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Smale-Scale Electricity Generation with Biohydrogen using PEM Fuel Cell

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I. Introduction

Hydrogen energy has emerged as an ideal source to reduce greenhouse gas emissions in recent years. Hydrogen, a clean energy source, can be obtained using electrical energy produced by PV panels or wind turbines Özgirgin et al.(2015), Karayel and Dincer. (2023). There are various methods for hydrogen production, one of which is wastewater treatment. This method purifies wastewater from contaminants and is used for hydrogen gas production. With the development of the economy and living standards, water environment protection has become the consensus. Generally, nitrate, nitrite, and ammonium are the typical inorganic nitrogen pollution sources that seriously affect water quality. The biological method is widely applied in wastewater treatment to solve this dilemma Wang et al.(2023). Anaerobic treatment is the most sustainable and cost-effective technology for waste treatment and resource recovery in the form of biofuels, which not only minimizes the amount of waste but is also an efficient means of converting organic matter into clean energy Yang et al.(2023). PEM fuel cells are among the most suitable sources due to their high power densities, low operating temperatures, low local emissions, quiet operation, less corrosion, simplification of stack design, and fast startup and shutdown Ćalasan et al.(2024).

II. Biohydrogen Production

Since anaerobic treatment is a biological process, the most crucial share in purification belongs to microorganisms. Therefore, many different types of microorganisms play a role in anaerobic treatment. However, the primary function is performed by two groups of microorganisms. These are acid bacteria and methanogens that make up the vast majority of archaea. The reactor used in this study is an upstream system with its primary operating feature. The reactor is made of fiberglass material. The schematic representation is in Figure 1. The entire prepared reactor has a volume of approximately 3.6 L and was manufactured in a cylindrical shape. As shown in Figure 1, oxygen entry into the reactor was prevented. Reactor inner and outer connection points are supported with silicone adhesive to ensure water-tightness. Many entry and exit points were created in the reactor. As a result of the liquid and air tests, the reactor was prepared for use. Reactor specifications are given in Table 1. Pleurotus fungi from the Pleurotaceae family, which are in the Basidiomycota branch, were used in the reactor.

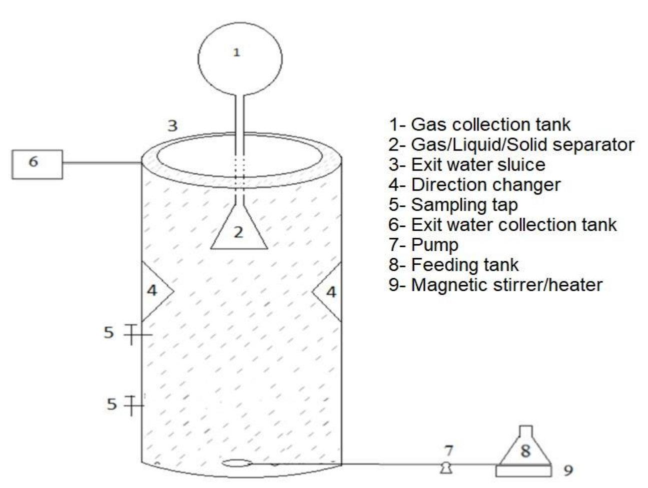


Figure 1. Schematic representation of the reactor

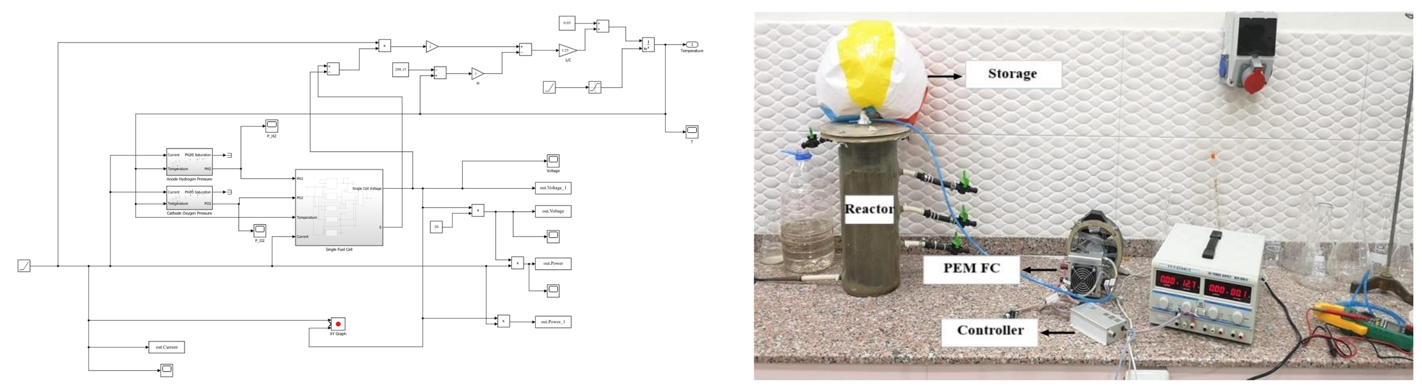
Table 1. Reactor specifications

Parameters	Value
Diameter	15 cm
Height	40 cm
Volume	3.6 L
Sample point	4 Pieces

III. Experimental Set-up

In this study, electricity was produced using hydrogen obtained from domestic wastewater and the H-100 PEM fuel cell manufactured by Horizon Company. To model this 100 W PEM fuel cell, some parameters specified by the manufacturer and studies in the literature were examined Soyturk et al.(2023), Özdemir (2020). Using the definition equations of the PEM fuel cell, its mathematical model was made in Matlab/Simulink. This model is given in Figure 2a, and Figure 2b shows the experimental set-up. During the experiments, the PEM fuel cell was connected to the rheostat, and the current and voltage were recorded instantly by multimeters by changing the resistance value. In this study, both wastewater treatment and electrical results were obtained. Hydraulic Retention Time (HRT) lasts 24-36 hours in this system. For the preferred fungus, the pH value of the wastewater is ideally kept close to 6, and the pH value of the refined water is also approximately 6. The diameter of the balloon used to store hydrogen gas is 12 cm, and its volume is about 7250 cm3.

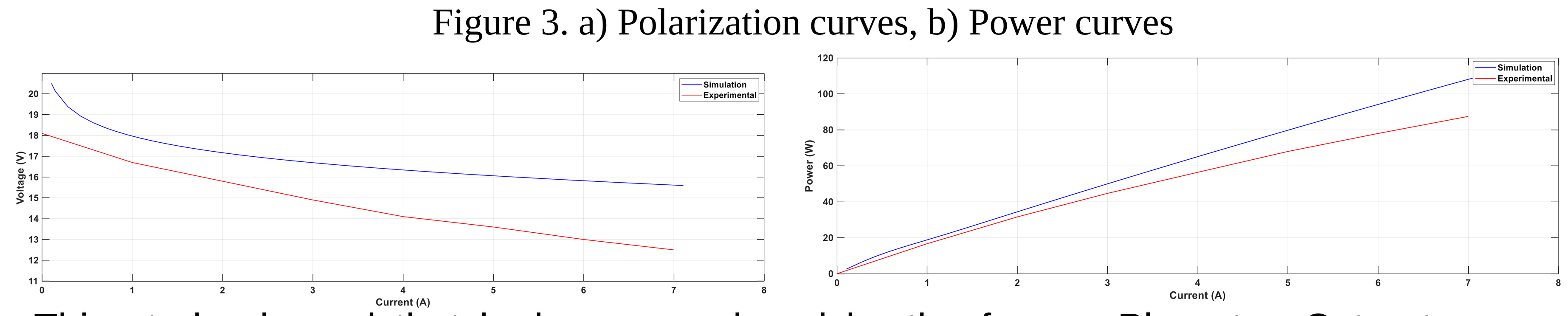
Figure 2. a) The model of the PEM fuel cell, b) The experimental set-up



IV. Results

Gas production began within two weeks, and the balloon was almost filled at the end of 19 days. At the end of 28 days, the balloon was filled. Electricity production experiments were carried out with PEM starting from the 14th day when hydrogen gas was more abundant than methane and carbon dioxide. Figure 3a shows the polarization curves, while Figure 3b shows the power curves. The results obtained are similar to the graphics shared by the manufacturer. The difference between the simulation and experimental curves is that some parameters in the mathematical model for the PEM fuel cell must be clearly known. In addition, not using the existing fuel cell for many years has gradually increased the value difference between the curves.

Figure 3. a) Polarization curves, b) Power curves



This study showed that hydrogen produced by the fungus Pleurotus Ostreatus can be used as fuel for PEM fuel cells. Thus, water pollution is reduced, and clean energy is produced through the fuel cell. In the experimental system, polarization and power curves were obtained by feeding the variable resistance load with the generated electricity, and the curves were approximately compatible. The deformation of the PEM fuel cell membrane used in the study due to not being used for many years caused its performance to decrease. This resulted in the difference between the curves. Regarding wastewater treatment, the change in COD and turbidity values showed that good treatment was achieved. Future studies aim to produce hydrogen at different levels by different organisms, measure this production in quantity, and obtain electrical results for other loads.

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