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Electricity Generation by the use of Double Chamber Microbial Fuel Cell: Comparative study of the Voltage Generated by Bread Factory Substrate and Waste Water from Poultry Farm

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Abstract

Microbial fuel cell (MFC) represents a new method for electricity generation and waste water treatment. Microbial fuel cells are devices that can use bacterial metabolism to produce an electrical current from wide range organic substrates. This research explores the application of Double chamber MFC in generating electricity using different waste water from Jabalpur. In order to obtain the aim of this research, a system of MFC with microbes has been used. Based on the result of different substrates, it can be reported that the maximum voltage generated among all the four substrates is 396mV at day five by slurry.

Keywords: Double chamber MFC, Electrodes, Micro-organisms, Salt Bridge.

Introduction

Recent rise in energy costs, rapidly dwindling crude oil supplies and concern over the negative effects of carbon emissions have reignited both public and private interest in finding cheap alternative renewable energy sources. Many “green” energy generating process rely on the metabolic activity of microbes to turn human waste products into usable energy. MFC is considered to be a promising sustainable technology to meet increasing energy needs, especially using wastewaters as substrates, which can generate electricity and accomplish wastewater treatment simultaneously, thus may offset the operational costs of wastewater treatment plant [1].

MFC can be best defined as a fuel cell where microbes act as catalyst in degrading the organic content to produce electricity. It is a device that straight away converts microbial metabolic or enzyme catalytic energy into electricity by using usual electrochemical technology [2]. Various types of the microbial fuel cell exists, differing majorly on the source of substrates, microbes used and mechanism of electron transfer to the anode. Based on mechanism of electron transfer to the anode, there are two types of microbial fuel cell which are the mediator microbial fuel cell and the mediator-less microbial fuel cell.

Mediator-microbial fuel cells are microbial fuel cells which use a mediator to transfer electrons produced from the microbial metabolism of small chain carbohydrates to the anode [3]. This is necessary because most bacteria

cannot transfer electrons directly to the anode [4]. Mediators like thionine, methyl blue, methyl viologen and humic acid tap into the electron transport chain and abstract electrons (becoming reduced in the process) and carry these electrons through the lipid membrane and the outer cell membrane [5],[6].

Mediator-less microbial fuel cells, on the other hand, use special microbes which possess the ability to donate electrons to the anode provided oxygen (a stronger electrophilic agent) is absent [4],[7]. There are variants of the mediatorless microbial fuel cell which differ with respect to the sources of nutrient and type of inoculum used.

In direct electron transfer, there are several microorganisms (Eg. *Shewanella putrefaciens*, *Geobacter sulfurreducens*, *G. metallireducens* and *Rhodospirillum rubrum*) that transfer electrons from inside the cell to extracellular acceptors via c-type cytochromes, biofilms and highly conductive pili (nanowires) [8]. These microorganisms have high Coulombic efficiency and can form biofilms on the anode surface that act as electron acceptors and transfer electrons directly to the anode resulting in the production of more energy [9] [10].

In indirect electron transfer, electrons from microbial carriers are transported onto the electrode surface either by a microorganism's (*Shewanella oneidensis*, *Geothrix fermentans*) own mediator which in turn facilitate

extracellular electron transfer or by added mediators. The MFCs that use mediators as electron shuttles are called mediator MFCs. Mediators provide a platform for the microorganisms to generate electrochemically active reduced products. The reduced form of the mediator is cell permeable, accept electrons from the electron carrier and transfer them onto the electrode surface [11]. Usually neutral red, thionine, methylene blue, anthraquinone-2, 6-disulfonate, phenazines and iron chelates are added to the reactor as redox mediators [12].

Material and Method

MFC construction

The pictorial representation of the MFC has been shown in the following Figure 1.

Electrodes

Carbon electrode was used at both the ends of cathode and anode and tightly fixed with the containers containing medium, culture and buffer.

Cathodic chamber

The cathode chamber of the MFC was made up of 2 liters plastic bottle filled with buffer solution.

Anodic Chamber

The 2 liters sterilized plastic bottle is used for this purpose. The bottle is surface sterilized by washing with 70% ethyl alcohol and 1% HgCl_2 solution followed by UV exposure for 15 minutes. Then the medium was filled in it. Methylene blue, waste water sample and bacteria was added to it.

Salt bridge

The salt bridge was prepared by dissolving 3% agar in 1M KCl. The mixture was boiled for 2 minutes and casted in the PVC pipe. The salt bridge was properly sealed and kept in refrigerator for proper settling.

Substrates

There are different types of substrates has been used. In my study, first substrates is collected from Waste water of bread factory Jabalpur, second is the waste water from poultry farm Jabalpur, third substrates is drain water and fourth is slurry from Jabalpur has been used. It contains organic matter like starch, glucose, and sucrose which is used by bacteria for growth.

Mediator

Methylene blue is a redox indicators act as electron shuttles that are reduced by microorganisms and oxidized by the MFC electrodes thereby transporting the electrons produced via biological metabolism to the electrodes in a fuel cell.

Circuit Assembly

Two chambers were internally connected by salt bridge and externally the circuit was connected with wires which were joined to the two electrodes at its two ends and to the multimeter by another two ends. The

potential difference generated by the Fuel Cell was measured by using multimeter.

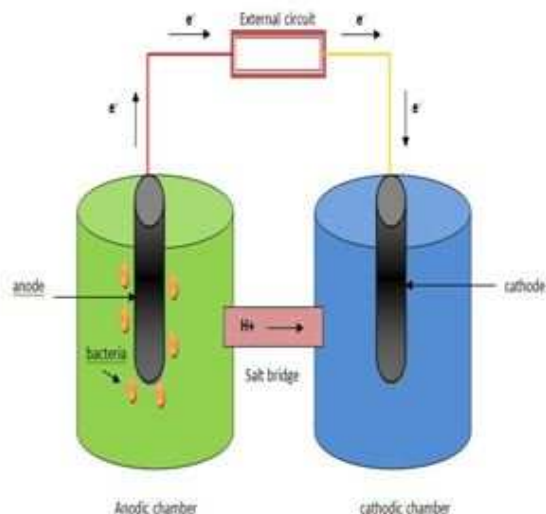


Figure 1- Schematic diagram of MFC

MFC Operation

This research intends to utilize the waste water to generate electricity in Double chamber Microbial Fuel Cell system. The micro organisms are used as biocatalyst. The bacteria will convert sugar components in the waste water into Carbon dioxide, where in the intermediate process will be released electron generating electricity in MFC system.

All the components of MFC are connected via salt bridge internally and externally with wires to the multimeter. The substrates (waste water) was added in the anodic chamber. The anodic chamber was completely sealed to maintain anaerobic condition. The voltage generation was recorded at daily basis for bacterial isolate in presence of mediator. The MFC set up was kept at static conditions. The value of voltage was recorded every day till 7 days.

Results

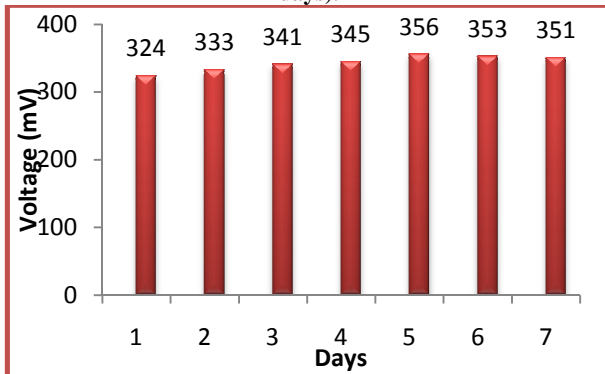
Voltage generation by use of Bread factory Substrate

The voltage generation was recorded per day throughout the week for the substrate obtained from bread factory. There was a definite increase in the voltage till the day five and after that voltage decreases as shown in Table-1.1. The results reveal the fact that on day 5 the maximum potential that obtained was 356 mV, whereas it was 324mV on day 1. The maximum current measured was found 0.31 mA on day 5.

Table-1.1: Maximum Voltage generated with Waste water from Bread factory.

Days	Maximum voltage generated in (mV)
1	324
2	333
3	341
4	345
5	356
6	353
7	351

Graph-1.1: Graph representing voltage generated with Waste water from Bread factory with respect to time (in days).



Voltage generation by use of waste water from Poultry farm

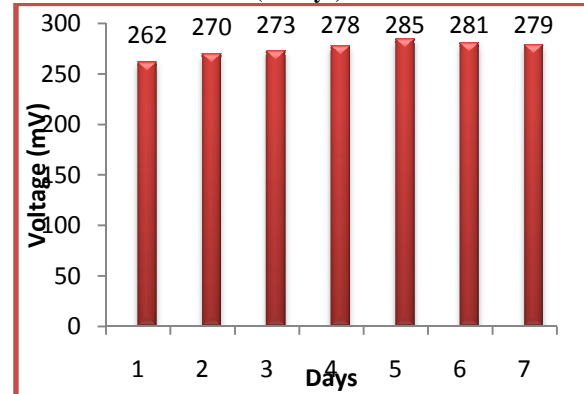
The voltage generation was recorded per day throughout the week for the substrate obtained from poultry farm waste water. There was a definite increase in the voltage till the day 5 and after that voltage decreases, as shown in Table-1.2. The results reveal the fact that on day 5 the maximum potential that obtained was 285mV, whereas it was 262mV on day 1. The maximum current measured was found 0.29 mA on day 5.

Table-1.2: Maximum Voltage generated with Waste water from Poultry farm.

Days	Maximum voltage generated in (mV)
1	262
2	270
3	273

4	278
5	285
6	281
7	279

Graph -1.2: Graph representing voltage generated with Waste water from Poultry farm waste with respect to time (in days).



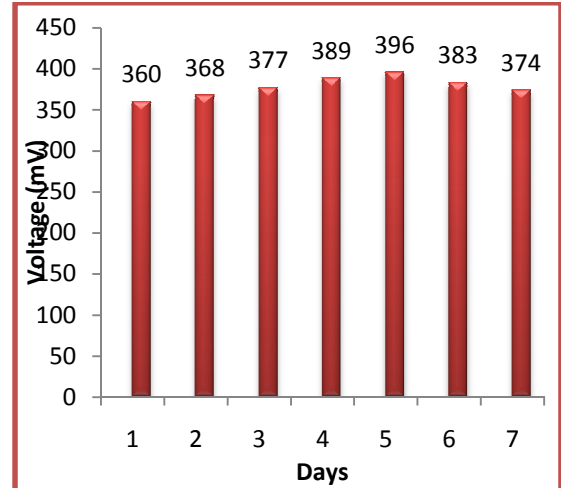
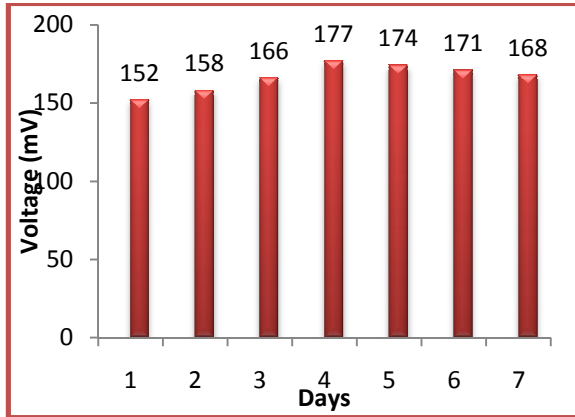
Voltage generation by use of Domestic Drain water

The voltage generation was recorded per day throughout the week for the substrate obtained from domestic drain water. There was a definite increase in the voltage till the day 4 and after that voltage decreases, as shown in Table-1.3. The results reveal the fact that on day 4 the maximum potential that obtained was 177mV, whereas it was 152mV on day 1. The maximum current measured was found 0.20 mA on day 4.

Table-1.3: Maximum Voltage generated with Drain water.

Days	Maximum voltage generated in (mV)
1	152
2	158
3	166
4	177
5	174
6	171
7	168

Graph-1.3: Graph representing voltage generated with Drain water with respect to time (in days).



Voltage generation by the use of Slurry

The voltage generation was recorded per day throughout the week for the substrate of slurry. There was a definite increase in the voltage till the day 5 and after that voltage decreases, as shown in Table-1.4. The results reveal the fact that on day 5 the maximum potential that obtained was 396mV, whereas it was 360mV on day 1. The maximum current measured was found 0.43 mA on day 5.

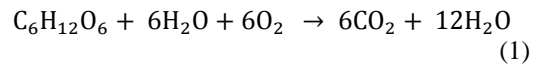
Table-1.4: Maximum Voltage generated with Slurry.

Days	Maximum voltage generated in (mV)
1	360
2	368
3	377
4	389
5	396
6	383
7	374

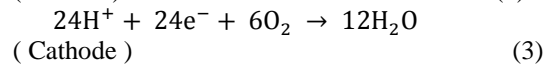
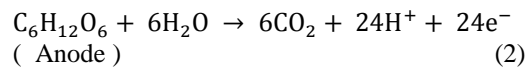
Graph-1.4: Graph representing voltage generated with slurry with respect to time (in days).

Discussion

Microbial fuel cell is based upon the basic principle in which biochemical energy is converted into electrical energy. Consumption of organic substrate (e.g. glucose) by microorganism in aerobic condition produce CO₂ and H₂O.



If the terminal electron acceptor oxygen is replaced by mediator then the electrons will be trapped by mediator, which will get reduced and transport to electrons to the electrode at anodic chamber .However when oxygen is not present (anaerobic condition) they produce carbon dioxide, protons and electrons as described below.



Based on the result, it was found that maximum voltage (356mV) at day five was generated by waste water of bread factory, maximum voltage (285mV) at day five was generated by waste water of poultry farm, maximum voltage (177mV) at day four was generated by drain water and maximum voltage (396mV) at day five was generated by slurry. The MFC was run up to one week and the voltage was recorded daily basis in the presence of mediator. The maximum voltage generated among all the four substrates is 396 mV at day five was generated by slurry.

Conclusions

Microorganisms that can combine the oxidation of organic biomass to electron transfer to electrodes put forward the self-sufficient systems that can successfully convert waste organic matter and reusable biomass into

electricity. Oxidation of these newly rigid sources of organic carbon does not supply net carbon dioxide to the environment and unlike hydrogen fuel cells, there is no requirement for wide pre-handing out of the fuel or for costly catalysts. With the suitable optimization, microbial fuel cells might be able to power an extensive collection of broadly used procedure. Technology of Microbial Fuel Cell is one alternative of energy production using renewable resource.

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