Influence Of Oregano Essential Oil in Bio Electrochemical System for Electricity Generation

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Abstract - *Bio electrochemical systems are revolutionary new bioengineering technologies which integrate microorganisms or enzymes with the electrochemical method to improve the reducing or oxidizing metabolism. Hence in present study MFC was applied to generate electricity using anaerobic sludge from Milma diary Kozhikode using carbon felt as anode and cathode. MFCs in terms of electricity generation were observed by measuring closed circuit voltage (CCV) and open circuit voltage (OCV) values on a daily basis. Average operating voltage (OV) of MFC-1, MFC-2 and MFC-C of 584 mV, 533 mV and 167 mV and average OCV of 881 ± 23 mV, 880 ± 14 mV, and 571 ± 41 mV were observed in MFC_O, MFC_H and MFC_C respectively after seventeen cycles each of 48 h. A gradual increase in OV is observed after each cycle. All the pre-treatment techniques used in this investigation exhibited a better operating voltage compared to that of MFC without any inoculum pretreatment. Even though pretreatment with heat and oregano extract had a comparable OV, a slightly higher OV was observed in case of oregano extract-based treatment.*

Key Words: ***Anaerobic sludge, Microbial fuel cell, bio electrochemical cell, Oregano essential oil, methane suppression.***

1.INTRODUCTION

Rapid population growth and urbanization has led to an increase in water usage and apparently gave way to increased wastewater generation. As it is always recommended to use water wisely, same is applicable for wastewater. Hence, wastewater generated from households, industries and agriculture should not be seen as a threat to environment rather should be looked into as valuable resource, which could meet the demands for water, energy and nutrients. Microbial fuel cells (MFCs) are one of the promising technologies capable of converting chemical energy contained in the wastewater into electrical energy by achieving simultaneous wastewater bioremediation [2]. Different micro-organisms, which can compete with the electrogens for the substrate, are capable of surviving in the anodic chamber of MFC's [2]. Since mixed anaerobic sludge is used as anoculum by many researchers, a significant amount of methane production has been reported in the biochemical cells [1]. is reported that methane production in MFCs increases with increasing substrate concentration, suggesting that organic rate is an important factor in methane production. the presence of methanogens leads to a decrease in the power output of MFCs as they compete with the electrogens for food and space on the anode. The sludge added as inoculum is the primary microbial reserve. If methanogens can be selectively eliminated from the inoculum itself, it is more likely that a greater proportion of substrate utilizing microorganisms will be electrochemically active. Therefore, pretreatment methods for anaerobic sludge must be used that are able to suppress the activity of methanogens without affecting the suppression of the activity of electrogenic microorganisms and other fermentative microorganisms [4]. Hence in order to reduce loss of electrons from the anodic chamber of MFC, it is necessary to suppress activity of methanogens. Essential oils such as oregano essential oil (OEO) which consist of bioactive compounds have been confirmed to modify the ruminal fermentation by enhancing the efficiency of energy utilization while decreasing methane emissions [6].

OEO inclusion rate with certain amount in anaerobic sludge can suppress the effective methanogenesis bacteria present in anaerobic inoculum. Oregano essential oil has been reported to have second-largest oxygen radical absorbance capacity compared with clove, followed by cinnamon, ginger and rosemary essential oil [1]. Oregano leaf material as an anti-methanogenic plant product, with no adverse effects on ruminal fermentation or neutral detergent fiber degradability has been reported in vitro [6].

2 METHODS AND MATERIALS

2.1 MFC setup

Experiments were performed in dual chambered aqueous cathode MFCs with an anodic liquid volume of 50mL. Baked clayware cylinders served as the anodic chamber of these MFCs and the wall material of the cylinder acted as a separator between anodic and cathodic chambers.

Fig -1 Bio electrochemical system

The anode and cathode electrodes of both MFCs were made up of carbon felt. Copper wire was used to connect both the electrodes through an external resistance of 100 Ω.

2.2 Operating conditions

Mixed anaerobic sludge collected from anaerobic digester was used as the inoculum in the anodic chamber. The control MFC (MFC-C) was inoculated 20 mL of sludge without any pre-treatment. The anaerobic sludge was pre-treated with 0.2 mL/L of oregano extract, which was provided in MFC-1 after incubating at room temperature for overnight in order to suppress the growth of methanogens. MFC-2 was inoculated with sludge heat treated at a temperature of 100 °C for 10 min. Synthetic wastewater containing sodium acetate as the carbon source having chemical oxygen demand (COD) of about 3000mg/L was used as the feed in both MFCs. These MFCs were operated under room temperature with a fresh feeding interval of 48 h.

3 Methane suppression using OEO

A known volume of anaerobic sludge was taken in conical flask. Rubber septum cap is used for covering the conical flask which is filled with anaerobic sludge. The set up was kept like that for 8 hours for methane gas production in it.

Fig -2 OEO treated anaerobic sludge in various concentration

A gas displacement set-up was used to calculate the methane gas production rate. PVC transparent pipe with one end fixed with a syringe-needle and other end is inserted to the conical flask having water were used to connect sludge containing conical flask to 1/3rd of water filled conical flask and beaker. After 8 hours, the needle is inserted through the rubber septum for the flow of gas produced inside the conical flask containing anaerobic sludge to water containing conical flask.

Fig -3 Gas displacement Method

Gas produced from the anaerobic sludge will pass through the needle and change in volume of water occurs due the pressure exerted by the gas produced. Some volume of water gets displaced into the beaker giving the amount of gas produced by the anaerobic sludge in the conical flask containing controlled cell. In the conical flask containing water, one PVC pipe is touched on the water surface and another is kept above water level. This displacement method is used to measure the volume of irregularly shaped object. Here the objective of set-up is to gas produced after the suppression of methanogenesis (ie, Methane gas).

The amount of water displaced can be concluded as the amount of gas generated by the action of electrogenesis bacteria, fermentative micro-organism, sulfate reducers. The more the water gets displaced from the different OEO concentration, inclusion rate can be taken as the optimum OEO dosage value.

2.4 Measurements and analysis

MCCs were continuously monitored for voltage produced using a data acquisition unit across a fixed external resistance (R_{ext}) of 100 Ω [8]and current (I) in amperes (A) was calculated from Ohm's law ($I= V/R_{ext}$), where V is the potential drop in volts (V) across external load resistance (R, Ohms). The overall performance of the MCCs was evaluated through power output (P, Watts) as per equation given below [9],

$$P=IV \quad (1)$$

The maximum power density was obtained from polarization curve plotted by varying the external resistances from 10000 to 10 Ω using the resistance box over a fixed time interval till a stable voltage was achieved.

$$P = V^2 / (V_{an} \times R_{ext}) \quad (2)$$

The volumetric power density (P, mW/m^3) was normalized to anodic chamber volume (V_{an}) as by using given equation (2)

3 Results and discussion

3.1 Specific methanogenic activity

Gas displacement method is monitored for 3 sets of inclusion rate of OEO and for control. For each set fresh anaerobic sludge is used. More water displaced at 0.2ml concentration of OEO (25ml) which is more than control, which means that gas produced after suppressing methanogenesis. For in controlled anaerobic sludge the gas produced is mixture of gases including methane. Optimum dosage is taken as 0.2ml/L OEO. Cell is fabricated for the optimum dosage of OEO as 0.2ml and voltage generated has been recorded.

3.2 Electricity generation

The performances of MFCs in terms of electricity generation were observed by measuring OV and OCV values on a daily basis. Maximum OV of 584 mV, 533 mV and 167 mV and average OCV of 881 ± 23 mV, 880 ± 14 mV, and 571 ± 41 mV were observed in MFC-1, MFC-2, and MFC-C, respectively after seventeen cycles each of 48 h.

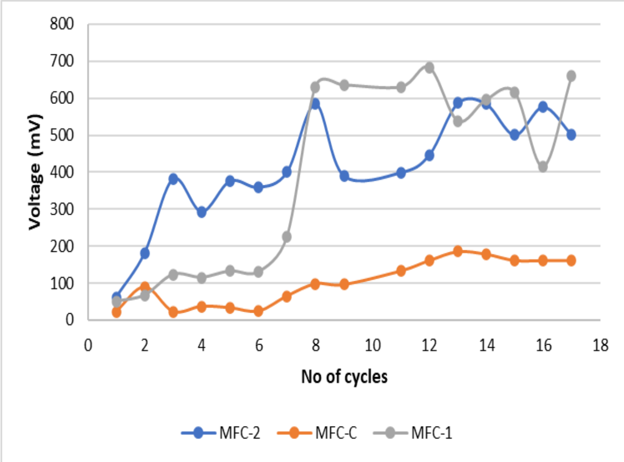

Fig 4: Variation of operating voltage (OV) with feed cycle

A gradual increase in OV is observed after each cycle. All the pre-treatment techniques used in this investigation exhibited a better operating voltage compared to that of MFC without any inoculum pretreatment. Even though pretreatment with heat and oregano extract had a comparable OV, a slightly higher OV was observed in case of oregano extract-based treatment.

4 CONCLUSIONS

The present study focused on the development of a bioelectric chemical cell and its performance evaluation on electricity generation, also progressive inhibition of methanogenesis from OC/CC operations within the developed system using Oregano essential oil (OEO).By using cost effective materials, a two-chambered bioelectric chemical cell was developed and evaluated electricity generation in the developed cell. MFC of treating capacity of 50 ml with a surface area of 324.99 cm^2 was constructed. The performance of MFC under three different inoculum condition was observed. They are as follows (i) heat treated (ii) OEO added (iii) control. This study aims to determine the electricity generation. By using different inoculum pretreatment techniques, a better performance was observed in MFCs that has undergone sludge pretreatment on addition of oregano extract as well as heat pretreated inoculum fed MFC.

REFERENCES

[1] Clauwaert, P., Mulenga, S., Aeltermam, P. (2009) Litre-scale microbial fuel cells operated in a complete loop, *Appl Microbiol Biotechnology*, 83, 241-247

[2] Rajesh, P.P., Jhadhav, D.A., Ghangrekar, M.M. (2014) Improving performance of microbial fuel cell while controlling methanogenesis by chaetoceros pretreatment of anodic inoculum, *Bioresource Technology*, 98, 994-998

[3] Rui, Z., Wu, J., Lang, X., Liu, L., Casper. P.D., Wang, Cailian, W., and Zhang, L.(2020) Effects of Oregano Essential Oil on in vitro ruminal fermentation, methane production and ruminal microbial community, *Animal Feed Science and Technology,* 148, 321-327.

[4] Santoro, C., Kodali, M., Sergio, H., Serov, A., Ioannis, I., Atanassov, P. (2018) Power generation in microbial fuel cells using platinum group metal-free cathode catalyst: Effect of the catalyst loading on performance and costs, *Journal of Power Sources*, 378, 169-175

[5] Tiwari, B.R., and Ghangrekar, M.M. (2015) Enhancing Electrogenesis by pretreatment of Mixed Anaerobic Sludge to be used as inoculum in microbial fuel cell, *Energy Fuels,* volume 29, Issue 5

[6] Tekippe, J.A., Tacoma, R., Hristov, A.N., Lee, C., Oh, J., Heyler, K.S., Cassidy, T.W., Varga, G.A., Bravo, D. (2013), *Journal Of Diary Science,* volume 96, Issue 12

[7] Walter, A. X., Madrid, A., Iwona, G., Greenman, J., Ioannis, I. (2022) Microbial fuel cell scale-up options: Performance evaluation of membrane (*c*-MFC) and membrane-less (*s*-MFC) systems under different feeding regimes, *Journal of Power Sources,*520, 230-275

[8] Winfield, J., Iwona, G., Greenman, J., and Ieropoulos, I. (2016) A review into the use of ceramics in microbial fuel cells, *Bioresource Technology,* volume 215, 296-303

[9] Xie, R., Wang, S., Wang, K., Chen, B., Wang, Z., and Tan, T. (2022) Improved energy efficiency in microbial fuel cell by bioethanol and electricity co-generation, *Biotechnology For Biofuels and Bioproduct,* volume 15, Issue 9