. Electrical value in MFC with (A) Without Active Sludge; (B) With Active Sludge Comparison 1:7

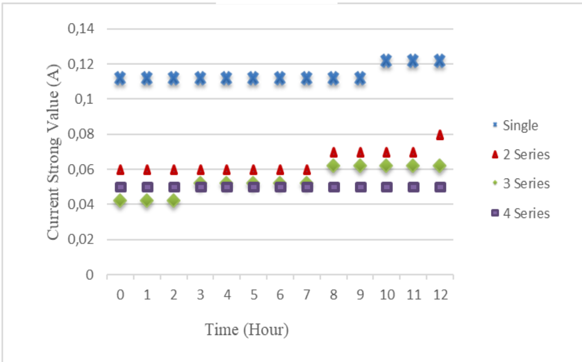
In MFC system without active sludge, the initial value was very high, but over time, it was dropped. It indicated that the systems with active sludge contain high organic matter as a byproduct of biodegradation of natural mixtures by certain microscopic organisms which can be used as a substrate for other types of microorganisms present in the active sludge. It causes oxidation inaccessible to carry free electrons and H^+ particles ideally so that electrons moving from the anode to the cathode are reduced and caused the dynamic result of the electrical voltage (Suyanto et al, 2010).

3.2. Electrification of MFC Series System

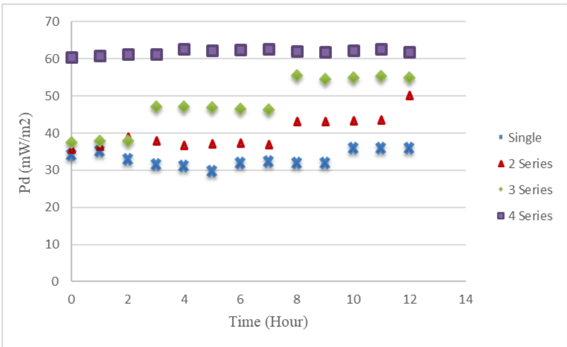
In a previous study by (Jaya et al, 2021) the optimal use of the electrode pair is zinc electrodes as anode and copper as chatode in generating electricity with highest voltage is 0.863 V , electric current value is 0.14 mA, maximum power density is 0.00464 W/m^2 and electrical energy is 0.75168 J., but the results of the electricity obtained are still on a small scale which cannot even turn on the lamp, so it needs to be developed by considering many factors, one of which is is the type of series circuit used. In this study various circuits were used to increase the electricity generated. In this research now measured voltage and current with single and serial systems where there were three variations of series systems with 2 MFC, 3 MFC, and 4 MFC. The purpose of the MFC series is to know the influence of the numbers and series of the chamber on electrical energy production. It is hoped that combining these series can increase the amount of electrical energy generated and turn on the lights.



(a)



(b)



(c)

Figure 5. (a) Voltage Value; (b) Current Strong Value and (c) Power Density Value in various Series MFC circuits. ■ = four series, ◆ = Three series ▲ = Two series X= Single series

Figure 5 shows the results of the Voltage Value; Rated Strong Current and Rated Power Density in various series MFC Series. Figure 5a shows the maximum voltage value achieved in the MFC 4 series system of 3.76 V and then followed by the MFC 3 series system of 2.78 V; MFC 2 series system of 1.95 V and on a single MFC of 0.94 V. Increasing the voltage value on the MFC 4 series can turn on the lamp.

Then the current-voltage (Figure 5b) decreases strongly when the system is assembled in series. The maximum current occurs in a single reactor at 0.12 mA for 10 to 12 hours. The average strong currents that were small in the system 4 series was 0.05 mA, it can occur due to the increase in the value of obstacles entering the MFC system. The value of this resistance was inversely proportional to the strong value of the current so the increase in resistance caused a small strong current to be produced.

The calculation was done on the power density value produced by the average power density on a single circuit of 32.37 mW/m^2 than in series 2 of 40.1 mW/m^2, series 3 of 46.96 mW/m^2 and series 4 of 61.87 mW/m^2 (Figure 5c) The increasing voltage causes a high-power density value in the MFC 4 series system. The electricity generated through the MFC series mostly has a higher electrical value.

Research results Aelterman et al. (2006) obtained an open circuit voltage of 0.67 V for parallel and 4.16 V for series. MFC systems in series will not provide higher power densities compared to single MFC but MFC series can create the possibility to produce more practical average voltage and current strong value.

In the principle of a series circuit, the total voltage measured was the sum of voltages from each power source. In this case, it is the MFC chamber, where the most MFC chambers are in the system 4 series so that the highest voltage value was obtained in the system 4 series. The treatment of two, three, and four chambers showed that the more vessels assembled in series, the higher the voltage value and power density produced. From this research, series MFC systems provide higher power, contrasting with single MFCs, where series MFC can make it possible to provide higher voltage averages and more practical currents.

3.3. Biochemical Oxygen Demand (BOD)

BOD, or Biological Oxygen Demand, is the amount of biological oxygen needed by microorganisms (usually bacteria) to break down organic matter aerobically [2]. Test results showed in Table 1 that BOD levels in each sample were different.

In the sample of waste without sludge, in the initial and final conditions of observation, there was a decrease in BOD levels. The BOD value decreased after the waste was used as a substrate for the MFC process without adding active sludge to 628 mg/L with a decreasing percentage of 18.02%.

Table 1. The comparison results of BOD level measurements in various samples

Treatment	BOD (mg/L)
No Treatment	766
MFC Without Active Sludge	628
MFC With Active Sludge	538

The decrease in BOD value indicates a process of decomposing organic compounds that occur in waste. As the amount of organic matter decomposed gets larger, more oxygen is used (Poppo et al, 2008). In addition, for the results of the active sludge test by comparison (1:7), the initial and final conditions of observation obtained a more significant decrease in BOD levels, where the initial waste before used had a BOD level of 766 mg/L. After being given active sludge and used as an MFC substrate, BOD levels decreased to 538 mg/L. It obtained a percentage decrease of 29.76%. It suggests that the treatment of active sludge in liquid waste has decreased compared to treatment without the addition of active sludge.

Based on the research of Ibrahim et al, 2014 the results of a decrease in BOD that occurred were 55.91% can be caused by the activity of microorganisms in degrading organic compounds present in waste samples to meet their needs. Syamsudin et al. (2008) stated that the activity of microorganisms in the treatment process with activated sludge is strongly influenced by the availability of nutrients and environmental conditions. The biodegradation process by aerobic microorganisms will take place optimally if dissolved oxygen and nutrients are available at appropriate concentrations.

3.4. Chemical Oxygen Demand (COD)

Chemical Oxygen Demand (COD) measures water pollution by organic matter that can normally be oxidized through a microbiological cycle. It results in a decrease in dissolved oxygen in water (Sinaga, 2017). The COD value on several samples was shown in Table 2.

Table 2. The results of the comparison of COD level measurements in various samples

Treatment	COD (mg/L)
No Treatment	3562.5
MFC Without Active Sludge	1737.5
MFC With Active Sludge	1725

Table 2 showed the varying levels of COD in each sample of waste. The initial waste contained a COD level of 3562.5 mg/L. In the example of active sludge absence, the resulting COD levels decreased at the end of the observation to 1737.5 mg/L with a percentage decrease in COD levels amounted to 51.23% of the initial waste. Then, in the sample which contained active sludge with a ratio of (1:7), the results in COD showed a value of 1725 mg/L with decreased COD levels, which was 51.58% of the initial waste.

Based on research conducted by Apriyani, the results obtained also showed a more significant decrease in COD in the presence of activated sludge. The COD value of wastewater without activated sludge on day 0 was 992 mg/L and on day 6 it was 816 mg/L. The decrease in the COD value of liquid waste by giving activated sludge experienced a greater decrease, namely 901 mg/L on day 0 to 781 mg/L on day 6. The decrease in COD value indicates the degradation of organic and inorganic compounds. It impacts the final result due to the presence of active sludge. COD levels showed that the active sludge used had the option to reduce the burden of liquid waste pollutants through microbial metabolic reactions that occur in MFCs during the process. The administration of active sludge will increase the number of microorganisms in the waste so that the degradation of organic waste materials will become faster (Ibrahim et al, 2014).

3.5. Total Suspended Solid (TSS)

The Total Suspended Solid (TSS) is the number of suspended solids present on various solids from the total number of solids held in a filter that can settle (Widyaningsih, 2011). The result of the TSS test on several samples was shown in Table 3.

Table 3. The results of the comparison of TSS level measurements in various samples

Treatment	TSS (mg/L)
No Treatment	613
MFC Without Active Sludge	311
MFC With Active Sludge	2620

It was recorded that the initial wastewater contained 613 mg/L TSS. The sample without the addition of active sludge contained 311 mg/L. The percentage decrease that occurred was 49.2%. It indicated for some time, the decomposition of organic matter has occurred and biofilm layers have been formed so that microorganisms can degrade organic matter in the wastewater. Solid particles in the waste form a layer of biofilms and partially settle at the bottom of the chamber.

In the sample of waste which contained active sludge, the value of TSS increased to 2620 mg/L with a percentage increase in levels of 76.7%. It indicates that there is high activity of microorganisms that cause many solids to dissolve in wastewater. That can happen due to the amount of active sludge added, where testing is completed without the deposition process. It can also be caused by a state of sludge that is difficult to settle so that it is carried away during the process.

4. Conclusion

The measurements in this study showed that the best treatment without sludge had a higher electrical than the treatment with activated sludge. The best electrical average is 1.02 V. Then to increase the electricity, various types of circuits are carried out, then based on the experimental results the best type of circuit is the MFC circuit in 4 series with an average voltage of 3.71 V and a power density of 61.87 mW/m^2. In the analysis results, the addition of active sludge with a ratio of 1: 7, effectively reduced the burden of pollutant levels in Chinese food restaurant wastewater at the best BOD levels with a percentage decrease of 29.27%. Then, in COD levels there was a percentage decrease of 51.58%. But in this case, the best TSS levels were obtained in samples without sludge with a percentage decrease of 49.2%. The study results did not include high overall, so further research is needed to improve MFC performance optimally, such as the selection of substrate types, the addition of specific microorganisms, the addition of volume, and several other factors.

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