# Microbial Fuel Cell (MFC) Mediated Food Waste Remediation with Simultaneous Bioelectricity Generation

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*Abstract*— A single chamber microbial fuel cell (MFC) was designed and fabricated for the production of bioenergy generation with simultaneous composite food waste remediation. The MFC demonstrated maximum open circuit potential of 402 mV on 14th day of operation and followed decreasing trend till the end of operation. Experimental data depicted that provision of solid electrode material facilitated favorable conditions for higher substrate degradation/hydrolysis by enhancing electrochemically active bacterial metabolic activities. However, accumulation of intermediate metabolites showed adverse effect on the overall process by lowering the system pH conditions. MFC also documented good substrate removal efficiency with simultaneous bioelectricity generation. Experimental results demonstrated that solid-state anaerobic fermentation process can be efficiently combined in MFC for the bioelectricity generation with concurrent food waste remediation.

***Key words:*** Microbial Fuel Cell, Bioelectricity; Food waste; Electrode; Waste remediation

## I. INTRODUCTION

In the current energy-demanding scenario, bioelectricity generation from wastewater treatment employing microbial fuel cell (MFC) technology is beneficial, for the reason that thermodynamic conversion step is not required[1]. MFC is an electrochemical system, which transforms chemical energy stored in the organic matter/substrate to bioelectricity via a series of biochemical redox reactions mediated by anodic biocatalyst[2]. Recently, MFC has emerged as a reliable and promising technology for the production of bioelectricity from wide variety of carbon rich waste materials[3,4]. This MFC technology delivers double benefits of wastewater remediation and bioelectricity generation.

Worldwide, one third of the foodstuff produced for human consumption is wasted annually[5]. Composite food waste is one of the carbon rich and highly biodegradable solid waste[6]. It is very important to treat this food waste before dumping in to the environment to avoid its adverse effect on ecosystem. Dumping of solid food waste into landfill sites is inappropriate, as it may causes severe health glitches in heavily populated areas[7].

Quite a few investigations were conducted which illustrate the opportunities of energy generation from solid food waste by incineration and anaerobic digestion. This carbon rich and highly biodegradable solid food waste can also act as potential feedstock for anaerobic digestion process for bioenergy generation[8]. In addition, food waste can be successfully utilized for bioelectricity by integrating anaerobic digestion with MFC. Consequently, current research was aimed to evaluate MFC technology for the treatment of food waste and bioelectricity generation simultaneously. In the present research, graphite electrodes were used as electrode materials.

## II. MATERIALS AND METHODS

### A. *Food Waste*

Composite solid food waste from the institute canteen was collected and used as potential feed for the MFC operation. The composite solid food waste majorly containing of cooked rice, vegetables, spoiled vegetables, edible oil, etc. with a water content ranging between 8 and 12%. Prior to feeding, substrate was stored in a closed container at 4 $^0$C. The initial characteristics of the solid food waste used in this study are given (Table 1)

| Sl. No | Parameter | Unit | Value Obtained |
|---|---|---|---|
| 1 | pH | - | 6.1 |
| 2 | TSS | g/L | 28 |
| 3 | TS | g/L | 38 |
| 4 | TDS | g/L | 13.6 |
| 5 | VFA | g/L | 6.8 |
| 6 | COD | g/L | 315 |
| 7 | BOD | g/L | 228 |

Table 1: Initial Characteristics of food waste

### B. *MFC Architecture and Operation*

A single chambered MFC with open air-cathode was fabricated with glass material (total/working volume of 300/200 ml and graphite electrodes (surface area 60 cm$^2$) were used as electrode materials (Fig 1). The reactor was operated at room temperature (30 °C) in fed-batch mode (30 days cycle period). Prior to feeding, substrate pH was adjusted to 8 using 1 N NaOH solution.

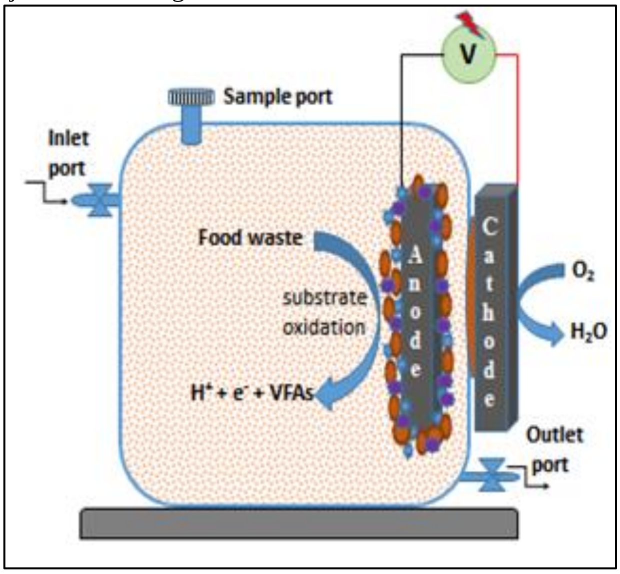


Fig. 1: Schematic illustration of MFC architecture

### *C. Anaerobic Mixed Consortia*

Anaerobic culture from biohydrogen producing UASB reactor was used as seed culture in MFC. Prior to the inoculation, seed culture was enriched with 3 g/L glucose under strict anaerobic conditions.

## III. ANALYSIS

The bioelectricity generation and substrate removal efficiency were measured as the two key parameters to assess MFC performance. Open circuit voltage (OCV) and current (I) were recorded manually on digital multi-meter equipment. Power density (PD) (mW/m$^2$) was considered with the function of electrode surface area (m$^2$). Polarization was performed to evaluate the polarization behaviour of MFC with a variable external resistance (range of 30 kΩ to 50 Ω). Both anode and cathode potentials were measured against reference electrode. Substrate removal efficiency was monitored by analysing pH, VFA and COD.

## IV. RESULTS AND DISCUSSION

### *A. Electro Genesis*

MFC was operated under strict anaerobic circumstances for a period of 30 days with frequent monitoring. The experimental results clearly depicted the influence of anolyte (substrate) on the fuel cell performance. Electrogenesis was noticed from the first day of MFC operation. Relatively low electricity generation (OCV, 24 mV) was documented during the initial day of operation followed by increasing trend and maximum OCV (402 mV; 20.2 mW/m$^2$) was noticed on 14$^{th}$ day of operation (Fig 2). From the 14$^{th}$ day of operation, electrogenesis was followed decreasing trend till end of the operation (Fig 2). From 26$^{th}$ day of MFC operation, drastic drop in both OCV (42 mV) and PD (1.01 mW/m$^2$) was noticed which further decreased on 30$^{th}$ day (OCV, 38 mV and PD, 0.21 mW/m$^2$). Comparatively higher power output noticed on 14$^{th}$ day of operation which might be due to the presence of simple substrate near the anode surface (in anode chamber) area for anodic biocatalyst. Gradual drop in the power generation after 26$^{th}$ day of MFC operation. This phenomenon might be due to the less metabolic activities of anodic biocatalyst due to drastic drop in system pH and also due to less substrate availability of mono sugars (simple sugars).

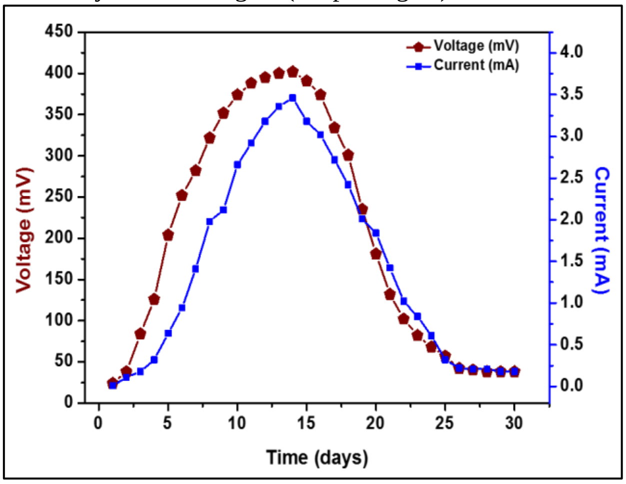


Fig. 2: Voltage and current generation with respective of time during MFC operation

### *B. Electron Losses*

To understand the fuel cell performance, polarization analysis was performed during the stable phase of MFC operation. During the MFC operation, polarization curve documented e$^-$ discharge at 4 kΩ on 14$^{th}$ day of MFC operation. Cell design point (CDP) during fuel cell operation was noticed at 200 Ω accounting for a power density (PD) of 19.45 mW/m$^2$. Therefore, MFC with solid food waste can be performed above 200 Ω.

### *C. Cell Potentials*

Changes in cell potentials ie., cathode potential (CP) and anode potentials (AP) were calculated, against the variable external resistance ($R_E$) ranging from 50 Ω to 30 kΩ during the stable phase of MFC operation. MFC showed more variations (482 to 46 mV) were noticed in CP under applied $R_E$ demonstrating that the current generated during MFC operation was not only restricted by the anodic redox reactions alone. Significant drop in AP was noticed during MFC operation when $R_E$ was decreased. AP controls the kinetics of e$^-$ flow from the biocatalyst to the electrode surface. Noteworthy drop in cell potential was noticed from or below 8 kΩ signifying the possibility of active e$^-$ transfer below 8 kΩ during fuel cell operation.

### *D. Substrate Degradation*

During MFC operation, organic fraction of the solid food waste will act as an e$^-$ donor in the anode chamber of MFC for power generation with simultaneous waste remediation. To understand the substrate removal efficiency, initial and final MFC reactor samples were collected and COD analysis was performed. Initial sample COD was performed as 320 g/L. At the end of the MFC operation (on 30$^{th}$ day), substrate COD was noticed as 180 g/L. Overall MFC system showed 140 g/L (43.75%) of food waste degradation was noticed. Observed substrate removal efficiency of MFC system enumerated the efficiency of MFC as a potential and viable waste treatment system apart from bioelectricity generation.

### *E. Ph and Volatile Fatty Acids (Vfas)*

To understand the system redox conditions and metabolic activities, the pH and VFA profiles of the MFC system were noticed at frequent time intervals. Fermentation of food waste for energy generation was accompanied with VFAs production as intermediate metabolites. In general, VFAs are considered as indicators to monitor the anaerobic digestion of substrate. Observed concentration of VFAs followed increasing trend till the end of the MFC operation (Fig 3).

 

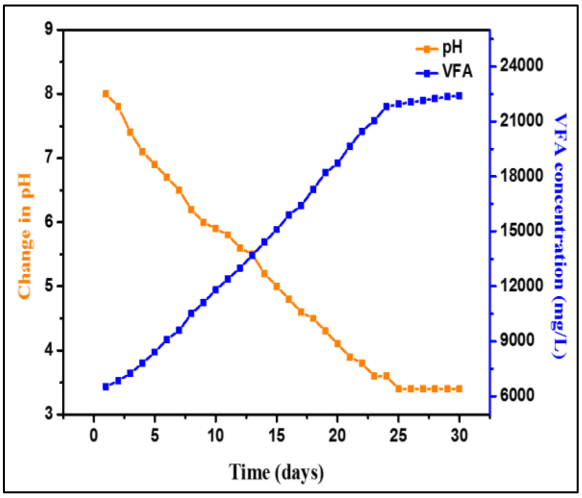


Fig. 3: Change in system pH and VFA concentration

Initially at 0th day of MFC operation, concentration of VFAs was observed as 6520 mg/L followed by increasing trend on 10th day (11800 mg/L), 20th day (18600 mg/L) and 30th day (22400 mg/L) (Fig 3). During stable phase of MFC operation, pH followed a decreasing trend from 1st day (8) to till 25th day (3.4) of operation, which indicate rapid metabolic activities of MFC system during the bioelectricity generation. From the 26th day of MFC operation, system pH was stabilized and no further change was noticed. This might be due to no further metabolic activities in the anodic compartment of the MFC. During the final stage of operation (after 25th day of operation), system pH might showed adverse effect on power generation which leads to drop in power generation. However, the pH below 4 is considered as unfavourable condition for anaerobic fermentation.

## V. Conclusions

Observed experimental results demonstrated the feasibility of using MFC system for bioelectricity generation from solid food waste fermentation apart from waste remediation. MFC system performance was found to depend on system pH and after pH drop below 4, no further bioelectricity was generation was noticed. However, VFAs accumulation is responsible for the drastic drop in system pH. During the MFC operation, formation of acid metabolites showed negative influence on bioelectricity generation and substrate removal efficiency of the fuel cell. MFC enumerated the functioning of solid-state fermentation for renewable energy generation from food waste and also forms the foundation for sustainable solid-waste management practices.

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