Jurnal Riset Sains dan Teknologi
Volume 9 No. 2 September 2025, 241-248

e-ISSN: 2549-9750
p-ISSN: 2579-9118

Comparison of Anode Types on Electrical Power and Organic Removal using Microbial Fuel Cells Integrated with Anaerobic Baffled Reactor

Perbandingan Tipe Anoda terhadap Daya Listrik dan Penyisihan Senyawa Organik Menggunakan Microbial Fuel Cells Terintegrasi dengan Anaerobic Baffled Reactor

Syadzadhiya Qothrunada Zakiyayasin Nisa'[1*], Restu H. A. Murti[1], Nurvita Cundaningsih[1], M. Ardiansyah Dwi Tama[1], Nur Laili A. Mukharomah[1]
[1]Environmental Engineering, Faculty of Engineering, UPN Veteran Jawa Timur
Jl. Rungkut Madya, Gunung Anyar, Surabaya 60294, Indonesia

*Corresponding author: syadzadhiya.tl@upnjatim.ac.id

DOI:
10.30595/jrst.v9i2.24240

Histori Artikel:

Diajukan:
17/10/2024

Diterima:
21/06/2025

Diterbitkan:
08/09/2025

ABSTRAK

Proses produksi tahu menghasilkan limbah cair yang memiliki kandunga organik yang tinggi dan berpotensi mencemari badan air jika tidak diolal Kombinasi *Microbial Fuel Cells* (MFCs) dan *Anaerobic Baffled Reacto* (ABR) menghadirkan solusi efektif untuk mengolah limbah cair ir sekaligus menghasilkan listrik. Tujuan penelitian ini yaitu menganalis pengaruh jenis anoda dalam sistem MFCs-ABR terhadap daya listrik (mW dan penurunan COD dalam limbah cair tahu. Metodologi yang digunaka meliputi pengolahan limbah cair tahu dengan variasi jenis anoda seng da baja tahan karat. Parameter yang diamati adalah daya listrik dan efisien penurunan COD pada waktu retensi 0, 24, 48, 72, dan 96 jam. Has penelitian menunjukkan bahwa anoda seng menghasilkan daya listri mencapai 0,38 mW dan menunjukkan efisiensi pengurangan COD sebesa 55,85% pada 96 jam. Pada anoda baja tahan karat menghasilkan day listrik 0,18 mW dan efisiensi pengurangan COD sebesar 52,80% paada 9 jam. Penelitian ini menunjukkan bahwa jenis anoda mempengaruhi day listrik yang dihasilkan pada sistem MFCs.

Kata Kunci: Microbial Fuel Cells; Anaerobic Baffle Reactor; Penyisihan Organik; Bioenergi

ABSTRACT

The tofu production process produces liquid waste that has a high organic content and has the potential to pollute water bodies if not treated. The combination of Microbial Fuel Cells (MFCs) and Anaerobic Baffled Reactors (ABR) presents an effective solution to treat this liquid waste while generating electricity. The purpose of this study was to analyze the effect of the type of anode in the MFCs-ABR system on electrical power (mW) and COD reduction in tofu liquid waste. The methodology used includes processing tofu liquid waste with variations in the types of zinc and stainless steel anodes. The parameters observed were electrical power and COD reduction efficiency at retention times of 0, 24, 48, 72, and 96 hours. The results showed that the zinc anode produced electrical power reaching 0.38 mW and showed a COD reduction efficiency of 55.85% at 96 hours. The stainless steel anode produced electrical power of 0.18 mW and a COD reduction efficiency of 52.80% at 96 hours. This study shows that the type of anode affects the electrical power generated in the MFCs system.

Keywords: *Microbial Fuel Cells; Anaerobic Baffle Reactor; Organic Removal; Bioenergy*

1. INTRODUCTION

Tofu waste originates from the byproducts of soybean processing that do not form tofu, consisting of solid and liquid waste (Pagoray et al., 2021). The solid waste includes the leftover tofu pulp, while the liquid waste is generated during the tofu washing process. Tofu wastewater contains high levels of organic matter, such as Chemical Oxygen Demand (COD), and if discharged directly into water bodies without treatment, it can degrade water quality in the environment (Sitohang et al., 2022). Furthermore, tofu wastewater is rich in protein, fat, and carbohydrates, leading to high ammonia (NH_3) content, which is an alkaline compound that can dissolve in water. Elevated ammonia concentrations can indicate environmental pollution, with a low acidity (pH) level of around 4-5 (Ariyetti et al., 2020). The ammonia content originates from the breakdown of the soybean raw material used in tofu production.

Processing the levels of organic pollutants and ammonia present in tofu wastewater is essential to maintaining water quality and preventing pollution. One effective solution for treating tofu wastewater is the use of an Anaerobic Baffled Reactor (ABR) wastewater treatment unit. The ABR technology utilizes anaerobic microorganisms to decompose organic materials such as COD and other pollutants in the wastewater (Dengo et al., 2020). ABR has advantages in technical aspects with better pollutant removal efficiency and financial aspects with lower operational costs compared to Anaerobic Filters (AF) (Trihidayanti et al., 2021). Additionally, ABR excels in energy efficiency because its process does not require aeration, which is typically the main cause of energy consumption in wastewater treatment systems.

As an effort to utilize the high organic content in tofu wastewater, Microbial Fuel Cells (MFCs) technology offers additional potential for wastewater treatment. MFCs are a promising technology for generating electrical energy by leveraging waste and organic materials (Dewi et al., 2020). The illustration of MFCs is shown in **Figure 1**, where MFCs consists of one chamber for the anode electrode and one chamber for the cathode electrode. The anode electrode chamber is where anaerobic microbes break down organic matter, and through this process will release electrons and protons. Electrons will flow through an external circuit to the cathode electrode chamber which is in aerobic conditions, while protons pass through a proton exchange membrane connected to the cathode electrode chamber. This movement of electrons creates a potential difference between the two electrodes and becomes an electric current. In the cathode electrode chamber, there is an electrolyte solution. Electrons, protons, and oxygen in the cathode electrode chamber react to form water. This system not only treats wastewater but also produces electrical energy as a by-product (Mohyudin et al., 2022;Saravanan et al., 2022).

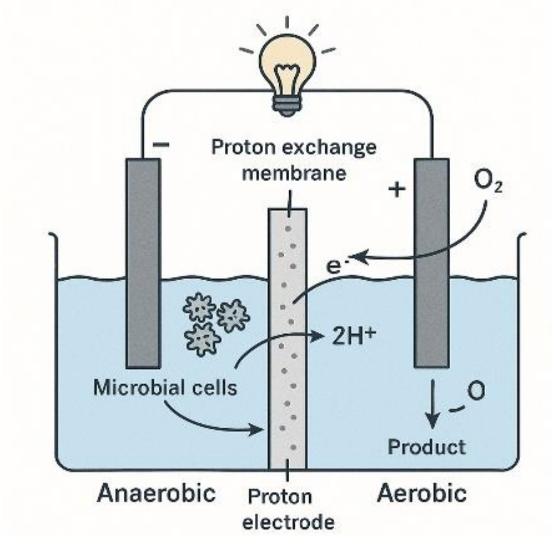

Figure 1. Working principle of Microbial Fuel Cells (MFCs)

Significant factor influencing electricity production is the type of anode used. The electrode material for the anode in MFCs must possess good conductivity to support efficient electrical flow (Do et al., 2020). Other studies have shown that utilizing tofu wastewater with MFC technology using ceramic electrodes demonstrates high effectiveness, where an anode electrode surface area ratio of 3.57 with ceramic material results in a power density of 205.88 mW/m^2 (Wafi et al., 2024).

Further research on tofu wastewater treatment using a combination of MFCs and ABR aims to achieve two main objectives: to reduce environmental impact and to explore the potential for bioelectricity production. ABR technology plays a crucial role in decreasing organic content in the wastewater, while MFCs utilize the remaining organic materials to generate electrical energy. The application of this technology can significantly reduce ammonia concentrations and produce sufficient electrical energy for reuse in the production process. Implementing this technology not only aids in more effective waste management but also contributes to the efficient utilization of energy resources, aligning with the principles of sustainable development.

Based on the background outlined above, this research focuses on analyzing the effect of different anode types on electricity production and the efficiency of COD removal from tofu wastewater using a combined MFCs-ABR reactor system.

2. METHODS

This study involves a series of steps that begin with the determination of the variables to be used. Four types of variables have been established to ensure that the research has a clear framework and produces accurate data. The constant variables include several important elements that will be kept constant throughout the study, namely tofu wastewater, the cathode, reactor volume, and the salt bridge. These variables were chosen because of their critical roles in the wastewater treatment process and energy output measurement. Next, the independent variables selected for this study include variations in anode type (Zinc and Stainless-steel) as well as variations in reactor residence time (0 hours; 24 hours; 48 hours; 72 hours; 96 hours). These two variables demonstrate how changes in system configuration can affect processing efficiency and energy production. The control variable used is the initial pH of the wastewater, maintained within the range of 6.5 to 8.5 to ensure that the reactor conditions are optimal for the biochemical processes occurring. The dependent variables measured include electrical power (mW), and concentrations of COD and ammonia.

In this study, the MFC reactor uses plate-shaped electrodes installed in the anode compartment as the negative pole, while the cathode functions as the positive pole. Both electrodes are connected via alligator clips to connecting wires (external circuit). The generated voltage is observed and measured every 24 hours until reaching 96 hours using a digital multimeter. The anode chamber in the Anaerobic Baffled Reactor (ABR) is located in the second compartment. According to the research by (Liu et al., 2021), the second compartment exhibits the highest power density. This is due to the partial breakdown of organic compounds in the first compartment, which can reduce toxicity levels in the water flow. This reduction in toxicity allows the second compartment to receive better nutrient supply and maintain lower toxicity levels for microorganisms compared to other compartments. The reactor design used in this study is illustrated in **Figure 2** as follows.

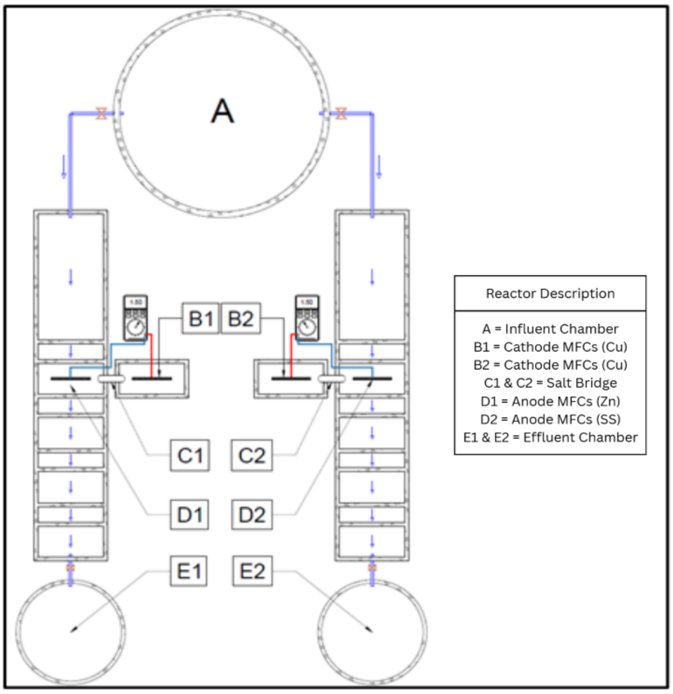

Figure 2. Schematic representation of the Microbial Fuel Cells (MFCs) Integrated with an Anaerobic Baffled Reactor (ABR)

In the **Figure 2**, the cathode and anode are labelled according to their actual materials: B1 and B2 that represent cathodes made of copper (Cu), while D1 and D2 anodes made of zinc (Zn) and stainless steel (SS), respectively. In the actual experimental setup, both reactors utilized the same cathode material copper ensuring consistent cathodic conditions. Consequently, the electrode pair configuration for Reactor 1 is Zn/Cu (zinc anode, copper cathode), and for Reactor 2 is SS/Cu (stainless steel anode, copper cathode).

Figure 3 shows a detailed illustration of the external wiring circuit connecting the anode and cathode electrodes. The anode and cathode electrodes chambers are each connected by an external cable—a black cable for the anode and a red cable for the cathode—which is connected to an electrical measuring instrument (Avometer) to measure the voltage or electric current produced.

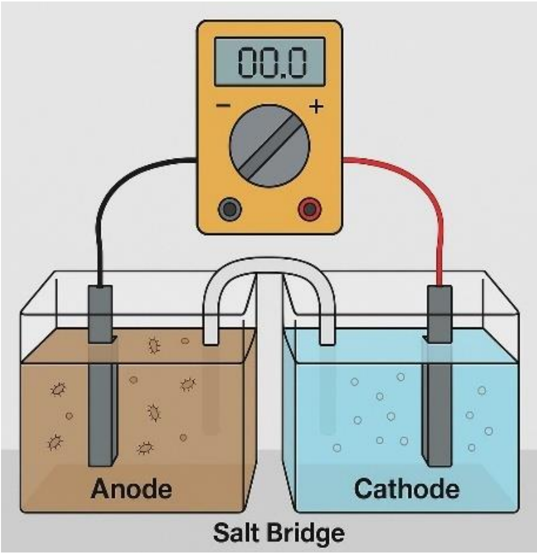

Figure 3. Microbial Fuel Cells (MFCs) Circuit Schematic with Avometer

3. RESULTS AND DISCUSSION

The Effect of Anode Type on the Generated Voltage Value

The type of anode and residence time have an impact on the voltage generated in Microbial Fuel Cells (MFCs). Data from the graph indicate an increase in the electrical voltage produced by the MFCs with zinc or stainless-steel anodes as the residence time increases. This suggests that the metabolic processes by microorganisms improve with longer operational time in the reactor, as evidenced by the rising voltage generated from these metabolic processes. The enhancement in metabolism occurs because, over time, the organic compounds become simpler, which affects the performance of the MFCs. MFC efficiency tends to increase when the substrate being processed by microorganisms is simpler (Novriandy et al., 2021).

Based on Figure 4, the stainless-steel anode at 0 hours of residence time produces a higher voltage (0.37 V) compared to the zinc anode (0.30 V), indicating that stainless-steel has better electron transfer efficiency at the initial stage. The generated voltage remains relatively low because the microbes have not fully adapted and optimal biofilm formation on the anode surface has not yet occurred. As the residence time increases, the microbial population on the anode rises and becomes more active in anaerobic respiration. This microbial activity plays a crucial role in the oxidation of organic substrates, generating electrons that are then transferred from the anode to the cathode.

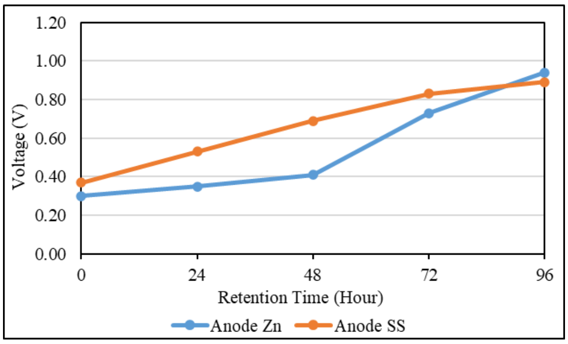

Figure 4. Correlation Between Voltage and Retention Time Using Different Anode Types

The use of a zinc anode shows a significant increase in voltage from 0.35 V at 24 hours to 0.94 V at 96 hours, with the largest increase occurring between 48 and 72 hours (from 0.41 V to 0.73 V). This increase indicates zinc's ability to support the formation of a more stable microbial biofilm and efficient electron transfer. Conversely, the stainless-steel anode produces a higher initial voltage (0.53 V at 24 hours), reaching a maximum of 0.89 V at 96 hours. This suggests that stainless-steel may be better at electron transfer in the early stages but is less efficient in the long term compared to zinc. Selecting the appropriate anode in MFCs is crucial, as zinc demonstrates advantages in efficiency and long-term stability, while stainless-steel is more optimal for scenarios requiring a quick initial response but does not maximize voltage over a longer period. In addition to voltage, another parameter measured to obtain electrical power (mW) is the electric current (I).

The Effect of Anode Type on the Generated Electric Current Value

Based on Figure 5, the electric current produced in each reactor ranges from 0.14 to 0.40 mA. During the running process, the highest current value is generated in the reactor with a zinc anode at a retention time of 96 hours, which is 0.40 mA. The zinc anode produces a higher current compared to the stainless-steel anode at every time interval. At a retention time of 0 hours, the current generated by the zinc anode is 0.17 mA, which is higher than the 0.14 mA produced by the stainless-steel anode. This indicates that the zinc anode has better capabilities in facilitating electron transfer during the initial stages of the process. As the retention time increases, the current generated by both types of anodes continues to rise, but the increase is more significant for the zinc anode. The notable increase in electric current from 48 to 96 hours suggests that microbial activity begins to play an effective role in degrading organic compounds. Microorganisms thrive by utilizing organic materials in the wastewater as a nutrient source, which are then converted into energy and new microbial cells (Ibrahim et al., 2019). At a retention time of 96 hours, the current generated by the zinc anode reaches 0.40 mA, while the stainless-steel anode only reaches 0.20 mA. This difference indicates that the zinc anode is more effective in supporting microbial activity and the electron transfer necessary for producing higher currents. The significant increase observed with the zinc anode suggests that this material can maintain a more supportive environment for microbial growth, enhancing its performance in MFCs. In contrast, the stainless-steel anode shows a slower and more limited increase, which may be attributed to its magnetic surface characteristics that affect interaction with microorganisms or its lower electron transfer efficiency (Wang et al., 2023).

The results of the measurements between the increase in voltage and electric current do not show significant differences, as both voltage and current increase with longer retention time in the reactor. After measuring voltage (V) and electric current (mA), the values of both are multiplied to calculate the electrical power (mW), which is one of the outcome parameters in this study.

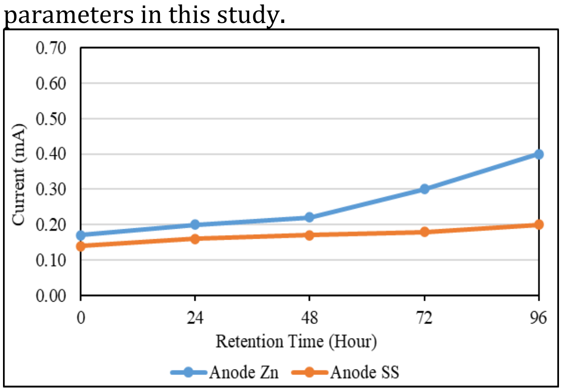

Figure 5. Correlation Between Electric Current and Retention Time Using Different Anode Types

The Effect of Anode Type on the Produced Electrical Power (mW)

Based on **Figure 6**, there is an increase in power values as retention time in the reactor increases, which corresponds to the rise in voltage and electric current produced in each reactor. The combination of Microbial Fuel Cells (MFCs) and Anaerobic Baffled Reactor (ABR) technology is effective in treating wastewater from the tofu industry, with the use of a zinc (Zn) anode in the MFCs system producing the highest power density of 4.17 mW.h (Afif, 2020). This research finding is also related to the generated data, which shows a significant difference between the two types of anodes in terms of electrical power produced over time. The electrical power in the reactor with the zinc anode increased from 0.07 mW at 24 hours to 0.38 mW at 96 hours, with a significant increase between 48 and 72 hours, rising from 0.09 mW to 0.22 mW/m^2. The stainless-steel anode increased electrical power from 0.08 mW at 24 hours to 0.18 mW at 96 hours. Although the stainless-steel anode produced higher power at the initial stages (24 to 48 hours), increasing from 0.08 mW to 0.12 mW, its rate of increase slowed compared to zinc, which experienced the most significant rise between 24 and 48 hours. This data indicates that the zinc anode is superior in generating higher power as retention time increases, demonstrating better efficiency in supporting electrochemical reactions and long-term stability. While the stainless-steel anode is more effective initially, it fails to maintain a significant increase in electrical power over time.

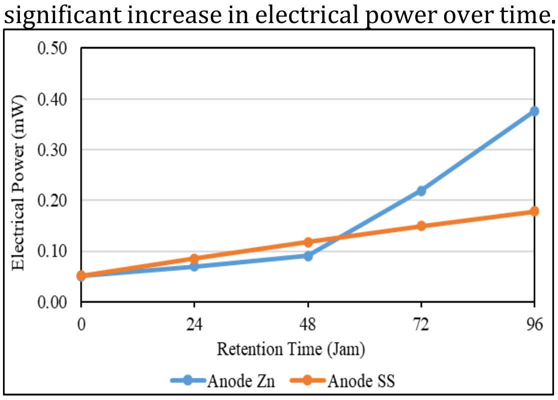

Figure 6. Correlation Between Electrical Power and Retention Time Using Different Anode Types

One factor that can influence energy production is the type of anode. The zinc anode is better at supporting bio-electrochemical processes, which lead to increased electrical power, as the microbial biofilm becomes more mature and efficient in electron transfer. This is due to zinc's high adsorption capability, allowing microorganisms to attach to the electrode surface in significant numbers (Radi et al., 2017). Additionally, zinc has a standard potential value of -0.76 in the electrochemical series (Akbar et al., 2017). In contrast, stainless-steel is an iron alloy that contains 10.5% chromium to prevent corrosion, with iron (Fe) positioned to the left in the electrochemical series and having a standard potential value of -0.44 (Ibrahim et al., 2019). A metal located further to the left in the electrochemical series tends to react more easily and release electrons. Conversely, metals situated further to the right tend to be more resistant to losing electrons (Nasution, 2019).

COD Removal from the MFCs-ABR Reactor Combination Process

The efficiency of COD removal in tofu wastewater during the process using a combination of Microbial Fuel Cells (MFCs) with Anaerobic Baffled Reactor (ABR) ranges from 33.01% to 55.85%. Throughout the study, the reactor was able to reduce the COD concentration in the tofu wastewater. The efficiency of COD reduction at this stage is evaluated based on the reduction of influent COD levels, maintaining the same concentration across each reactor. According to **Figure 7**, the reactor using a zinc anode showed the highest COD removal efficiency, achieving 55.85% with a remaining COD concentration of 3525 mg/L. In contrast, the stainless-steel reactor experienced a reduction of 52.80% with a COD concentration of 3769 mg/L. The highest efficiencies in both reactors were achieved at the same retention time of 96 hours. This indicates that the retention time plays a crucial role in the efficiency of COD removal. According to (Susilo et al., 2016) longer contact between microorganisms and wastewater allows for a more efficient processing.

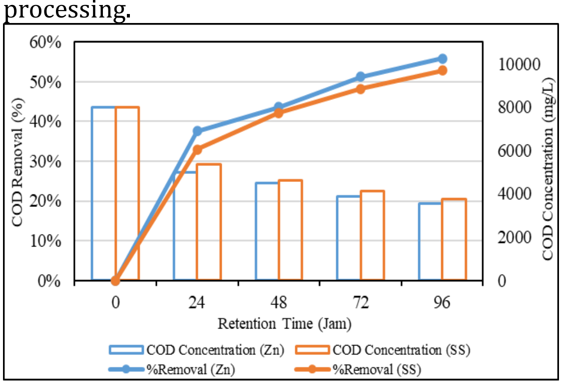

Figure 7. The Correlation Between COD Removal and Retention Time Using Different Anode Types

The reduction of COD concentration has proven to be more effective in reactors utilizing zinc anodes compared to those using stainless-steel anodes. This is attributed to the exceptionally high adsorption capacity of zinc, which allows microorganisms to adhere firmly and effectively to the electrode surface. The microorganisms present in the reactor tend to thrive and attach more efficiently to the zinc anode, significantly enhancing the process of COD degradation in the treated wastewater. Therefore, the use of zinc anodes not only improves the overall efficiency of the treatment process but also supports the sustainability and effectiveness of the wastewater treatment system as a whole.

Ammonia Removal from the MFCs-ABR Reactor Combination Process

Based on **Figure 8**, the ammonia removal efficiency during the running process using the combination of Microbial Fuel Cells (MFCs) and Anaerobic Baffled Reactor (ABR) ranges from 13.41% to 40.24%. Both reactors exhibit the lowest ammonia removal values at a retention time of 24 hours, where the reactor utilizing a zinc anode and the one using a stainless-steel anode show respective ammonia concentration reductions of 13.41% and 17.07%. The highest ammonia removal efficiency is achieved in the reactor with a zinc anode, which is capable of removing ammonia by 40.24% at a retention time of 96 hours, resulting in a final ammonia concentration of 4.9 mg/L. In contrast, the stainless-steel anode at the same retention time of 96 hours displays a lower removal efficiency of 24.34%, with a final ammonia concentration of 6.2 mg/L. However, both reactors demonstrate peak results at the same retention time of 96 hours, indicating that given sufficient time, the biological and electrochemical processes within the MFCs can reach optimal efficiency. Additionally, throughout the ongoing operational process, the zinc anode consistently exhibits a higher level of efficiency in ammonia removal when compared to the stainless-steel anode. This suggests that the electrokinetic characteristics of the zinc anode are more compatible with the environment found within the Microbial Fuel Cells (MFC) system, thereby facilitating biological processes and redox reactions that occur with greater efficiency.

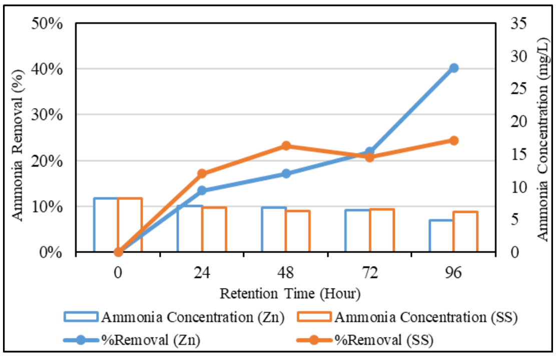

Figure 8. The Correlation Between Ammonia Removal and Retention Time Using Different Anode Types

4. CONCLUSION

The type of anode has a significant impact on electrical power generated in the combined Microbial Fuel Cells (MFCs) and Anaerobic Baffled Reactor (ABR) system. The zinc anode outperformed the stainless-steel anode, particularly at longer retention times. At a retention time of 96 hours, the zinc anode produced an electrical power output of 0.38 mW, then the stainless-steel anode produced an electrical power output of 0.18 mW. Although stainless-steel exhibited a higher initial voltage, its increase slowed over time. The zinc anode was also more effective in supporting the formation of microbial biofilm and in facilitating electron transfer.

Both reactors demonstrated the highest removal efficiency for COD parameters at a retention time of 96 hours, with the zinc anode achieving 55.85% and the stainless-steel anode reaching 52.80%. Furthermore, the maximum reduction of ammonia parameters also occurred in the reactor using the zinc anode at 96 hours, achieving a removal efficiency of 40.24%. Therefore, the zinc anode proves to be more optimal in the MFCs-ABR combination system for generating bioelectricity and removing both COD and ammonia from soy waste water.

ACKNOWLEDGMENT

This work was financially supported by LPPM UPN Veteran Jawa Timur. Therefore, we are grateful for this funding and support of this research.

REFERENSI

Akbar, T. N., Kirom, M. R., & Iskandar, R. F. (2017). Analisis Pengaruh Material Logam Sebagai Elektroda Microbial Fuel Cell Terhadap Produksi Energi Listrik. *E-Proceeding of Engineering*, *4*(2), 2123–2138.

Ariyetti, A., Anggia, M., & Wijayanti, R. (2020). Analisa Kualitas Air Limbah Tahu Di Kecamatan Nanggalo Kota Padang. *Jurnal Katalisator*, *5*(1), 74. https://doi.org/10.22216/jk.v5i1.4868

Dengo, V. A., Isri, M., & Roski, L. (2020). Perencanaan Anaerobic Baffled Reactor (ABR) Sebagai Unit Pengolahan Air Limbah Peternakan Babi Kabupaten Minahasa. *Jurnal Sipil Statik*, *8*(4), 601–606.

Dewi, A. K., Djajakirana, G., & Santosa, D. A. (2020). Potensi Limbah Tahu untuk Menghasilkan Listrik pada Tiga Model Sistem Microbial Fuel Cell (MFC). *Jurnal Ilmu Tanah Dan Lingkungan*, *22*(1), 29–34. https://doi.org/10.29244/jitl.22.1.29-34

Do, M. H., Ngo, H. H., Guo, W., Chang, S. W., Nguyen, D. D., Liu, Y., Varjani, S., & Kumar, M. (2020). Microbial fuel cell-based biosensor for online monitoring wastewater quality: A critical review. *Science of The Total Environment*, *712*, 135612. https://doi.org/10.1016/J.SCITOTENV.2019.135612

Ibrahim, B., Uju, U., & Mukti, A. C. (2019). Biofilm Density on the Electrode is Positively Correlated with the Bioelectricity of the Microbial Fuel Cell of Fisheries Wastewater. *Jurnal Pengolahan Hasil Perikanan Indonesia*, *22*(1), 71. https://doi.org/10.17844/jphpi.v22i1.25880

Liu, N., Yun, Y., Hu, L., Xin, L., Han, M., & Zhang, P. (2021). Study on Start-Up Membraneless Anaerobic Baffled Reactor Coupled with Microbial Fuel Cell for Dye Wastewater Treatment. *ACS Omega*, *6*(36), 23515–23527. https://doi.org/10.1021/acsomega.1c03560

Mohyudin, S., Farooq, R., Jubeen, F., Rasheed, T., Fatima, M., & Sher, F. (2022). Microbial fuel cells a state-of-the-art technology for wastewater treatment and bioelectricity generation. *Environmental Research*, *204*, 112387. https://doi.org/10.1016/J.ENVRES.2021.112387

Nasution, M. (2019). Kajian Tentang Hubungan

Deret Volta dan Korosi Serta Penggunaannya Dalam Kehidupan Sehari-Hari. *Seminar Nasional Teknik (SEMNASTEK) UISU*, 251–254.

Novriandy, M., Tamjidillah, M., Ramadhan, N., Studi, P., & Mesin, T. (2021). Pengaruh Mikroorganisme Terhadap Produktivitas Energi Listrik Mfc Dengan Variasi Limbah Pabrik Tahu Dan Limbah Perikanan. *JTAM ROTARY*, *3*(1), 107–118. https://doi.org/10.20527/JTAM_ROTARY.V3I1.3430

Pagoray, H., Sulistyawati, S., & Fitriyani, F. (2021). Limbah Cair Industri Tahu dan Dampaknya Terhadap Kualitas Air dan Biota Perairan. *Jurnal Pertanian Terpadu*, *9*(1), 53–65. https://doi.org/10.36084/JPT..V9I1.312

Radi, M. H., Radi, M. H., Al-Fetlawi, H. A.-Z., & Al-Fetlawi, H. A.-Z. (2017). Influence of Electrodes Characteristics on The Performance of a Microbial Fuel Cell. *Journal of University of Babylon*, *25*(4), 1328–1338. https://www.researchgate.net/publication/349435225_Influence_of_Electrodes_Characteristics_on_the_Performance_of_a_Microbial_Fuel_Cell

Saravanan, A., Kumar, P. S., Srinivasan, S., Jeevanantham, S., Kamalesh, R., & Karishma, S. (2022). Sustainable strategy on microbial fuel cell to treat the wastewater for the production of green energy. *Chemosphere*, *290*, 133295. https://doi.org/10.1016/J.CHEMOSPHERE.2021.133295

Sitohang, A. R., Yuliati, S., & Hasan, A. (2022). Pengaruh PAC dan Variasi Tekanan Pada Pemurnian Limbah Cair Tahu Menggunakan Membran Polisulfon Ultrafiltrasi. *Jurnal Pendidikan Dan Teknologi Indonesia*, *2*(9), 411–416. https://doi.org/10.52436/1.jpti.219

Susilo, F. A. P., Suharto, B., & Susanawati, L. D. (2016). Pengaruh Variasi Waktu Tinggal Terhadap Kadar BOD dan COD Limbah Tapioka dengan Metode Rotating Biological Contactor. *Jurnal Sumber Daya Alam Dan Lingkungan*, 21–26.

Trihidayanti, H., Ratnaningsih, R., & Iswanto, B. (2021). Study of tofu wastewater treatment using anaerobic baffled reactor: laboratory scale. *IOP Conference Series: Earth and Environmental Science*, *894*(1), 012017. https://doi.org/10.1088/1755-1315/894/1/012017

Wafi, M. A., Ahmad, M. G., Misto, M., Cahyono, B. E., Mulyono, T., & Mutmainnah, M. (2024). Utilization of Tofu Liquid Waste with Ceramic-Based Microbial Fuel Cell (MFC) Technology. *Jurnal ILMU DASAR*, *25*(2), 95. https://doi.org/10.19184/JID.V25I2.29949

Wang, X., Zhang, Y., Zhang, C., Li, J., Xue, M., & Xia, W. (2023). Influence of Electrodes Configuration on Hydraulic Characteristics of Constructed Wetland–Microbial Fuel Cell Systems Using Graphite Rods and Plates as Electrodes. *Sustainability 2023, Vol. 15, Page 6397*, *15*(8), 6397. https://doi.org/10.3390/SU15086397