Abstract— Biomass is an important renewable source contributing to the world’s economy, sustainability and energy security. Direct carbon fuel cells with solid oxide electrolyte (DC-SOFC) has attracted growing attention recently as an efficient generator of electricity. In this research, Palm oil Mesocarp Fiber is used as the raw material to produce biochar. Pyrolysis condition of heating rate and residence time is held constant at 10°C/min and 2 hours respectively. Three set of temperature are used which are 400, 600 and 800°C. The biochar’s is fed into a Solid Oxide Fuel Cell to generate electricity. Biochar produce at 400, 600 and 800°C have surface area of 353.0, 548.6 and 706.0 m²/g respectively. Biochar produce from Mesocarp fiber have high surface area and porosity which would make it a suitable fuel source in a DCFC.

Keywords— Direct carbon fuel cells, Biomass, Biochar, Pyrolysis

1. Introduction

Global energy demand throughout the world is increasing at a very rapid rate. Much of the energy consumption comes from non-renewable source that contribute heavily to air pollutions and global warming. At least 168 million tons of biomass such as timber, palm oil waste, rice husks, coconut trunk fiber and sugar cane waste is produced annually[1]. This research aim to test lignocellulosic biomass as a suitable fuel source in a direct carbon fuel cell (DCFC’s). DCFC are a relatively new technology that opens new opportunities to convert carbonaceous fuels to electricity. The biggest attraction in DCFC is that it can run on carbon products produced from biomass waste called biochar. Biochar are intermediate solid residue of thermal conversion of organic substance formed through the process of pyrolysis of lignocellulosic biomass.

1.1 Objective

The objective of this research is to:

• Optimize the production of biochar from palm oil Mesocarp Fibre using slow pyrolysis process;

• Characterize the biochar for its carbon properties such as surface area, porosity, structure, carbon content and impurities;

• Measure the performance of the biochar in DCFC;

• Access and optimize biochar carbon properties in generating electricity in a DCFC.

A wide variety of biomass material have been used to produce biochar however no work have been done on producing biochar from Mesocarp Fibre. Significant majority of research on biochar are in the areas of soil amendments for fertilization of crops and as an activated carbon for CO₂ capture. They have been no work done on using biochar from palm oil waste as a fuel source in a DCFC system.

1.1 Scope

Mesocarp Fibre is used as the raw material to produce biochar. Pyrolysis condition of heating rate and residence time is held constant at 10°C/min and 2 hours respectively. Three set of temperature is used which are 400, 600 and 800°C. The biochar’s is fed into a Solid Oxide Fuel Cell to generate electricity.

2. Theoretical Framework

2.1 Direct Carbon Fuel Cells (DCFC)

Direct carbon fuel cells (DCFC) convert carbonaceous fuels directly into electricity. Fine carbon particles are directly oxidized in an electrochemical cells at high temperature ranging from 600°C to 900°C. This process is a half-cell notation where the overall reaction is [2]:

\[
\text{C} + 2\text{O}_2 \rightarrow \text{CO}_2 + 4\text{e}^- \quad (1)
\]

In this research, Solid Oxide fuel cell is chosen as it is the most developed fuel cell with benefits of fuel flexibility and simplicity to operate [2]. Figure 1 depicts the mechanism of a solid oxide fuel cell using carbon as a fuel source.

![Figure 1: Mechanism of Solid Oxide Fuel Cells [2]](image)

2.1.1 DCFC Fuel Source

A large number of carbon rich fuels such as coal and activated carbon can be fed into a DCFC. A study on the interaction between carbon and anode in a SOFC using four grades of coal found that the higher the pore size and surface area of the coal the higher the power output of the fuel cell [3]. The carbon fuel must be of highly porous material with high surface area to be able to adsorb oxygen which acts as an electrolyte in a SOFC system [3].

2.2 Lignocellulose Biomass

Biomass composition can vary depending on biomass type and origin. The term “lignocellulose biomass” is used when referring to woody biomass. The main components of the lignocellulose materials are cellulose, hemicellulose and lignin [4]. Lignin is reported to be the most thermally resistance component in biomass and start to decompose at temperatures above 400°C [4]. This decomposition of lignin produces some bio-oil but the majority of the lignin remains as a solid and contributes heavily to the mass of the biochar product.

2.3 Biochar Preparation

Pyrolysis is the thermal decomposition process of biomass which takes place in the absence of oxygen at atmospheric pressure. Biochar are black solid. The biochar is intermediate solid residue, which is formed in the pyrolysis of most biomass. At low temperature and low heating rate process, high bio-char production can be gained from the process [5]. A study on the characterization of biochar products from pyrolysis of Miscanthus at a constant temperature of 600°C and varying residence time of 10, 30 and 60 minutes found that the longer the residence time the more developed the surface area of biochar.

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3. Research Methodology

3.1 Sample Preparation
Palm Oil Mesocarp Fibre was dried at 103°C. The dried palm oil waste is then milled using a cutting mill with a 1 mm blade and then sieved with a Retch sieve shaker ranging between 1.00 to 2.00 mm.

3.2 Pyrolysis Experiment

The pyrolysis of Mesocarp Fiber samples is carried out using a reactor equipped with an electric furnace heater as shown in Figure 2. 1 g of each sample is placed into the reactor tube on a wire mesh sample holder. Three set of temperatures would be perform at 400, 600 and 800°C. The heating rate of 10°C min⁻¹ is chosen as it coincide with slow pyrolysis method in producing high yield of biochar. Pyrolysis residence time is measured from the time when samples in the reactor reached the desired temperature and isothermal heating is held. The experiment will be conducted for residence time of 2 hours. The reactor is purge with nitrogen gas at a rate of 100 l/min to ensure no oxygen is present in the reactor tube.

Figure 3: Schematic diagram of the pyrolysis system

The TGA analysis shows the thermal behavior of biomass samples by recording peaks of volatile matter release at different temperature. Four peaks around 53.4, 274.3 and 334.6°C is due to volatiles release from decomposition of moisture, hemicellulose and cellulose while the lignin decomposes at a much higher temperature around 411.5°C.

4. Results

4.1 Thermogravimetric Analysis (TGA) on Mesocarp Fiber

Figure 1: TGA analysis on dry Mesocarp Fiber

Table 2: Results of surface area and pore size at 400, 600 and 800°C

<table>
<thead>
<tr>
<th>Temp (°C)</th>
<th>Surface Area (m²/g)</th>
<th>Total pore area (cm²/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>353</td>
<td>219.38</td>
</tr>
<tr>
<td>600</td>
<td>548.6</td>
<td>379.4</td>
</tr>
<tr>
<td>800</td>
<td>706</td>
<td>482.126</td>
</tr>
</tbody>
</table>

From table 2, it is clear that the higher the temperature the higher the surface area and total pore area of the biochar. At 400°C, the total surface area is 353 m²/g while at 800°C the surface area is double at 706 m²/g. This indicates a linear relationship between temperature and surface area.

5.0 Conclusion

From the research, it was found that the lignin in Mesocarp fiber starts decomposing at 411°C. Biochar produce from Mesocarp fiber have high surface area and porosity which would make it a suitable fuel source in a DCFC. The carbonization step at high temperature is detrimental to the development of a porous structure in the biochar.

REFERENCE