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CONSTRUCTION OF AGAR SALT BRIDGE MICROBIAL FUEL CELL (MFC) AND BIOELECTRICITY PRODUCTION FROM WASTE

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Short Profile

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ABSTRACT:

In the current study MFC were constructed using PVC Schedule Tee, PVC Schedule Connector, PVC Schedule Slip Cap, Titanium fishing lead, Clear plastic wrap, Rubber bands, Salt Bridge Medium (Sodium chloride, Agar and Water). It mainly consists of anode and cathode chamber connected to a multimeter to complete the circuit. Wires and carbon brushes were used to make the carbon electrodes. Four different waste water samples were (Stagnant waste water, Dairy waste, Liquid waste containing algae and Fermented municipal solid waste-FMSW) and E.coli pure culture was used as microbial sources. The sample was fed in the anode chamber. Biological fuel cells convert the chemical energy of carbohydrates, such as sugars, directly into electric energy. Once the MFC was stabilized the results were obtained and the documented report shows that, FMSW was showing 195.00mV potential difference, Dairy waste 113.00mV, Drainage Water 130.0mV, waste containing algae was shown 98.00mV and E.coli 4.01mV at 60minutes of time interval. FMSW was given high potential difference due to presence of a variety and bulk amount of microorganism.

The outcome of our studies conveys that using a combination of microorganisms yields higher voltage when compared to single organism.

KEYWORDS

Bioelectricity, MFC, Agar salt bridge, mixed culture, Anode, Cathode.

INTRODUCTION :

Fossil fuels have supported the industrialization and economic growth of countries during the past century, but it is clear that they cannot indefinitely sustain a global economy. Renewable energy will one day be a large portion of global energy production and usage. Microbial fuel cells are not new – the concept of using microorganisms as catalysts in fuel cells was explored from the 1970s (Suzuki, 1976; Roller et al., 1984) and microbial fuel cells treating domestic wastewater were presented in 1991 by Habermann and Pommer . Microbial fuel cells (MFCs) are bio-electrochemical transducers that convert microbial reducing power (generated by the metabolism of organic substrates) into electrical energy (Bennetto, 1984; Allen et al., 1993). MFCs have operational and functional advantages over the technologies currently used for generating energy from organic matter (Abhilasha, 2009) and wastewater have been studied quite extensively (Kim et al., 2000; Huang et al., 2004; Logan, 2004; Ginkel et al., 2005; Logan and Regan, 2006 ; Muralidharan, 2011). Trapping renewable energy from waste organic sources has facilitated energy production and at the same time accomplishes wastewater treatment (Logan, 2004; Liu et al., 2004).

The infrastructure changes needed to address our global energy needs will be far more extensive and will likely require changes not only to our infrastructure but also to our lifestyle. Changes will affect everything from home heating and lighting, to where we prefer to live and work and how we get there. The costs of energy and how much energy we use will come to dominate our economy and our lifestyle in the coming decades. Energy, in any form, plays the most important role in the modern world. We need energy, especially electrical energy in our daily needs of life. Biological fuel cells offer a potential solution to all these problems, by taking nature's solutions to energy generation. They use the available substrates from renewable sources and convert them into harmless by-products with simultaneous production of electricity (Mohan et al., 2008). A typical microbial fuel cell consists of anode and cathode compartments separated by a membrane. In the anode compartment, fuel is oxidized by microorganisms, generating electrons and protons. Electrons are transferred to the cathode compartment through an external electric circuit, and the protons are transferred to the cathode compartment through the membrane. Electrons and protons are consumed in the cathode compartment, combining with oxygen to form water (Girbal et al., 1995; Rozendal et al., 2006). Renewable energy will one day be a large portion of global energy production and usage. Microbial fuel cell (MFC) technology represents a new form of renewable energy by generating electricity from what would otherwise be considered waste. According to the Logan and Regan (2006) this technology can use bacterium already present in wastewater as catalysts to generating electricity while simultaneously treating wastewater. Although MFCs generate a lower amount of power, a combination of both electricity production and wastewater treatment could reduce the cost of treating primary effluent wastewater. Currently, most of the research performed on MFCs is concerned with increasing the power density of the system with respect to the peripheral anode surface area.

MFC are constructed using variety of materials to produce electricity. Aishwarya et al., (2011) were constructed using two borosil bottles (500ml capacity) with agar salt bridge, Salt bridge-Immersed-Air Cathode MFC (SBIAC-MFC) consisted of a plastic container of capacity 2 liters was designed by Muralidharan et al., (2011), 500 ml polyacrylic jars were used by Debajit et al., (2013), MFC was constructed using air-tight food grade plastic containers of 1.3 litres volume (Ramya Nair, 2013), Ganesan et al., (2014) used pet bottles of one litre capacity. In the current study PVC material with 2% agar salt bridge was used for 500ml capacity MFC construction which is a new approach and producing successfully the bioelectricity from different waste.

MATERIALS AND METHODS

Materials needed to construct the MFC:

PVC Schedule Tee, PVC Schedule Connector, PVC Schedule Slip Cap, Carbon Brushes, Clear plastic wrap, Rubber bands, Salt Bridge Medium, Household salt, Drill Press or Drill with bits, Soldering iron with solder, Measuring cups, Skewer (wood or metal). NaCl; agar 2%; Distilled water.

E.coli pure culture and four different waste water samples were collected from various sources, such as:

Stagnant waste water, Dairy waste, Liquid waste containing algae & Fermented municipal solid waste (S4)

Figure 1a PVC schedule tee pipes

Figure 1b Carbon brushes

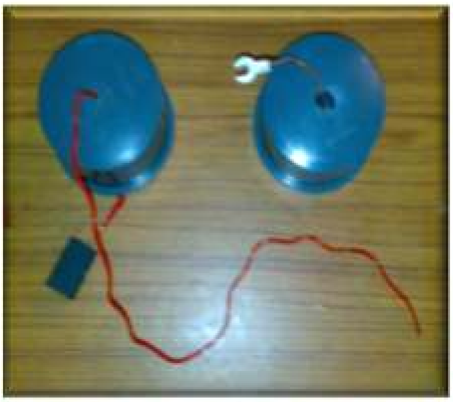

Figure 1c PVC schedule slip cap fitted

Figure 1d Assembled MFC with carbon brushes

Figure 1 materials used for MFC construction

The main three components of the MFC are the anode, cathode, and if present, the membrane.

Anode

The requirements of an anode material are: highly conductive, non-corrosive, high Specific surface area (area per volume), high porosity, non-fouling (i.e., the bacteria do not fill it up), inexpensive, and easily made and scaled to larger sizes. We need to find materials that are highly electrically conductive-but they must also be non-corrosive, which rules out many metals. In addition, bacteria must be able to attach to the material and achieve good electrical connections. Carbon-based electrodes were used as anode in the anode chamber; it's commonly used because of its high conductivity and appears to be well suited for bacterial growth. Carbon brush is stiff and slightly brittle but it is easily connected to a wire. It should be sealed to the wire using epoxy, with all exposed surfaces of the wire covered or sealed with epoxy as well.

Cathode

The design of the cathode is the single greatest challenge for making an MFC a useful and scalable technology. The chemical reaction that occurs at the cathode is difficult to engineer as the electrons, protons and oxygen must all meet at a catalyst in a tri-phase reaction (solid catalyst, air, and water). The catalyst must be on a conductive surface, but it must be exposed to both water and air so that protons and electrons in these different phases can reach the same point. The same materials that have been described above for use as the anode have also been used as cathodes.

Agar salt bridge as membrane

The purpose of an agar salt bridge is to provide an electrical connection to the both solution while minimizing the transfer of ions or solute from the electrical environment. With a salt bridge, the desired cation (Positive ions) is isolated in one chamber. As electrons leave one half of a cell and flow to the other, a difference in charge is established. If salt bridge is not used, this charge difference will prevent further flow of electrons. A salt bridge allows the flow of ions to maintain a balance in charge between the two chambers while keeping the contents of each separate. With the charge difference balanced, electrons can flow easily.

Preparation of the salt bridge

Initially 150ml of water was boiled in a beaker, 3gms of agar and 15gm of NaCl was added to the boiling water, the mixture was further boiled for 3-5 minutes. Simultaneously, plastic wrap was firmly placed over one end of the coupler and secured with a rubber band to form a tight seal and the other end of the coupler was left open. The mixture prepared earlier was poured into the open end of the coupler. Care was taken at maximum to prevent air bubbles during pouring. The set up was allowed to stand for a few minutes till it solidifies and was left in the refrigerator until final assembly.

Figure 2 Preparation of the salt bridge

Assembling of electrodes

First, one wire and one carbon brush was used to make a carbon electrode. Dry sponge was taken and cut with a dimension of 3/4" wide and an inch long. This piece had to fit smoothly into the neck opening of the screw top. Then the screw top was taken back out using a skewer, nail was used to punch a hole big enough for the wire to pass through.

Smallest drill bit was used to have equal to or greater than the size of the wire drill a small hole in the center of the screw cap. The electrode lead was threaded through the sponge and slided into the neck of the screw top. The wire was threaded through the cap, such that it had to pass through freely. Water was added to the sponge by screwing top down lightly which will expand to fill the neck and provide a slight over cover at the base.

It is an anode assembly. It is used for the anaerobic (microbe cell). The small gap will allow the decomposition gasses to escape while the sponge will inhibit the passage of air into the chamber. To add nutrients to the anode chamber simply unscrewed the top and nutrient medium was gently poured through the sponge.

For the cathode different approach was used. The cathode is inserted into the sponge (placed between two pieces of sponge) where air can circulate freely. To make the cathode assembly the coil wire was removed from the remaining brush. From the remaining section of the sponge a strip of 1" wide by 4" inches long was cut, which was made into two strips. The remaining carbon brush was placed between the two strips so that only the top is exposed. Thus the carbon brush was inserted into one of the 1" connector and the sponge was wetted which will expand to hold the electrode in place.

Assembling of fuel cell

Once the salt bridge has cooled and solidified the assembling of the device was done. For easier dis-assembly and maintenance, the PVC was coated with the graphite powder while assembling. The two remaining couplers were taken and end caps were carefully fixed into them to provide feet for standing. The salt bridge was inserted into the center tee. Hence the fuel cell was completed and ready to be charged.

Operation of MFC

One of the two chambers was picked as anode (microbe) chamber and the other was opted as cathode chamber. Saturated NaCl solution was prepared. The sponge slices were removed from the cathode assembly and the sponge slices were thoroughly soaked in the salt solution. The rest of the salt solution was poured into the cathode chamber until only the salt slurry retained. The carbon electrode was placed on top of one sponge, and was gently covered with the slurry and then the remaining slice of sponge was completely sandwiched. It was then placed gently back into its connector and inserted into the cathode tube. The tube overflowed as the cathode was inserted.

The anode chamber was 3/4 filled with a sample of interest (waste). Then 5gm of sugar and 2gm of shredded papers were added to provide nutrients for the microorganisms. The anode assembly was fully inserted into the anode chamber. The internal wiring of anode and cathode were connected to a multimeter to complete the circuit. The entire set up was left for 30min for stabilization and the deflection in the multimeter was noted down for every time period of 15min.

RESULTS AND DISCUSSIONS:

Microbial fuel cells (MFCs) were designed successfully and the voltage difference was also fund in the multimeter as shown in the Fig 3. The designed MFC was easy to handle, and can be used repeatedly.

Figure 3 Setup of MFC and voltage fluctuation in the multimeter after 30minutes of stabilization

Production of bioelectricity

In the current investigation *E.coli* pure culture and four different waste water samples were used and their BOD and COD were calculated.

SL NO	SAMPLE	BOD mg/L	COD mg/L
1	Stagnant waste Water	290	945
2	Dairy Waste	454	768
3	Algae	541	792
4	Fermented municipal solid waste	368	981

Table 1 BOD and COD of different samples before bioelectricity production/ substrate degradation.

Pure culture of *E.coli* was solely used as sample; a minute deflection of 4.01mV current was obtained. Where in less amount of current was generate, hence we focused our work on using samples containing many different microorganisms which gave a higher voltage. Bond and Lovely, (2003) produced 33.4mW/m^2 power density using pure culture of *Shwenella Putrefaciens*. Min et al., (2005) reported that pure culture of *Geobacter metallireducens* produced a power output of 2.2 mW/m^2, In contrast, we obtained a maximum power output of 130,113,98,195 (Table 2) from Stagnant Water, Dairy Waste, algae contaminated waste water and FMSW respectively which contains mixed cultures. Liu et al., (2005a) generated 860mW/m^2, and Cheng et al., (2006b) produced 480 mW/m^2 using mixed cultures of microorganisms. It is signifying that a group of microorganisms are able to produce more power synergistically than a single pure culture. It also proves the fact that performance of microbial fuel cells with respect to electricity generation dependent on availability of various types of microbes found in biological waste/ effluents Mahendra et al., (2013). It can also noted that, high voltage was obtained from FMSW which was contaminated with variety of microorganisms than Drainage Water, dairy waste, algae contaminated water and E.coli pure culture respectively.

SL NO	Sample	Stabilizing time (minutes)	Potential difference (mV)
1	*E.coli*	60	4.01
2	Stagnant Water	60	130
3	Dairy Waste	60	113
4	Algae	60	98
5	Fermented municipal solid waste (FMSW)	60	195.0

TABLE 2 voltage obtained from different samples after 60min stabilization of MFC

The MFC was operated at room temperature, with increase of time the voltage fluctuation was decreased, when added 5gm of glucose and 2gm of cellulose paper strips, again the multimeter was shown increased voltage. It is due to continuous operation of MFC the nutrients get depleted and the microbial metabolism gets decreased, after addition of nutrients microbes started their metabolism and voltage fluctuations increased. BOD and COD measurement was also done at the end of MFC operation and the percentage of BOD and COD removal efficiency or substrate degradation rate obtained was represented in Table 2, which indicates the possibility of waste water treatment by MFC.

SL NO	SAMPLE	BOD removal efficiency% (or) substrate degradation rate	COD removal efficiency% (or) substrate degradation rate
1	Stagnant waste water	83	91
2	Dairy Waste water	76	97
3	Algae	60	74
4	Fermented municipal solid waste	88	99

Table 3 percentage of BOD and COD after substrate degradation.

CONCLUSION

MFCs represent a promising technology for renewable energy production; their most likely near-term applications are as a method of simultaneous wastewater treatment and electricity production. Designed MFC model was successfully produced electricity and it is easy to maintain. This model also gives scope to develop large scale production of bioelectricity and waste water treatment. It can also conclude that mixed cultures can produce better energy than the pure cultures. The BOD and COD measurements also proved that, waste water treatment can also possible from MFC. The most immediate and useful applications of MFCs are in the classroom: Students find electricity generation by bacteria both fascinating and fun! We have found MFCs to be an effective educational tool to capture student interest.

Hence these small and portable systems serve as a wonderful platform for motivating to generate bioelectricity at industrial scale.

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