Electrochemical Characterization of Direct Ethanol Fuel Cell (DEFC) with Crude Bioethanol Feed

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Abstract

The main source of energy in the world is usually derived from fossil fuel consisting of petroleum, coal and natural gas. The use of fossil fuels as an energy source has a negative impact on the environment, such as causes of air pollution, greenhouse gas emission, and the depletion of natural resources, so it is necessary to develop alternative renewable energy sources. Fuel cell has become an alternative renewable technology to substitute the use of fossil fuel. Fuel cell is an energy supply system that converts directly chemical energy into electricity with electrochemical process. One of the development of the fuel cell system is the direct ethanol fuel cell (DEFC) ethanol as a fuel can be produced from the fermentation of biomass, known as bioethanol. However, bioethanol not only produced ethanol but also contains some impurities or by-products which affect the performance of DEFC. Some of major by-products are ethyl acetate, methanol, and acetic acid. Previous research performed using synthetic bioethanol and addition of a mixture of three organic compounds. The results indicated that the presence of organic compound impurities can affect the performance of DEFC, due to the existence interaction between acetic acid, methanol, and ethyl acetate when mixed with ethanol. The focus of this researched is the effect of using ethanol fermented that contain many impurities as fuel on DEFC. Bioethanol was derived from glucose and starch material. The performance DEFC were measured during electrochemical characterization methods, comprising open circuit potential measurement, potentiodynamic, and electrochemical impedance spectroscopy.

Keywords: DEFC; bioethanol; fuel cell; impurities

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Introduction

Energy has become fundamental human needs throughout the world. Energy consumption has increased steadily over the last century as the world population has grown and more countries have become industrialized. One form of renewable energy as an alternative fuel is hydrogen fuel cell.

Fuel cell is an electrochemical device that converts chemical energy into electrical energy directly with high energy conversion efficiency. Fuel cells hold the potential to fulfill these objectives, due to their low emissions, high efficiency and the ability to be fueled with energy produced with renewable sources such as wind, solar or biomass [1-3].

Direct alcohol fuel cells (DAFCs) are a new source of energy that has recently attracted much attention. Direct ethanol fuel cells (DEFCs) have been paid more and more attention in recent years due to the natural availability of bioethanol and its low toxicity except for the advantages of direct methanol fuel cells [4-5]. Detail electrode and overall reactions of DEFC is shown below:

Anode reaction: \( \text{CH}_3\text{C}_2\text{H}_5\text{OH} + 3\text{H}_2\text{O} \rightarrow 2\text{CO}_2 + 12\text{H}^+ + 12\text{e}^- \)

Cathode reaction: \( 3\text{O}_2 + 12\text{H}^+ + 12\text{e}^- \rightarrow 6\text{H}_2\text{O} \)

Overall reaction: \( \text{CH}_3\text{C}_2\text{H}_5\text{OH} + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 3\text{H}_2\text{O} \)

Ethanol can be produced from agricultural bioprocesses and is considered a renewable energy. Bio-ethanol is produced by fermentation of biomass materials. When oxygen is insufficient for normal cellular respiration, anaerobic respiration takes place by yeasts, converting glucose into ethanol and carbon dioxide. This is the reaction of production bioethanol [5-6].

\[ \text{C}_6\text{H}_{12}\text{O}_6\text{fermentation} \rightarrow 2\text{CH}_3\text{C}_2\text{H}_5\text{OH} + 2\text{CO}_2 \]
However, bioethanol not only produced ethanol but also contains some impurities or by-products. Some of major by-products are ethyl acetate, methanol, acetic acid and some other organic acids. The existence of by-products can influence the performance of DEFC. Previous research performed using synthetic bioethanol and addition of a mixture of three organic compounds indicated that the presence of organic compound impurities can affect the performance of DEFC [7].

This research emphasized on using crude bioethanol as a fuel on DEFC. Bioethanol was derived from three raw materials.

**Methodology**

This tests on DEFC were performed with a commercially-available DEFC stack. Crude bioethanol is used as a fuel in DEFC stack were derived from three raw materials. The materials containing glucose, and starch material. The concentration of each crude bioethanol were similar, that was 5 vol%. In addition, DEFC user manual states that be safe experimentation range for DEFC is within ethanol concentration ranging from 5-15%. Ethanol 5 vol% used as a comparison in this research.

Effects of various ethanol concentration was studied through electrochemical characterisation, comprises of open-circuit potential (OCP) and potentiodynamic measurement. All electrochemical characterisations were performed using Gamry3000 potentiostat.

**Results and discussion**

The performance of DEFC was determined by set of test, in order to obtained the polarization and power density curves. Figure 1 show the OCP that investigated ethanol with concentration 5% between crude bioethanol from glucose with the same concentration.

![Open Circuit Potential curve for ethanol 5 vol% and crude bioethanol feed](image1)

**Figure 1.** Open Circuit Potential curve for ethanol 5 vol% and crude bioethanol feed

OCP measurement aims to see the difference in potential between the anode and the cathode is free from load. The results showed the potential of crude bioethanol OCP of glucose is higher when compared to ethanol and there are some peaks in that curve. This was caused by the presence of chemical reaction were dissolved in crude bioethanol.

![Power (W) vs Potential (V) curve](image2)

**Figure 2.** Potentiodynamic characteristic (I-V-P curve) for ethanol 5 vol% and crude bioethanol feed

The polarization and power density curve identified by potentiostat which shown in Figure 2. The potentiodynamic curve described that the ascending curves showed the power – current density curve (I-P curve), while the descending ones showed the polarization curve (I-V curve). In the I-V curve, the potential of crude bioethanol decreased significantly while the current increased, when compared with I-V curve of ethanol. However, in I-P curve, crude bioethanol produced greater power, 0.0023 W, than ethanol, 0.0021 W. This possibility because of the existing some by-product content on the crude bioethanol that influenced performance of DEFC. Characterisation using EIS was described in Figure 3.

![Nyquist plot of DEFC for ethanol 5 vol% and crude bioethanol feed](image3)

**Figure 3.** Nyquist plot of DEFC for ethanol 5 vol% and crude bioethanol feed

As it seen the semicircle that occurs both in mass transfer area shown that resistance in ethanol higher than bioethanol. It can decrease the power result on DEFC.

**Conclusions**
Crude bioethanol can be used as fuel in DEFC and has higher potential also power density some by-product contain inside the crude.

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References


