ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785
(ISRA), Impact Factor: 2.114

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

BIO-ELECTRICITY PRODUCTION FROM ORGANIC WASTE USING SINGLE CHAMBER MICROBIAL FUEL CELL (MFC)

Ganesan Vijayan Siva*, Rajaram Prashanthi, Natarajan Mohan
* Department of Biotechnology, University of Madras, Guindy campus, Chennai 600025, India.
Department of Biotechnology, University of Madras, Guindy campus, Chennai 600025, India.
Centre for Advanced Study in Botany, University of Madras, Guindy campus, Chennai 600025, India.

ABSTRACT

Microbial fuel cells (MFCs) are devices that use microorganisms including bacteria and yeast to generate electricity from organic matter. In this paper we report the generation of electricity using a single chamber microbial fuel cell in which grape waste extract was used as organic substrate with and without the use of thionine, neutral red and toludine blue as mediators. Further, we compared the efficiency of different electrodes like magnesium, graphite, copper and zinc in bioelectricity generation as the electrodes play a major role in harnessing the electricity without any loss. The power generation while using the mediator thionine has showed the maximum voltage of (2.5 V) with magnesium electrode compared to toludine blue (2.35 V) and Neutral Red (2.2 V). Various parameters such as change in pH, conductivity and specific gravity were also studied. The conductivity of the samples increased from 2.5 m℧ to 3 m℧ indicating the release of ions during the break down of organic substrate.

KEYWORDS: Single chamber MFC, Grape waste extract, electrodes, mediators.

INTRODUCTION

Fuel cells are the devices that convert chemical energy directly into electricity. Chemical conversion occurs at an anaerobic electrode, where a catalyst is used to speed up the oxidation of a fuel cell. In biological fuel cells, the catalyst is either a microorganism as simple as Baker‘s yeast or an enzyme [2,4,18,19,20]. Biological fuel cells convert the chemical energy of carbohydrates, such as sugars and alcohols, directly into electric energy. As most organic substrates undergo combustion with the evolution of energy, bio-catalyzed oxidation of organic substances by oxygen at the two electrode interfaces provides a means for the conversion of chemical energy into electrical energy. In normal microbial catabolism, a substrate such as carbohydrate is oxidized initially without participation of oxygen, while its electrons are taken up by an enzyme-active site, which acts as a reduced intermediate [3].

Microbial fuel cells typically appear in two configurations: two chambers separated by a proton exchange membrane (PEM) or a single chamber. The focus here is in a membrane less single-chamber MFC [13]. Recent research shows that electricity in MFC can be produced with and without the help of mediators and through the exchange of electrons from a group of organisms. Among different advantages, single compartment MFC includes its reduced setup costs (due to absence of expensive membrane and cathodic chambers) that make flexible application in wastewater treatment and power generation [13].

A granular activated carbon based single chamber microbial fuel cell was designed for the first time using activated carbon as biocathodes for decolourization of real dye wastewater. Preliminary treatment was done at anode and further polishing steps occurred at aerobic cathode. Toxicity measurement showed that final effluent was less toxic compared to the original dye waste water. Power density achieved by this type of Mfc was 8 W/m3 [17]. The objective of this study was to estimate electricity generation using a Single chamber MFC. A single chamber microbial fuel cell was constructed using a boiling tube (50 ml) with magnesium, graphite, copper and zinc as electrodes. The grape waste extract was used as substrate along with Saccharomyces cerevisiae as an inoculum. The voltage generated from grape waste extract as substrate and Saccharomyces cerevisiae as biocatalyst in the single chamber MFC was recorded using a USB data logger connected to electrodes. Various parameters such as change in pH, conductivity and specific gravity were also studied.

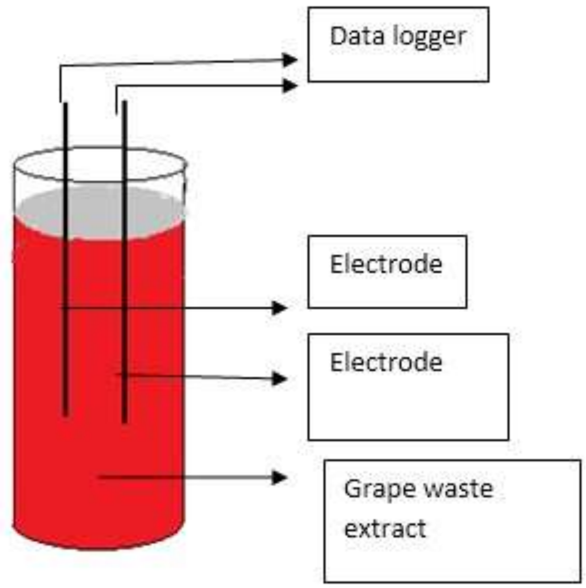
MATERIALS AND METHOD

Collection of grape waste

The grape wastes were collected from local fruit juice shops. They were collected in a clean and sterile container and stored in refrigerator till the experiments have been carried out.

Construction of single chamber MFC

The single chamber microbial fuel cell was made from a 50 ml boiling tube fitted with a stopper on which electrodes were inserted and sealed as shown in (Fig. 1)



A ***B***

Fig.1 A. Single chamber MFC B. Schematic diagram of single chamber MFC

Preparation of samples for MFC chamber

100 grams of grape waste sample was ground in a homogenizer and aqueous extract of the waste sample extracted using 200 ml of double distilled water. The extract was filtered using nylon mesh. The extract was centrifuged at 5000 rpm for 15 min to remove the debris. The centrifuged sample was used as the substrate in MFC. The pH, conductivity specific gravity and sugar estimation were carried out using this extract.

Study of pH, Conductivity, and Specific gravity

Change in pH, conductivity, initial sugar content and specific gravity of the extract was determined. The pH of the sample was measured by using portable pen type electronic pH meter and conductivity of the extract was determined by using a Siemens conductivity meter.

Generation of electricity from MFC

Grape waste extract was taken in boiling test tube and 100 micro liters of 0.5 OD pure cultures of Saccharomyces cereviseae was added to it. Different types of electrodes like graphite / magnesium / copper and zinc were inserted in to the chambers separately. Before using the electrodes they were soaked in de-ionized water for a period of 24 hrs. The entire set up was kept at room temperature. To study the effect of mediator like thionine, neutral red and toludine blue, known concentrations (0.1 M) of the mediator was added to grape waste extract in separate set up. The voltage was measured with an external resistance of 470 Ω across the anode and cathode electrodes using a data logger (EL-

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785
(ISRA), Impact Factor: 2.114

USB-3 Voltage data logger) at an interval of 24 hrs over a period of 21 days. The power densities were calculated from P=E2cell/AAnRext, where E is voltage, A is surface area of anode and R is the external resistance. [14]

RESULTS

Effect of pH, conductivity, sugar content and specific gravity

The pH of the graph waste extract varied between 4.5 to 4.8 and the conductivity of the samples increased from 2.5 mƱ to 3.0 mƱ. The specific gravity of the extract decreased. The initial specific gravity of the sample was 1.070. As the fermentation progressed, the specific gravity decreased gradually and reached a value of 0.995. The decrease in specific gravity is clear indication of yeast fermenting the sugar resulting in alcohol production. The specific gravity reaching a constant value is the indication of end of fermentation. The sugar content of grape waste extract was estimated using DNS method and it decreased from 110 ug /ml of extract to 30 ug/ ml of extract at the end of the experiment (Table:1)

Table 1: Grape waste characteristic

S.no	Grape waste	Initial	Final
1	pH	4.5	4.8
2	Conductivity	2.5 mƱ	3.0 mƱ
3	Sugar	110 ug /ml	30 ug /ml
4	Specific gravity	1.070	0.995

Generation of electricity from Single chamber MFC

Results obtained from single chamber MFC showed that maximum voltage was obtained from Magnesium and Graphite (2.0 V) as anode and cathode followed by Copper and Graphite (1.82 V) and Zinc and Graphite (1.55 V) (Fig 2 and Table. 2) Voltage started increasing from 3rd day reached maximum between 5th to 11th day and started declining after 11th day. In another experiment with single chamber MFC, grape waste extract was amended with mediator like Neutral Red, Toludine Blue and Thionine as they are reported to enhance transfer of electrons to anode. Addition of mediators enhanced the voltage generation in all electrodes. Among the mediators, thionine (2.5 V) was found to generate more voltage than Toludine blue (2.35 V) Neutral Red (2.2 V) (Fig: 3, 4 & 5) and Table: 3) Current Density and Power Density also was high with Magnesium and graphite electrodes as anode and cathode respectively and thionine as mediator (Fig: 5 & Table 4a). Figures 7, 8, 9 and 10 represent the real time data obtained from USB Data Logger for 21 days of experimentation.

Table: 2 Effect of electrode

S.no	Electrode	Voltage
1	Magnesium and Graphite	2.0 V
2	Copper and Graphite	1.82 V
3	Zinc and Graphite	1.55 V

Table: 3 Effects of Mediators

Sno	Mediators	Electrode	Highest voltage
1	Thionine	Magnesium and Graphite	2.5 V
2	Toludine blue	Magnesium and Graphite	2.35 V
3	Neutral red	Magnesium and Graphite	2.2 V

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785
(ISRA), Impact Factor: 2.114

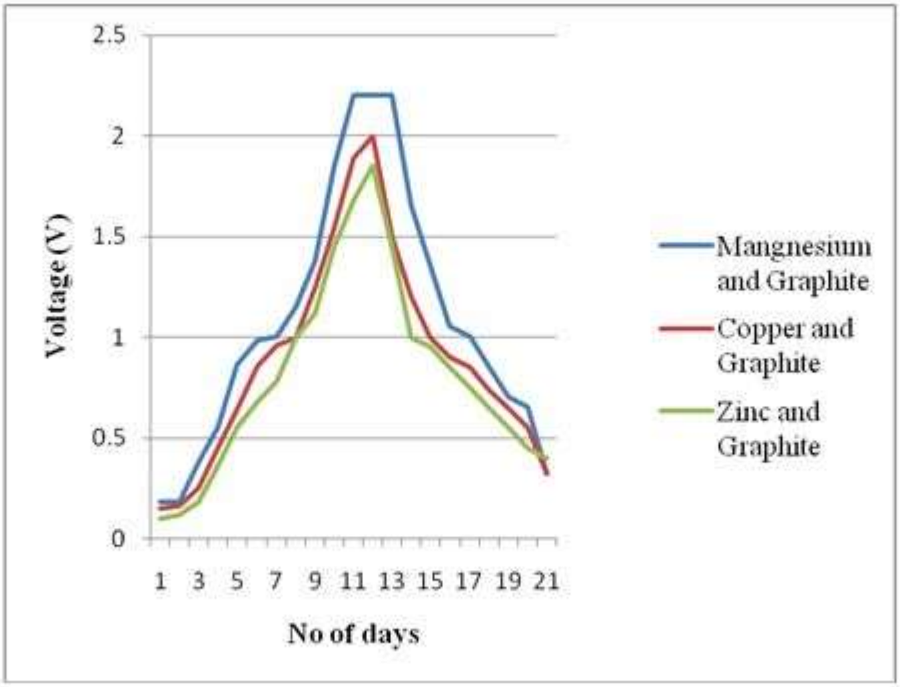


Fig: 3 Single chamber MFC with grape waste and neutral red

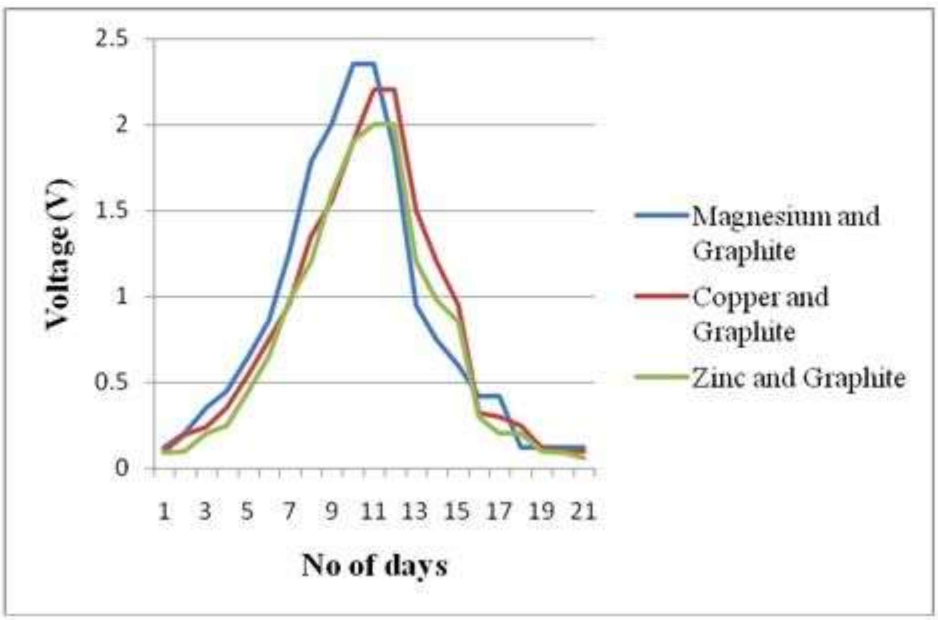


Fig: 4 Single chamber MFC with grape waste extracts and toludine blue

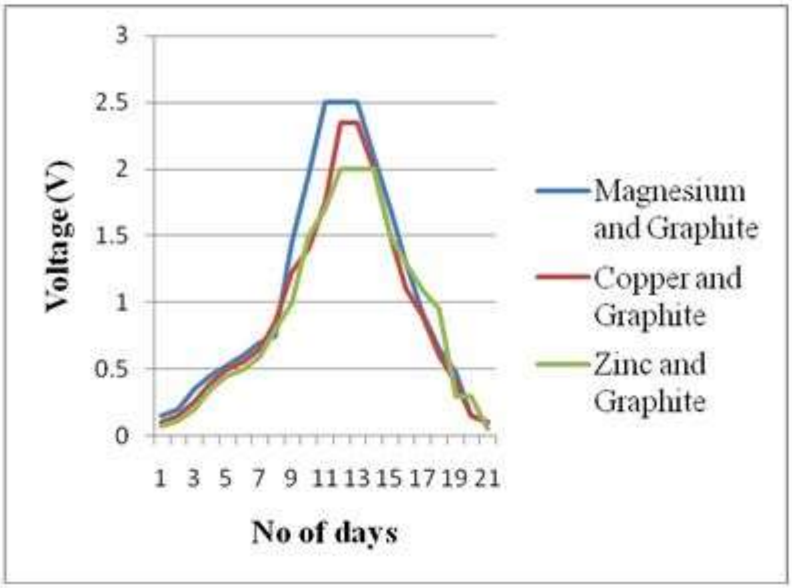


Fig: 5 Single chamber MFC with grape waste extracts and thionine
Power density and current density analysis in single MFC chamber grape waste

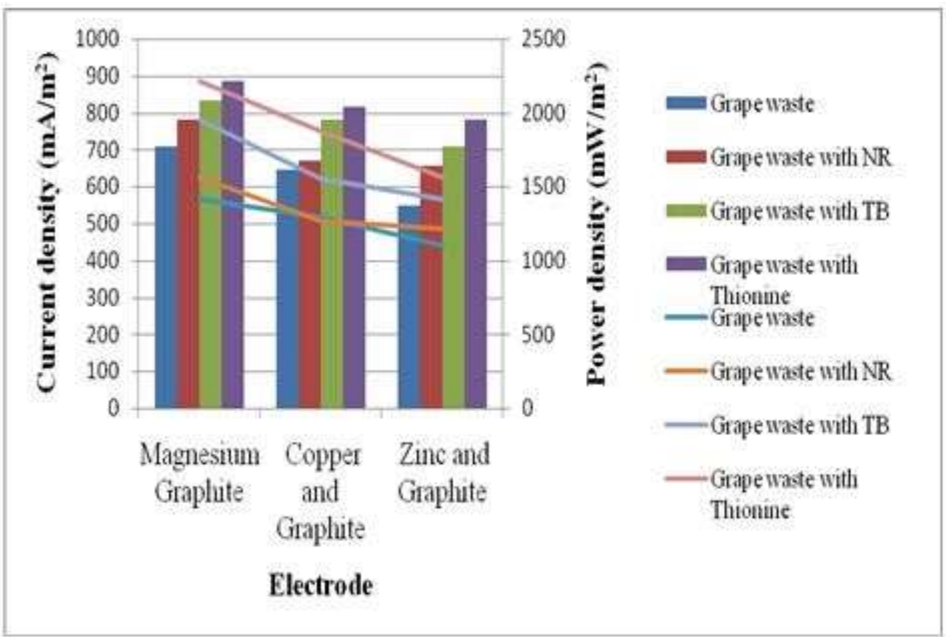


Fig: 6 Single chambers MFC with grape waste, various mediators and various electrodes for power and current density analysis

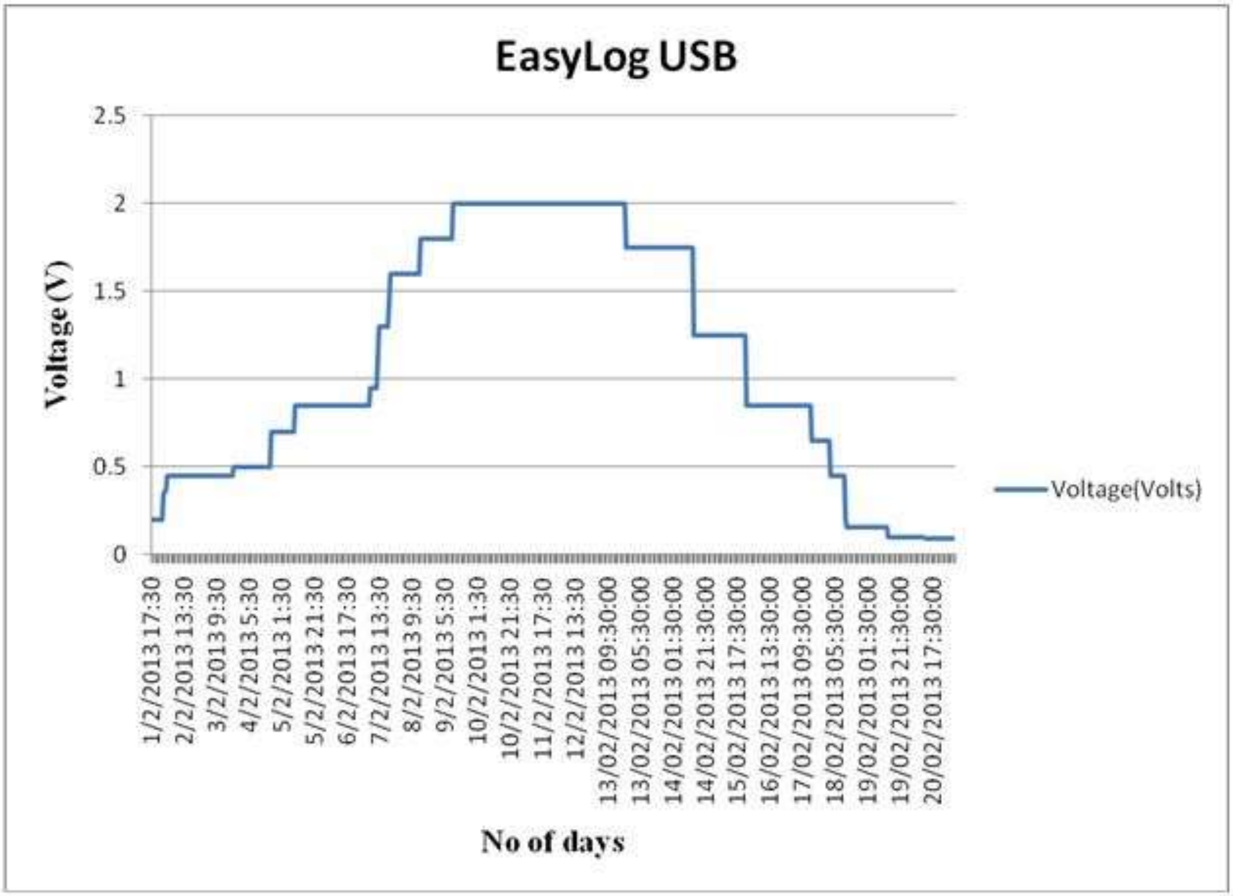


Fig: 7 Data logger graph for grape waste extract with magnesium and graphite electrode

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785
(ISRA), Impact Factor: 2.114

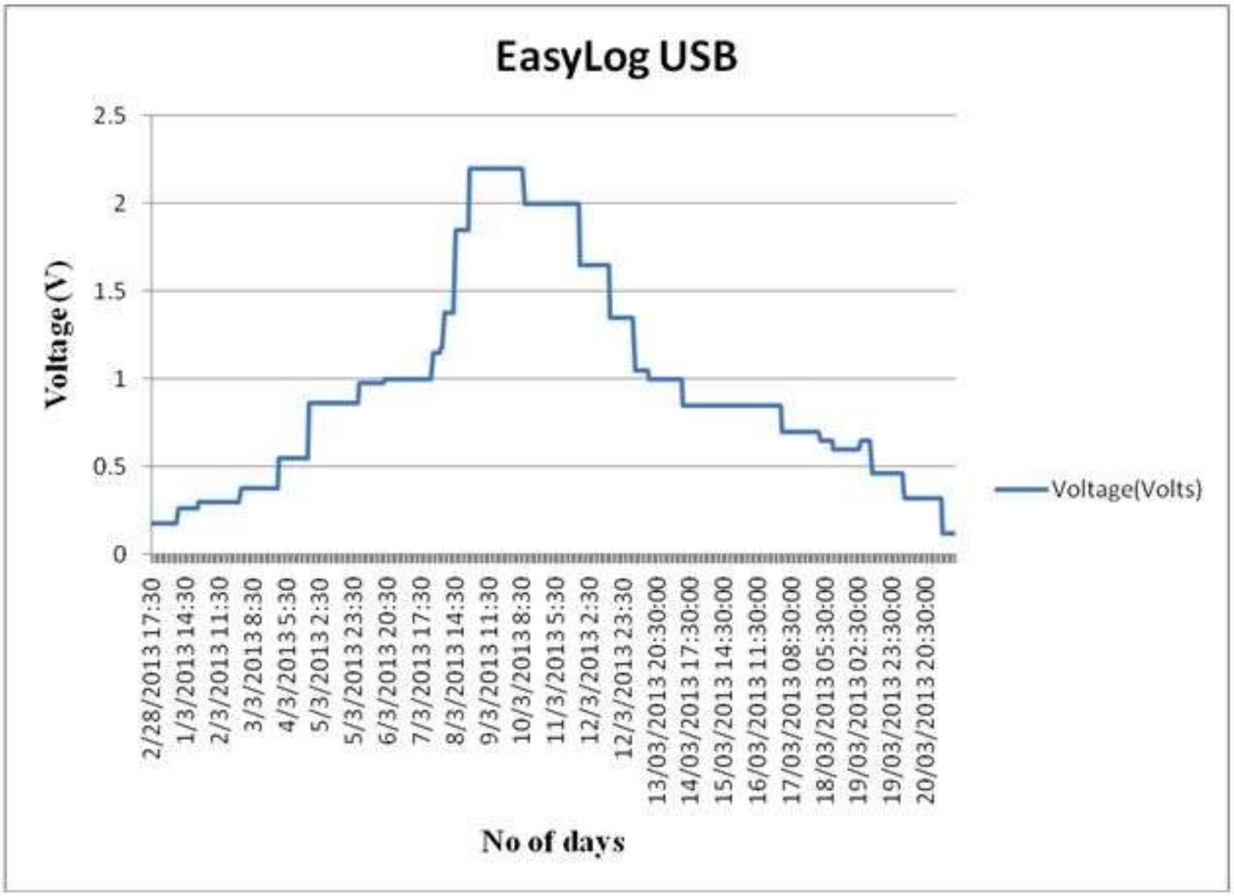


Fig: 8 Data logger graph for grape waste extract with neutral red magnesium and graphite electrode

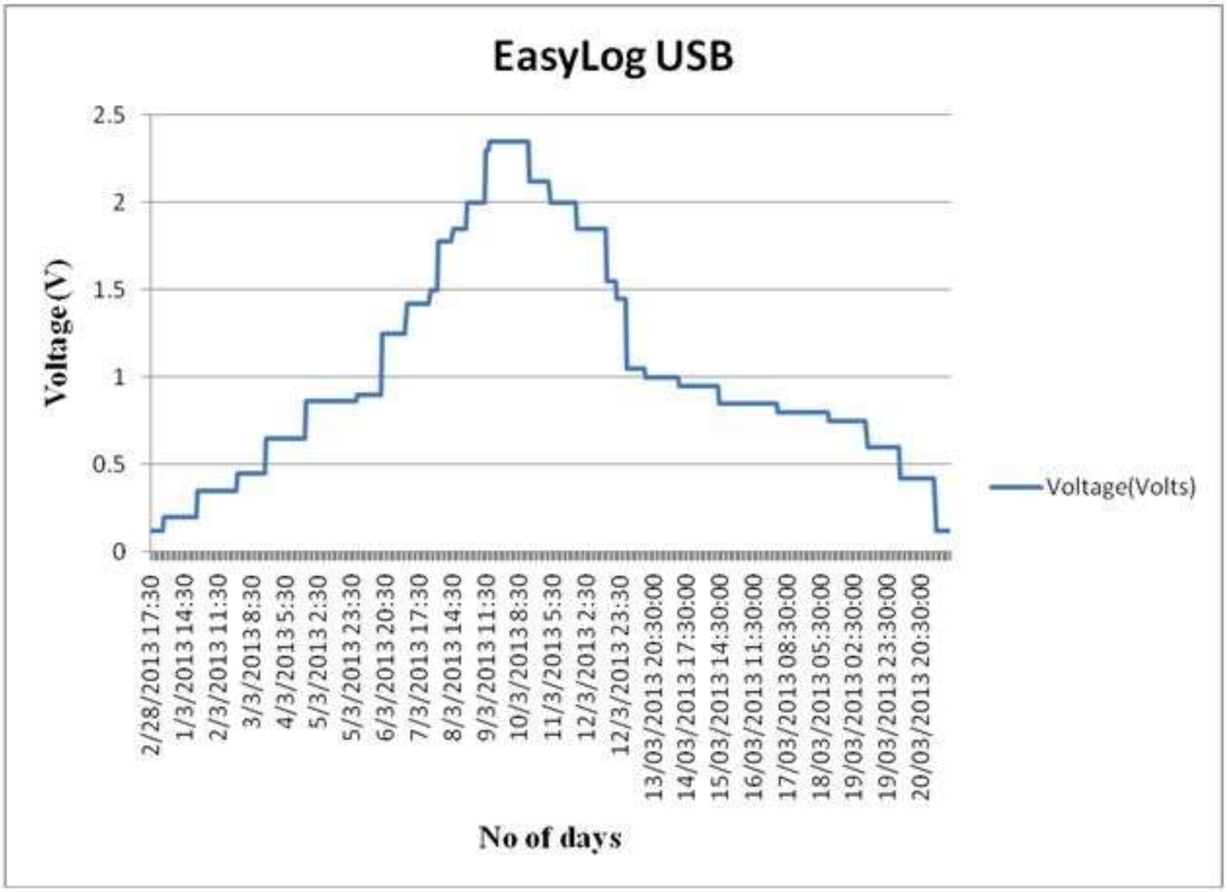


Fig: 9 Data logger graph for grape waste extract with toludine blue, magnesium and graphite electrode

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785
(ISRA), Impact Factor: 2.114

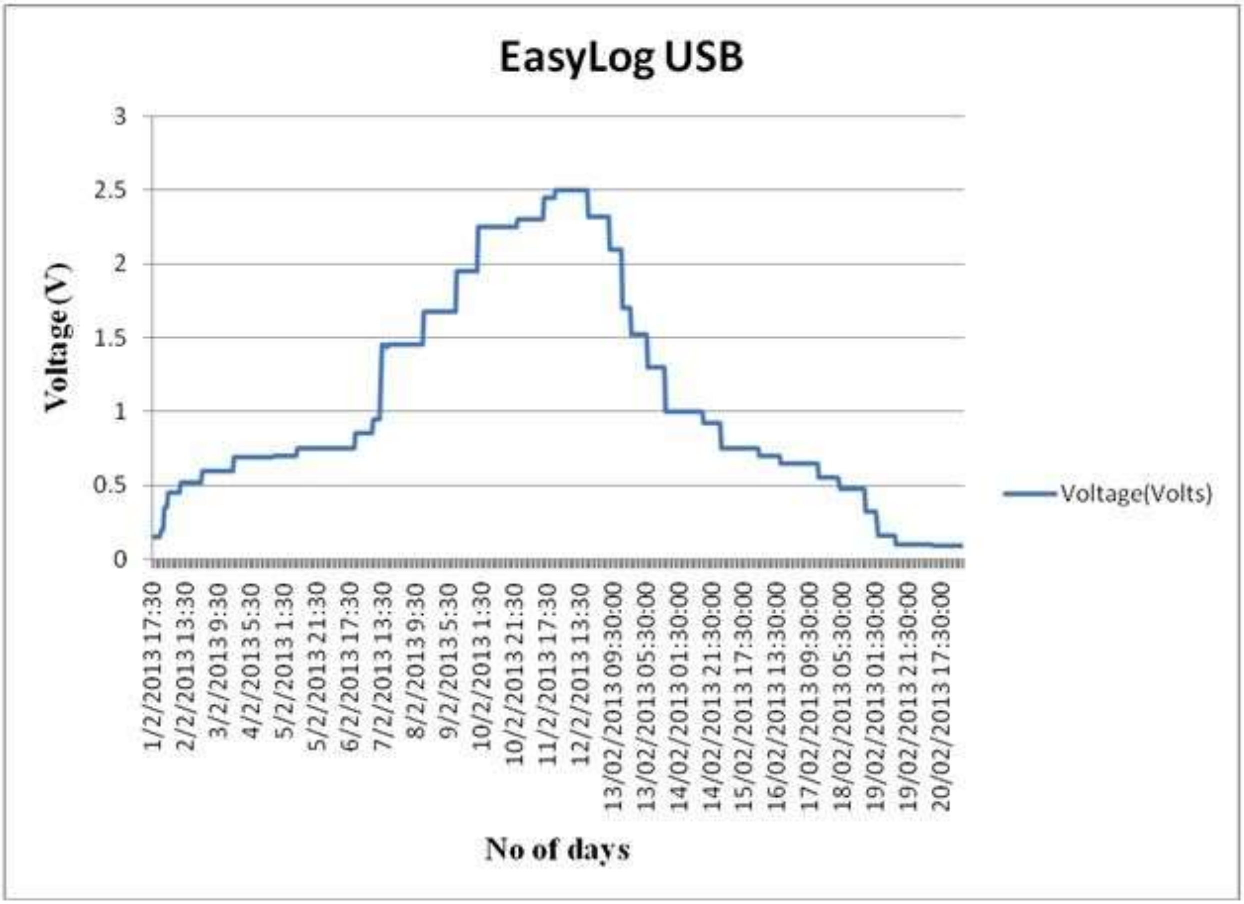


Fig: 10 Data logger graph for grape waste extract with thionine, magnesium and graphite electrode

Table: 4 Maxium voltage generated in single chamber MFC with grape waste extract with and without mediator

	Single chamber MFC with grape waste extract only	**Single chamber MFC with grape waste and Neutral Red**	**Single chamber MFC with grape waste and Toludine Blue**	**Single chamber MFC with grape waste and Thionine**
MFC chamber with electrode	**Voltage (V)**	**Voltage (V)**	**Voltage (V)**	**Voltage (V)**
Magnesium and graphite	2 ± 0.031	2.2 ± 0.040	2.35 ± 0.035	2.5 ± 0.033
Copper and Graphite	1.82 ± 0.033	1.89 ± 0.085	2.2 ± 0.063	2.3 ± 0.062
Zinc and Graphite	1.55 ± 0.045	1.85 ± 0.043	2 ± 0.044	2.2 ± 0.04

Table: 4a. Current and Power Density from Single chamber MFC with grape waste extract with and without mediators

	Single chamber MFC with grape waste extract		**Single chamber MFC with grape waste and Neutral Red**		**Single chamber MFC with grape waste and Toludine Blue**		**Single chamber MFC with grape waste and Thionine**	
MFC chamber with electrode	**Max current (mA/m^2)**	**Max power (mw/m^2)**	**Max current (mA/m^2)**	**Max power (mw/m^2)**	**Max current (mA/m^2)**	**Max power (mw/m^2)**	**Max current (mA/m^2)**	**Max power (mw/m^2)**
Magnesium and graphite	709 ± 2.2	1418±4.3	780 ± 9.10	1560 ± 15	833 ± 8.0	1958± 4.5	886 ± 7.0	2216 ± 9.0
Copper and Graphite	645 ± 7.0	1290 ± 5.0	670 ±6.0	1266 ± 9.00	780 ± 8.0	1560 ± 4.0	815 ± 6.0	1875 ± 7.5
Zinc and graphite	549 ± 7.00	1099 ± 3.90	656 ± 7.0	1213 ± 6.00	709 ±7.0	1418 ±6.0	780 ± 6.5	1560 ± 5.0

DISCUSSION

A microbial fuel cell has great potential as a wastewater treatment process since organic contaminants are converted into electricity. Using a single-chambered MFC, (12) reported that the power generated with acetate (506 mW/m^2) as a substrate was up to 66% higher than that produced with butyrate (305 mW/m^2). In our experiment with single chamber MFC, a maximum power density of 2216 mW/m^2 was obtained with grape waste extract as substrate. The reason for higher power out reported in our work is due the nature of electrode used by us. We used magnesium electrode as anode. Similarly, [10] have tested four kinds of anode electrodes in their MFCs using sediment as substrate. ; a magnesium electrode (M), a magnesium electrode supplied with chitin particles (M+C), a graphite electrode (G), and a graphite electrode supplied with chitin particles (G+C). Average maximum power density was highest in Mg+C (1878 ± 982 $mW\ m^{-2}$), followed by M (848 ± 348 $mW\ m^{-2}$), G+C (1.9 ± 0.6 $mW\ m^{-2}$) and G (0.7 ± 0.6 $mW\ m^{-2}$). Maximum power densities of the magnesium electrodes were ~1,000 times larger than those of the graphite electrodes. The chitin supplement increased maximum power densities by 121% in the magnesium anodes and 164% in the graphite anodes on average. Further, a magnesium electrode in M+C degraded more slowly than that of Magnesium alone. Our experimental results with magnesium electrode conform to the results of the above work in terms of power density obtained from grape waste extract. Similarly, in our work also graphite electrode comes next to Magnesium electrode in producing electricity on par with the results of the above research work. [6] Have researched on using the *Pseudomonas sp*.and mediators like methylene blue and neutral red for the generation of electricity in microbial fuel cell using waste water. The measurements showed that the open-circuit potential in a single MFC with methylene blue was almost the double than that generated when using neutral red as mediator. They indicated the specificity in mediator– microorganism combination for improved performance of a MFC. In our experiments with mediators like Neutral Red, Toludine Blue and Thionine showed that Neutral Red is less effective compared to other mediators. This result is in conformity with the above report.

Several designs are possible for single chamber MFCs, in the first design used in laboratories which is used to demonstrate electricity generation from wastewater, the cathode was placed in the center of a cylinder so that anode chamber formed a concentric cylinder around the cathode (large SCMFC) [5]. Graphite rods were placed inside the anode chamber and these rods extended outside of the anode chamber and were connected to the cathode via an external circuit. In another type of SCMFC there is a single tube with the two circular electrodes placed on opposite ends of the tube (small SCMFC) [5]. [1] studied focused on a biodegradable organic matter through the development of a MFC sensor system for the fast estimation in single chamber microbial fuel. The microorganism acted as biocatalysts in oxidizing the complex organic matter and involved in transferring the electrons to the anode. The microbial fuel cell with continuous replacement of consortium could be used as a biosensor for on-line monitoring of organic matter.

According to [11], their prototype Single chamber MFC with graphite electrode generated a maximum electrical power output of 18 mWm^2. However, we obtained a higher power density of 1418 and 2216 mW/m^2 respectively with Magnesium electrode with and without mediator. An earlier report from this laboratory [8] showed that bio electricity was generated using mediator-less Microbial fuel cell utilizing effluents food based industries like dairy and sugar industries which are rich in organic substrates as well as microorganisms. The maximum voltage and power densities generated from diary and sugar industry effluents measured using USB data logger with an external resistance across anode and cathode were 450 mV, 143.6 mW/m^2 and 400 mV, 113.4 mW/m^2 respectively for a period of twenty one days.

From this study magnesium and graphite as anode and cathode electrodes respectively, was found to be a best choice from others for electricity generation in microbial fuel cell. It demonstrated that different electrodes exhibited different behaviors. From the perspective of current development, the exploration of electrode materials will be more important and attractive as a reasonable price and excellent performance will greatly expand the application of MFCs.

According to [16] reported that single-chamber MFCs produced the highest maximum power density of 706 mW/m^2, while the two-chamber MFC produced 590 mW/m^2 with 50 mM phosphate buffer. The fact that under very similar experimental conditions, different microorganisms and the different types of substrates produce different electric yields is an interesting scientific problem still to be clarified. According to [12] the output power depends on the rate of substrate degradation, the rate of electron transfer from the microbes to the electrode, microbial synergistic effect, and the circuit resistance and proton mass transfer rate in the liquid.

The results obtained with our experiments can be further optimized with various parameters including use of different mediators, various microorganisms in pure and as consortium which would increase the power output from our MFC. Further optimization of various parameters is under progress.

REFERENCES

[1] Ampai Kumlanghan , Jing Liu , Panote Thavarungkul ,Proespichaya Kanatharana , Bo Mattiasson. Biosensors and Bioelectronics. 2007, 22, 2939.
[2] Aston, W. J. and Turner, A. P. F. Biotechnol. Gen. Eng. Rev. 1984, 1, 89.
[3] Bennetto, H. P. Biotechnol. Educ. 1990,1, 63.
[4] Bennetto, H. P Harwood Academic London. 1984, 2, 363.
[5] Cheng, S., Liu, H., Logan, B.E. Electrochemistry Communications. 2006, 8, 484.
[6] David K. Daniel, Bijith Das Mankidy, K. Ambarish and R. Manogari. International journal of hydrogen energy. 2009,34,7555.
[7] Fatemi S, Ghoreyshi, AA, Najafpour G, Rahimnejad M . Journal of Energy & Environment. 2012, 3, 104.
[8] Ganesan Vijayan Siva, Rajaram Prashanthi, Natarajan Mohan. Journal of environmental and applied bioresearch. 2014, 0 2, 44 .
[9] John Greenman, Antonia Gálvez , Lorenzino Giusti and Ioannis Ieropoulos. Enzyme and Microbial Technology. 2009, 44,112.
[10] Jung, S.P., Mi-Hwa Yoon, Seung-Mok Lee, Sang-Eun Oh, Hojeong Kang, Jae-Kyu Yang. Int. J. Electrochem. Sci. 2014, 9, 315.
[11] Kim , K.-J.C., Mi-Jin Choi . Environmental Engineering research. 2008, 13.
[12] Liu H, Cheng S and Logan BE. Environmental Science & Technology. 2005, 39, 5488.
[13] Liu H, Ramnarayanan R, Logan B. Environ. Sci. Technol. 2004 ,38, 2285.
[14] Logan BE, Regan JM . Trends Microbiol. 2006, 14, 512.
[15] Pandey, B.K., V. Mishra, S. Agrawal. International Journal of Engineering, Science and Technology. 2011, 3, 42.

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785
(ISRA), Impact Factor: 2.114

[16] Yongtae Ahn, and Bruce E. Logan. Bioresource Technology. 2013, 132, 436.
[17] Shafeer Kalathil, Jintae Lee and Moo Hwan Cho. Bioresource Technology. 2012, 119, 22.
[18] Sisler, F. D. In Progress in Industrial Microbiology (ed. Hockenhull, D. J. D.), Churchill, London. 1971, 9,1.
[19] Wingard LB Jr, Shaw CH, Castner JF Bioelectrochemical fuel cells. Enzyme Microb Technol. 1982, 4,137,142
[20] Yahiro, A. T., Lee, S. M. and Kimble, D. O. Bioelectrochemistry.I Biochim Biophys Acta. 1964, 88, 375.