Extensive analysis of electrolyte concentrations in selected organic wastes using a double-chamber microbial fuel cell.

Mrs.V.Thushyanthini[a], Mrs.V.Kirusanthy[b]
[a] *thushyanthiniv@esn.ac.lk*
[a]*Eastern University, Sri Lanka, Nilaveli, Trincomalee, 31010, Sri Lanka.*
[b]kirusanthys@esn.ac.lk, [b]*Eastern University, Sri Lanka, Nilaveli, Trincomalee, 31010, Sri Lanka.*

Abstract

Microbial fuel cell (MFC) technology is considered a highly promising alternative energy source for generating bioelectricity from a wide variety of substrates using bio electrogenic microorganisms. This technology is particularly appealing for meeting the energy needs of small devices by utilizing waste materials. In this study, a prototype double-chamber MFC was constructed using copper electrodes for both the anode and cathode, with a salt bridge serving as the proton exchange membrane. The system's performance was evaluated over a 14-days period without renewing the substrates, operating in batch mode. Substrate extracts from waste fruits including Lemon and Pineapple were used to produce bioelectricity. The average open circuit voltages recorded for lemon and pineapple were 225 mV and 245 mV, respectively. The generated voltage was found to depend on factors such as microbial activity, electrode material, and environmental conditions. Notably, during the growth and multiplication phases of the microorganisms, the output voltage was higher. The voltage trend throughout the testing period closely aligned with the microbial growth curve.

Keywords: Microbial fuel cell, double chamber, microorganism and electricity;

1. Background and Objectives

In Microbial fuel cell (MFC) technology has emerged as one of the most innovative and environmentally friendly approaches for renewable energy production. As the global demand for sustainable energy solutions increases, MFCs offer a promising avenue by enabling the direct conversion of chemical energy stored in organic and inorganic materials into electrical energy. These systems operate based on bio-electrochemical processes, where microorganisms act as biocatalysts to drive electron transfer reactions that ultimately result in electricity generation [1].

A typical double-chamber microbial fuel cell consists of two separate compartments an anode chamber and a cathode chamber connected through a proton exchange membrane (PEM). This PEM serves a critical role by allowing the selective passage of protons produced at the anode side to the cathode, while preventing the mixing of different chamber contents. The two electrodes, commonly made from conductive materials such as copper or titanium, are connected externally using a conductive wire, completing the electrical circuit necessary for current flow.

Within the anode chamber, organic substrates are metabolized by electrochemically active microorganisms. During this oxidation process, the microbes break down the organic matter, releasing electrons, protons, and carbon dioxide. The electrons generated from microbial metabolic activity are transferred to the anode surface through specialized redox-active proteins, such as cytochromes. From there, the electrons travel through the external wire to the cathode, while the protons move internally across the PEM, where they combine with electrons and oxygen to form water [2].

The current study explores the feasibility of producing bioelectricity from organic waste derived from commonly discarded fruits specifically lemon and pineapple. A prototype double-chamber MFC was developed for this purpose, and the system was operated in batch mode to monitor electricity generation over a defined testing period. Furthermore, this study aims to investigate the relationship between the different phases of bacterial growth - such as lag, log, stationary, and death - and the open circuit voltage generated from each type of organic waste. By analyzing the voltage trends and comparing them with bacterial growth patterns, the study seeks to better understand how microbial activity influences electricity generation in MFCs using biodegradable waste as fuel.

2. Materials and Methods

Microbial fuel cell (MFC) technology functions with the anode chamber maintained under anaerobic conditions, while the cathode chamber operates in the presence of oxygen, i.e., under aerobic conditions. Typically, these two compartments are separated by a proton exchange membrane (PEM) to facilitate proton transfer while preventing mixing of the chamber contents [3]. In this study, however, a salt bridge was used as an alternative to the PEM in the design of the double-chamber MFC. Copper plates measuring 25 mm × 15 mm were used as electrodes for both the anode and cathode. The anode chamber contained organic waste material, while the cathode chamber was filled with water. The system operated in batch mode for a continuous period of 14 days, without replenishing the microbial fuel. The open circuit voltage (OCV) was recorded daily using a digital multi-meter to monitor the performance of the MFC.

3. Results and Discussion

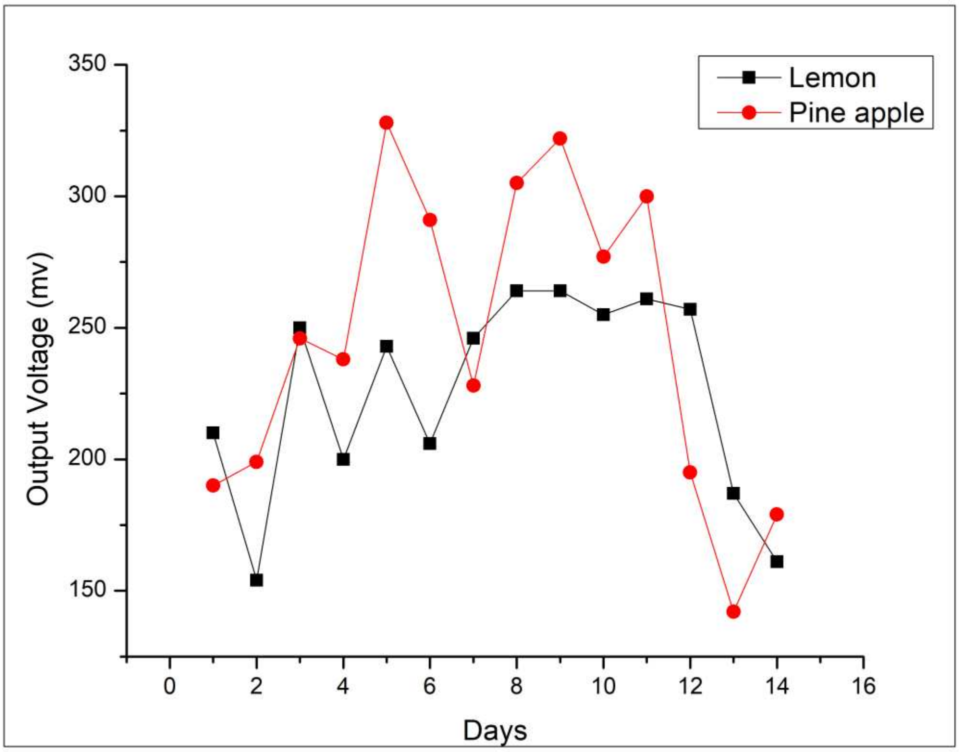

Figure 1 shows that the variation in open circuit voltage over a 14-day period for both lemon and pineapple waste. In the case of lemon waste, the open circuit voltage remained relatively low during the first 3 days, as microbial growth had not yet begun. After this initial period, microorganisms started to grow and multiply, resulting in a sharp increase in voltage. By the fourth day, the microbial population entered a stationary phase, and the voltage stabilized. Around day 12, microbial activity declined significantly, leading to a sudden drop in open circuit voltage. A similar trend was observed for pineapple waste, although the pattern occurred slightly earlier. During the first 5 days, microbial growth and multiplication caused a rapid rise in voltage.

After this, the microorganisms entered the stationary phase, and the voltage remained constant. By day 11, the decline in microbial activity led to a noticeable decrease in voltage. These patterns reflect the typical bacterial growth curve, consisting of the log phase, stationary phase, and death phase.

4. Conclusion

A prototype double-chamber microbial fuel cell was successfully developed and tested using waste lemon and pineapple. The output voltage pattern observed over the 14 days period closely aligns with the typical microbial growth curve. During the active growth and multiplication phase of the microorganisms, the open circuit voltage increased significantly. As the microorganisms entered the stationary phase, the voltage stabilized, and during the death phase, the voltage dropped sharply. This confirms that microbial activity plays a key role in power generation and demonstrates the potential of using fruit waste as a sustainable energy source in microbial fuel cells.

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References

[1] Borole AP, Reguera G, Ringeisen B, Wang ZW, Feng Y, Kim BH (2011) Electroactive biofilms: current status and future research needs. Energy Environ Sci 4:4813–4834. doi:10.1039/ C1EE02511B.
[2] Bergel A, Feron D, Mollica A (2005) Catalysis of oxygen reduction in PEM fuel cell by seawater biofilm. Electrochem Commun 7:900–904. doi: 10.1016/j.elecom.2005.06.006.
[3] Gil GC, Chang IS, Kim BH, Kim M, Jang JK, Park HS, Kim HJ (2003) Operational parameters affecting the performance of a mediator-less microbial fuel cell. Biosen Bioelect 18:327–334. doi:10.1016/S0956-5663(02)00110-0.