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Electricity Generation in Double Chamber Microbial Fuel Cell with different Salts Concentration

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Abstract

Microbial fuel cell (MFC) represents a new method for electricity generation. Microbial fuel cells are devices that can use bacterial metabolism to produce an electric potential from a wide range organic substrates. This research explores the application of Double chamber MFC in generating electricity using mixture of the waste water of bread factory and slurry collected from Jabalpur. The different concentration of NaCl and KCl in salt bridge has been performed. The maximum voltage obtained with respect to time (days) by these results. The potential difference generated by the MFC was measured using multimeter.

Keywords: Double chamber MFC, Electricity, Salt bridge, Waste water.

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].

In direct electron transfer, there are several microorganisms (Eg. *Shewanella putrefaciens, Geobacter sulferreducens, G. metallireducens and Rhodoferax ferrireducens*) 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

Electrode

Carbon electrode was used at both the ends of cathode and anode and tightly fixed with the two 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 KCl and NaCl . 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

In my study, the waste water of bread factory mixed with slurry are used. Both are collected from Jabalpur. 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 MFC.

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 MFC was measured by using multimeter.

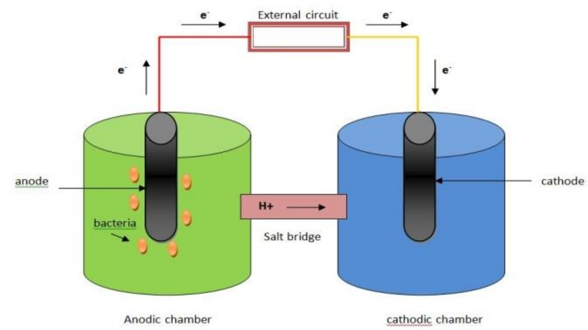

Figure 1- Schematic diagram of Double chamber MFC

MFC Operation

This research intends to utilize the waste water to generate electricity in Double chamber MFC 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.

Results

Effect on voltage generation by variation in salts concentration.

A two chamber MFC setup was adopted initially with 1M KCl solution to make the salt bridge. After that it was checked for 1M NaCl. Again KCl and NaCl were used in different concentrations such as 3M and 5M for fabricating salt bridge. After comparing the results of different KCl and NaCl concentrations, it was found that the salt bridge made up of KCl functions better than that of NaCl.

1M KCl and 1M NaCl

In the experiment, 1M KCl and 1M NaCl were used to transport H^+ ions in the salt bridge. The voltage generation was recorded per day throughout the week for the mixture of bread factory substrate and slurry. On day 5 the maximum generated voltage obtained with 1M KCl and 1M NaCl was 434mV and 369mV respectively. The MFC was run for a period of 7 days and readings were noted at regular intervals.

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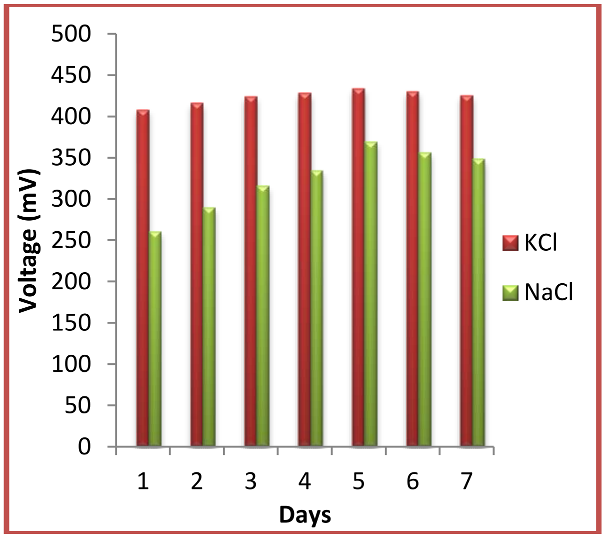
Table-1.1: Maximum voltage obtained with 1M KCl and 1M NaCl

Days	Maximum voltage (mV)	
	KCl	NaCl
1	408	260
2	416	289
3	424	315
4	428	334
5	434	369
6	430	356
7	425	348



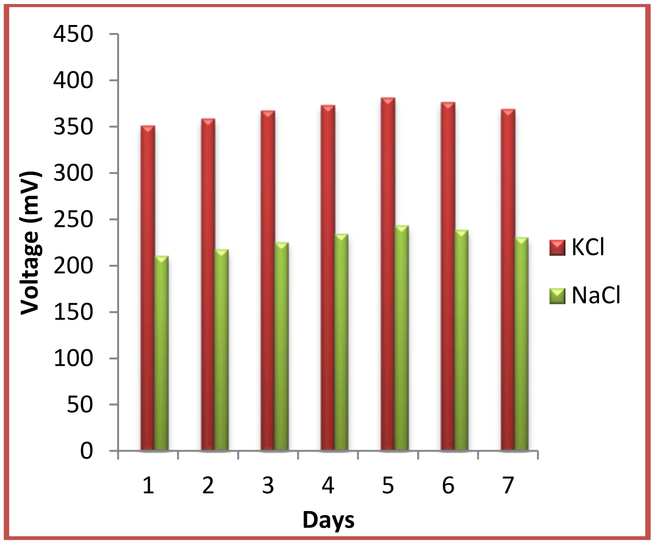
Graph -1.1: Graph representing voltage generated in Double chamber-MFC for 1M KCl and 1M NaCl with respect to time (in days).

3M KCl and 3M NaCl

In the experiment, 3M KCl and 3M NaCl were used to transport H^+ ions in the salt bridge. The voltage generation was recorded per day throughout the week for the mixture of bread factory substrate and slurry. On day 5 the maximum generated voltage obtained with 3M KCl and 3M NaCl was 381mV and 243mV respectively. The MFC was run for a period of 7 days and readings were noted at regular intervals.

Table-1.2: Maximum voltage obtained with 3M KCl and 3M NaCl

Days	Maximum voltage (mV)	
	KCl	NaCl
1	351	210
2	358	217
3	367	225
4	373	234
5	381	243
6	376	238
7	369	230



Graph -1.2: Graph representing voltage generated in Double chamber-MFC for 3M KCl and 3M NaCl with respect to time (in days).

5M KCl and 5M NaCl

In the experiment, 5M KCl and 5M NaCl were used to transport H^+ ions in the salt bridge. The voltage generation was recorded per day throughout the week for the mixture of bread factory substrate and slurry. On day 4 the maximum generated voltage obtained with 5M KCl and 5M NaCl is 342mV and 204mV respectively. The MFC was run for a period of 7 days and readings were noted at regular intervals.

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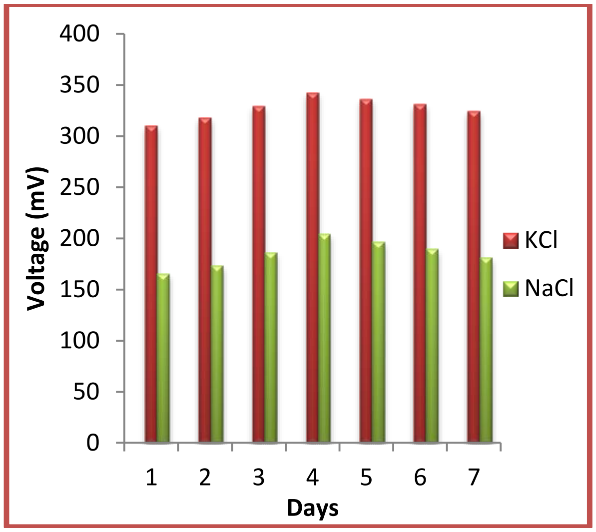
Table-1.3: Maximum voltage obtained with 5M KCl and 5M NaCl

Days	Maximum voltage (mV)	
	KCl	NaCl
1	310	165
2	318	173
3	329	186
4	342	204
5	336	196
6	331	189
7	324	181



Graph -1.3: Graph representing voltage generated in Double chamber-MFC for 5M KCl and 5M NaCl 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 CO_2 and H_2O.

$$C_6H_{12}O_6 + 6H_2O + 6O_2 \rightarrow 6CO_2 + 12H_2O \quad (1)$$

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 [13].

$$C_6H_{12}O_6 + 6H_2O \rightarrow 6CO_2 + 24H^+ + 24e^- \quad (2)$$
(Anode)

$$24H^+ + 24e^- + 6O_2 \rightarrow 12H_2O \quad (3)$$
(Cathode)

Based on the result, the maximum generated voltage obtained with 1M KCl and 1M NaCl was 434mV and 369mV on day 5. The maximum generated voltage obtained with 3M KCl and 3M NaCl was 381mV and 243mV on day 5. The maximum generated voltage obtained with 5M KCl and 5M NaCl is 342mV and 204mV on day 4.

Conclusion

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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