

Design and Fabrication of a Double Chamber Microbial Fuel Cell for Voltage Generation from Biowaste

Anand Parkash*

Department of Chemical Engineering, Mehran University of Engineering & Technology, Jamshoro, Pakistan

Abstract

Electrical energy needs in Pakistan are expected to continue to rise. The use of petroleum as a source of energy still dominates, although oil reserves in Pakistan are increasingly being depleted. Therefore, there is a need to develop alternative source of sustainable energy, such as, Microbial Fuel Cell (MFC). MFC shows another type of renewable energy by changing natural matter into power with the help of microbes. In the current study, an attempt has been made to find the effect of molar concentration of salt bridge on electron transferring potential and to find the efficiency of bioelectricity generation by yeasts such as *Hansenula anomala* and *Saccharomyces cerevisiae*. Maximum current of 1.9 mV and 1.4 mV was generated by yeasts *Hansenula anomala* and *Saccharomyces cerevisiae* in 1M potassium chloride salt bridge with duration of 96 hrs. This work also demonstrates the feasibility of using yeasts *Hansenula anomala* and *Saccharomyces cerevisiae* for current generation, in a mediator less MFC. During the metabolism the fuels like glucose gets oxidized when they pass through the metabolic cycle. The possibility of alternative sources is one particular method of generating power is with the help of microbial fuel cell, which can minimize the usage of fossil fuels. MFCs can produce energy directly from biomass (electricity production) or producing hydrogen from biomass (fuel production). Biological fuel cell converts the chemical energy of carbohydrates such as sugar and alcohol indirectly into electrical energy.

Keywords: Salt bridge; Electrical energy; Microbial fuel cell; *Saccharomyces cerevisiae*

Introduction

Every year the global energy demand increases. Approximately 86% of the world energy production comes from fossil fuels. Fossil fuels especially petroleum. Coals are being exhausted, leading to an energy crisis in the near future [1-4]. Furthermore the combustion of the fossil fuels adds CO₂ to the atmosphere and causes global warming. Consequently there is a need to develop a new type of energy source as alternative to fossil fuels [5-7]. To overcome this energy requirement mankind has been exploring the possibility of alternative sources of energy and has been trying tapping the energy resources of all origin; solar power, nuclear power, water power, wind power, geothermal power, tidal power, wave and ocean currents etc. One particular method of generating power is with the help of fuel cell, which can minimize the usage of fossil fuels [8,9]. Unlike chemical fuel cell, such as methanol and hydrogen fuel cells, biofuel cells operate under mild reaction conditions, mainly ambient operational temperature and pressure. They also employ neutral electrolyte and use inexpensive catalyst such as copper rods. In Microbial Fuel Cell (MFC) the catalyst is either a microorganism or an enzyme. Biological fuel cell converts the chemical energy of carbohydrates such as sugar and alcohol, indirectly into electrical energy [10,11]. As most organic substrate undergoes combustion with the evolution of energy, biocatalyst oxidation of organic substances by oxygen at the two electrode interfaces provides a means for the conversion of chemical energy into electrical energy. MFC may be best described as a bioreactor, where microbes act as biocatalyst in metabolizing the organic substances containing the organic carbon to generate electricity [12,13]. Electrons are produce by the oxidation of organic materials in which microbes act as catalyst [14,15]. The electrons thus produced are transferred to a terminal acceptor such as O₂, nitrate and sulphate. These terminal electron acceptors are get reduced by these electrons [16,17]. A new product is found which can leave the cells when terminal electron acceptors are diffused into the cells. However, there are some microbes specially yeast that can transfer their electrons in the outer space surrounding the cells which

are accepted by the awaiting terminal electron acceptors [18,19]. These types of microbes are called exogenic and can be utilized to generate electricity within a MFC. The advantages of MFC are easily available exogenic materials which are used as substrate and microbes which act as biocatalyst [20]. It is a simple system and unlike the hydrogen fuel cells, a MFC does not require extremely synchronized division system. It is more effective than enzymatic fuel cell in harvesting electrons from transport system of microbes [21]. This MFC mainly consists of two chambers, one of the chambers, where, oxidation takes place is called anodic chamber (anode) and the other chamber where reduction takes place is called cathodic chamber (cathode) [12-15]. In the presence of oxygen, microbes oxidize organic compounds to produce CO₂ and H₂O, but if the reaction takes place in anaerobic environment then microbes decomposes organic materials to produce CO₂, while proton and electrons are produced simultaneously [22-24]. Electrons thus produced are transfer to the cathodic chamber via an external circuit while protons are transferred through salt bridge [23]. These flow of electrons generate voltages [24]. Unique design adjustments utilized these years have given huge yields and opened wild in the multidisciplinary MFC research [24,25]. The aim of this research is to take the inward assents of waste materials, like sewage sludge using double chamber MFC for electricity generation and concentrates on the study including different centralizations of salt in salt extension of an arbiter MFC. This paper focuses on the study involving various concentrations of salt in salt bridge of a mediator MFC.

*Corresponding author: Anand Parkash, Department of Chemical Engineering, Mehran University of Engineering & Technology, Jamshoro, Pakistan, Tel: 0333-796-2266; E-mail: parwani_anand@yahoo.com

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Materials and Methods

Strain

In the present study *Hansenula anomala* Strain number: 237 and *Saccharomyces cerevisiae* Strain number: 2918 Procured from MTCC Chandigarh, India was used. The stock culture was maintained separately in slant and stored in refrigerator.

MFC components

Microbial Fuel Cell majorly constitutes Electrodes, Anodic and Cathodic Chamber and Salt Bridge. The Anodic chamber is an anaerobic chamber, which holds the substrate and the biocatalyst-Microorganisms. The cathodic chamber was maintained in aerobic condition. The salt bridge that forms a bridge between cathodic and anodic chamber facilitates the transfer of ions (protons). Graphite electrodes were used as anode and cathode.

MFC set-up construction

A two chambered fuel cell was constructed. Two plastic containers each with diameter 20 mm were taken and marked cathode and anode. Two holes of diameter 6 mm and 1.5 mm were made on each of the lids for the insertion of the salt bridge and electrodes. In the anode container, 300 mL of the anodic inoculation was used and in the cathode container 300 ml Potassium dichromate solution was used and the anodic container lids were closed air tight and sealed with tape (Figure 1).

Salt bridge preparation

Salt bridge was made with 5mm diameter level tube. The salt bridge was prepared using Potassium chloride with 5% Agar was boiled for 5-10 minutes. The mixture was sucked into the level tube and allowed to solidify. This individual salt bridge was inserted into the corresponding MFC and sealed with tape.

Electrodes used

Graphite rod from HB Pencil of 10 cm length was used as electrodes to collect the electrons in both anode and cathode with copper wire connections at the other hole on both the containers and sealed with tape. These electrodes were relatively inexpensive and available easily. The electrodes were pretreated in 100% ethanol for 30 min. After this the electrodes were washed in 1M hydrochloric acid followed by 1M Sodium hydroxide, each for 1 hr to neutralize and to remove possible inorganic contaminants. They were then stored in distilled water before use.

Construction of *Hansenula anomala* biofuel cell

Anodic inoculation: 50 mL of 24 hrs. old broth culture of *Hansenula anomala* along with 200 ml of sterile nutrient broth containing 1% glucose was prepared and transferred to anodic chamber, anaerobic condition was maintained.

Construction of *Saccharomyces cerevisiae* biofuel cell

Anodic inoculation: 50 mL of 24 hrs. old broth culture of *Saccharomyces cerevisiae* along with 200 ml of sterile nutrient broth containing 1% glucose was prepared and transferred to anodic chamber, anaerobic condition was maintained.

Result and Discussion

Efficiency of bioelectricity generation

The efficiency of bioelectricity generation was tested in between the two strains *Hansenula anomala* and *Saccharomyces cerevisiae*. The cell

voltage was measured for the mediator less MFC using a multimeter for every twenty four hour. This value was monitored over a period of 15 days was tabulated (Table 1 and Figures 2-8).

The concentration of salt in salt bridge is highly critical in transporting the hydrogen ions. Maximum current of 1.9 mV and 1.4 mV was generated by *Hansenula anomala* and *Saccharomyces cerevisiae* in 1 Molar potassium chloride Salt Bridge with duration of 96 hrs. The results showed that 1 Molar potassium chloride was suitable for efficient bioelectricity generation were as 2 Molar potassium chloride the maximum bioelectricity generated was 1.2 mV and 1.3 mV by *Hansenula anomala* and *Saccharomyces cerevisiae*. 1.3 mV by both strains in 3M potassium chloride, varied with duration. Earlier Muralidharan et al. constructed Microbial Fuel Cells (MFCs) represent a new form of renewable energy by converting organic matter into electricity with the help of bacteria already present in waste water. The efficiency of bioelectricity generation was tested in between the two strains *Hansenula anomala* and *Saccharomyces cerevisiae*. The results showed that both the strains having the capability to generate bioelectricity. *Hansenula anomala* more efficiently generated bioelectricity with a short duration confirming that it oxidizes



Figure 1: Fabricated MFC.

Number of days	Electricity generation (mV) in <i>Hansenula anomala</i>			Electricity generation (mV) in <i>Saccharomyces cerevisiae</i>		
	Molar concentration			Molar concentration		
	1M	2M	3M	1M	2M	3M
1	0.9	0.3	0.4	0.5	0.4	0.3
2	1.3	0.5	0.5	0.7	0.7	0.4
3	1.5	1.1	1.4	1.3	1.2	0.8
4	1.9	1.3	1.5	1.6	1.4	1.7
5	1.8	1.3	1.6	1.5	1.2	1.6
6	1.7	1.4	1.7	1.4	1.2	1.5
7	1.6	1.3	1.8	1.3	1.2	1.4
8	1.5	1.2	1.3	1.3	1.1	1.3
9	1.5	1.2	1.2	1.2	1.0	1.2
10	1.4	1.1	1.1	1.2	0.9	1.1
11	1.3	0.9	1.0	1.1	0.9	0.9
12	1.2	0.7	0.9	1.1	0.8	0.8
13	1.1	0.5	0.8	1.0	0.7	0.7
14	0.9	0.3	0.7	0.8	0.5	0.6
15	0.8	0.1	0.5	0.5	0.4	0.3

Table 1: Effect of molar concentration on salt bridge.

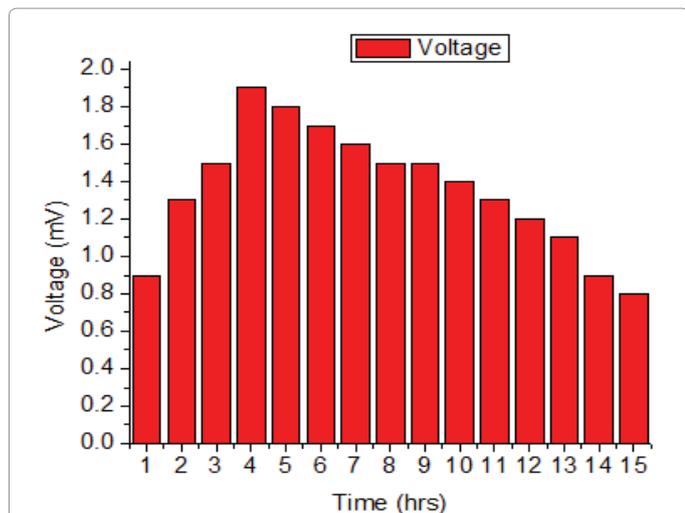


Figure 2: Voltage generated by *Hansenula anomala* in 1M KCl salt bridge at 96 hrs. duration.

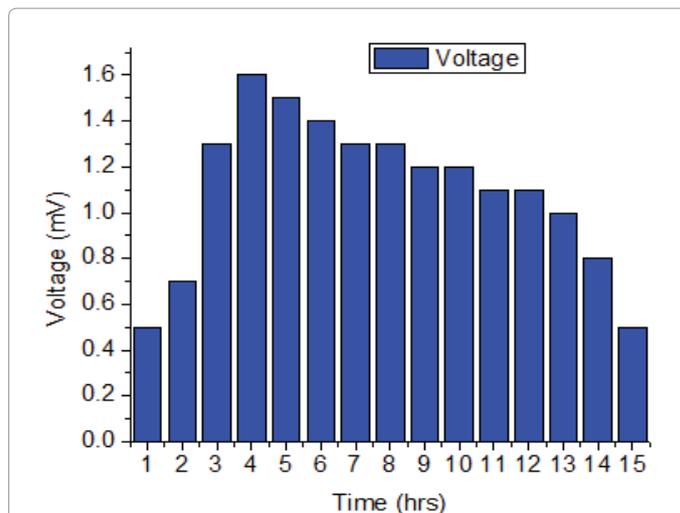


Figure 5: Voltage generated by *Saccharomyces cerevisiae* in 1M KCl salt bridge at 96 hrs. duration.

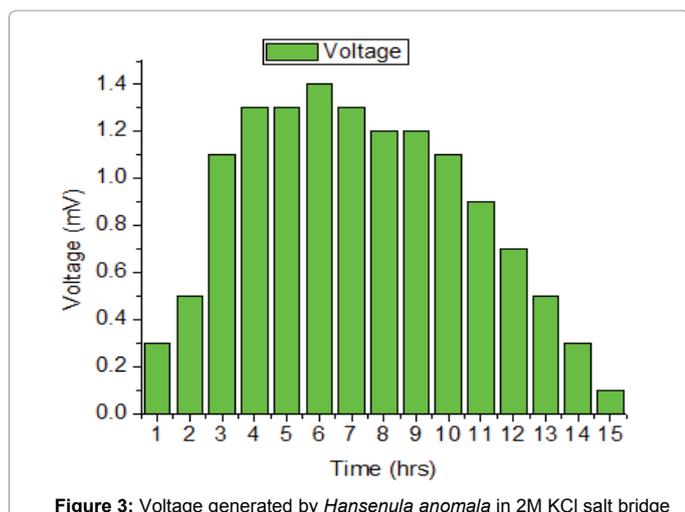


Figure 3: Voltage generated by *Hansenula anomala* in 2M KCl salt bridge at 96 hrs. duration.

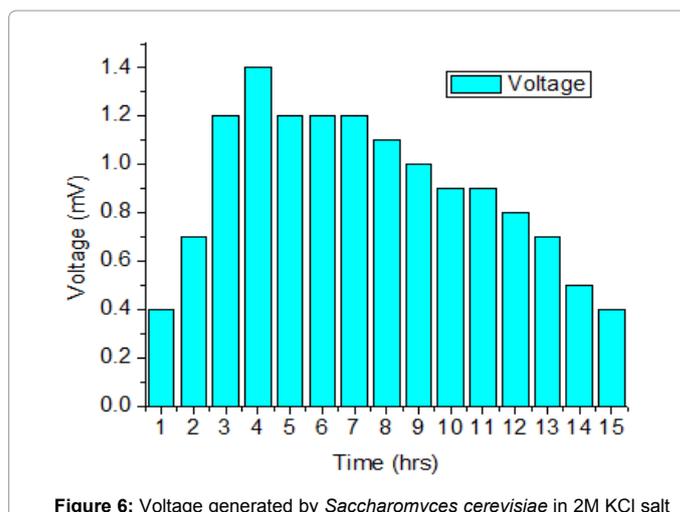


Figure 6: Voltage generated by *Saccharomyces cerevisiae* in 2M KCl salt bridge at 96 hrs. duration.

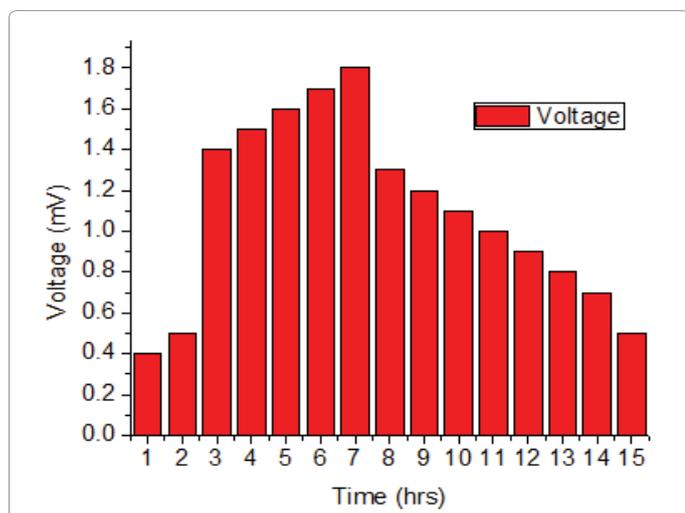


Figure 4: Voltage generated by *Hansenula anomala* in 3M KCl salt bridge at 96 hrs. duration.

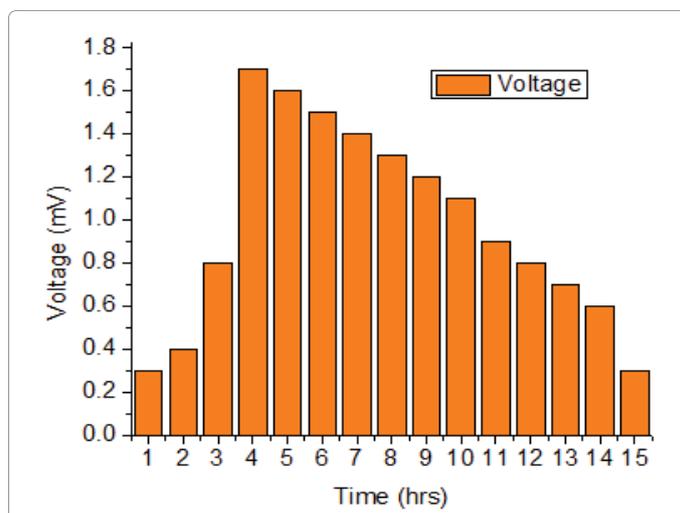
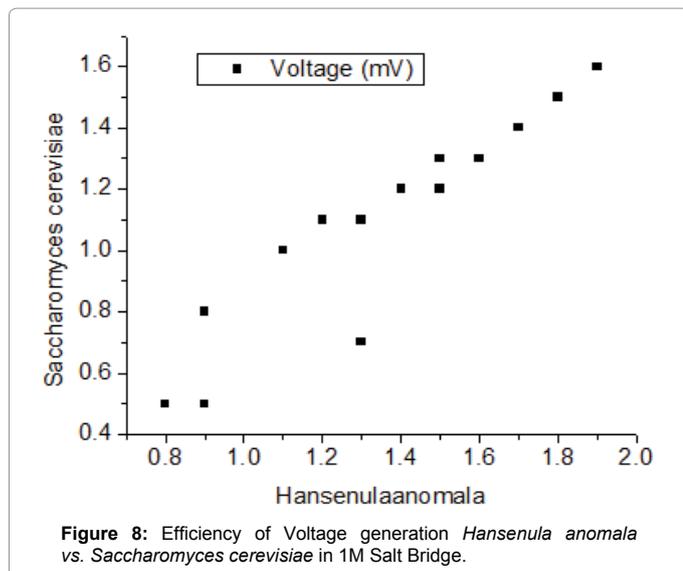


Figure 7: Voltage generated by *Saccharomyces cerevisiae* in 3M KCl salt bridge at 96 hrs. duration.



glucose rapidly when compared to *Saccharomyces cerevisiae*. Biofuel cells will become part of the technology mainstream through multiple, incremental breakthrough in materials, components and infrastructures. Only when all the pieces fall into place perhaps 10 years from now, the emergence of a true industrial-sized fuel cell supply chain will be seen. The results obtained were helpful in designing an optimized MFC reduced cost, increased yield are central to successful commercial employment of MFC.

Conclusion

In the present work, an attempt has been made to find the effect of molar concentration of salt bridge on electron transferring potential and to find the efficiency of bioelectricity generation by yeasts such as *Hansenula anomala* and *Saccharomyces cerevisiae*. Maximum current of 1.9 mV and 1.4 mV was generated by yeasts *Hansenula anomala* and *Saccharomyces cerevisiae* in 1 Molar potassium chloride salt bridge with duration of 96 hrs. This work also demonstrates the feasibility of using yeasts *Hansenula anomala* and *Saccharomyces cerevisiae* for current generation, in a mediator less MFC. Power generation even in the absence of mediators the analytical data revealed that the double-chambered Mediator less MFC with salt bridge as proton exchange membrane is more effective for practical applications such as bio-electricity generation and waste-water treatment due to easy scale-up, eco-friendliness, cost effectiveness, reduced operational conditions, accelerated oxygen diffusion and direct electron transfer to anode.

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