Electrical Power Generation from Direct Carbon Duel Fuel Using Biochar from Eucalyptus, Neem and Mast Leaves

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ABSTRACT

This paper titled "Electrical Power Generation from Direct Carbon Duel Fuel Using Biochar from Eucalyptus, Neem and Mast Leaves" is a research on the use of biochar as sources of fuel from Eucalyptus, Neem and Mast (*Eucalyptus, Azadirachtaindica* and *polyalthialongifolia*) leaves for a direct carbon fuel cell (DCFC). The biomass was subjected to pyrolysed at 500^{o}C, 600^{o}C and 700^{o}C with particle sizes of 0.2 mm. The electrode assembling system consists of molten carbonate direct carbon fuel cell using sodium carbonate and potassium carbonate with aluminum mesh. The pyrolysis, was to enhanced the properties and quality of the biochar fuel produced. Electrochemical reactions of the biochar shows that Mast leaves gave the highest open circuit voltage (OCV) of 0.84 V while Eucalyptus gave 0.73V, Neemgave 0.71 V at the same operating condition. The best peak power density was recorded from Mast bio-char produced at 700^{o}C with resistance swap and the least was recorded for Eucalyptus. The best peak current density was recorded from Mast tree bio-char and the least recorded for Neem bio-char. The overall performance indicated that Mast tree bio-char performed better than the other two bio-char followed by Eucalyptus and Neem gave the least electrochemical performances.

Keyword: Eucalyptus, Neem, Mast, voltage, power, current density, DCFC,

1. INTRODUCTION

ONE of the major difference between developed and developing countries is the availability of energy. Energy is required to drive major sectors of any country's economy. The need for energy and its great importance is the reason why many countries use conventional fossil fuels; which has its own effects on the environment which is majorly pollution. As a result of pollution, many countries have sought through research, alternative means of energy production, which are renewable and environmental friendly. The use of biochar a fuel plus the direct carbon fuel cell technology is one of the promising solutions to environmental issues (Dominik*et al*., 2003).Biomass refers to all organic material, originated from plant materials and animal waste. After coal and oil, biomass is the third world largest primary energy resource, producing 35% of all energy required in most developing countries. Biomass is a good substitute for fossil fuel, with the added advantage of reducing global warming (Ayhan, 2002).

The direct carbon fuel cell (DCFC) is a technology that dates back to the mid-19th century. It was used to convert the chemical energy of solid carbon fuel to electricity with efficiency higher than coal-fired generation and greater than many other fuel cells. With a potential operating efficiency of 80% using coal as fuel, DCFC technology provides a powerful value proposition by contributing to the realization of the virtually 160-year-old dream of converting raw coal directly to electric power without combustion, gasification (reforming) or the thermal efficiency limitations of heat engines (Cao *et al*., 2007), combined with the possibility of reducing carbon emissions by 50% and reducing the off-gas volume by 10 times compared with conventional coal- fired power stations (Adeniyi *et al*., 2014). However, instead of using gaseous fuels, the DCFC technology uses aggregates of extremely fine (10- to 1,000-nanometer-diameter) carbon particles distributed in a mixture of molten lithium, sodium, or potassium carbonate at a temperature of 750 to 850°C (Adeniyi and Ewan, 2011).

Eucalyptus (*Eucalyptus*) is a fresh, tall ever green, flowering tree. There are over 700 species of Eucalyptus and almost all of them are in Australia but has spread to other part of the world including South Africa, Europe, India and Nigeria. Eucalyptus trees are also known as fever tree, stringy back or blue gum tree. Masqueradetree is also known as Mast Tree (*polyalthialongifolia*).It is a lofty evergreen tree, native to India, commonly planted due to its effectiveness in alleviating noise pollution. It exhibits symmetrical pyramidal growth with willowy weeping pendulous branches and long narrow leaves with undulate margins. The tree grows as tall as over

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30ft in height.Neem (*Azadirachtaindica*) is a plant of mahogany belonging to *meliaceae* family. It is an evergreen tree, which is grown mostly in India and Nigeria.Neem tree is a drought resistant perennial tree which grows in all types of soil with a life span of approximately 150 -200 years. Every year, a Neem tree produce 30 to 50 kg of fruit which reach up to a height of 15- 20m, it is distinguished by series of white flowers with sweet scent and appears for the first time when the tree is 2 to 3 years old, it bears fruit between 3 to 5 years, the ripe fruit are closely 2 cm long with an oval shape containing one kernel per seed (Ragit *et al.,*2011). As a result of seasonal changes the leaves of these trees from time to time falls off and are swept away to be thrown in the dustbin. This research work investigates an alternative use to the waste leaves to generate electrical power for domestic and industrial purposes using the DCFC technology.

2.0 Materials and Methods

2.1Materials

The materials used for this research work include sodium and carbonate salts, current collector, lagging material, steel pipes, thermoplastic pipes, ceramic tubes, heating element, Eucalyptus, Neem and Mast tree leaves.

Eucalyptus, Neem and Mast tree leaves were obtained from the crop production Nursery Federal University of Technology Minna. Most of which were obtained from the trees during the time of pruning.The samples were carefully sorted, ground and oven dried at 105^{o}C for one hour residence time. The proximate analysis was carried out before and after the pyrolysis - to determine the ash content, moisture content and the effect of the pyrolysis on the chemical composition of the samples. Ultimate analysis was also carried out to determine the elemental composition of the biomass and biochar fuel produced. The pyrolysis of the three biomasses were carried out to produce rich carbon fuel from the biomass needed to power the DCFC.

2.2 methods

Preparation of Carbon Fuel Particles: The fuel used in the DCFC was a mixture of biochar and carbonate salts. The biochar was the actual fuel and was mixed with carbonates which became molten at the operating temperature of the cell and gives room for quick electrochemical reaction in the cell. The eutectic mixture was prepared consisting of biochar carbon (15 wt.%), Sodium carbonate (46.6 wt.%) and potassium carbonate (53.4 wt.%). In conversion, this interprets, Na_2CO_3 to be 13.98g, K_2CO_3 to be 16.02g and biochar carbon to be 4.5g. The carbonate mixture (Na_2CO_3/K_2CO_3) was thoroughly mixed together and dissolved in 25ml of distilled water to give proper mixing. The mixture was placed in oven at 100^{o}C for 4 hours to dry off moisture. The carbonate mixture was finely ground and mixed with the biochar powder to form the fuel in the DCFC(Adeniyi*et al.*, 2014; Cooper, 2008; Cooper *et al.*, 2004).

3.0 Results and Discussion

3.1results of proximate analysis

Table 1 shows the result of proximate analysis, calorific value and ultimate Analysis respectively of the biomass samples (Eucalyptus, Neem and Mast tree) before pyrolysis. The ash content of Eucalyptus was 5.47 wt.% and Neem 4.88 wt.% while Mast tree was 4.28 wt.%. Eucalyptus has higher ash content than the other two samples. The volatile content of Eucalyptus was 85.59 wt.% while that of Neem was 85.55 wt.% and Mast tree 86.82 wt.%. The calorific value was gotten from correlation. The calorific value of Eucalyptus is 15.24 MJ/kg,Neem is 15.13MJ/kg and Mast tree 14.99 MJ/kg. Eucalyptus has a higher calorific value than Neem and Mast tree biomass.

Table 1: Proximate ultimate analysis and calorific value of biomass leaves

	Proximate Analysis					Ultimate Analysis		
Biomass	Moisture content wt. %	Ash content wt.%	Fixed carbon wt. %	Volatile content wt. %	Calorific Value (MJ/Kg)	Carbon wt. %	Oxygen wt. %	Nitrogen wt. %
Eucalyptus	3.80	5.47	5.70	85.59	15.24	72.22	25.93	1.85
Neem	4.43	4.88	5.13	85.55	15.13	97.90	0.85	1.22
Mast	4.42	4.28	4.48	86.82	14.99	96.20	1.06	3.46

Table 2: Proximate analysis and calorific value for biocharprolysed at 700^{0}C

Biomass	Moisture content wt.%	Ash content wt.%	Carbon wt.%	Calorific value MJ/Kg
Eucalyptus	0.20	33.21	67.59	27.37
Neem	0.25	24.87	74.87	28.79
Mast	0.30	40.55	59.12	25.71

Figure 1 is a graph showing the comparism of the electrochemical performances of Mast, Eucalyptus and Neem biomass fuel pyrolysed at 700ᵒC. From the graph, the performances of the three biomass fuel are close to each other until 300ᵒC. At temperatures higher than 300ᵒC, the performance of Mast tree biomass is higher than the other two until it got to 800ᵒC and a voltage of 0.82 V. The performance of the other two biomass fuels pyrolysed at 700ᵒC is close and not much can be differentiated from the graph.

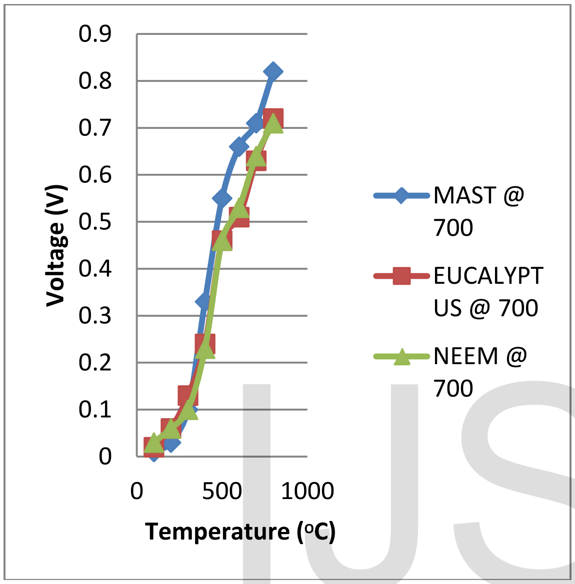

Figure 1 Voltage against Temperature for Mast, Eucalyptus and Neempyrolysed at 700^{o}C

Figure 2 shows the current density, power density and OC Voltage curves for eucalyptus biomass fuel pyrolysed at 700ᵒC. This graph shows the overall characteristic behaviour of the biomass fuel in the molten carbonate direct carbon fuel cellof particular interests are open circuit voltage, peak power, current density and the area specific resistance behaviour. The best peak power density was recorded for eucalyptus at 800ᵒC. The best current density was recorded for the highest OCV is given by eucalyptus at 500ᵒC, from the graph, there is a decrease in voltage as current density increase and an increase in power density as current density increases.

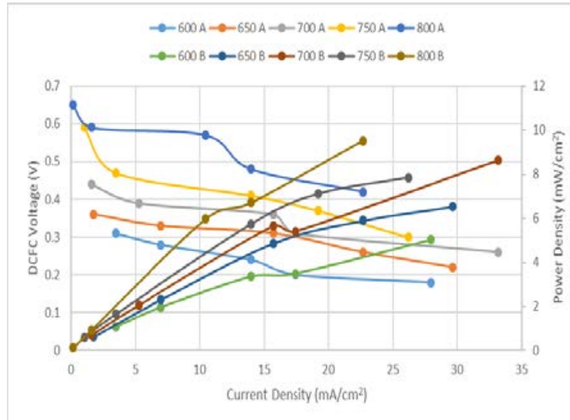

Figure 2: Electrochemical performance of Eucalyptus biochar at different temperature.

Figure 3 shows the current density, power density and OC Voltage curves for Neem biomass fuel pyrolysed at 700ᵒC. This graph shows the overall characteristic behaviour of the biomass fuel in the molten carbonate direct carbon fuel cell. (MCDCFE) of particular interests are open circuit voltage, peak power, current density and that area specific resistance behaviour. The best peak power density was recorded for the voltage swap at 700ᵒC. The best current density was recorded for the highest voltage (OCV) is given by the voltage swap of 400ᵒC, from the graph, there is a decrease in voltage as current density increase and an increase in power density as current density increases.

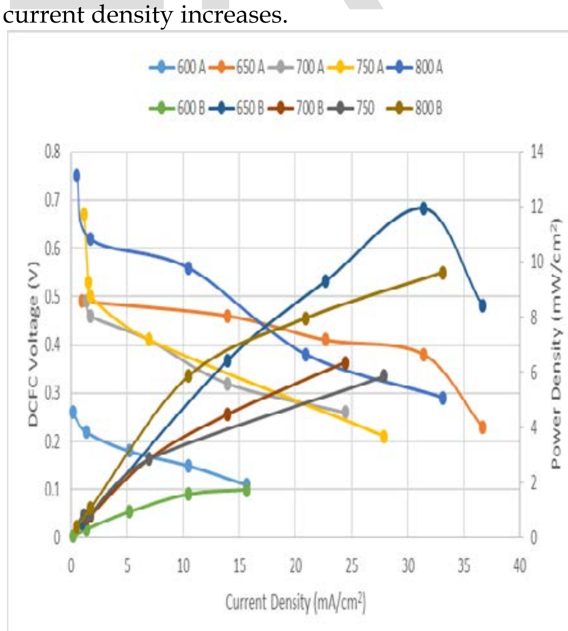

Figure 3: Electrochemical performance of Neem biochar at different temperature.

Figure 4 shows the current density, power density and open circuit voltage (OCV) curves for Mast tree biomass fuel pyrolysed at 700°C. This graph shows the overall characteristic behaviour of the biomass fuel in the molten carbonate direct carbon fuel cell. MCDCFC of particular interests are open circuit voltage, peak power, current density and the area specific resistance behaviour. The best peak power density was recorded for the voltage swap of 700°C. The best current density was recorded for the highest voltage (OCV) is given by the voltage swap of 700°C, from the graph, there is a decrease in voltage, as current density increase and an increase in power density as current density increase. Mast tree biomass fuel at 700°C, gave the highest performances and highest power densities.

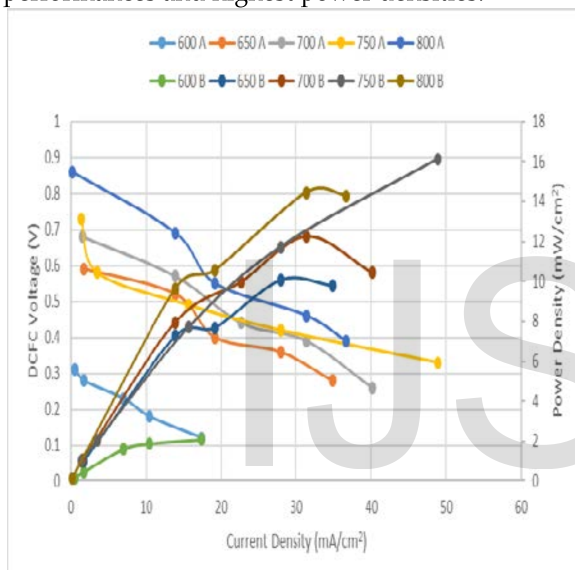

Figure 4: Electrochemical performance of Mast biochar at different temperature.

4.0 Conclusion

Pyrolysis greatly enhanced the properties of the bio-char used as there was a significant increase in carbon content, ash content and calorific values for each biomass fuel while there was a decrease in moisture contents and hydrogen composition. The values were compared and found to be within recorded values from literature.

The effect of pyrolysis temperature on the properties of the biomass fuel was also considered; the biomass samples pryrolysed at 700°C gave better properties than those pyrolysed at 600°C and the least is the biomass samples pyrolysed at 500°C. This same trend was observed for the three samples. The open circuit voltage (OCV) for the three samples were compared with literature and found to be proportionate. Mast tree biomass gave the highest over all voltage of (0.84V) followed by Eucalyptus at (0.73V) and Neem at (0.71V).

The effect of temperature on each biomass fuel was also considered; and for pyrolysis 500°C, Mast tree gave(0.67V), followed by Eucalyptus at (0.64V) and Neem (0.62V). For pyrolysis 600°C, Mast tree biomass gave (0.72V) followed by Eucalyptus (0.66V) and Neem (0.69V). Finally at 700°C, Mast tree biomass gave (0.84V), Eucalyptus 0.73 and Neem (0.72V). It can therefore be concluded that pyrolysis temperature has an effect on the biomass fuel. That is, the higher the pyrolysis temperature; the better the electrochemical performance of the biofuel in the molten carbonate direct carbon fuel cell.

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