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Article

Utilisation of Fruit Waste for Bio-Electricity Production with Microbial Fuel Cell

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A B S T R A C T

The prodigious energy consumption in conjunction with the fleet growth of population, made the need to develop energy resources. Energy sources available have been classified into fossil fuels, nuclear and renewable energy sources based on their mode of origin and reliability. Microbial Fuel Cell is one the advancement in the future of environment protection. The technology will be closer to realistic applications with the introduction of highly efficient electrode materials and catalysts to decrease production costs. The primary components of fuel cells are electrodes i.e. anode and cathode. The anode is an electrode that induces oxidation and loss of electrons. The cathode is where there is reduction and the production of electrons. Anode surface fuel oxidation produces electrons and oxidized by-products. The electrons later pass through an outside circuit to the cathode. The experiment with biomass of organic fruit waste the result comes around 80-250 mV. This study shows that monosaccharide, disaccharides and polysaccharides present into fruits wastes are frequently used in the metabolic routes of the high microbial populations for the bioelectricity production. The new bridge introduced as sulphuric acid works effectively when operated in microbial fuel cell.

Keywords: Environment, Microbial Fuel Cell, Electricity, Catalyst, Biomass

Introduction

The detrimental impact of carbon energizing fuels on the atmosphere has recently prompted an overall reawakening of natural resources. Mostly non-renewable resources such as fossil fuels were used for burn to generate electricity. The burning of fossil fuels has not just created harmful effects on environment; also it aroused the threat towards the exhaustion of non-renewable resources. Recently, people are getting awake regarding it. Therefore, it assists to use green technology. Hence, it is expected that environmental discussions and energy sustainability are major part of future market In recent years, fuel cell technology has attracted great interest for its positive impacts as a clean, portable, alternative electricity production and for its compatible in many applications.[1] MFC is a new method to improve the valorisation of organic substrates/waste and to create electric energy by using the electrons exchange from the respiratory chain via oxidation and reduction reactions. Its mechanism is similar with the batteries concept, which is constituted by an anode and a cathode, thus the fuel cells receive a constant supply of energy.[2]

Rise in the demand of energy adds up rapid extinction of hydrocarbon deposit. These sources are best substitute for fossil fuels moreover, these are renewable and sustainable. Completing the basic world's need of energy it not only the problem nowadays, Global warming is the major problem of today. Greenhouse gases i.e CO2 are released on the combustion of hydrocarbons which rises up the temperature

of earth due to its properties. Once fossil fuels get consumed it take millions of year to form hydrocarbon deposit again. Hence, there is tremendous need of innovation that can substitute the need of fossil fuels to the world before they get completely exhausted.[3]

In last few decades due to the production of energy from renewable source of energy such as waste water, in the form of either electricity or hydrogen, Microbial Fuel Cells have become significant source of renewable energy. There are various aspects seen from progress of design. These aspects needed to investigate that cell yields significantly. All living organisms reproduce rapidly and store nutrients. This is carried out by the energy produced by the utilization of materials as the source of food required for energy. Organic substances like alcohol and carbohydrates utilize by the microorganisms like bacteria to achieve required amount of energy. During the process electrons and protons are generated in high amount. These electrons combine with proton molecules of oxide to form water. The reaction goes through electrons transfer chain. The concept of cell is driven from this test on the basis of substituting oxygen with substance that can utilize electrons to generate specific energy. This begins the study of technology that can naturally generate electrons for generating energy. Microbial fuel cell offers carbon-neutral alternatives in this field. MFCs utilize organic substrates and subsequently convert their chemical energy to electricity in a single step using microorganisms. There has been an increasing interest for the production of non-grid electricity from decentralized diffused sources (sunlight, biomass, etc.), which can be produced at the site of requirement and cater to the local needs. In this respect, in the future, MFCs may find potential applications such as decentralized wastewater treatment, bioremediation, and renewable energy harvesting to supply off-grid and remote devices.

In this study, a novel approach in microbial fuel cell was designed to improve waste treatment of fruit juice waste and to investigate their potency to generate electric energy. This experiment related to bioelectricity has no pretreatment required, and it solely works with the help of living microorganisms. The new chemical to introduce in the salt bridge as sulphuric acid. MFCs have a direct positive impact on the environment. They provide an alternative solution to the use of fossil fuels as a source of energy and reduce the carbon dioxide emissions and greenhouse gases while at the same time produces electricity. MFCs play another important role in the cleaning the environment by recycling the waste which may pollute the surroundings, solving the problem of disposal.

The aim of this project is to minimize the cost efficiency of the microbial fuel cell by using fruit waste and also introducing biomass activated carbon as electrode and dilute sulphuric acid as its salt bridge. The sustainability and environment impact of this microbial fuel cell has also been discussed.

Material and Methods

Material

The Fruit waste (fruit extract) which served as the substrate for the MFC and was collected from in campus fruit juice shop. The fresh fruit waste pulp is potentially active substrate. It is provided that the citrus works more efficiently like lemons or oranges. The natural microbial present in the fruit waste was used in the experiment. The all required fruit waste was then placed in the anodic chamber. The main idea using this material to is reuse the waste and to generate electricity in a microbial fuel cell. Fruit extracts have different microbes present. Escherichia coli and Staphylococcus-aureus were detected in a few samples. Candida sp., Curvularia, Colletotrichum, and Acetobacter were observed only in citrus juice samples. Solid fruit extract in the samples was stored in air tight plastic containers (away from sunlight) until needed for analysis.

Reaction Raw Material

Fruit juice waste:- In the MFC, one chamber (the Anodic chamber) was filled with Fruit Juice Waste. The bacteria like E coli can be added to the waste of lemon, orange, grape fruit or mixed fruit juices and the reaction with it takes place in a sealed compartment to prevent the entrance of air. Thus, fermentation occurs which helps in production of electricity.

Algae from Wetland

Algae are aquatic, plant-like organisms. They encompass a variety of simple structures from single-celled phytoplankton floating in the water to large seaweeds (macroalgae) attached to the ocean floor. Algae can be found residing in oceans, lakes, rivers, ponds and even in snow, anywhere on Earth. In this case, we obtained it from a nearby pond/ lake.

Chemical used: Sulfuric acid (H2SO4) [1M]; Sodium hydroxide (NaOH) [1M]; Distilled water (Maurya Distillers & Bottlers Pvt. Ltd.); Sugar (glucose).

Equipment Used

- Digital multimeter – It was used during the process of generating electricity to measure the current (Amp.), voltage and resistance in the circuit.
- pH Meter – pH Meter was used to check the pH of the fluids present and that of the washed saw dust(for catalyst).
- Thermometer.

Methods

Experimental Producer

The various steps followed for the generation of electricity by microbial fuel cell are given below: The setup was installed with two jars (2L) attached with PVC pipe, which act as a salt bridge. Initially, a cotton cloth was dipped in NaOH [1M] overnight so that it absorbs the salt. Then the cloth was inserted in the PVC pipe joints to the jars. One of the jars which contain the fruit waste is anode and the other jar filled with sugar water (to amplify) is the cathode. We connected the anode with the cathode using an external copper wire which overall complete the cell circuit. The potential difference between the anode and the cathode results in the flow of current through the circuit. The bacteria present in anode helps in Oxidation of the Organic Compound (Fruit Juice Waste), releasing electrons which flow through the external circuit to the cathode chamber. The Hydrogen ion supplied by the salt bridge combines with Oxygen and the electron through the circuit to form water and heat. Bacteria such as E coli help in fermentation of Organic Waste. The Salt Bridge here helps in maintaining the potential difference between the anode and the cathode. It acts as a membrane which collects Hydrogen ions from the anode side and distributes them in the cathode side, thus continuously amplifying the reactions.

By connecting the Multimeter, took the readings in voltage (millivolt) and also calculated resistance. Afterwards, calculated the current and power density using voltage and resistance. Took the reading at different time and temperature. At last plotted the graph between voltage, current, power density.

Figure 1.Setup of Microbial Fuel Cell.

Preparation of Catalyst

- To prepare a catalyst, we selected production of Activated Carbon from Sawdust.
- The sawdust was initially screened and we took the particulate size of 0.5mm.
- The sawdust went through the process of acid wash by HCl [1M].
- Then the amount was placed in an oven till the temperature reached 80°C. It was meant for drying to make sure that there was no moisture content.
- After acid wash, the material was cleaned through base wash by NaOH [1M].
- Again, the material was heated to remove all the moisture content after the wash.
- The dried material was then ready for the neutral wash; the material was washed with distilled water until the pH of 7 was retained.
- This made the material free from all the impurities and then the material was put in crucible for pyrolysis (up to 200°C).

Figure 2.Activated Carbon

Electrodes Preparation

Electrode was fabricated using different methodologies to investigate the physical parameters that influence the performance of capacitors. A 5×5 cm piece of Nickel perforated plate was used. The binding material used to cover the Nickel plate was cotton cloth, over which the prepared activated carbon was spread evenly. Further this electrode was sundried for 2 days until the approximate takes 50˚C makes it completely binds. Afterwards, the electrode was connected securely with piler and a hand press. This whole process helps the conductive additives like activated carbon to channelize the flow of current.

Analytical Method

Characterization Techniques

A digital multimeter (Keithley 2000 Multimeter) was connected to the system to monitor the value of the cell

voltage continuously at the value of the external load (120Ω). Three important parameters were evaluated: the Open Circuit Voltage (OCV) or the maximum allowable MFC voltage, the maximum intensity and the maximum power density of the MFC. In addition, the shape of curves gives important information about the limiting processes, which control the performance of the cell.

The experiment is done at Moderate temperature typically between 20°C (68°F) to 45°C (113°F).

The pH of the substrate calculated from pH meter was 5, which basically indicates as acidic nature.

Formula used:

Current(I) = Voltage(V)/ Resistance(R)

…….Ohm's law….(mA)(weber,2012)

Power density = Voltage (V) * Current(I)/ Volume (V)

……(watt/meter cube)

Figure 3.A Digital Multimeter

Optimizing the design of MFC

By varying electrode types and material which can be purchased from chemical supplier, comparisons can be made and establish the best design. Various substrates and bacteria will be used and tested to determine maximum current output. Once the MFC systems are tested and established, different bacteria and electrode types will be used in an attempt to optimize the overall power generation. The voltage and resistance will be measured by a highly-sensitive multimeter from which the current can be calculated. As time will be limited, the MFC system will be tested for a short period of time and the inoculums will be replaced periodically for a fair comparison.

Result and Discussion

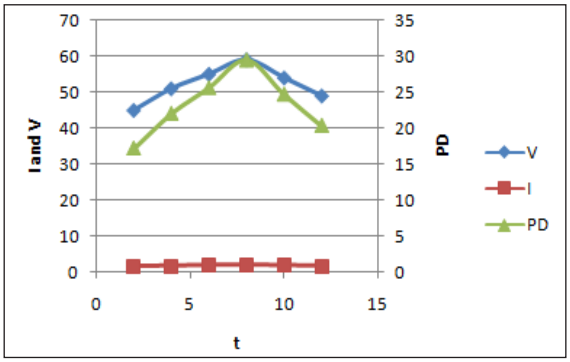
Fruit Waste for Electricity Generation

Fruit waste constitutes the major part solid waste, the conventional method such as disposal of waste into the land causes serious problem to the environment as well as them produce the bad smell and leachate polluting.[4] MFC has the potential for generating- electricity by using fruit waste as a substrate and helps for the conversion of waste into wealth, usually, the performance of MFC to yield electricity depends on the available food waste concentration. The obtained result from the study conducted shows that different types of sugar such as monosaccharides, disaccharides and polysaccharides from fruit and vegetable waste along with high Andean soils can produce electricity. There are several microorganisms available in canteen food waste, most of them belong to Geobacter, where the Geobacter species alone enable to produce electric current directly from food waste, moreover, fermentative bacteria is essential for the effective performance of MFC. The wastewater that is available from food processing industry can also use for the production of electricity has revealed that use of sago wastewater is a viable and sustainable process and the addition of salt in the MFC can improve the performance as well as electricity generation. Microbes reside in the anode compartment, where they metabolize organic compounds such as glucose which act as electron donor. The metabolism of these organic compounds generates electrons and protons. Electrons are then transferred to the anode surface. From anode, the electrons move to cathode through the electrical circuit, while the protons migrate through the electrolyte and then through the cationic membrane. To accelerate the oxygen reduction on the surface of the cathode, platinum is commonly used because of its excellent catalytic ability. However, the high cost of platinum is a major limitation to MFC application and economic viability. Replacement of platinum with alternative cheap metals, such as carbon embedded metals could also improve the oxygen reduction rate with cost saving. The use of fruit waste as a source of substrate has a dual advantage; first, the electricity produced is cheap, and second, it leads to a cleaner environment by reusing the waste.

Using Fruit Waste as Anode

Table 1.Normal Sample at 30 Ohm

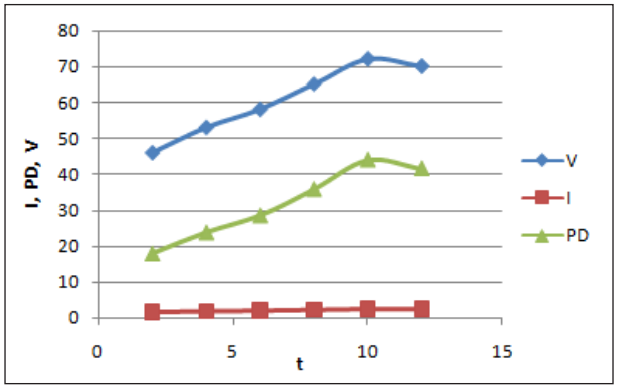
Normal Sample at 30 ohm				
S. No.	**TIME (h)**	**V**	**I**	**PD**
1.	2	45	1.5	17.19745
2.	4	51	1.7	22.08917
3.	6	55	1.833333	25.69002
4.	8	59	1.966667	29.56263
5.	10	54	1.8	24.76433
6.	12	49	1.633333	20.39066



This above figure indicates that we examined the setup within the time period of 2 to 12 hours to get the required result. The reading get are from 2 hours gap. Therefore, the result we get is, the current (I) ranging from 1.5-1.9 milli Ampere, this graph show rapid increase from 1.5 mA, after reaching 1.9 mA it starts decreasing. The peak is almost at 1.96 milli Ampere. Secondly, we notice the Voltage (V) hike at 59 milli volts having its maximum voltage. Therefore, the Power Density (PD) after gaining all the required values, is highest at 29.5 milli W/m^3. Also, the resistance is at 30 ohm of this normal solution.

Table 2.Observations 1M Solution

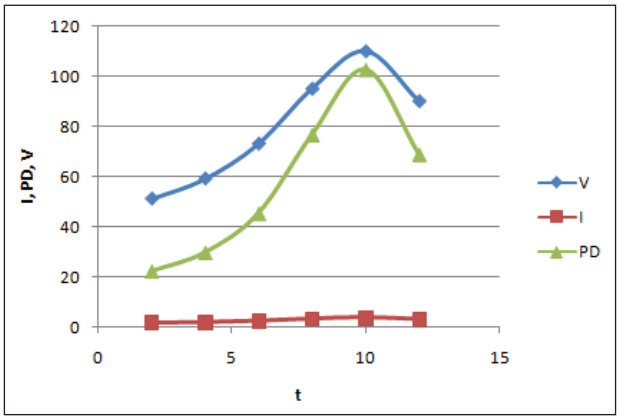
1M Solution Sample				
S. No.	TIME (h)	V	I	PD
1.	2	46	1.533333	17.97028
2.	4	53	1.766667	23.85563
3.	6	58	1.933333	28.569
4.	8	65	2.166667	35.8811
5.	10	72	2.4	44.02548
6.	12	70	2.333333	41.61359



The above figure is the result of 1 molar solution. This whole graph shows the exponential growth in Voltage (V) and Power Density (PD) reaching to its highest point and then due to loss of energy it lowers down whereas, the current (I) has average fluctuation. And the overall peak is after 10 hours to the exposure of the setup.

Table 3.Observations 5M Solution

5M Solution Sample				
S. No.	No. Days	V	I	PD
1.	2	51	1.7	22.08917
2.	4	59	1.966667	29.56263
3.	6	73	2.433333	45.2569
4.	8	95	3.166667	76.64544
5.	10	110	3.666667	102.7601
6.	12	90	3	68.78981



This above figure is the representation of the result having 5M solution. Also the time taken in the result is in days as it amplifies the reaction over long period of time. As the time increases steadily the result of power density reaches to its highest value of 102.7 milli W/m^3 due to the catalytic properties.

Table 4.Observations 10M Solution

10M Solution Sample				
S. No.	TIME (h)	V	I	PD
1.	2	85	2.833333	61.35881
2.	4	98	3.266667	81.56263
3.	6	115	3.833333	112.3142
4.	8	140	4.666667	166.4544
5.	10	132	4.4	147.9745
6.	12	120	4	122.293

This above figure is the graphical representation when we introduce 10M of the solution into our setup. As with the increase in the molar quantity, the rate of reaction also speed up then goes up to its peak and after that it slows down . It shows best result within 8 hours as the voltage is as high as 140 mV with maximum current of 4.6 mA, and provides power density of 166.4 milli W/m^3.

This whole result explains the catalytic property acting on the Microbial Fuel Cell.

Conclusion

MFC has great potential for generating electricity from readily available waste and it can be a waste stabilization method and renewable energy production technique. The use of MFC can assure the decrease of waste in the environment and in waste into wealth conversion. Though, as the available conventional waste treatment methods around the globe are very energy intensive for its efficient operation, MFC can serve as an alternative competent technique, because it requires less energy for its operations Microbial manufacture of electricity may become an important form of bioenergy in future because, MFC offers the possibility of extracting electric current from wide range of readily available food waste. The usage of food waste as a substrate in MFC will require effective waste treatment along with the production clean energy, so it can be adopted as a sustainable technique for producing electrical energy and treatment of food waste. The new MFC equipment is still undertaking massive do research touching upon many characteristics including its design, power optimization, reduction of internal resistance and potential scaleup. It is important to consider reducing the cost of the electrodes by avoiding precious metals at the cathode. In addition, it is essential to try different types of proton exchange membranes that is both cheap and efficient in terms of separating the chambers and allowing the passage of protons while hindering the migration of other substrates.

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