Electricity generation using maize wastewater by single chambered microbial fuel cell

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Abstract— Increased human activity and consumption of natural energy resources have led to decline in fossil fuel. The current methods of energy production are not compatible with the environment. Therefore, a new treatment approach of using Microbial fuel cell (MFC) has been developing recently. The technology of Microbial Fuel cells is the latest method for producing electricity from biomaterial by using microorganisms. In this study microbial source uses Maize wastewater as a substrate and is inoculated with cow dung for the production of electricity and used to remove the concentration of COD, BOD and Solids. This research explores the application of single chambered MFC in generating electricity. The maximum current, voltage and power produced were respectively 5.56mA, 4.89V and 1.637W/m² at 30th day and 6000 mg COD/L feed concentration. The maximum removal efficiency of COD, BOD5, TS, and DS was respectively achieved at 79.51%, 76.52%, 72.56%, and 75.07%. The results showed that generating bioelectricity and treatment of Maize wastewater by single chambered MFC is a good alternative for producing energy and treating wastewater at the same time.

Key words: Microbial fuel cell (MFC), Maize wastewater, Electricity generation, Single chambered MFC

I. INTRODUCTION

Energy calamity in India is rising each year, as there is constant activity in the price of fuels and also due to depletion of fossil fuels to a larger level. The demand for an alternating fuel has erupted extensive research in discovering a potential, economical and reusable source for energy manufacture. Rapid urbanization and industrialization in the developing countries like India pose severe problems in collection, treatment and disposal of effluents. This situation leads to serious public health problems. For constructing a sustainable world we require to minimize the expenditure of fossil fuels as well as the pollution generated. These two aims can be accomplished all together by treating the wastewater (From disposing waste to using it). Industrial waste, agricultural waste and household waste are ideal substrates for energy productions as they are rich in organic contents.

Many researchers have shown that hydrogen and bioelectricity can have an important role as fuel in the future [4]. The technology of MFC is the latest method for producing electricity from biomaterial by using microorganisms. MFCs are electrochemical converters and convert the chemical energy stored in organic material to current energy by microorganisms which act as biocatalysts in anaerobic condition [5], [12]. Microorganisms in the anode chamber oxidize the substrate added to the system such as Maize wastewater and produce electrons and protons. Free electrons are transferred to the anode electrode and through the external circuit they reach the surface of the electrode cathode. The produced protons pass through the proton exchange membranes or salt bridges and reach the cathode surface and in the presence of oxygen and electrons from water molecule [6]. In this process along with the production of electric power, the wastewater in the anode chamber is used as a substrate for treatment. The function of microbial fuel cells is affected by several factors such as the amount of oxidation and electron transfer to the electrodes by microorganisms, loading rate, the nature of the used carbon source, the nature of the proton exchange membrane, proton transfer through the membrane to the cathode chamber, oxygen supply in the cathode, the nature and type of electrodes, circuit resistance, the electrolyte used, pH and sedentary time [8], [9], [12]. Industrial Maize wastewater is an important source of organic material for electricity production by using MFC. In this study we are showing the electricity production.

Directly from Maize wastewater and its simultaneous treatment by using single chambered MFC technology.

Now a days starch has become one of the major agro based industries. The starches that are obtained from various kinds of grains such as maize (corn), rice and wheat and from roots like tapioca, arrowroot, etc. have got major industrial importance and applications. maize is well suited for starch processing due to its availability, long storage life and high starch content. Maize is processed into starch and other by products by milling process. The pure starch slurry thus produced is converted to glucose either by acid hydrolysis or enzymatic conversion process. Wet milling process adopted in starch conversion require large volume of water and it generates substantial quantity of effluent. The treatment of effluent is carried out by various methods and the treated effluent water is very much suitable for farming and well accepted by the farmers. [1]

The industrial Processing of starch to sugar can be carried out either by acid or enzymatic hydrolysis. However the use of enzymes is preferred to acid, once it produces high yields of desire products and less formation of undesired products such as toxic compounds. chemically, sugar is the substance sucrose which can be hydrolysed in acidic solution (i.e below pH 7) to form the mono-saccharides glucose and fructose. or starch production, maize grains are digested, which is capital intensive and time consuming (24 to 52h) and acidic pH(4 to 5) created with lactic bacteria which inhibits the survival and multiplication of bacteria pathogens. [2]

II. MATERIALS AND METHODOLOGY

A. Treatment by Microbial Fuel Cell (MFC)

Single (MFC-1) Microbial fuel cells have been fabricated for the treatment of Maize industry wastewater.
1) Materials used for the fabrication of MFC
Various materials used for the construction of MFCs were as follows:
- one Non-Reactive plastic box of ten liter capacity.
- Agar agar bacto (for bacteriology), SDFCL
- Sodium Chloride (1M).
- Carbon rods of 4mm Diameter & 47mm length extracted from battery cells.
- PVC pipe 3.2cm diameter and length of 22cm
- Sealant: M-seal, pidilite industries ltd.
- Digital Multimeter (DT-830D)
- Functions of the materials used for the fabrication of MFC
a) Plastic box
used to prepare anode chamber. The anode chamber had 10 litres capacity with a working volume of 7.5 litres.
b) Agar Agar Bacto
It was used to prepare agar salt bridge i.e., proton exchange membrane for keeping the anode and cathode containing liquid separately. This membrane is permeable so that protons produced at anode can migrate to the cathode[3].
2) Construction of Microbial Fuel Cell
1) Step 1: Selection of Anode Chamber
Non-reactive, nonconductive and non-biodegradable plastic box is selected as anode chambers the dimensions of plastic box are shown in figure 1.

![Fig. 1: Plastic box. (All dimensions are in cm)](image)

2) Step 2: Preparation of Agar Salt Bridge
The Agar salt bridge is constructed using common salt, agar and water. 650ml of water is boiled in a beaker, 65 grams of agar and 75 grams of salt are added to the boiling water, and the mixture is further boiled for 3-5 minutes. Later on the mixture is filled in PVC pipe and allowed to solidify and is kept in the refrigerator for 24 hours. The agar salt bridge is shown in figure 2.

![Fig. 2: Agar salt bridge](image)

3) Step 3: Assembling of Electrodes
27 numbers of carbon rods extracted from battery cells as shown in figure 3 and are inserted in the flexible plastic pipe for the construction of Anode. The arrangement of Anode (electrode) is done on a flexible plastic pipe in such a way that it looks like a carbon brush as shown in figure 4.

![Fig. 3: Extracted carbon rod from battery cell for preparing carbon brush](image)

![Fig. 4: Arrangement of electrodes](image)

In single chambered MFC there is no cathode chamber. Instead, the carbon rods extracted from Battery cell have been placed on one end of the agar salt bridge which is exposed to the air and the copper wire is wound on it. This acted as cathode for MFC. The oxygen from air would help in accepting the electrons from anode chamber.

4) Step 4: Assembling Of Microbial Fuel Cell
The assembled electrodes is placed into the Anode chamber, a circular hole is made on the side of the working volume of the center of the plastic box for fitting the PVC pipe containing agar salt, then the pipe is sealed and made air tight as shown in figure 5 and figure 6. The reactor is checked for water leakage. [8]
3) MFC Operation

The 1.9 L volume of the reactor is filled with a mixture of cow dung slurry prepared with septic tank waste as inoculums. The 7.5 L working volume of reactor is filled with Maize wastewater. In the beginning the Anode chamber of MFC is loaded with 1000 mg/L of COD and the electricity generated is measured for 5 days. On the 5th day the current and voltage dropped down which shows the stabilization of the reactor for this loading. Similarly the same process is carried out for other 8 sets of readings till the final loading of 8000 mg/L of COD with an increment of 1000 mg/L of COD for each loading.

III. RESULTS AND DISCUSSION

A. Sample Point

Maize industrial wastewater was collected from Gujarat Ambuja Export Limited, Hubli, Karnataka and kept in a refrigerator at 4°C before use. Wastewater is Generated From various processing units such as Gluten decanter, Ion Exchange water, Corn Steep Liquor, Process cleaning, Drum Cleaning, Starch decant water, Bioler Blow Down Water. Some of the characteristics of Maize wastewater are shown in Table 1. In order to evaluate the efficiency of wastewater treatment through the MFC system, the effluent from the anode chamber is examined with regard to COD, BOD5, Total solids, Dissolved solids and pH according to the standard methods in the textbook of standard methods for water and wastewater examination. Similarly Current, Voltage and power is also measured.

B. Characteristics of Maize wastewater

The characteristics of Maize wastewater are presented in Table 1.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Characteristics</th>
<th>Unit</th>
<th>Maize Wastewater</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>pH</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>Color</td>
<td></td>
<td>Blackish</td>
</tr>
<tr>
<td>3</td>
<td>Total solids</td>
<td>mg/L</td>
<td>12461</td>
</tr>
<tr>
<td>4</td>
<td>Dissolved solids</td>
<td>mg/L</td>
<td>9526</td>
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<tr>
<td>5</td>
<td>Suspended solids</td>
<td>mg/L</td>
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<tr>
<td>6</td>
<td>COD</td>
<td>mg/L</td>
<td>8000</td>
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<tr>
<td>7</td>
<td>BOD5 @20°C</td>
<td>mg/L</td>
<td>5624</td>
</tr>
<tr>
<td>8</td>
<td>Chlorides</td>
<td>mg/L</td>
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</tr>
</tbody>
</table>

Table 1: Characteristics of Maize wastewater

C. COD Removal Efficiency of Maize wastewater for Various Feed concentrations in MFC

Maize wastewater showed its potential for COD removal indicating the functions of microbes present in wastewater in metabolizing the carbon source as electron donor. Continuous COD removal was observed from day 1 to 30, for feed concentration 1000 to 6000 mg COD/L, from 46.2% to 79.51%. Then onwards COD removal efficiency decreased to 75.20% at 8000 mg COD/L.

D. BOD Removal Efficiency of Maize wastewater for Various Feed concentrations in MFC

Maize wastewater showed its potential for BOD removal indicating the functions of microbes present in wastewater in metabolizing the carbon source as electron donor. Continuous BOD removal was observed from day 1 to 30, for feed concentration 1000 to 6000 mg COD/L, from 43.31% to 76.52%. Then onwards BOD removal efficiency decreased to 71.36% at 8000 mg COD/L.

E. TS Removal Efficiency of Maize wastewater for Various Feed concentrations in MFC

Maize wastewater showed its potential for BOD removal indicating the functions of microbes present in wastewater in metabolizing the carbon source as electron donor. Continuous BOD removal was observed from day 1 to 30, for feed concentration 1000 to 6000 mg COD/L, from 38.1% to 72.56%. Then onwards BOD removal efficiency decreased to 68.01% at 8000 mg COD/L.
F. DS Removal Efficiency of Maize wastewater for Various Feed concentration in MFC

Maize wastewater showed its potential for DS removal indicating the functions of microbes present in wastewater in metabolizing the carbon source as electron donor. Continuous DS removal was observed from day 1 to 30, for feed concentration 1000 to 6000 mg COD/L, from 40% to 75.07%. Then onwards DS removal efficiency decreased to 70.02% at 8000 mg COD/L.

![Fig. 10: DS Reduction of Maize wastewater at various feed concentrations in MFC](image)

G. PH Variation of Maize wastewater for Various Feed concentrations in MFC

Maize wastewater showed its potential for increments of pH. Continuous increment is observed in MFC, the pH increased from 6. to 7.79 as the feed concentration increased from 1000 mg COD/L to 6000 mg COD/L respectively as shown in chart 5. pH was neutralized for every 24 hours and pH varied from neutral to slightly alkaline during the oxidation process.

![Fig. 11: pH variations of Maize wastewater at various feed concentrations in MFC](image)

H. Current and voltage Generation of Maize wastewater for various feed concentrations in MFC

The average value of current and voltage for each feed concentration in MFC is given in the chart 6 and 7. The current and voltage showed a gradual increase with respect to increase in feed concentration. The highest average values of current and voltage obtained as 5.56 mA in MFC with a feed concentration of 1000 mg COD/L to 6000 mg COD/L respectively as shown in chart 6. Similarly the voltage value is obtained as 4.89 V in MFC as shown in chart 7. The power produced for 1m² area is 1.637 W for single chambered MFC.

![Fig. 12: Voltage generation of Maize wastewater at various feed concentrations in MFC](image)

I. Overall Treatment Efficiency of Maize

The percentage removal of COD, TS, DS and BOD are represented, and the overall treatment efficiencies in single chambered MFC is given in Chart 8. The COD, BOD, TS & DS percentage reduction is highest at 6000mg COD/L. The chart 8 clearly depicts that the optimal feed concentration for MFC is 6000 mg COD/L. The optimal COD, BOD, TS &DS removal efficiencies are 79.51%, 76.52%, 72.56% & 75.07% respectively.

![Fig. 13: Overall treatment efficiency of Maize wastewater at various feed concentration.](image)

IV. CONCLUSION

On analyzing the results based on the laboratory experiments conducted, the following conclusions are drawn.

- For the maximum feed concentration of 6000 COD mg/L the corresponding removal efficiency of COD, BOD, TS and DS are 79.51%, 76.52%, 72.56% and 75.07% respectively.
- At the maximum feed concentration of 6000 mg COD/L the current, voltage and power generation in the reactor are 5.56 mA, 4.89 V and 1.637 W/m² respectively.

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REFERENCES


