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Use of various agricultural wastes to produce bioenergy in microbial fuel cells

Jina Tanzadeh[1]* and Ali Haghighat[2]

1.Waste group of Environmental Research of Institue of Jahad Daneshgahi, rasht.iran and teacher of Azad university of Rasht, iran
2. Gilan Power Department employe, Iran

Corresponding author: Jina Tanzadeh

ABSTRACT: Microbial fuel cell (MFC) is a new type of renewable and sustainable technology that converts chemical energy in the chemical bonds in organic compounds to electrical energy through catalytic reactions of microorganisms under anaerobic conditions.A developing primary application of MFCs is its use in the production of sustainable bioenergy, organic waste treatment coupled with electricity generation.In the present contribution we demonstrated electricity production by beer brewery wastewater, sugar industry wastewater, dairy wastewater, municipal wastewater and paper industry wastewater. Up to14.92 mA current and 90.23%COD(chemical oxygen demand) removal was achieved in 10 days of operation .Bioreactors based on power generation in MFCs may represent a completely new approach to wastewater treatment. If power generation in these systems can be increased, MFC technology may provide a new method to offset wastewater treatment plant operating costs, making advanced wastewater treatment more affordable for both developing and industrialized nations.Results of recent studies suggest that MFCs will be of practical use in the near future and will become a preferred option among sustainable bioenergy processes.

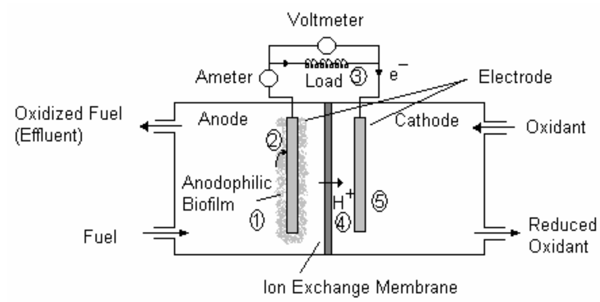
***Keywords*:** Bioenergy, wastewater , Microbial Fuel Cells, microorganism and COD

INTRODUCTION

The high energy requirement of conventional sewage treatment systems are demanding for the alternative treatment technology which will be cost effective and require less energy for its efficient operation. In past two decades, high rate anaerobic processes are finding increasing application for the treatment of domestic as well as industrial wastewaters. The major advantages these systems offer over conventional aerobic treatment are no energy requirement for oxygen supply, less sludge production, and recovery of methane gas. While treating sewage, particularly in small capacity treatment plant recovery of methane may not be attractive, because most of the methane produced in the reactor is lost through effluent of the reactor. The methane concentration of about 16 mg/L (equivalent COD 64 mg/L) is expected in the effluent of the reactor due to high partial pressure of methane gas inside the reactor(1). Hence, while treating low strength wastewater major fraction of the methane gas may be lost through effluents, reducing the energy recovery. In addition, due to global environmental concerns and energy insecurity, there is emergent interest to find out sustainable and clean energy source with minimal or zero use of hydrocarbons. Electricity can be produced in different types of power

plant systems, batteries or fuel cells. Bacteria can be used to catalyze the conversion of organic matter into electricity(2,3,4,5,6,7). Fuel cells that use bacteria are classified as two different types: biofuel cells that generate electricity from the addition of artificial electron shuttles (mediators) and microbial fuel cells (MFCs) that do not require the addition of mediator[8]. Unlike a battery, a fuel cell does not store energy. Instead, it converts energy from one form to another (much like an engine) and will continue to operate as long as fuel is fed to it. However, unlike internal combustion generators, fuel cells convert chemical energy directly into electricity without an intermediate conversion into mechanical power. Fuel cells, if used for wastewater treatment, can provide clean energy for people, apart from effective treatment of wastewater. The benefits of using fuel cells include: clean, safe, quiet performance; high energy efficiency; low emissions; and ease in operating.(12)

The schematic diagram of mediator less MFC is shown in the Figure 1. In a MFC, two electrodes (anode and cathode) are placed in water in two compartments separated by a proton exchange membrane (PEM). Most studies have used electrodes of solid graphite(7), graphite-felt(14), carbon cloth(15) and platinum coated graphite cathode electrode(16). Microbes in the anode compartment oxidize fuel (electron donor) generating electrons and protons. Electrons are transferred to the cathode compartment through the external circuit, and the protons through the membrane. Electrons and protons are consumed in the cathode compartment reducing oxygen to water.(18,19)



Rate Limiting Steps: (1) Oxidation of Fuel, (2) Electron transfer from the microbial cells to the electrode, (3) Electric load in the circuit, (4) Proton supply into the cathode compartment, (5) Oxygen supply and reduction at the cathode (Gil et al.[6]).

Figure 1. Mediator Less Microbial Fuel Cell with rate limiting steps

Although MFCs operating on wastewaters generate a lower amount of energy than on pure compounds, a combination of both electricity production and wastewater treatment would reduce the cost of treating primary effluent wastewater. In the present demonstration, we compared the electricity production capacity of beer brewery waste water, sugar industry waste water, dairy waste water, municipal waste water and paperindustry waste water through microbial fuel cell technology.(14,20)

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MATERIALS AND METHODS

Waste water samples

Beer brewery wastewater was collected from the Central Distilleries and Breweries Ltd. Meerut, India. Sugar industry wastewater was collected from Daurala Sugar Works, Meerut. Dairy Industry wastewater was collected from New Kailash Dairy, Meerut.

Municipal wastewater was collected from nearby Municipal waste tank; Meerut and Paper Industry wastewater was collected from Star paper Mills Ltd. Saharanpur, India. Table 1 shows general characteristics of all wastewaters. All wastewater samples were

named as: beer brewery wastewater: BW,Sugar industry wastewater: SW, Dairy wastewater: DW

Municipal wastewater: MW, Paper industry wastewater: PW

All five wastewater samples were kept in a refrigerator at 4**o**C before use. The wastewaters were used as the inoculum for all MFC tests without any modifications such as pH adjustments or addition of nutrients, mediator or trace metals. Experiments were conducted using full-strength wastewater, at 35**o**C and stagnant condition except as indicated.

MFC Construction

The MFCs were constructed from glass (16x16x10 cm) with a total volume of 1000 ml, and working volume of 700 ml. Both anode and cathode were separated by a glass, containing hole (6x6 cm) which was covered with a proton exchange membrane (Nafion TM 117, DuPont Co. USA). Three electrode arrangements consisting of plain carbon paper (7x7cm) as anode and graphite (7x7 cm) as cathode were used in this study. The electrodes were attached using copper wire with all exposed metal surfaces sealed with a nonconductive epoxy. The anode chamber was filled (600 mL) with various mediums respectively for separate study. The anode was continuously flushed with N2/CO2 (80:20) to maintain anaerobic conditions. Cathode chamber (aerobic chamber where oxygen was100mM phosphate buffer and pH adjusted to 7 by 0.5 N NaOH. The cathode chamber was provided with air that was passed through a0.45μm pore size filter.

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MFC operation

Initially MFCs were inoculated with artificial wastewater containing glucose as carbon source. The composition of wastewater was (g l-1): 1.0 g glucose, 450.0 mg NaHCO3, 100 mg NH4Cl, 10.5 mg K2HPO4, 6.0 mg KH2PO4, 64.3 mg CaCl2.2H2O, 18.9 mg

MgSO4.7H2O, 10.0 mg FeSO4.7H2O, 6 mg MnSO4, 0.5 mg ZnSO4.7H2O, 20 mg CoCl2.6H2O, 0.65 mg CuSO4.5H2O. After two cycles, feed solution containing 50% artificial wastewater and 50% different wastewater samples, separately inoculated into MFCs. After four cycles, feed solution was switched to various wastewater samples.

Table 1. Characteristics of different waste waters

S No	Wastewater	pH	BOD (mg/L)	COD (mg/L)	TSS (mg/L)
1	Beer brewery wastewater	6.4	429	1778	405
2	Sugar industry wastewater	6.1	539	1229	287
3	Dairy wastewater	5.5	654	1487	329
4	Municipal wastewater	7.6	234	1235	256
5	Paper industry wastewater	8.3	267	1581	395

Monitoring Electricity and COD

Current (*I*) measurements were recorded using a Digital Multimeter (Kusam electrical industries, India, Model – 108) by connecting with 10Ω external circuit. COD measurements were conducted using standard methods (Greenberg A et al. 1992). All samples were filtered through a 0.22 μm (pore diameter) membrane filter prior toCOD measurements. COD removal was calculated as ECOD=(CODin–CODout/CODin) x 100%, where CODin is the influent COD and CODout is the effluent COD.

Statistical analyses

All experiments were conducted using 3 separate microbial fuel cells. When a single MFC was used, the experiments were repeated at least 3 times and results were presented as average values or a typical result. We found that the all data presented were statistically significant

RESULTS AND DISCUSSION

Current generation

After setting the experiment, all two chambered Mediator Less MFCs were operated with different wastewater samples at different conditions, as feed to support the formation of biomass and subsequent generation of electricity. The MFCs were continuously monitored during experiment and readings were taken after each 24 hr, inoculation time was considered as time 0. Fuel Cells were operated for 15 days and readings were taken up to 10 days. Preliminary experiments conducted using MFCs showed that electricity could be generated using different wastewaters. Stable current output was achieved after two to three cycles.

When MFCs were inoculated with different wastewater samples, there was about 24 h Lag phase followed by an increase in cell current. The initial increase of current here can be attributed to the presence of components that are easily utilized by mixed microorganisms present in the wastewaters. When these easily degradable substrates were exhausted, the current outputs began to decrease. Meanwhile, degradation of complex components was taken place by which a lower current was still obtained.

Fresh feed was supplemented when a drop in current was observed. A steady increase in current generation was observed with additional feed and might be attributed to the adaptation, phenomenon and development of the biofilm on the surface of the anode. Electrode fouling was not observed and the electrodes could be used in further experiments without remarkable activity loss.

Effect of temperature

To evaluate the effect of temperature on current generation, five MFCs were operated with different wastewater samples. Initially all the samples were operated at 35oC, after 5 days temperature was increased up to 45oC. Figure 1 show the current generation by all wastewater samples at both temperatures.

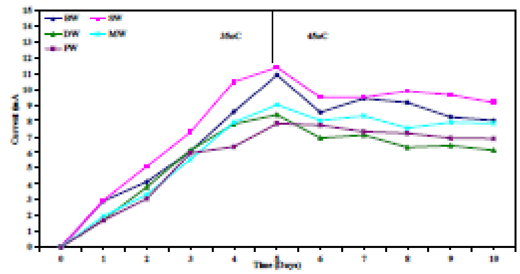

Figure 1. Current Generation by all wastewaters at different temperatures

Experimental data indicate that performances of MFCs were slightly decreased with increase of temperature from 35 to 45oC. All wastewater samples started fermentation and current generation after about 24 hrs. SW (Sugar industry wastewater) showed best result at both the temperatures, this sample started current generation after 24 hrs. and reached its maximum value of 11.39 mA after 5th day of operation. As the temperature increased to 45oC, a major current fall observed which continued in the sample.

Similarly, BW (Beer brewery wastewater) started current generation after 24 hrs and reached its maximum value of 10.92 mA after 5 days. This sample also showed decreased current at 45oC, yet current recovered after 7 days and maintained up to 8th day. Same pattern was followed by DW (Dairy wastewater), MW (Municipal wastewater) and PW (Paper Industry wastewater) these samples generated 8.39 mA, 9.01 mA and 7.82 mA current after 5 days of operation at 35oC. These results were not unexpected as the ambient temperature for most of the microorganisms is 30-35oC. Higher temperature might resulted in less cell multiplication and growth so less availability of catalysts leading to electron release by oxidation of wastewater and ultimately less current generation.

Effect of wastewater concentration

To evaluate the effect of wastewater concentration on electricity production, all MFCs were operated with different wastewater samples. Initially full strength wastewater was used in the anodic chamber, after 5 days 50% part of wastewater was replaced by Ultra pure water. The effect of wastewater concentrations on current response is shown in Figure 3. Experimental data indicated that, current generation was decreased with decrease of waste water concentration from 100% to 50%. Current fall was not observed in DW, it might be due to presence of some bacteria, which faced substrate inhibition at higher waste water concentration. BW, SW, DW, MW and PW achieved maximum 10.29 mA, 11.37 mA, 7.49 mA, 8.98 mA and 7.83 mA current in full strength waste water while 9.76 mA, 9.48 mA, 8.96 mA, 8.56 mA and 7.39 mA respectively in 50% waste water. This variation in current generation may be due to availability of less oxidizable substrates in 50% wastewater samples.

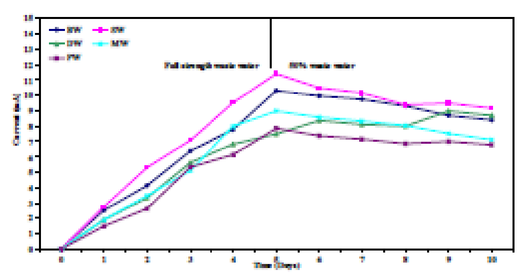

Figure 2. Current Generation by all wastewaters at different waste concentration

COD removal efficiency

During operation, all MFCs were continuously monitored for waste (as COD) removal to enumerate the potential of fuel cell to act wastewater treatment unit. All wastewater samples showed their potential for COD removal indicating the function of microbes,present in wastewaters in metabolizing the carbon source as electron donors**.** It is evident from experimental data that current generation and COD removal showed relative compatibility. Continuous COD removal was observed in all MFCs

Conclusion

Under present investigation, electricity was successfully generated with waste (as COD) removal from all different wastewaters using Microbial Fuel Cell technology, and the microorganisms responsible for electricity generation and COD removal were already present in the wastewater. The microbial electricity technology is still in an early stage of development, but shows great promise as a new method to accomplish both wastewater treatment and electricity generation. Major issues to be solved for practical application are to overcome the activity loss, cost factor and incomplete utilization of wastewater. If power generation in these systems can be increased, MFC technology may provide a new method to offset wastewater treatment plant operating cost, making wastewater treatment more affordable for developing and developed nations. Thus, the combination of wastewater treatment along with electricity production may help in saving money as a cost of wastewater treatment at present.

REFERENCES

Allen RM and Bennetto HP. 1993. Microbial fuel cells: electricity production from carbohydrates. Appl Biochem Biotechnol, 39-40:27-40.

Allen MJ. 1972. Cellular electrophysiology. In Norris J.R. and Ribbons D.W. Methods in microbiology. Academic Press, New York, N. Y. p.247-283.

Angenent LT, Karim K, Al-Dahhal NH, Wrenn BA and Domiguez Espinosa R. 2004. Production of bioenergy and biochemicals from industrial and agricultural wastewater. Trends in Biotechnology, 22:9:477-485.

Bond DR and Lovley DR. 2003. Electricity production by Geobacter sulfurreducens attached to electrodes. App. Environ. Microbiol., 69:1548-1555.

Chaudhuri SK, Lovely DR. 2003. Electricity generation by direct oxidation of glucose in mediatorless microbial fuel cells. Nat. Biotechnol. 21(10):1129-1232.

Gil GC, Chang IS, Kim BH, Kim M, Jang JK, Park HS and Kim HJ. 2003. Operational parameters affecting the performance of a mediator-less microbial fuel cell. Biosens. Bioelectron. 18:327-334.

Haandel van Adrianus C and Lettinga G. 1994. Anaerobic Sewage Treatment, John Wiley & Sons, Singapore.

Jang JK, Pham TH, Chang IS, Kang KH, Moon H, Cho KS and Kim BH. 2004. Construction and operation of a novel mediator-and membrane-less microbial fuel cell. Process Biochem. 39:1007-1012.

Kaufmann F and Lovely R. 2001. Isolation and characterization of a soluble NADPH-independent Fe(III) reductase from geobacteria sulphur reducens. J. Bacteriol. 185:15: 4468-4476.

Kim HJ, Park HS, Hyun MS, Chang IS, Kim M and Kim BH. 2002. A mediator-less microbial fuel cell using a metal reducing bacterium, Shewanella putrefaciens. Enzyme. Microb. Technol., 30:145-152.

Kosaric N and Velikonja J. 1995. Liquid and gaseous fuels from biotechnology: challenge and Opportunities. FEMS Microbiology Reviews 16: 111-142.

Liu H, and Logan BE. 2004. Electricity generation using an air-cathode single chamber microbial fuel cell in the presence and absence of a proton exchange membrane. Environ. Sci. Technol., 38(14):4040-4046.

Liu H, Ramnarayanan R and Logan B. 2004. Production of electricity during wastewater treatment using a single chamber microbial fuel cell. Environ. Sci. Technol., 38:2281-2285.

Magnuson TS, Hodges Myerson AL, Lovely DR. 2000. Characterization of the membrane-bound NADH-dependent Fe(III) reductase from the dissmilatory Fe(III)-reducing bacterium geobacteria sulphur reducens. FEMS Microbial Letter, 185:205-211.

Park DH and Zeikus JG. 2002. Impact of electrode composition on electricity generation in a single-compartment fuel cell using Shewanella putrefaciens. Appl. Microbiol. Biotechnol., 59:58-61.

Rabaey K, Lissens G, Siciliano SD and Verstraete W. 2003. A microbial fuel cell capable of converting glucose to electricity at high rate and efficiency. Biotechnol. Lett., 25:1531-1535.

Reimers CE, Tender LM, Ferig S and Wang W. 2001. Harvesting energy from the marine sediment-water interface. Environ. Sci. Technol., 35:192-195.

Sawyer CN and McCarty Parkin PL. 1994. Chemistry for environmental engineering. McGraw-Hill Book Co., Singapore.

Williner I, Arad G and Katz E. 1998. A biofuel cell based on pyrroloquinoline quinine and microperoxidase-11 monolayer-functionalized electrodes. Bioelectrochem. Bioenerg., 44:209-214.

Wingard LB, Shaw CH and Castner JF. 1982. Bioelectrochemical fuel cells. Enzyme Microb. Technol., 4:137-142.