HYDROGEN PRODUCTION FROM GLYCEROL USING MICROBIAL ELECTROLYSIS CELL

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Abstract

Energy is an important component in the current scenario. Creating new technologies for improving the energy demand and supply balance is important. Microbial electrolysis cell is a developing technology to generate hydrogen which could save on the fossil fuels conventionally used as source of energy. In this study, the possibility was explored to use glycerol which is one of the by products from biodiesel plant as the substrate for hydrogen production. The microbial electrolysis cell consists of stainless steel as cathode and graphite plate as anode. Cationic exchange membrane (CMI 7000) was used for the exchange of hydrogen ions from anode chamber to cathode chamber. External voltage of 0.8 V was supplied to the microbial electrolysis cell using a regulated power supply. Pseudomonas bacteria were added along with the substrate. The hydrogen gas evolved was collected by the downward displacement of water. The gas was sampled and analyzed using gas chromatography. The concentration of hydrogen in the gas was found to be 50.3%.

Keywords: *Microbial electrolysis cell, Regulated power supply, Cation exchange membrane, Glycerol*

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1. INTRODUCTION

Driven by the worldwide energy crisis, global interest in biofuels continues to increase. Among the various biofuels, bio hydrogen is expected to play an important role in a non-fossil fuel future economy, owing to the clean and highly efficient production of electricity in hydrogen fuel cells. Over the past 20 years, two bioprocesses for hydrogen production from organic matter have been studied extensively: converting carbohydrates to hydrogen by fermentative bacteria (dark fermentation) and converting organic acids to hydrogen by photosynthetic bacteria (photo fermentation). One of the major barriers to the practical application of dark fermentation is low yield [1].

Microbial Electrolysis Cell (MEC), which has previously been referred to as a bio electrochemically assisted microbial reactor or a bio catalyzed electrolysis cell. In MEC, electrochemically active microbes growing on the surface of the anode break down organic matter into CO2, electrons and protons. The electrons and protons travel through the external circuit and solution, respectively, and combine at the cathode to generate hydrogen. The anode process of MEC is the same as that of a Microbial Fuel Cell (MFC) and the cathode process is the same as that of a water electrolyzer. In MFC, oxygen is used as the electron acceptor at the cathode, instead of protons in the solution. Since oxygen has a higher redox potential than the microbial anode, electrons flow spontaneously from the anode to the cathode, generating electricity.

In the MEC, however, the reduction reaction of H+ ions to H2 at the cathode has a lower redox potential than the anode, such that electrons do not flow spontaneously through the circuit; an additional voltage must be applied in order for the reaction to proceed.[2]

Experiments were conducted by B.E. Logan et al on MEC for high-yield bio-hydrogen production from fermentable substrates [3]. Experiments on advancing MEC for renewable hydrogen production through a scalable and economical design were carried out by Douglas F. Call et al [4]. Hydrogen and electricity production from a food processing wastewater using fermentation and MFC technologies were studied by SangEun Oha et al [5]. Experiments on hydrogen production from proteins via electrohydrogenesis in MEC was done by Lu Lu et al[6].Sustainable and efficient biohydrogen production via electrohydrogenesis was studied by Shaoan Cheng et al [7]. Hydrogen production from wastewater using a MEC was studied by Yu Hong Jia et al [8]. Experiments on MEC with a microbial biocathode were conducted by Adriaan W. Jeremiasse et al [9].

2. MATERIALS AND METHODS

2.1 Substrate Preparation

Glycerol obtained from biodiesel plant at R.V.College of Engineering, Bangalore(by products) was purified before using it as substrate.100ml of 5% (v/v) phosphoric acid was added to 150ml of crude glycerol and kept under stirring using magnetic stirrer for 30 minutes and transferred to separator flask. It was left undisturbed, for 1 hour until 3 layers were formed. Bottom layer consisted of phosphate salts, middle layer was glycerol layer and top layer was the residual fatty acid. About 85 ml of glycerol was obtained. This procedure was repeated to obtain the required volume of glycerol for the experiment. The glycerol obtained was alkaline with pH of 8.6. 4 drops of glacial acetic acid was added to the obtained glycerol to bring the pH down to 7. This glycerol was left for 3 hours and pH was tested every hour to ensure that pH was constant.

2.2 Microbe Preparation

Nutrient broth solution was prepared by adding 1.3 grams of nutrient broth powder to 100 ml of distilled water in a 250 ml conical flask. This conical flask was autoclaved for 3 hours. Pseudomonas bacteria was transferred from the culture obtained from the microbiology department of Mangalore University to the conical flask in LAF (Laminar Air flow). After the transfer of Pseudomonas to the conical flask, it was kept in the orbital shaker for 3 days. The clear solution turned turbid which indicates Pseudomonas growth. The culture was stored in a refrigerator at 12^{o}C until it was used.

2.3 Construction of MEC

Acrylic sheets were used to construct 3375 cm3of MEC with dimension of 15cm X 15 cm X 15cm. The cell was divided equally in to anode chamber and cathode chamber by an acrylic sheet partition consisting of CMI 7000 membrane (Cation Exchange Membrane) with a dimension of 10cm X 10cm. Each chamber has a volume of 1.69 liters. Silicone sealant and M-seal were used as sealants in order to make the apparatus leak proof.

Fig -1: Microbial electrolysis cell

2.4 External Voltage

0 V to 5 V Regulated Power Supply (RPS)was used for applying the external voltage to the MEC. Stainless steel anode was connected to the negative terminal of the RPS while the graphite electrode was connected to the positive terminal of the RPS. This completes the circuit.

3. EXPERIMENTAL WORK

100 ml of glycerol was added to 900 ml of distilled water and the pH of the resulting solution was adjusted to7. This solution was heated to 100^{0} C and subsequently cooled in a water bath. To this solution, 50 ml of Pseudomonas bacterial culture was added. The substrate along with the microbes was added to the anode chamber which contains graphite plate as the electrode.

1000ml of distilled water was added to the cathode chamber which contains stainless steel plate as the cathode. The MEC was closed with the lid and sealed to ensure no air goes in or out. The external voltage was set to 0.8 V and setup is checked for the proper connection. The evolved gas is connected to the downward displacement setup as shown in Figure 2.

Fig -2: Downward displacement setup

4. RESULTS AND DISCUSSION

The gas evolution from the MEC started from the second day onwards. The gas is collected by the downward displacement of water. The cumulative gas production with time is presented in Table 1.

Table -1: Cumulative gas production with time

Time(Days)	Cumulative gas collection (cm^3)
1	0
2	8.15
3	19.02
4	26.49
5	31.24
6	35.99
7	44.14
8	52.29
9	57.05
10	61.12
11	64.52
12	66.56

The gas collection increased from day 2 onwards till the tenth day because of the biofilm formed around the anode which indicates the growth of pseudomonas *Aeruginosa*microbe which increases the substrate decomposition rate. From the tenth day onwards, the gas collected per day started decreasing which indicates that the substrate decomposition rate is decreasing and the gas evolution stopped from day 12 onwards.

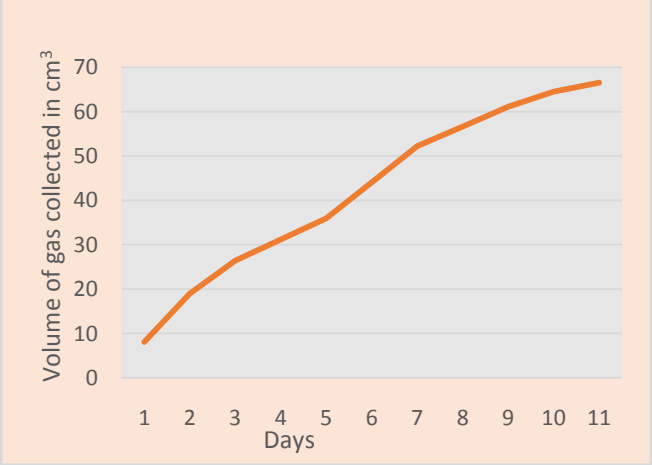

Fig -3: **C**umulative gas production with time

The collected gas was sampled and analyzed for hydrogen concentration using gas chromatography as per IS 13270:1992. Gas chromatography was operated with thermal conductivity detector, nitrogen as carrier gas (20ml per minute), molecular sieve column. The oven temperature and detector temperature were 50°C and 250°C respectively. The composition of the gas is reported in Table

Table -2: Composition of the gas

Gas	Composition (in % v/v)
Hydrogen	50.3
Oxygen	5.1
Nitrogen	29
Carbon di oxide	15.6

5. CONCLUSIONS

In today's era in which the demand exceeds the supply there is a need for alternate energy resources. This technology helps in converting glycerol to hydrogen rich gas.

FUTURE WORK

The future work will be based on altering the cathode material with platinum, increasing the concentration of glycerol and altering the Pseudomonas Aeruginosa bacteria with Shewanella putrifaciens bacteria.

REFERENCES

[1]. Logan BE. Feature article: biologically extracting energy from wastewater: bio hydrogen production and microbial fuel cells. Environ. Sci. Technol. 38, 160A–167A (2004).
[2]. Miyake J, Masato M, Yasuo A. Biotechnological hydrogen production: research for efficient light energy conversion.
[3]. B.E. Logan, P. Selembo, E. Lalaurette, G. Rader and P.-C. Maness, "Microbial Electrolysis Cells for High-yield Biohydrogen Production from Fermentable Substrates", 18th World Hydrogen Energy Conference (2010).
[4]. Douglas F. Call, Matthew M. Merrill and Bruce E. Logan, "Advancing microbial Electrolysis Cells for Renewable Hydrogen Production through a scalable and Economical Design".
[5]. SangEun Oh and Bruce E. Logan, "Hydrogen and Electricity Production from a Food processing wastewater using fermentation and Microbial Fuel Cell Technologies" Water Research Vol. 39 (2005) 4673–4682.
[6]. Lu Lu, Defeng Xing, Tianhui Xie, Nanqi Ren and Bruce E. Logan, "Hydrogen Production from proteins via electrohydrogenesis in microbial electrolysis cells" Biosensors and Bioelectronics Vol.25 (2010) 2690–2695.
[7]. Shaoan Cheng and Bruce E. Logan, "High Hydrogen Production rate of Microbial Electrolysis Cell (MEC) with reduced electrode spacing", Bioresource Technology Vol.102 (2011) 3571–3574.
[8]. Yu Hong Jia, Ji Youn Choi, Jae Hun Ryu, Cho Hui Kim, Woo Kyung Lee, Hung Thuan Tran, Rui Hong Zhang, and

Dae Hee Ahn," Hydrogen Production from Wastewater using a Microbial Electrolysis Cell" Korean J. Chem. Eng., Vol.27(6) (2010) 1854-1859.
[9]. Adriaan W. Jeremiasse, Hubertus V.M. Hamelers and Cees J.N. Buisman, "Microbial Electrolysis Cell with a Microbial Biocathode", Bio electrochemistry (2009).

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