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Generation of Electricity from Fruit and Vegetable Waste

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Abstract: ***Roughly 1.3 million tons of food accounting to one-third of the annual food production meant for human consumption is wasted annually. Food wastage can be reduced to a great extent by proper post-harvest treatments, cold storage as well as improving the supply chain. However, food waste such as vegetable peels, meat carcasses and teabags is almost unavoidable and accounts for 19% of the total waste and can be used for energy generation by anaerobic digestion where microorganisms convert the waste material into biogas that can be utilized to produce electricity. Three set-up were made using E. Coli stains for the same- control set-up, set-up containing glucose to act as a substrate for E. Coli bacteria and a set-up containing KCl as it is an electrolyte and can help in transfer of charge. Set-up was made using air tight plastic containers connected with a salt bridge. Graphite rods were placed in each container and connected with wire. Slurry was poured in the container and connected to another container with water and air pump. The control MFC set-up produced the least amount of electricity followed by set-up containing KCl and most electricity production was found in set-up containing glucose. Thus, providing a substrate to the waste can help in production of electricity from waste thus giving a way to utilise the organic waste material in a judicious way.***

Keywords: E.Coli, Electricity, MFC, Organic waste

I. INTRODUCTION

HISTORY

The concept of MFC had been demonstrated in 1910 by Potter (Ieropoulos, 2005). Escherichia coli and Saccharomyces living cultures were used in order to produce electricity by using platinum electrodes (Potter, 1912). However, it did not gain much interest and popularity until it was discovered that electron mediators can be used to enhance the current density and output of power. Electrochemical mediators can be used for transferring the electrons from the MFC to the electrode (Jang et. al., 2004).

MECHANISM OF WORK

Food losses may occur during production, postharvest as well as during the processing stage in the food supply chain (Parfitt, 2010). A lot of studies suggest that around 1.3 billion tons of food is wasted per year accounting to almost one-third of the annual food production. MFC is a bioreactor making use of anaerobic conditions in order to generate electrical energy via microorganism's catalytic action which extracts chemical energy directly from the bonds of organic compounds (Sreedharan, 2016). MFC devices generate electricity by oxidizing organic as well as inorganic matter by using bacteria as a catalyst, that produce electrons from the organic matter and the electrons are then transferred from the anode (negative terminal) towards the cathode (positive terminal) linked via a conductive material. The electron donors are consumed in fuel cell and biocatalysts such as an enzyme or microorganisms liberates the electrons.

Positive current travels from the negative terminal towards the positive terminal via convention i.e. in the direction opposite to that of the electron flow. The device should be capable to replenish substrate being oxidized intermittently or continuously or else the set up is considered as a biobattery. Electrons are transferred via electron mediators through membranes or by nanowires produced by the bacteria to the anode. For electron transport, neutral red can be used with bacteria as a mediator for producing electricity in a MFC by degradation of various organic compounds (Fathey, 2015).

Chemical oxidizers may also be added although these must be replaced or regenerated. Electron liberation occurs at the anode by the catalytic action of the microorganisms and subsequent consumption of electrons occurs at cathode.

MFCs can be constructed using various materials and are operated under many conditions of temperature, pH, electron acceptor, reactor size etc.

Anode reaction: $C_6H_{12}O_6 + 6\ H_2O \rightarrow 6\ CO_2 + 24\ H^+ + 24\ e^-$

Cathode reaction: $24\ H^+ + 24e^- + 6O_2 \rightarrow 12\ H_2O$

$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6H_2O$ + Electrical energy

"H shape" design of MFC is widely used and is inexpensive. In this design two bottles are connected via a tube containing a cation exchange membrane (CEM) or a salt bridge. It is important to choose a membrane that will allow passing of the protons among the chambers, but will not allow the passing of the electron acceptor present in cathode chamber as well as the substrate.

Organic waste such as fruit and vegetable peels can be used to produce electricity. Rice, cocnut water, milk etc are all good substrates for the microorganism to ferment. Saccharification of watermelon waste in the presence of *A. niger* and *S. cerevisiae* has been done to get ethanol (Ratnakaram et.al., 2019)

Several members of the family Geobacteraceae, including

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Geobacter sulfurreducens and G.Metallireducens are able to transfer electrons via direct contact to the anode. E.Coli or even yeast cells can be used for the same. The waste slurry generated by MFC may be used as manure in farms if non pathogenic bacteria strain is used for electricity generation.
MFCs include ability to produce energy from sources that are useless such as organic matter or wastewater.
Organic matter can be used directly in MFC without any preliminary treatment, thus reducing the treatment energy expenditure. Also, this process has less impact on the greenhouse gas emission as it is not dependent of using fossil fuels. Another benefit of MFCs is that they use bacteria which are relatively inexpensive and can be grown easily and does not require the use of expensive catalysts such as platinum.
However, they can produce only limited power which might not be sufficient in order to run a sensor continuously. However, electrode's surface area can be increased to solve this problem. Another solution is to use a suitable power management program i.e., transferring the data only after sufficient energy has been stored in it which is done via ultra-capacitor (Rahimnejad, 2015). Moreover, it is difficult to operate MFCs at lower temperatures as the microbial reactions are slowed down at lower temperatures.

II. MATERIALS AND METHODS

1. *Procurement of Raw Materials*

Air tight containers (6 containers- 2 for control setup, 2 for setup containing glucose and 2 for setup containing 15g Kcl), graphite plates, air pump, multimeter, hollow PVC pipe and copper wires were procured from local market area in order to make the setup.

2. *Media Prepration*

E. Coli strain was prepared using Eosin Methylene Blue Agar by dissolving 35.96 g in 1000 ml distilled water with proper stirring and dissolving followed by autoclaving (15 lbs pressure (121°C) for 15 minutes). Sterilized medium was then cooled to 45-50°C and shaken in order to cause suspension of precipitate and cause oxidation of methylene blue, the E. coli cultures were inoculated on plates and incubated for 24-48 hours at 30°to 35°C. Agarose, KCl, neutral red and glucose were taken from the laboratory. Fruit and vegetable waste were collected from kitchen over 4-5 days, shredded into small pieces and converted into a slurry form and then poured in 3 containers of 1kg each- one control, 15g KCl added in the second container along with the slurry and 15g Glucose added in the third container along with the slurry.

3. *Assembling of the Set-Up*

a) Salt Bridge- Agarose (10%) was dissolved in boiling water, salt (5%) was added to the mixture of agar and water while the mixture was still hot. One end of all 3 plastic pipes was sealed and the mixture was then poured in the plastic pipe while it was still warm before it begins to thicken and was then allowed to cool and solidify.
b) Assemble electrodes- 2 electrodes for each jar were joined with the help of copper wire. Anode was coated by solution of neutral red (1%) and then, E coli bacteria were coated over neural red with help of inoculation loop.
c) Preparation of plastic containers- At the top of each jar small holes was made, so that, wires can passes through them. At side of each jar holes of nearly 1 cm diameter were created to connect salt bridge. In all the 3 jars, two extra holes were made to connect air pump near bottom of container and one at the top for exchange of gases.

4. *Recording of Voltage Produced*

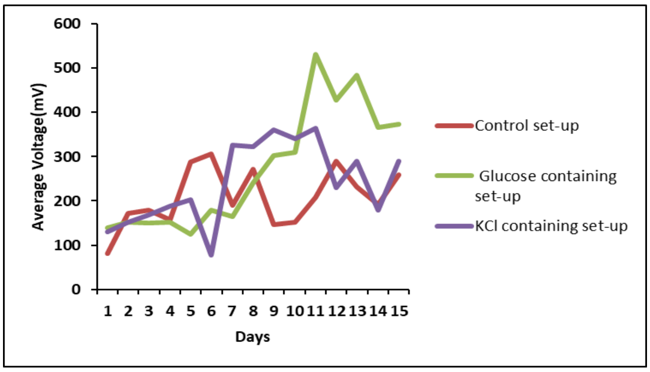
Voltage produced in each setup was measured by multimeter. Readings were recorded after every 12 hours.

III. RESULT AND DISCUSSION

The present study developed Microbial Fuel Cell to produce electricity from fruit and vegetable waste. Graphs of control cell, cell containing glucose as well as cell containing KCl showed a steadily rising curve, however KCl containing cell showed more fluctuations in voltage.

TYPE OF MFC	AVERAGE VOLTAGE (MV) GENERATED PER 0.026M^2	AVERAGE VOLTAGE (V) GENERATED PER M^2 PER DAY
CONTROL CELL	208.193 MV	8.007 V
CELL CONTAINING GLUCOSE	273.08MV	10.503V
CELL CONTAINING KCL	241.54 MV	9.920V

Control model gave an average voltage of 208.193mV while setups containing glucose and salt (KCl) gave 273.08mV and 241.54 mV respectively.



Set up containing glucose gave maximum voltage as glucose acted as a substrate for E. coli bacteria and hence provided it more oxygen to act upon. Set up containing KCl also gave better results than control set up as the salt breaks down into ions and help in transfer of electrons.

IV. CONCLUSION

Although electricity was produced by system but it still needs further optimization. Efficient seeding may help in increasing the electric potential of MFC.

Also the optimization of procedures and yet more combinations of producing EMF cells with glucose and other substrate to increase the electricity should be explored. There is a potential of producing energy from unavoidable waste material and thus contributing to the reduction of the environment waste load.

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