**Efficacy of Marine Microalgae as Exoelectrogen in Microbial Fuel Cell System for Bioelectricity Generation**

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**Abstract:** Microbial fuel cell (MFC) is a promising new technology for generating electricity directly from biodegradable compounds. More recently, generation of electricity using MFC gaining important attention in the research fraternity. MFC is a type of fuel cell converts the chemical energy contained in organic matter to electricity using microorganisms as a biocatalyst. The bioelectricity generation was studied by using nine marine microalgae. The marine microalgae *Isochrysis* sp., *Nanochloropsis* sp., *Dicarteria* sp., *Chaetoceros calcitrans*, *Pavlova* sp., *Synecocystis* sp., *Dunaliella* sp., *Chlorella salina*, *Tetrasilmis gracilis*, are capable of producing electricity when it cultured in microbial fuel cell system.

**Key words:** Marine microalgae, Microbial fuel cell, Electricity production, *Nanochloropsis*

**INTRODUCTION**

The increasing demand for energy combined with decreasing supplies of fossil fuels has led to great interest in alternate energy production technologies [1]. The ongoing use of petroleum-based fossil fuel is now also widely considered to be unsustainable due to both diminishing supplies and the contribution of these fuels to the accumulation of carbon dioxide in the environment [2]. The generation of energy product from microalgae has been examined by a number of workers [3]. Microalgae have been tested as a raw material for the production of bio-oil, methane, methanol and hydrogen [4].

Algal biomass can also be used as a substrate for anaerobic digestion. Their high growth rate, high CO₂ fixation and their lack of requirement for fertile soil surface represent several advantages as compared to conventional crops [5]. The production of microalgae during operation also provides opportunity for the production of other energy byproducts. Renewable transport fuels are becoming increasingly important as environmental friendly and sustainable energy source [6-8].

The microbial fuel cell (MFC) is a new power generation technology, which uses the electron released in the oxidation-reduction reaction of microbial metabolism to generate electricity. Studies employing a wide variety of designs, microorganisms and substrates, have been performed using microbial anodic half cells [9-11] coupled to electrochemical half cells and more recently microbial bacterial cathodes have also been developed.

Microbial fuel cells (MFCs) offer an alternative way to obtain electricity from the hydrolysis and fermentation of algae in only one process unit. MFCs consist of an anode and cathode connected by a copper wire. The anode contains mixed or pure cultures of microorganisms that are used to catalyze the decomposition of the organic matter into electrons and protons. Power is produced through the reduction of oxygen or another chemical at the cathode [12-15].

Based on the facts mentioned above, the main aim of the present work was an attempt to produce electricity from marine microalgae. We also evaluated the performance of MFCs using different type of algae as substrates, because they have been widely tested in other technologies for energy generation. Moreover, this study may pave way to meet the demand for electricity in future by cost-effective method.

**MATERIALS AND METHODS**

**Collection and Maintenance of Marine Microalgae:** Different groups of microalgae such as *Isochrysis* sp.,
Nanochloropsis sp., Dicarteria sp., Chaetoceros calcitranis, Pavlova sp., Syneccystis sp., Dunaliella sp., Chlorella salina, Tetrasilmis gracilis, were obtained from Central Marine Fisheries Research Institute (CMFRI), Tuticorin, India. For the cultivation filter sterilized seawater was used along with the required nutrients. About 10-20% of the inoculum in the growing phase was transferred to the culture flask and those were placed under the white fluorescent light (1000 lux) up to 4-5 days for attaining log phase. The time required for the maximum cell growth varies depending on the species, almost most of the species require two weeks for completion of the growth. The flagellates can be kept for two months in their stationary phase in the stock culture room under the controlled light and temperature condition.

**Mass Cultivation of Marine Microalgae:** Initially 250ml conical flask having 200ml media was used for culturing algae. All the glass wares used were properly sterilized. The filtered sea water was sterilized by autoclaving and after cooling to room temperature 200ml was poured into each conical flask. Prior to sterilization salinity and pH was checked by refractrometer and pH meter, respectively. The filtered sterilized sea water was enriched with required quantity of Walne’s medium (Solution A [Macro nutrients]: Potassium nitrate-100gL\(^{-1}\), Sodium dihydrogen orthophosphate-20gL\(^{-1}\), EDTA, Sodium salt-45gL\(^{-1}\), Boric acid-33.4gL\(^{-1}\), Ferric chloride-1.3gL\(^{-1}\), Manganese chloride-0.3gL\(^{-1}\). Solution B [Trace metals]: Zinc chloride-4.2gL\(^{-1}\), Copper sulfate-4gL\(^{-1}\), Cobalt chloride-4gL\(^{-1}\), Ammonium molybdate-1gL\(^{-1}\). Solution C [Vitamins]: Thiamine20mg and Cyanocobalamine 10mg dissolved in100ml distilled water. For the preparation of working solution 1ml of solution A,0.5ml of solution B and 0.1ml of solution C were added to 1 litre of filter sterilized sea water. Then 20ml of the inoculums in the growing phase is transferred to the culture flask with 200ml medium. Finally, the culture flasks were placed under the white fluorescent light of 1000 lux illumination.

**Construction of Double Chambered Microbial Fuel Cell:** The microbial fuel cell constructed with two 600ml acrylic chambers. The MFC had the provision for the electrode and substrate inlet in anode and cathode chambers and provision for aeration in cathode chamber [16-19 ]. The chambers were joined by PVC pipe bridge contain a cation exchange membrane (CMI 7001S, Membrane International, USA). The cathode was made from a stainless steel rod (10cm length and1.0cm width) and the anode was made by cylindrical carbon rod (5.5cm length and 0.6cm in diameter).

**Inoculation of Marine Microalgae Culture in the Microbial Fuel Cell:** The anode chamber was filled with 500ml of seawater and 20ml of microalgae. The cathode chamber contained 500ml of 100mM Phosphate buffer (pH 7.0) with 10mM NaCl as electrolyte and 0.5 M potassium ferricyanide added in this chamber as mediator. The electrodes were connected to the multimeter through wires. Two set of experiment were carried out for high electricity generating microalgae, one with artificial light source another with solar light. The electricity generation measured in open circuit voltage by using a multimeter (MASTECH MAS 830 SERIES), for about 20 hours for every 15 minutes intervals.

**Analysis of Biofilm Formation on the Electrode:** Analysis of biofilm formation on the electrode was observed by scanning the electrode surface in Scanning Electron Microscope (SEM, Philips LX-20). SEM analysis was done at Department of Mechanical Engineering MEPCO SCHLENK Engineering College, Sivakasi.

**RESULTS AND DISCUSSION**

In this present investigation, nine marine microalgae were used as exoelectrogen through double chamber MFC system for bioelectricity generation. For determination of power output the readings were taken without connecting any external resistor/load. The voltage was measured with digital multimeter. The mass cultivation of microalgae was done by using suitable Walne’s medium. Fig. 1 shows that the growth of microalgae exponentially up to 9 days followed by stationary phase. Microalgae were used as an exoelectrogen for MFC operation with artificial light and solar light. Among the two light sources, artificial light was highly support the electricity production when compared to solar light.

The electricity generation by nine marine microalgae which was maintained in artificial light source was evaluated. Figs.2-10 shows that the electricity generation by nine marine microalgae after the 42 hours of inoculation in anode chamber. Among the nine microalgae, only six microalgae such as Isochrysis sp., Nanochloropsis sp., Chaetoceros calcitrans, Pavlova sp., Chlorella salina and Tetrasilmis gracilis were selected for further investigation. Electricity generation by these six marine micro algae under solar light was shown in Figs.11-16. In this experiment artificial light shows high electricity generation when compare to solar light [20].
Fig. 1: Growth curve of marine microalgae

Fig. 2: Electricity generation by *Isochrysis* sp

Fig. 3: Electricity generation by *Nanochloropsis* sp.
Fig. 4: Electricity generation by *Dicarteria* sp.

Fig. 5: Electricity generation by *Chaetoceros calcitrans*.

Fig. 6: Electricity generation by *Pavlova* sp.
Fig. 7: Electricity generation by *Syneocystis* sp.

Fig. 8: Electricity generation by *Dunaliella* sp.

Fig. 9: Electricity generation by *Chlorella salina*.
Fig. 10: Electricity generation by *Tetrasilmis gracilis*.

Fig. 11: Electricity generation by *Isochrysis* sp. under artificial and solar light.

Fig. 12: Electricity generation by *Nanochloropsis* sp. under artificial and solar light.
Fig. 13: Electricity generation by Chaetoceros calcitrans under artificial and solar light

Fig. 14: Electricity generation by Pavlova sp. under artificial and solar light

Fig. 15: Electricity generation by Chlorella salina under artificial and solar light
Based on the results obtained, the electricity generation was higher in *Tetrasilmis gracilis*, (0.792V), the power generation was very low in *Dicarteria* sp. (0.64V) and *Syneocystis* sp. (0.69V), when compared to other microalgae. Recent report states [21] that the phototrophic MFCs in which electricity production was stimulated by sunlight, while sunlight was indispensable to current generation, no increase in current generation was seen upon illumination. Both the sediment and the air-cathode phototrophic MFCs of this study showed an increased electric current in the dark and a decreased current with the light. Another report [22] revealed that electricity production via solar energy capturing by living higher plants and microalgae in combination with microbial fuel cell are attractive because these systems promise to generate useful energy in renewable, sustainable and efficient manner.

To elucidate electron transfer system in the double chamber MFC and investigation was also done on biofilm growth by subjecting the electrodes for Scanning Electron Microscope.
Microscope (SEM) observation. The SEM image of exposed anode rod being removed from the fuel cell that was operated for 72 hours for microalgae culture. It shows that the biofilm formed on stainless steel electrode. The biofilm coverage appears on the surface of the electrode (Fig.17).

Current study demonstrated that the behavior of double chambered microbial fuel cell system which is characterized by using marine microalgae as exoelectrogen fed with seawater responded positively. It revealed that it is possible to produce the electric potential from seawater by using marine microalgae.

REFERENCES