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Optimization And Energy Production By Microbial Fuel Cell

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Abstract: Microbial fuel cell (MFC) involves the bioelectrochemical reaction which produces electricity by the microorganisms. MFC converts the biochemical metabolic energy to electrical energy through microbial catalyst at the anode under anaerobic conditions. It is the apt answer of alternative energy source in recent increasing energy crisis. In microbial fuel cells, bacteria generate electricity by mediating the oxidation of organic compounds and transferring the resulting electrons to an anode electrode. The power output depends on the types of microbes used in anodic chamber, configuration of MFC and operating conditions. In the present work, different microbial cultures were isolated and screened from waste water sample. The bacterial isolates, *Enterobacter* sp., *Staphylococcus* sp. and *Pseudomonas* sp. showed maximum power density. The voltage was measured and compared among all the microorganisms. For the efficient energy generation, the biological optimization also was done.
Keywords: Microbial fuel cell, electricity, waste, bacteria, optimization.

Introduction

Microbial Fuel cells are the alternative source of electricity from microorganisms for satisfying the high demand of energy. MFCs are devices that use bacteria as the catalysts to oxidize the organic and inorganic matter and generate current [1-5]. The microbes in the anodic chamber of MFC oxidize the substrate and produce electrons, but these electrons are subsequently conducted over a resistance or power user towards a cathode and thus, bacterial energy is directly converted to electrical energy [2]. Electric current generation is made possible by keeping microbes separated from oxygen or any other terminal acceptor. Other than the anode and this requires an anaerobic anodic chamber. As overall reaction is the breakdown of substrate to carbon dioxide and water with a concomitant production of electricity as a by-product. Based on the electrode reaction, an MFC bioreactor can generate electricity from the electron flow from the anode to cathode in the electrical circuit [6]. As the concern of the performance of MFCs, there has been considerable work on MFC configurations, their physical and chemical operating conditions, the choice of microorganisms and optimization of the microbial metabolism to increase electron donation to the electrodes [7-13]. Resulting, currently MFC power production has increased by several orders of magnitude (10^{-6}) in less than a decade [14].

In the recent years, there are rapid advances in MFC research. Bacteria used in MFC to generate electricity while the biodegradation of waste or organic matter was done [15, 16]; the design, characterization and performances of MFC was also evaluated [17]. The most unique aspects of an MFC is that a biofilm of anode respiring bacteria (ARB) transfers electrons to the surface of the anode [18] while it is possible that direct contact of the ARB with the anode can play a role, large scale electron transfer uses soluble electron shuttles, conduction through the biofilm matrix, or a combination [19-23].

In this context, the objective of this study was the power generation by a MFC using the bacterial culture from the waste sample and also the optimization of the performance of the MFC.

Experimental

Collection of Sample

The effluent water sample was collected from the Koyambedu waste management plant, Chennai, Tamil Nadu.

Preparation of media

Two types of culture media were prepared such as Nutrient agar and Luria-Bertani broth. The nutrient agar medium was used for isolation of bacteria from waste water with dilution 10^{-4} - 10^{-6}. From the consequent dilution 0.1ml suspension was plated on agar medium and plates were incubated at 37° C for 18-24 h.

Identification of bacteria

The twelve isolates were subjected to the staining techniques and various biochemical tests to identify the bacteria like Voges-proskauer test, Methyl Red test, Simmon's citrate test, Urease test.

Immobilization of the Identified bacteria

5ml of liquid culture was mixed with 100ml of 3% sodium alginate (Hi-Media) solution. This polymer solution was dropped into excess amount of 0.2 M $CaCl_2$ (Hi-Media) solution with stirring at room temperature. Then the beads were collected, dried, and stored at 30° C for further use.

Determination of growth phase

1ml of 1% of overnight culture was inoculated in 100ml of nutrient broth. At each hour interval, 1ml sample was withdrawn and OD value was measured. The production of electricity was measured at the stationary phase.

MFC Set up

The design of the microbial fuel cell was consisted of two chambers with 200ml capacity. Different types of electrodes were used, for example graphite sheet, carbon rod and stainless steel mesh. The electrodes were sterilized by soaking in 100% ethanol for 30 min followed by 1M HCl for 24 h. The electrodes were inserted through a hole on the top of the chamber. The anodic chamber was fed with 24 h grown culture and cystein was added to the culture to maintain the anaerobic condition and the cathodic chamber was fed with oxidizing agent such as $KMnO_4$. The anode chamber was kept in a magnetic stirrer and the cathode chamber was connected with oxygen pump. The electrodes were suspended by a copper wire which was connected with ammeter. Both chambers were connected through a salt bridge consisting KCl in a plastic tube to allow proton passage from the anaerobic anode to the aerobic cathode.MFC with immobilized culture was set up by the using same MFC chamber except the anodic chamber was fed with immobilized cell.

Results And Discussion

Isolation of bacteria

From the waste water sample twelve different bacteria were isolated based on their morphology using 10^{-6} and 10^{-5} dilution. The bacterial isolates were designated as SM1, SM2, SM3, SM4, SM5, SM6, SM7, SM8, SM9, SM10, SM11 and SM12.

Identification of bacteria

Among the twelve isolates, the strain SM4, SM7, SM10 were found as the best organism for the stable electricity generation for long period of time **(**Fig. 1). So further work was proceed with theses isolates. These three best strains were identified using biochemical test. Table 1 shows the biochemical analysis for SM4, SM7 and SM10. Based on the staining and the biochemical test the bacterial isolates were identified (Table 2).

Immobilization of bacteria

For the longer survivability and stable power generation the three isolates (SM4, SM7 and SM10) were immobilized and from Figure 2., it showed that among these three, strain SM10 produced maximum voltage for longer time.

Effect of growth phase on voltage generation

Growth phase study was carried out using the bacterial strain SM10 (Fig. 3). It was found that the OD value increased from the 5^{th} hr to 24^{th} h in the logarithmic phase. After 24^{th} h, it reached to the stationary phase and OD value remained at the same value for several hours. The MFC was constructed using the 24 h grown culture. The voltage was started to increase during the stationary phase and it increased up to several day.

Optimization of Power generation condition

Optimization of culture media for voltage production

For optimizing the culture media for voltage production, the bacterial isolates SM10 was cultured in Nutrient broth (NB) and Luria Berteni (LB) broth in the MFC. It was observed that power generation was more in LB media than NB (Fig 4.) because LB contains more NaCl which act as electrolytes compare to NB.

Optimization of pH

The bacterial isolate SM10 was grown in MFC at different pH range (5.0 to 8.0) to optimize the pH for electricity generation. The Fig 5 shows the maximum power generation occurred at pH 7 compare to other pH (Fig 5).

Table 1. Morphological and biochemical characteristics of the isolates SM4, SM7 and SM10

Character	SM4	SM7	SM10
Morphology	Gram negative, motile	Gram positive, non-motile	Gram negative, motile
Catalase test	+ve	+ve	+ve
Methyl red test	-ve	+ve	-ve
Voges-Proskaur	+ve	+ve	-ve
Indole test	+ve	-ve	+ve
Citrate test	-ve	-ve	+ve
Nitrate test	+ve	+ve	+ve
Urease test	-ve	+ve	-ve

Table 2 Identification of bacterial isolates

Strain	Identified bacterial isolates
SM4	*Enterobacter* sp.
SM7	*Staphylococcus* sp.
SM10	*Pseudomonas* sp.

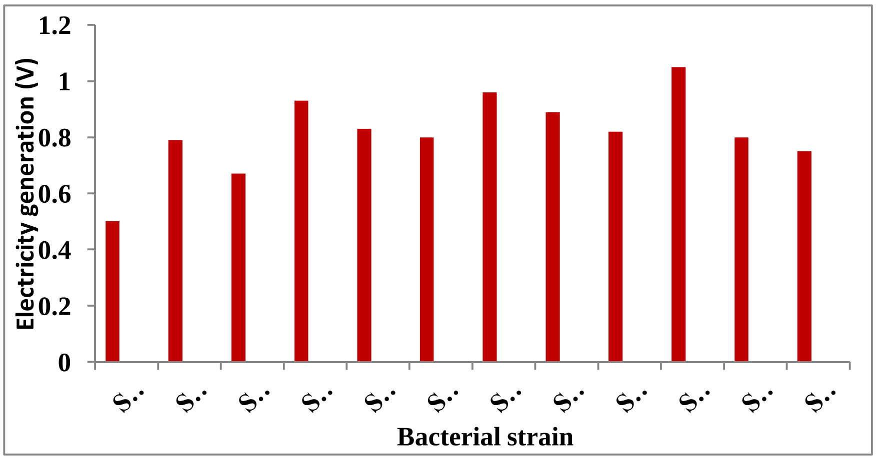

Figure 1. Electricity generation by bacterial isolates

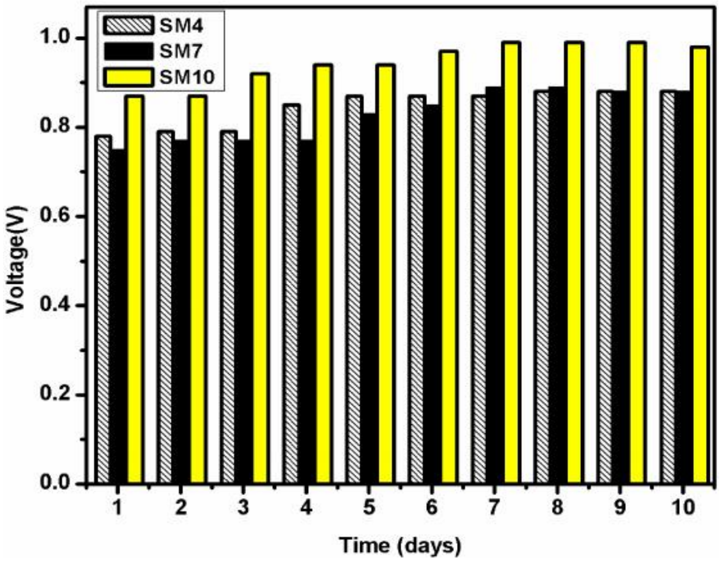

Figure 2. Power generation by Immobilized strain

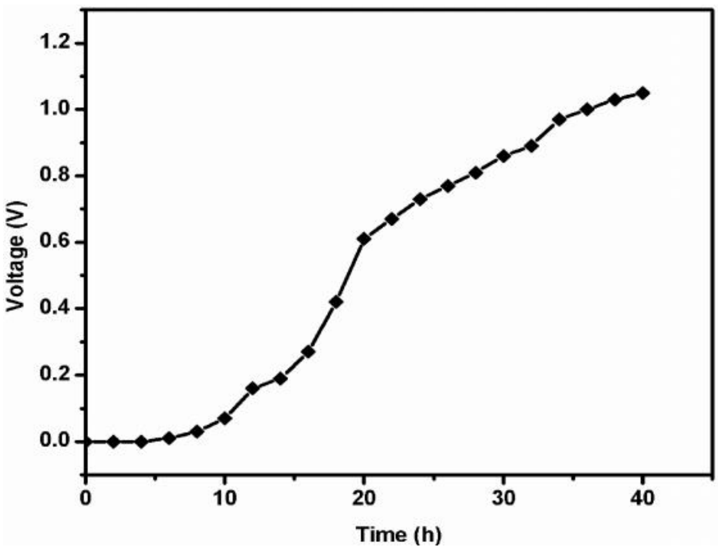

Figure 3. Effect of growth phase on voltage generation by bacterial strain SM10

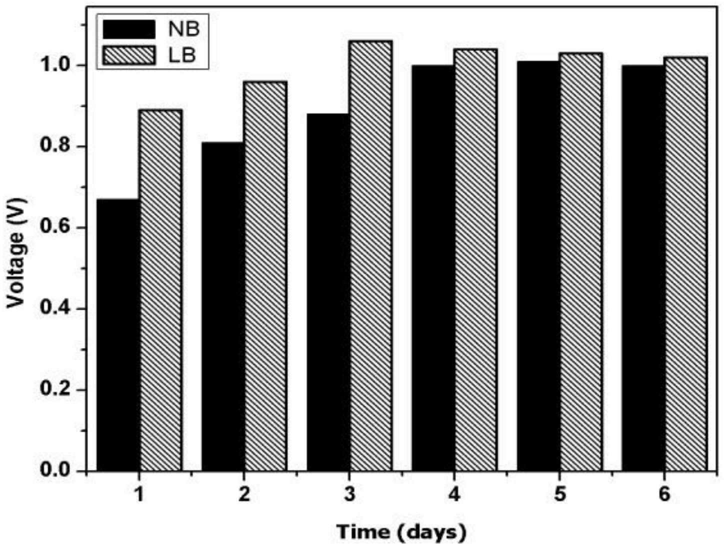

Figure 4. Optimization of culture media for voltage production

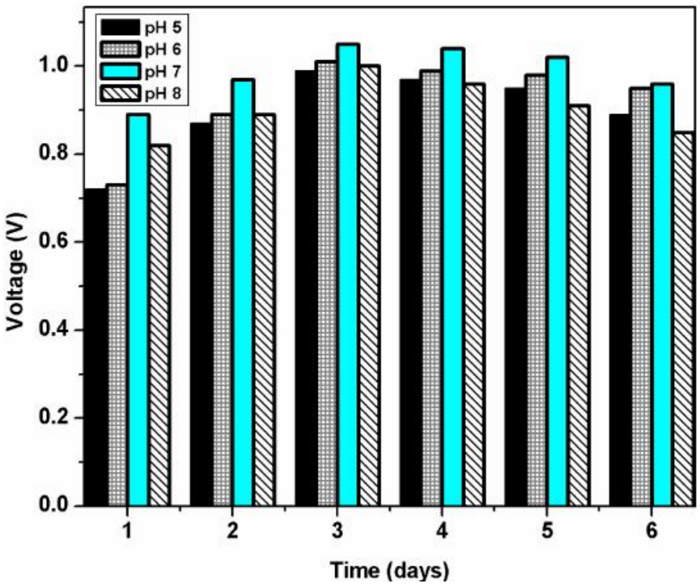

Figure 5. Optimization of pH for voltage production

Conclusion

Microbial fuel cell has the capability to generate electricity from the waste. The present work showed that the three bacterial species, *Enterobacter* sp., *Staphylococcus* sp. and *Pseudomonas* sp. were produced maximum voltage of 0.89 V, 0.96 V and 1.05 V respectively among the all the 12 species. With the immobilized isolates, the *Pseudomonas* sp. showed stable power generation for longer period of time. In the growth phase study it was found that for *Pseudomonas* sp., the voltage production was started from logarithmic phase and during the stationary phase the voltage keeps on increasing up to several days. For optimizing the voltage generation, the *Pseudomonas* sp. should be cultured at pH 7 in Luria- Bertani broth. The maximum power generation with this system can be further improved by increasing proton generation, transport rates and using a proton exchange membrane (PEM).

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