https://dx.doi.org/10.4314/dujopas.v9i4a.8
ISSN (Print): 2476-8316
ISSN (Online): 2635-3490
Dutse Journal of Pure and Applied Sciences (DUJOPAS), *Vol. 9 No. 4a December 2023*

Generation of Bioelectricity in Microbial Fuel Cell using Kitchen Waste Obtained from Dutse Urban, Nigeria

**Sadiq Haruna[1], Hindatu Yusuf[1*], Ahmad Muhammed Gumel[1],
Aisha Salisu Buhari[2], Umar Umar Abubakar[1]**

[1]Department of Microbiology and Biotechnology,
Faculty of Science
Federal University Dutse,
7156 Dutse, Jigawa
Nigeria

[2]Department of Science Laboratory Technology,
Jigawa State Polytechnic,
7040 Dutse, Jigawa
Nigeria

Corresponding author:
Email hindatyusuf2012@gmail.com;hindatu.y@fud.edu.ng

Abstract

Microbial fuel cells (MFCs) have shown promise as a sustainable technology for wastewater treatment and energy recovery. In this study, cattle dung was used as an inoculum and kitchen waste (KW) from Dutse urban, Nigeria was used as a substrate for bioelectricity generation in MFC. The MFC was operated in a fed-batch mode over 37 days, spanning three cycles. During characterization, the chemical oxygen demand (COD) of the KW was found to be 30421 ± 124 mg/L, indicating a high concentration of organic pollutants. The MFC's performance was evaluated based on the voltage generated, with the first cycle reaching a peak of 254 mV, the second cycle 247 mV, and the third cycle 242 mV. Current and power densities during the three cycles decreased gradually from 66.84 mA/m^2 and 16.84 mW/m^2 in the first cycle to 63.68 mA/m^2 and 15.41 mW/m^2 in the third cycle respectively. Furthermore, there was a notable reduction in COD from the influent diluted from initial measured COD, from 1120 ± 63 mg/L to an effluent level of 226 ± 49 mg/L, indicating approximately 80% removal rate. The pH of the anolyte progressively dropped with each cycle, reflecting the metabolic activities of bacteria in the anode chamber. The findings underscore MFC's potential for organic waste management and electricity generation, with results outperforming some contemporary studies.

Keywords: Microbial Fuel Cell, Kitchen waste, Chemical Oxygen Demand, Bioenergy, Global warming

INTRODUCTION

The need for bioelectricity generation in microbial fuel cells (MFCs) to treat municipal solid waste (MSW) stems from the potential of this technology to simultaneously address waste management and renewable energy production challenges. MFCs have emerged as promising tools for sustainable waste treatment due to their ability to generate electricity through the metabolic activity of microorganisms (Hindatu *et al.*, 2017). MFCs harness the electrogenic

---

[*] Author for Correspondence

potential of microorganisms to oxidize organic matter present in MSW, resulting in the production of electricity (Logan *et al.,* 2006). This electricity generation process facilitates the decomposition of organic waste while providing an alternative energy source. By utilizing the organic matter as a substrate for microorganisms, MFCs offer an efficient and environmentally friendly means of waste treatment (Oh *et al.,* 2010). Furthermore, MFC-based waste treatment processes contribute to waste volume reduction, minimizing the strain on landfills and reducing the need for incineration (Saravanan *et al.,* 2022). As global energy demand continues to rise, bioelectricity from MFCs presents a renewable and clean alternative to conventional fossil fuel-based sources (Logan *et al.,* 2006). The combination of waste treatment and renewable energy production in MFCs offers a viable and sustainable solution to MSW management. By addressing two pressing global challenges simultaneously, MFCs contribute to environmental protection, climate change mitigation, and the transition to a circular economy model (Logan *et al.,* 2006). As a result, MFCs have gained increasing attention and importance in the field of waste management and renewable energy generation (Logan *et al.,* 2006).

Kitchen waste (KW) which comprises food scraps and organic matter, holds significant potential as a feedstock for MFCs due to its high organic content (Jia *et al.,* 2013). KW is readily available in households, restaurants, and food processing facilities, making it an abundant and accessible substrate for MFCs (Moqsud *et al.,* 2013). The use of KW in MFCs contributes to waste diversion from landfills, mitigating the environmental impact of organic waste decomposition. In landfills, organic matter undergoes anaerobic degradation, producing methane, a potent greenhouse gas (Shirmer *et al.,* 2014). By diverting KW to MFCs, the organic matter undergoes anaerobic degradation, significantly reducing methane emissions and their contribution to climate change (Kumar *et al.,* 2022). Using well-mixed kitchen waste (including fruit and vegetable leftovers, leaf mold, microorganisms, and distilled water), Moqsud & Omine (2010) filled a rectangular acrylic container used as the cell. A total of 682 mW/m^2 of power was produced. The use of Nigerian corn starch wastewater as a substrate for a dual-chamber MFC setup using Iron electrodes was investigated by Nwaokocha *et al.,* (2021). In 9 days of the experiment, 1.43 mA current, 0.97 V, a maximum current density of 8.10 mA/m^2, and a maximum power density of 7.7 mW/m^2 were achieved. There is a dearth of published research on the MFC technology's use of Nigerian KW effluent as a substrate for electricity production. The need to investigate whether the currently underutilized and abundant KW effluent can be suitably employed as a substrate for the production of electricity in order to fill the knowledge gap in this area is desirable. Therefore, the aim of the current work was to evaluate the KW collected in Dutse urban as a potential feedstock for the generation of electricity using MFC technology.

MATERIALS AND METHODS

Materials

The KW was sourced from some kitchens in Dutse urban, Jigawa state, Nigeria, and cattle dung was collected from local cattle grazing field around Madobi village near Dutse urban. Electric blender (Zhongshan Haishang Electric Co., China, SK149S), stainless steel sieve and stainless steel meshes were purchased from Dutse ultra-modern market. Nafion 117 membrane was procured from DuPont, Delaware, USA. Sulphuric acid (0.1 M), hydrogen peroxide (0.1 M) and deionized water were sourced from Bauchi central market, Nigeria. For the MFC bioreactor, poly vinyl chloride (PVC) bottles (250 mL) and a PVC pipe (2.5 cm diameter by Geeta Plastic Products Nigeria Ltd.), Copper wires, resistors (550 Ω-15 KΩ), digital multimeter (model DT-9205A, from Frankever, China) were acquired from Azare main market, Bauchi state. A rubber gasket, used for sealing, was locally procured. Solution of 3% sodium hypochlorite, distilled water, 70% ethanol for sterilization, and Phosphate buffer solution (by Paramount Chemical and Acid Corporation, Mumbai, India) were all purchased from Sabon Gari market, Kano, Nigeria. Infrared thermometer (BTG06) was obtained from Guangdong Bioall Medical Technology, China. Lastly, tools and chemicals for KW analysis were bought locally from Bauchi surgical store in Bauchi metropolis.

Sample Collection

Fresh cattle dung was collected from a cattle grazing field around Madobi village near Dutse urban using a sterile container as per Teo and Teoh (2011). An overnight culture of the cattle dung was prepared in nutrient broth with a volume ratio of 10% and incubated at 30°C with a shaking speed of 150 rpm (LI-9022), which was then used as an inoculum in the anode compartment according to Nor *et al.* (2015). Unconsumed food and remnants from meal preparation, referred to as KW, were collected from several kitchens in Dutse urban to be used as substrate in the MFC. The collected KW was processed by grinding it using an electric blender (SK149S) and filtering it with a stainless-steel sieve to remove larger pieces and prevent blockage issues, as suggested by Moqsud *et al.* (2011). To kill any resident microbes, the filtered KW was sterilized using an autoclave (STP-M Series, Infitek, China) set at 121°C, 15 psi for a duration of 15 minutes before being introduced into the anode compartment, as recommended by Nor *et al.* (2015).

Pretreatment of Nafion Membrane

Before implementation, the Nafion 117 membrane (DuPont, Delaware, USA) underwent a pretreatment. It involved immersing the membrane successively in 0.1 M H_2SO_4 and 0.1 M H_2O_2 solutions, followed by rinsing it with deionized water. Each step was conducted at 60°C for a duration of 60 minutes, as described by Nor *et al.,* (2015).

Cell Assembly and Operation

Throughout this study, a laboratory-scale two-chamber MFC depicted in Plate 1 was employed. It consists of PVC plastic bottles with a capacity of 250 mL each and a working volume of 230 mL. These chambers were interconnected using a PVC pipe with a diameter of 2.5 cm. The proton exchange membrane (PEM) utilized was Nafion 117. It was positioned between the two chambers to facilitate the transfer of protons from the anode to the cathode chamber (Hindatu *et al.,* 2017). Stainless steel meshes (SSM) with total surface area of 38 cm^2 were utilized as electrodes in both the anode and cathode chambers (Hindatu *et al.,* 2017). To prevent leakage, the PEM was fitted with a rubber gasket onto the plastic pipe assembly. The MFC reactor was sterilized prior to operation using a two-step chemical procedure. Initially, the reactor was thoroughly rinsed with a 3% sodium hypochlorite solution to ensure the elimination of microorganisms and organic contaminants. After a 30-minute exposure, the reactor was drained and rinsed with distilled water to remove any residual hypochlorite. Subsequently, the reactor was filled with a 70% ethanol solution, providing further sterilization and ensuring the removal of any remaining contaminants. After a 20-minute exposure to ethanol, the reactor was emptied and allowed to air dry before use (Rutala and Weber, 2008). In the anode chamber, 230 mL of sterilized KW substrate, containing 23 mL (10% v/v) of the inoculum, was used and sealed tightly to maintain anaerobic conditions (Hindatu *et al.,* 2017). The cathode compartment was filled with phosphate buffer solution (PBS) as catholyte and kept aerated. To form a closed electrical circuit, the two electrodes were connected to copper wires with an external resistor of 1k Ω (Hindatu *et al.,* 2017). The MFC was operated in a fed-batch mode over 37 days (three cycles) at room temperature (Nor *et al.,* 2015). The anode medium was replenished whenever the voltage dropped below 50 mV (Hindatu *et al.,* 2017).

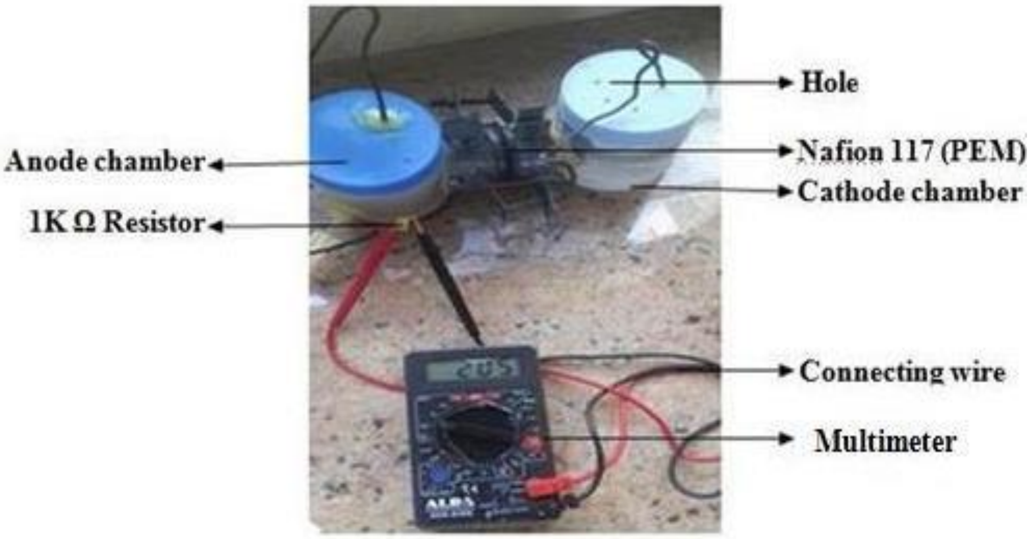

Plate 1: Laboratory scale set-up of a dual chamber MFC utilized

Microbial Fuel Cell Performance

The performance of the MFC was evaluated by measuring the generated voltage. A digital multimeter (DT- 9205A) was used to measure the voltage across a load 1k Ω at 24-hour intervals. Once the voltage value reached a stable level, polarization data was gathered by monitoring the voltage across a wide range of resistances as reported by Hindatu *et al.* (2017) (550 Ω - 15k Ω). The polarization curve was obtained by plotting the voltage against current density (mA/m^2) (Hindatu *et al.,* 2017). To further analyze the data, the voltage was employed to calculate the current (I) using Ohm's law with equation (1), the power density (PD) with equation (2) and the current density (CD) with equation (3) (Hindatu *et al.,* 2017).

$$I=\frac{V}{R} \tag{Equation1}$$

Where I= current (amperes), V= voltage (volts) and R= resistance (Ω)

$$PD=\frac{I \times V}{ASA} \tag{Equation2}$$

Where ASA= anode surface area

$$CD=\frac{I}{ASA} \tag{Equation3}$$

Kitchen Waste Characterization

Before operating the MFC, the properties of the KW, including its chemical oxygen demand (COD), biological oxygen demand (BOD), total suspended solids (TSS), temperature, and pH, were evaluated using the standard method outlined by the American Public Health Association (APHA) for water and wastewater analysis (APHA, 2017). The KW generated was then diluted to obtain a lower COD concentration which was used consistently across all three batches. The leachate from the KW was stored at a temperature of 4°C in a refrigerator.

RESULTS AND DISCUSSION

Characterization of Substrate

Standard methods were used for characterization of substrate. The obtained substrate for the anode chamber in the MFC was characterized based on several parameters prior to the operation as shown in Table 1. The COD value of the substrate was measured to be 30421 ± 124 mg/L. A high COD value indicates a significant concentration of organic pollutants in the substrate (Wei *et al.,* 2019). The BOD value was found to be 23398 ± 98 mg/L. The high BOD value indicates that the substrate contains a substantial amount of readily biodegradable organic compounds, which can potentially serve as a rich source of energy for the MFC's microbial community (Ngoc *et al.,* 2020). The TSS concentration in the substrate was measured at 2600 ± 75 mg/L. High TSS levels can indicate a higher concentration of particulate organic matter, which can also contribute to the microbial activity in the MFC's anode compartment (Aubeeluck-Ragoonauth *et al.,* 2022). The initial pH of the substrate was determined to be 6.72 ± 0.02. An optimal pH range is essential for the growth of electrogenic microorganisms, and a pH of around 6.5 to 7.5 is generally considered favorable for MFC performance (Kiely *et al.,* 2011). The substrate's temperature was recorded at 33.3 ± 0.0 °C. Higher temperatures can enhance the metabolic rates of microorganisms, leading to increased substrate degradation and electricity generation (Gadkari *et al.,* 2020

Table 1: Characteristics of Kitchen Waste Leachate

Parameters	Values	
COD (mg/L)	30421	± 124
BOD (mg/L)	23398	± 98
TSS (mg/L)	2600	± 75
pH	6.72	± 0.02
Temperature (°C)	33.3	± 0.0

Chemical Characteristics of the Microbial Fuel Cell Anolyte

Each cycle of the MFC shows a progressive drop in pH over their duration as shown in Table 4.2. The decrease in pH suggests an increase in the concentration of protons (H^+) within the anolyte, typically resulting from the metabolic activity of electroactive microorganisms (Guo *et al.,* 2020). In the first batch, the pH started at a slightly acidic value of 6.72 and over the 12-day period, gradually fell to 4.32. The second batch began with a slightly basic pH of 7.21 due to the introduction of fresh substrate into the chamber, thereafter declining to 4.24 after 11 days. In the third batch, the starting pH was 7.11, decreasing to a much more acidic value of 3.80 over the course of 14 days. The drop in pH in each cycle indicates ongoing microbial activity and the associated biochemical reactions occurring within the MFC (Guo *et al.,* 2020). The reasons for the pH decrease in the anolyte could be attributed to the metabolic activities of electrogenic bacteria residing in the anode chamber. This has been reported in numerous studies (Logan and Regan, 2006; Liu *et al.,* 2005). The anaerobic breakdown of organic matter by these bacteria often leads to the production of hydrogen ions (H^+) and electrons. These H^+ ions contribute to the acidity of the solution and hence lower the pH (Puig *et al.,* 2010). It is also worth noting that the progressive drop in pH over time was more pronounced in the third batch as compared to the first two. This could be due to a more robust establishment of the microbial consortium in the MFC or a more favorable operating condition that promotes microbial activity (Liu and Logan, 2004; Ieropoulos *et al.,* 2008). These results are in line with the general understanding of MFC operation.

Table 2: Variation of pH with time in the Microbial Fuel Cell

First Batch		Second Batch		Third Batch	
Day	**pH**	**Day**	**pH**	**Day**	**pH**
1	6.72	13	7.21	25	7.11
2	6.46	14	7.09	26	6.87
3	6.07	15	6.88	27	6.56
4	5.91	16	6.5	28	6.02
5	5.53	17	6.11	29	5.78
6	5.21	18	5.88	30	5.41
7	5.07	19	5.62	31	5.01
8	4.93	20	5.07	32	4.89
9	4.71	21	4.73	33	4.43
10	4.48	22	4.51	34	4.2
11	4.39	23	4.24	35	4.08
12	4.32			36	3.92
				37	3.80

The COD of the influent was diluted to 1120 ± 63 mg/L from the initially obtained substrate to reduce its concentration. By the final day of operation (Day 37), the COD of the effluent had decreased to 226 ± 49 mg/L. The reduction in COD indicates that the microorganisms in the MFC were effective in breaking down the organic matter in the KW, transforming it into electricity. The decrease in COD from 1120 ± 63 to 226 ± 49 mg/L represents approximately 80% removal of the initial COD, highlighting the potential of MFCs in waste management and energy generation. The 80% COD removal rate is comparable or even superior to many reported rates in the literature. For instance, a study by Li *et al.* (2013) reported a COD removal rate of 75% over a 14-day period using food waste mixture (bread, rice, cabbage and pork) in their MFC.

Microbial Fuel Cell performance

Voltage generation

A constant ohmic resistance of 1k Ω was maintained for measuring the output voltage generated using a digital multi-meter (DT- 9205A). The MFC operation was maintained at an average surrounding temperature of 29 ± 2˚C. An analysis of the voltage outputs from the MFC over three cycles of operation using KW as a substrate shows some interesting patterns (Figure 1). The MFC was operated for 12 days during the first cycle, 11 days in the second cycle, and 14 days in the third cycle. The voltage readings during the first cycle ranged from 15 to 254 mV. The maximum voltage of 254 mV was observed, indicating a significant electrical output from the MFC during this cycle. The mean voltage for this cycle was approximately 162 mV. In the second cycle, the voltage readings varied between 36 and 247 mV. The peak voltage observed during this cycle was 247 mV, which is lower than the maximum voltage obtained in the first cycle. The mean voltage for this cycle was approximately 138 mV. During the third cycle, the voltage readings ranged from 32 to 242 mV. The peak voltage observed during this cycle was 242 mV, and the mean voltage was approximately 138 mV, similar to that of the second cycle. The specific results may vary due to different experimental setups, substrates, and operational condition, the trend of voltage generation aligned with other MFCs using organic waste as a substrate. Konovalova *et al.* (2018) reported electricity generation from glucose in MFCs. They achieved a maximum voltage output of approximately 183 mV, which is lower to the peak voltage of 247 mV observed in the second cycle of this study. A research conducted by Kumar *et al.* (2018) using dye wastewater as a substrate reported a peak voltage outputs of 235 mV during the first hydraulic retention time (HRT) of 35 days which is also lower than the peak voltage value of 254 mV obtained during the first operation.

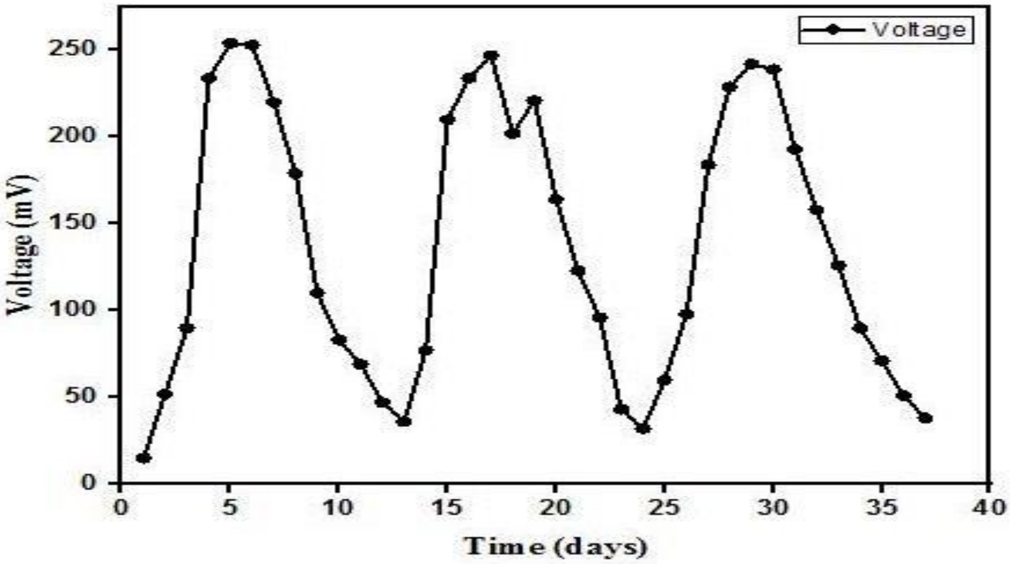

Figure 1: Variation of voltage with time in MFC using KW

Current and Power Densities Generation

During the operation of the MFC over three cycles, notable trends were observed in the current and power densities, along with their corresponding voltages. In the first cycle, which spanned 12 days, the MFC demonstrated a current density of 66.84 mA/m² and a power density of 16.84 mW/m² at a voltage of 254 mV. Subsequently, during the second cycle spanning 11 days, the MFC achieved a current density of 65 mA/m² and a power density of 16.05 mW/m², while operating at a voltage of 247 mV. Finally, in the last cycle which lasted for 14 days, the MFC yielded a current density of 63.68 mA/m² and a power density of 15.41 mW/m² at a voltage of 242 mV. Comparing the obtained results, it is evident that the MFC exhibited a gradual decrease in both current and power densities over the successive cycles which might have been influenced by factors such as biofilm thickness (Logan *et al.,* 2006), substrate Depletion (Logan *et al.,* 2006), accumulation of Metabolites (Logan *et al.,* 2006), loss of active microbial population (Logan *et al.,* 2006), changes in pH (Rabaey & Verstraete, 2005) and competitive microbial processes (Lovley, 2006).

The highest current density was achieved during the first cycle, with is 66.84 mA/m², while the highest power density was also obtained during this cycle, measuring 16.84 mW/m². It is important to note that these results contribute to our understanding of the MFC's performance and the variation in its efficiency over multiple operational cycles. One relevant study by Nwaokocha *et al.* (2021) explored a similar MFC setup using a Nigerian corn starch wastewater as substrate. The research demonstrated a much lower current and power densities of 8.10 mA/cm² and 7.7 mW/cm² respectively than the findings of this present study.

Polarization Curve of Microbial Fuel Cell

The polarization curve of MFC system represents the voltage as a function of the current density (Hindatu *et al.,* 2017). It illustrates the electrochemical performance of the MFC under different external loads, indicating its power generation capabilities. The polarization curve was generated by varying the external resistance in the circuit while maintaining a constant circuit voltage (Hindatu *et al.,* 2017). Current density values were recorded at each resistance, and corresponding cell voltage measurements were noted (Figure 2). The polarization curve of the MFC revealed a clear connection between the applied external resistance and the resulting power density and current density of the system. The highest power density of 28.69 mW/m² and a current density of 121.57 mA/m² were recorded at an applied external resistance of 510 Ω, corresponding to a voltage of 234 mV. Conversely, the lowest power density and current density recorded were 5.53 mW/m² and 9.84 mA/m² respectively, at the highest applied resistance of 15,000 Ω. This suggests that the MFC performance in terms of power and current density decreased as the external resistance increased, this finding is in agreement with the expected behavior from the known relationship between resistance, current, and voltage in electrical circuits. The range of external resistances applied in this study was quite extensive, starting from 510 Ω and going up to 15,000 Ω. Such a broad range allowed for a more comprehensive understanding of the MFC performance under varying electrical loads. A study by Chatzikonstantinou *et al.* (2018) investigated the polarization curve of an MFC using resistor values in the range of 0.1-1000k Ω. These authors reported a maximum power density of 20.2 mW/m² and a current density of 76.2 mA/m². Interestingly, our study recorded slightly higher power density and current density values. This indicates that our MFC might have exhibited better performance under those specific conditions.

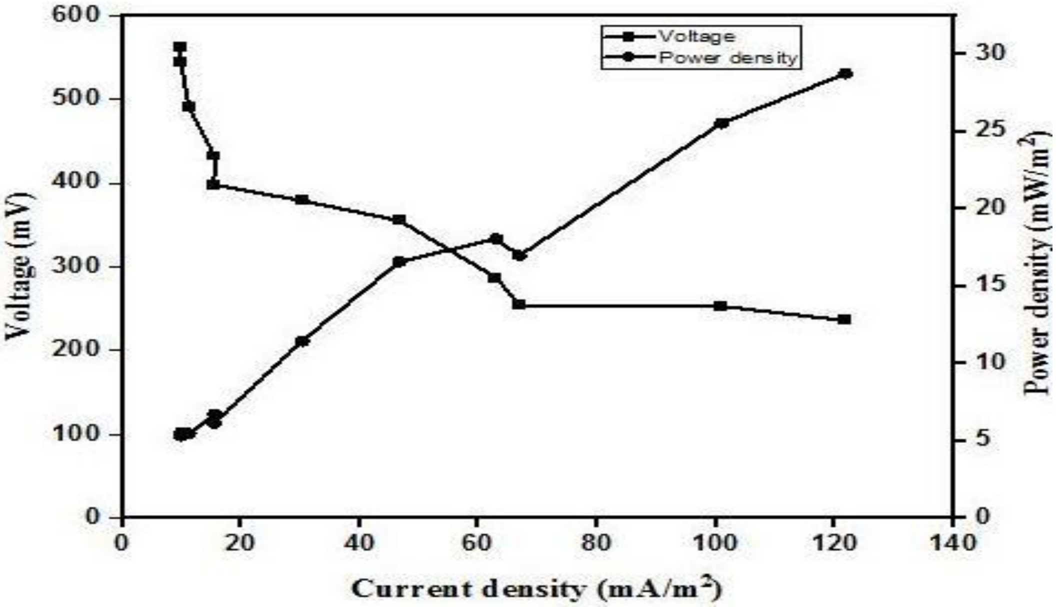

Figure 2: Power density and polarization curve for the MFC setup

CONCLUSION

The MFC's performance, measured in terms of voltage generation, indicated interesting trends across the three cycles. The highest voltage obtained was 254 mV during the first cycle, followed by 247 mV in the second cycle and 242 mV in the third cycle. Additionally, the MFC demonstrated a decline in both current and power densities over successive cycles, with the highest values observed during the first cycle; 66.84 mA/m² current density and 16.84 mW/m² power density. These findings underscore the potential of using KW and cattle dung as substrates for MFC operation, as indicated by their competitive performance compared to previous studies. The polarization curve analysis revealed a strong connection between external resistance and power and current densities. The highest power density (28.69 mW/m²) and current density (121.57 mA/m²) were achieved at an applied external resistance of 510 Ω. Furthermore, the KW organic matter load greatly decreased by 80% indicating that the microorganisms in the cattle dung were able to utilize the organic matter for bioelectricity generation. This research contributes to a deeper understanding of MFC performance and its relationship with varying operational conditions.

REFERENCES

APHA (2017) ‘Standard methods for the examination of water and wastewater (23rd ed.)’, Washington D.C: American Public Health Association.

Aubeeluck-Ragoonauth, I., Rhyman, L., Somaroo, G. D., and Ramasami, P. (2022) 'Physicochemical analysis of wastewater generated from a coating industry in Mauritius', *Environmental Monitoring and Assessment*, 194(10). https://doi.org/10.1007/s10661-022-10309-z.

Chatzikonstantinou, D., Tremouli, A., Papadopoulou, K., Kanellos, G., Lampropoulos, I., and Lyberatos, G. (2018) 'Bioelectricity production from fermentable household waste in a dual-chamber microbial fuel cell', *Waste Management & Research*, 36(11), pp. 1037-1042. https://doi.org/10.1177/0734242x18796935.

Gadkari, S. F., Jean-Marie, Yu, E., and Sadhukhan, J. (2020) 'Influence of temperature and other system parameters on microbial fuel cell performance: Numerical and experimental investigation', *Chemical Engineering Journal*, 388, pp. 124-176. https://doi.org/10.1016/j.cej.2020.124176.

Guo, S. L., Chaoyang, W. K., Wang, J. Z., Zhiping, J. Y., and Zhang, Q. (2020) 'Enhancement of pH values stability and photo-fermentation biohydrogen production by phosphate buffer', *Bioengineered*, 11(1), pp. 291-300. https://sdoi.org/10.1080/21655979.2020.1736239.

Hindatu Y., Annuar M.S.M., Subramaniam R., and Gumel A.M. (2017) 'Medium-chain-length poly-3-hydroxyalkanoates-carbon nanotubes composite anode enhances the performance of microbial fuel cell', *Bioprocess and Biosystems Engineering*, 40(6), pp. 919-928. https://doi.org/10.1007/s00449-017-1756-4.

Ieropoulos, I., Greenman, J. and Melhuish, C.R. (2008) 'Microbial fuel cells based on carbon veil electrodes: stack configuration and scalability', *International Journal of Energy Research*, 32(13), pp. 1228-1240. https://doi.org/10.1002/er.1419.

Jia, J., Tang, Y., Liu, B., Wu, D., Ren, N., and Xing, D. (2013) 'Electricity generation from food wastes and microbial community structure in microbial fuel cells', *Bioresource Technology*, 144, pp. 94-99. https://doi.org/10.1016/j.biortech.2013.06.072.

Kiely, P., Cusick, R., Call, D., S., P., Regan, J., and Logan, B. (2011) 'Anode microbial communities produced by changing from microbial fuel cell to microbial electrolysis cell operation using two different wastewaters', *Bioresource Technology*, 102(1), pp. 388-394. https://doi.org/10.1016/j.biortech.2010.05.019.

Konovalova, E., Stom, D., Zhdanova, G., Yuriev, D., Li, Y., Barbora, L. and Goswami, P. (2018) 'The microorganisms used for working in microbial fuel cells', *Nucleation and Atmospheric Aerosols* [Preprint]. https://doi.org/10.1063/1.5031979.

Kumar D., S., Yasasve, M., Karthigadevi, G., Aashabharathi, M., Subbaiya, R., Karmegam, N., and Govarthanan, M. (2022) 'Efficiency of microbial fuel cells in the treatment and energy recovery from food wastes: Trends and Applications - A review', *Chemosphere*, 287, pp. 132-439. https://doi.org/10.1016/j.chemosphere.2021.132439.

Kumar, D., Gunasekaran, M., and Banu, R. (2018) ‘Generation of Electricity from Dye Industry Wastewater in Dual Chamber Fed-Batch Operating MFC’, *International Journal of Technology and Globalisation*, 4, pp. 902-907.

Li, X.M., Cheng, K.Y. and Wong, J.W.C. (2013) 'Bioelectricity production from food waste leachate using microbial fuel cells: Effect of NACL and PH', *Bioresource Technology*, 149, pp. 452-458. https://doi.org/10.1016/j.biortech.2013.09.037.

Liu, H. and Logan, B.E. (2004) 'Electricity generation using an Air-Cathode single chamber microbial fuel cell in the presence and absence of a proton exchange membrane', *Environmental Science & Technology*, 38(14), pp. 4040-4046. https://doi.org/10.1021/es0499344.

Liu, H., Grot, S.A. and Logan, B.E. (2005) 'Electrochemically assisted microbial production of hydrogen from acetate', *Environmental Science & Technology*, 39(11), pp. 4317-4320. https://doi.org/10.1021/es050244p.

Logan, B.E. and Regan, J.J. (2006) 'Electricity-producing bacterial communities in microbial fuel cells', *Trends in Microbiology*, 14(12), pp. 512-518. https://doi.org/10.1016/j.tim.2006.10.003.

Logan, B.E., Hamelers, B., Rozendal, R., Schrőder, U., Keller, J., Freguia, S., Aelterman, P., Verstraete, W., and Rabaey, K. (2006) 'Microbial Fuel Cells: Methodology and technology', *Environmental Science & Technology*, 40(17), pp. 5181-5192. https://doi.org/10.1021/es0605016.

Lovley, D.R. (2006) 'Bug juice: harvesting electricity with microorganisms', *Nature Reviews Microbiology*, 4(7), pp. 497-508. https://doi.org/10.1038/nrmicro1442.

Moqsud, A. and Omine, K. (2010) 'Bio-electricity generation by using organic waste in Bangladesh', *Conference: Proceedings of the International conference on Environmental aspects of Bangladesh*, 4th September, Kitakyushu, Japan, 122-124.

Moqsud, M. A., Omine, K., Yasufuku, N., Hyodo, M., and Nakata, Y. (2013) 'Microbial fuel cell (MFC) for bioelectricity generation from organic wastes', *Waste Management*, 33(11), pp. 2465-2469. https://doi.org/10.1016/j.wasman.2013.07.026.

Moqsud, M.A., Bushra, Q.S. and Rahman, Md.M. (2011) 'Composting barrel for sustainable organic waste management in Bangladesh', *Waste Management & Research*, 29(12), pp. 1286-1293. https://doi.org/10.1177/0734242x10383621.

Negassa, L.W., Mohiuddin, M. and Tiruye, G.A. (2021) 'Treatment of brewery industrial wastewater and generation of sustainable bioelectricity by microbial fuel cell inoculated with locally isolated microorganisms', *Journal of water process engineering*, 41, pp. 102018. https://doi.org/10.1016/j.jwpe.2021.102018.

Ngoc, L. T. B., Tu, T. A., Hien, L. T. T., Linh, D. N., Tri, N., Duy, N. P. H., Cuong, H. T., and Phuong, P. T. T. (2020) 'Simple approach for the rapid estimation of BOD5 in food processing wastewater', *Environmental Science and Pollution Research*, 27(16), pp. 20554-20564. https://doi.org/10.1007/s11356-020-08703-6.

Nor M. H. M., Mubarak M. F. M., Elmi H. S. A., Ibrahim N., Abdul Wahab M. F. and Ibrahim Z. (2015) 'Bioelectricity generation in microbial fuel cell using natural microflora and isolated pure culture bacteria from anaerobic palm oil mill effluent sludge', *Bioresource Technology*, 190, pp. 458-465. https://doi.org/10.1016/j.biortech.2015.02.103.

Nwaokocha C. N., Giwa S. O., Layeni A. T., Kuye S. I., Samuel O. D., Ogunbona C.K., Adebayo J. K., Sosanya A. and Babalola A. (2021) 'Microbial fuel cell: bio-energy production from Nigerian corn starch wastewater using iron electrodes', *Materials Today*: Proceedings, 46, pp. 5565-5569. https://doi.org/10.1016/j.matpr.2020.09.345.

Oh S. T., Kim J. R., Premier G. C., Lee T. H., Kim C. and Sloan W. T. (2010) 'Sustainable wastewater treatment: How might microbial fuel cells contribute', *Biotechnology Advances*, 28(6), pp. 871-881. https://doi.org/10.1016/j.biotechadv.2010.07.008.

Puig, S., Serra, M., Coma, M., Cabré, M., Balaguer, M., and Colprim, J. (2010) 'Effect of pH on nutrient dynamics and electricity production using microbial fuel cells', *Bioresource Technology*, 101(24), pp. 9594-9599. https://doi.org/10.1016/j.biortech.2010.07.082.

Rabaey, K. and Verstraete, W. (2005) 'Microbial fuel cells: novel biotechnology for energy generation,' *Trends in Biotechnology*, 23(6), pp. 291–298. https://doi.org/10.1016/j.tibtech.2005.04.008.

Rutala, W.A. and Weber, D.J. (2008) 'Guideline for Disinfection and Sterilization in Healthcare Facilities, 2008', *Infection Control and Hospital Epidemiology*, 18, pp. 240-264. http://bpssoutheast.com/content-dir/docs/enviroment-healthcare/CDC-Guideline-for-Disinfection-and-Sterlization-in-Healthcare-facilities-2008.pdf.

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

Shirmer W.N, Jucá, J. F., Schuler A.R.P., Holanda, S., and Jesus L.L. (2014) 'Methane production in anaerobic digestion of organic waste from Recife (Brazil) landfill: Evaluation in refuse of diferent ages', *Brazilian Journal of Chemical Engineering*, 31(2), pp. 373-384. https://doi.org/10.1590/0104-6632.20140312s00002468.

Teo, K.C. and Teoh, S.M. (2011) 'Preliminary biological screening of microbes isolated from cow dung in Kampar', *African Journal of Biotechnology*, 10(9), pp. 1640-1645. https://www.ajol.info/index.php/ajb/article/download/93020/82427.

Wei, C., Wu, H., Kong, Q., Wei, J., Feng, C., Qiu, G., Wei, C., and Li, F. (2019) 'Residual Chemical Oxygen Demand (COD) fractionation in bio-treated coking wastewater Integrating Solution property characterization', *Journal of Environmental Management*, 246, pp. 324-333. https://doi.org/10.1016/j.jenvman.2019.06.001.