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Electricity generation form dairy waste water through microbial fuel cell technology

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ABSTRACT

The increasing risk of global warming by greenhouse gasses requires further development of renewable energy sources. Sharp escalation in prices and fast depletion of conventional energy sources leads to search for an alternative energy. Microbial fuel cell technology is a new type of renewable and sustainable technology for electricity generation. It recovers energy from materials that are difficult to dispose of such as sugar waste water, municipal waste water, dairy waste water and paper industry waste water. Biological hydrogen production processes are found to be more environment friendly and less energy intensive.

Microbial fuel cells are electrochemical device used for converting chemical energy contained in organic matter into electricity by means of catalytic (metabolic) activity of living microorganisms. It is an alternative method to reduce cost of treatment and generate electricity. Microbial source uses dairy waste water as a substrate for the production of electricity. Microbial fuel cells have an advantage over other electricity production methods because of their high efficiency. Some experimentation was carried out by using waste water from various sources and urine as microbial fuel cell feed. Using Proton exchange membrane as electrolyte open circuit voltage of 0.46V with waste water and 0.42V using urine waste was observed.

KEYWORDS

Renewable energy;
Microbial fuel cell;
Electricity generation;
Electrolyte;
Waste water;
Urine.

INTRODUCTION

It is evident that humankind is increasingly dependent on energy with the advancement of science and technology. Increased economic growth and social development are leading to a large gap between energy demands and the availability of fossil fuels. The present day energy scenario in India and around the globe is precarious, thus driving to the search of the alternative to the fossil fuels. Current methods to produce energy are not sustainable, and concerns about the climate change and global warming require developing new methods of energy production using renewable and carbon neutral sources.

In our energy based society, the value of any energy rich matter is increasing. Thus, the high organic load in waste waters is no longer seen as waste, but instead as a valuable energy resource. Finding a way to exploit this biological substrates degradation for the generation of the electricity of the driving force for the development of the microbial fuel cells (MFCs) although the concept of the electricity production from bacteria was conceived nearly a century ago by potter (Potter 1911), only recently the technology has been sufficiently improved to make it useful as a method for energy production and its capability becomes more than laboratory novelty. The reason for this recent interest in using the bacteria to generate electricity are a combination of the need for new resources of energy, discoveries about microbial physiology related to electron transport and advancement of the fuel cell technologies.

From the 1960s until quite recently, it was thought that exogenous mediators needed to be added into the fuel cell to generate reasonable amount of power. However, it was demonstrated that power could be generated by a naturally existing consortium of bacteria in absence of exogenous mediator. One near term application of MFCs will be to produce electricity from waste water, providing a new way to simultaneously treat waste water while obtaining a source of clean and renewable energy (Lui et al.2004;Min and Logan 2004).

Microbial fuel cells are electrochemical devices that convert the chemical energy contained in organic matter into electricity by means of the catalytic (metabolic) activity of living micro organisms (Mathuriya and Sharma 2009; Kim et al.2002). An MFC consists of anode and cathode separated by a cation specific membrane. In the anode compartment of an MFC micro organisms oxidize fuel (substrate) generating electrons and protons. Electrons are transferred through an external circuit while the protons diffuse through the solution to the cathode, where electrons combine with protons and oxygen to form water. Oxygen is superior to the other electron acceptors for its unlimited availability and its high redox potential[5]. Microbial fuel cells are not yet commercialized but they show great promise in future as a power source from waste water.

MICROBIAL FUEL CELL

Microbial fuel cell (MFC) is a bioreactor that converts chemical energy in the chemical bonds in organic compounds to electrical energy through catalytic reactions of micro organisms under anaerobic conditions. Proton exchange membrane (PEM) allows protons to move across to the cathode while blocking the diffusion of the oxygen into the anode (Logan et al.2005)(Du et al.2005). Electrons produced by the bacteria from the substrate are transferred to the anode (Negative material) and flow to the cathode (Positive terminal) linked by the conductive material containing a resistor, or operated under a load (Logan et al.2006). Bacteria can be used in MFCs to generate electricity while accomplishing the biodegradation of the organic matters or waste (Oh and Logan, 2005).

MFCs have operational and functional advantages over the other technologies currently used for generating energy from organic matter.

- The direct conversion of substrate energy to electricity enables high conversion efficiency.
- MFCs operate efficiently at ambient temperature.
- An MFC does not require gas treatment because the off gases of MFCs are enriched in carbon dioxide and normally have no useful energy content.
- MFCs do not need energy input for aeration provided the cathode is passively aerated.
- MFCs have potential for widespread application in locations lacking electrical infrastructures and can also operate with diverse fuels to satisfy our energy requirements.

Power densities obtained with these substrates vary with MFCs architecture. MFCs operating on waste water generate a lower amount of energy than on pure compounds.

Anodic reaction

Cathodic reaction

There are two types of MFCS:

- Single chambered MFCs(SCMFCs)
- Double chambered MFCs(DCMFCs)

PROTON EXCHANGE MEMBRANE

A Proton Exchange Membrane (PEM) or polymer exchange membrane is a semi-permeable membrane generally from ionomers and designed to conduct protons while being impermeable to gases such as oxygen or hydrogen. This is their essential function when incorporated into a membrane electrode assembly of a proton exchange fuel cell. Separation of reactant and transport of protons.

PEM can be made from either pure polymer membranes or from composite membranes, where other materials are embedded in a polymer matrix. One of the most common and commercially available PEM materials is a fluoropolymernafion, a dupont product. PEMs are primarily characterized by proton conductivity, methanol permeability and thermal stability.

Proton exchange membrane fuel cells contain advantages over other types of fuel cells such as solid oxide fuel cells. They operate at lower temperature are lighter and are more compact, which makes them ideal for application such as cars. However, some disadvantages are ;the operating temperature is too low for co-generation like in SOFCs and that the electrolyte for PEMFCs must be water saturated.

LITERATURE SURVEY

Biological mechanism

The basic of microbial catabolism consists of an oxidation /reduction process between a substrate and an enzyme. This normal oxidation/reduction process consists of an electron transfer that can be harnessed in a MFC due to the characteristics of certain bacteria or microbes(Bond et al.2003). The bacteria identified in MFCs are known as shewaneltaputrefaciens, geobacterssulfurrenducens, geobactermetallireducens and are commonly identified from anywhere from marine sediments to domestic waste water. some research suggested that this bacteria is directly transferred an electron to any type of conducted material(Bond et al.2003,Min 2004). In case of an MFC, this conductive material is known as anodic electrode and cathodic electrode.

The energy available from the proton gradient due to the anode can be harnessed by connecting a circuit from the anode to the cathode to allow the electron, oxygen and the hydrogen proton catalytically from water via a platinum catalyst (Bond and lovely 2003, Lui et al.2004). The mechanism of MFC technology is still in research stages and many possible reasons for electricity generation cannot be answered without a better understanding of the characteristics of the electricity generating the bacteria in MFCs

Design structures

Typical MFCs consists of two separate chambers which can be inoculated with any type of carbon source liquid(i.e. biological oxygen demand contributing liquid). These two chambers consists of an anode chamber and a cathode chamber and are generally separated by a PEM. PEM fuel cell researchers know that PEMs are designed to allow oxygen from the air to react at the cathode(Lui and Logan 2004).

Electrodes in MFCs

The electrode material used can have a significant impact on density, anode electrodes are typically constructed out of different graphite materials including plates, paper, felt and foam. More porous material generally have a higher density due to more intricate surface area available for microbial colonization and demonstrated that the power output was strongly co-related to anode surface area (Bond and Lovely 2002). The cathode surface area in contrast has only a minor effect on power output.

Microorganisms in MFCs

The type of microbe to be used in a fuel cell depends on what substrate is intended to be oxidized. The different substrate also can produce different power outputs even if the same microbe is used.

MATERIALS AND METHODS

Anode

The most versatile material is carbon, available as compact graphite rods, plates or granules and a glassy carbon. The anode used for study was graphite rod.

Cathode

Graphite rods were used as cathode.

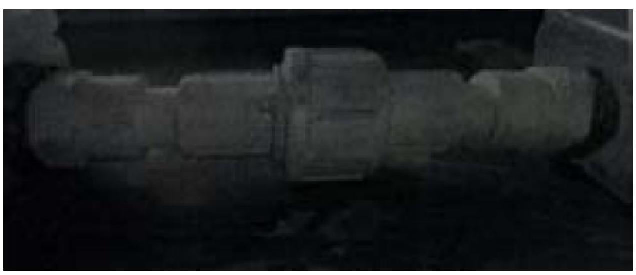
Substrate

Substrate concentration, type and feed rate can greatly affect the efficiency of a cell. Common laboratory substrate includes acetate, glucose or lactate, sucrose, amino acids or proteins, while real world application to waste water and landfills are also abundant. Here substrate used is dairy waste water(Katraj dairy, Pune) and usine was also used as substrate.

Innoculum

For mediator MFC

- YEAST(Obtained from Laboratory)



proton exchange membrane(pem)

EXPERIMENTAL PROCEDURE

- Firstly, two chambers were taken of plastic materials (approximately 2 liters each).
- Dairy waste water was obtained from a well renowned firm (Katraj Dairy, Pune).
- Other apparatus were arranged from nearby shops.
- In one chamber 1500ml of water was taken and in 2nd chamber 1500ml of dairy waste water was added.
- Carbon rods were inserted in both the cylinders, anodic chamber contained dairy waste water and cathodic chamber contained distilled water.
- Readings were taken for setup without any mediator or micro organisms and readings were taken down after period of every 2 hours.
- In the same setup micro organisms (yeast) were added and in similar way readings were noted.
- In the last setup micro organisms along with mediator (neutral red) were added to the anode containing dairy waste water and changes in the voltage was observed.

RESULT

Experiment no: 1.1

Anodic chamber: Dairy waste water (1500ml)
Micro organism: No
Mediator: No
Cathodic chamber: Distilled water (1500ml)
Electrode: Carbon rod
Aeration

Experiment no: 1.2

Anodic chamber: Dairy waste water (1500ml), Activated sludge:55ml
Micro organisms: Yeast
Mediator:No
Cathodic chamber: Distilled water(1500ml)
Electrode: Carbon Rod
Aeration

Experiment no: 1.3

Anodic chamber: Dairy waste water (1500ml), activated sludge:55ml
Micro organism: Yeast
Mediator: Neutral Red
Cathodic chamber: Distilled water (1500ml)
Electrode: Carbon rod
Aeration

Experiment no: 2.1

Anodic chamber: Urine (1500ml)
Micro organisms: No
Mediator: No
Cathodic chamber: Distilled water (1500ml)
Electrode: Carbon Rod
Aeration

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TABLE 1 : Measures of current, voltage, power density, and current density without micro organisms.

Sr.no	Time(hr)	Current(A)	Voltage(V)	Power density(w/m2)	Current density(A/m2)
1	00	00	00	00	00
2	02	00	0.09	00	00
3	04	00	0.12	00	00
4	06	0.1	0.17	4.1	25
5	08	0.1	0.21	4.9	25
6	10	0.1	0.25	6.3	25
7	12	0.1	0.27	6.7	25
Average		0.06	0.16	3.14	14.3

TABLE 2 : Measures of current, voltage, power density, and current density without mediators.

Sr.no	Time(hr)	Current(A)	Voltage(V)	Power density(w/m2)	Current density(A/m2)
1	00	00	0.09	00	00
2	02	00	0.17	00	00
3	04	0.1	0.22	5.4	25
4	06	0.1	0.25	6.1	25
5	08	0.1	0.29	6.7	25
6	10	0.1	0.31	7.2	25
7	12	0.2	0.34	7.8	50
Average		0.09	0.24	4.74	21.42

TABLE 3 : Measures of current, voltage, power density, current density of micro organisms with mediator.

Sr.no	Time(hr)	Current(A)	Voltage(V)	Power density(w/m2)	Current density(A/m2)
1	00	00	0.07	00	00
2	02	00	0.16	00	00
3	04	00	0.21	00	00
4	06	0.1	0.29	6.3	25
5	08	0.1	0.32	7.9	25
6	10	0.1	0.36	9.2	25
7	12	0.1	0.39	9.5	25
Average		0.05	0.26	4.7	14.3

TABLE 4 : Measures of current, voltage, power density, current density of urine.

Sr.no	Time(hr)	Current(A)	Voltage(V)	Power density(W/m2)	Current density(A/m2)
1	00	0.1	0.16	4.1	25
2	02	0.1	0.24	5.9	25
3	04	0.1	0.37	9.2	25
4	06	0.2	0.42	10.1	50
5	08	0.3	0.49	13.3	75
6	10	0.3	0.58	21.7	75
7	12	0.3	0.67	39.7	75
Average		0.2	0.42	14.9	50

Experiments 1.1, 1.2, 1.3 were carried out for dairy waste water and Experiment 2.1 was carried out for urine.

- The average peak voltage obtained for experiment no 1.1 is 0.16mv, experiment no '1.2 is 0.24V, and experiment no 1.3 is 0.26V,

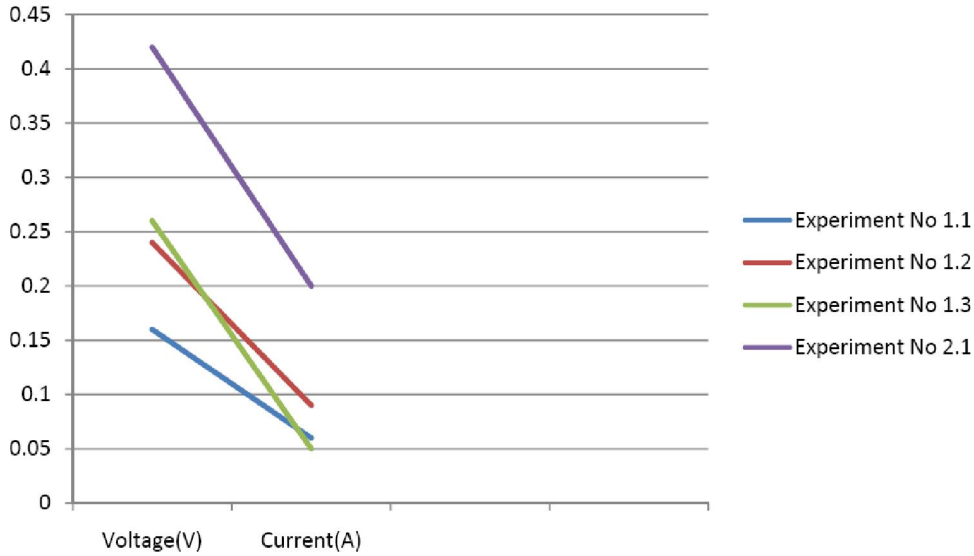

Figure 1 : Graphical representation of voltage and current.

and that for experiment no. 2.1 is 0.42V.

- Comparing the results of experiments 1.1 and 1.2, with yeast and without yeast, without mediator suggests that higher peak voltage was obtained for experiment no.1.2(with yeast).
- Comparing the results of experiment no. 1.2 and 1.3 and without mediator suggest that higher peak voltage is obtained for experiment no. 1.3(with mediator).

Thus results show that more peak voltage is obtained with bacteria and mediator rather than just bacteria for dairy waste water and urine.

EXPERIMENTAL PROCEDURE FOR SEWAGE WASTE WATER

- Same procedure was followed as the previous experiment.
- In 1st chamber instead of dairy waste water 1500ml of sewage waste water was used and in 2nd chamber 1500ml of distilled water was used.
- Remaining setup was earlier.
- Readings were first taken at normal operating conditions with and without use of micro organisms.

Experiment no: 3.1

Anodic chamber: sewage waste water (1500ml)
Micro organism: No
Operating Conditions: Normal room temperature (28 deg C to 35 deg C)
Cathodic chamber: Distilled water (1500ml)
Electrode: Carbon Rod

Experiment no: 3.2

Anodic chamber: Sewage waste water (1500ml)
Microorganisms: Yes (E.coli)
Mediator: Neutral red
Cathodic chamber: Distilled water (1500ml)
Electrode: Carbon rod
Operating conditions: Normal room temperature (28 deg C to 33 deg C)

- Experiment 3.1 and 3.2 were carried out for sewage waste water.
- Both experiments were carried out at normal room temperature (28 deg C to 35 deg C)
- In experiment 3.1 no microorganisms were used so it resulted in a lower peak voltage whereas in experiment 3.2 microorganisms along with mediator were used which resulted in a higher peak voltage.
- Comparing the results of 3.2 and 3.2 with and without use of microorganism suggest that higher peak voltage is obtained for experiment no 3.2.
- Peak voltage increase with increase in volume of sewage waste water.
- Thus results show that more peak voltage and current is obtained by using microorganisms along with mediator rather than just waste

TABLE 5 : Measure of current, voltage, power density, current density of sewage waste water without mediator.

Sr.no	Time(hr)	Current(A)	Voltage(V)	Power density(W/m2)	Current density(A/m2)
1	00	00	0.05	00	00
2	02	00	0.14	00	00
3	04	00	0.19	00	00
4	06	0.1	0.38	5.43	25
5	08	0.1	0.25	8.26	25
6	10	0.2	0.41	17.83	50
7	12	0.2	0.43	18.69	50
Average		0.08	0.26	4.52	21.42

TABLE 6 : Measures of current, voltage, power density, current density of sewage waste water with microorganisms

Sr.no	Time(hr)	Current(A)	Voltage(V)	Power density(W/m2)	Current density(A/m2)
1	00	0.2	0.23	10	50
2	02	0.3	0.28	18.26	75
3	04	0.3	0.34	22.17	75
4	06	0.3	0.42	27.39	75
5	08	0.4	0.59	51.30	100
6	10	0.4	0.66	57.39	100
7	12	0.5	0.75	81.52	125
Average		0.34	0.46	34	85.71

water.

CONCLUSION

The results obtained from the following experimental data shows us that more electricity is Is acquired from mediator and yeast rather than only yeast or with only mediator for dairy waste Water.

The value of voltage category change according to the type of microorganisms used.

The mediator enhances the transferof electrons and thus increasing the acquired voltage.

The more the dairy water or urine or sewage waste water chamber are kept for degradation, better the results are obtained up to a certain limit.

In sewage waste water microorganisms play a vital role in producing large number of electrons and if a mediator is introduced it enhances the increased transfer of electrons which help to get better results.

Results for sewage treatment may vary from mediator to mediatorand also from electrogenic microorganisms to some other kinds.

This shows that the MFC is relatively efficient waste water treatment system. A moderately efficient, recyclable. Waste water treatment system is the first to an alternatively energy resources that is copied with cleansing of the environment.

SCOPE OF IMPROVEMENT

Experiment using various microbes and different electrodes at different operating conditions and effect of temperature on the system and microbes and fuel cell along with various waste water like industrial waste water, also at various pH conditions behavior of system will be conducted in the future. However. This technology is only at the research stage. and more research is required before household MFCs can be made available. Increasing the efficiency. finding alternatives to hazardous electron mediators and researching new microbes are the aspects on which we must focus. The present studies contribute to the on-going pursuit of the most productive microbial fuel cell.

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REFERENCES

[1] V.D.Patil, D.B.Patil, M.B.Deshmukh, S.H.Pawar; Intenational Journal of Chemical Sciences and Applications ISSN 0976-2590, Comparative study of bioelectricity generation along with treatment of different sources of waste water, **2(2)**, 162-168 **(June 2011)**.

[2] E.Bruce Logan, M.John Regan; TRENDS in microbiology, **14(12)**, Electricity-producing bacterial communities in microbial fuel cells.

[3] S.S.Patil, G.M.Verulkar; Department of Biotechnology, Bioelectricity Generation along with the treatment of Dairy waste water through microbial fuel cell.

[4] S.Aktan, A.Bozkurt, E.M.U.Cokgor, B.I.Yazicioglu, et al; Electricity generation by a mediator less microbial fuel cell using mixed culture, **(2009)**.

[5] Dr.Z.He.F.Zhang et al.; Using microbial fuel cells to treat raw sludge and primary effluent for bio electricity generation, **(2013)**.

[6] S.Venkata Mohan, G.Mohanakrishna et al; Biochemical Engineering Journal, Bioengineering and environmental centre, Indian Institute of Chemical technology, Biotechnology, Bioelectricity generation from chemical wastewater treatment in mediator less (anode) microbial fuel cell (MFC) using selectively enriched hydrogen producing mixed culture under acidophilic microenvironment, **39(2008)**, 121-130 **(2007)**.