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NEW TECHNOLOGY FOR BIOCHAR PRODUCTION FROM OIL PALM EMPTY FRUIT BUNCH

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ABSTRACT

This paper presents a process to utilize oil palm empty fruit bunch (EFB) by thermochemical conversion to produce carbon-infiltrated biochar, which can be used as an efficient alternative energy source. An integrated process of pyrolysis and decomposition of pyrolysis vapor was employed by chemical vapor infiltration (CVI) process. For preparation, raw EFB was made into highly porous biochar by slow pyrolysis process at 500-800°C to provide active sites for decomposition of pyrolysis vapor. In the general fast pyrolysis process of EFB, the main pyrolysis vapor product will undergo a secondary decomposition to produce secondary char and gases. In this study, this secondary decomposition is of interest. Fast pyrolysis of EFB was carried out at 400, 450 and 500°C to produce pyrolysis vapor to be infiltrated within the pores of biochar substrate and decomposed on its active sites. Secondary decomposition of pyrolysis vapor produced secondary char, where solid carbon was deposited within the porous biochar substrate, increasing the total carbon content of the resultant carbon-infiltrated biochar. This process was developed to produce a value-added EFB-derived biochar. One special application of this product is in steel industry, mainly in their sintering plants; as an efficient alternative energy source to partially substitute coke breeze.

Keywords: empty fruit bunch, biochar, thermochemical conversion, biofuel, chemical vapor infiltration.

INTRODUCTION

In the oil palm industry, especially in Malaysia, one of the biggest concerns raised is the issue of its agricultural waste. It is expected that by year 2020, 100 million dry metric tons of palm waste will be generated [1], and one of the most abundant waste generated is the empty fruit bunch, EFB. EFB contains more than 50 percent moisture [2], which makes it less efficient to be used as an alternative energy source in the form of solid, for easier storage and transportation.

Solid product from thermochemical conversion of biomass is biochar and as compared to char produced from the non-renewable coals, biochar contains lower sulfur content and it is more environmentally friendly which makes it favorable to be used as an alternative fuel source. However, an EFB-derived biochar normally does not contain sufficient amount of carbon to be used as a biofuel. Most EFB-derived biochars are being used in agricultural industry for carbon sequestration in soils, improvement of soil quality, nutrient retention and enhancement of water holding capacity [3, 4].

In order to upgrade this EFB-derived biochar for it to be able to be utilized as an alternative biofuel, the amount of carbon content needs to be increased, so that the heating value will also increase. These two characteristics are required for a material to be used as an alternative energy source [5].

In this study, a process was developed by integrating pyrolysis and tar decomposition process using chemical vapor infiltration (CVI) method. First, porous biochar was produced by slow pyrolysis of raw EFB. This porous biochar was used as substrate for tar decomposition to take place. Biochar is a good candidate because it has high porosity for chemical reactions to take place at its active sites [6, 7]. In the second step, tar vapor generated by fast pyrolysis of raw EFB, infiltrated within biochar pores produced in the first step via CVI method, and upon decomposition produce secondary char and gases. The secondary char is deposited on the pore surface, increasing the total carbon content of the product, namely carbon-infiltrated biochar. The purpose of this study is to examine the amount of carbon deposit within an EFB-derived biochar by this process.

MATERIALS AND METHOD

Material preparation

Raw EFB was collected from a nearby palm oil mill for this research. The C/H/O contents of this EFB were 45.64, 6.19 and 48.17 mass %, respectively. Firstly, EFB was prepared by shredding it into 300-600 µm particle size range before being compacted into pellets. The pellets weighed approximately 3 g each with 10 mm height and 20 mm diameter. These pellets were made into biochar by slow pyrolysis at 500, 600, 700 and 800°C with a heating rate of 10°C/min or 30°C/min to compare the resulting products.

Experiments

EFB-derived biochar pellets produced from slow pyrolysis were used as substrate for pyrolysis vapor to infiltrate and decompose into carbon within its pores by CVI method. For this process, a tube furnace was used for

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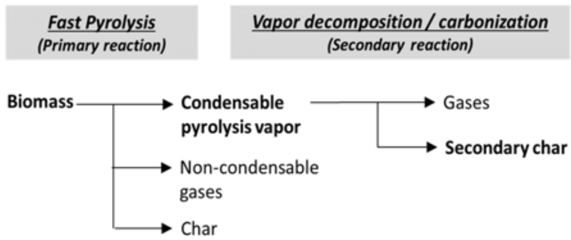

Figure-1. Fast pyrolysis process and the secondary decomposition reaction.

heating purpose in argon atmosphere. Inside the furnace, biochar pellets were placed in an opened stainless steel mesh bag, and EFB loose particles were prepared in another mesh bag as the source of pyrolysis vapor. The furnace with flowing argon was heated rapidly to 400°C at a ramping rate of 60°C/min, and the EFB particles produced pyrolysis vapor to be infiltrated within the biochar substrate to undergo secondary decomposition as presented in Figure-1. The secondary char was expected to be deposited on the pore surface of the biochar substrate. This experiment was repeated for EFB-derived biochar pellets produced at 500-800°C, and this was the first set of carbonization experiments.

In the second set of experiments, similar steps were repeated where biochar pellets produced at 500°C were used as the substrate. The temperatures for fast pyrolysis and vapor decomposition were increased from 400 to 450 and 500°C to investigate the deposition and/or gasification rates.

After the carbonization process, the resultant biochars, namely carbon-infiltrated biochar were analyzed by carbon analyzer for the total carbon contents.

RESULTS AND DISCUSSIONS

For preparation, EFB pellets were heated slowly in the tube furnace with flowing argon to produce biochar substrate at 500-800°C with heating rates of 10°C/min or 30°C/min. Figure-2 presents the carbon contents of biochar pellets after this slow pyrolysis process. The results clearly showed that lower heating rate is more favorable to retain more carbon in the resultant biochar. As temperature increased, carbon content also increased because more volatiles were liberated in gaseous form.

In the next step, biochars produced at these temperatures were used as substrates for carbonization process by pyrolysis vapor at 400°C. Figure-3 depicts the increase in carbon contents after these biochars were deposited by carbon produced from secondary decomposition of pyrolysis vapor. The pyrolysis vapor was also produced at 400°C by fast pyrolysis process with a ramping rate of 60°C/min. The data indicated that the highest amount of carbon deposition was within the biochar substrate produced at 500°C, followed by those produced at 600, 700 and 800°C.

From this result, the next set of carbonization experiments was conducted by using biochar produced at 500°C as the substrate, with 78.0 mass % of carbon. The

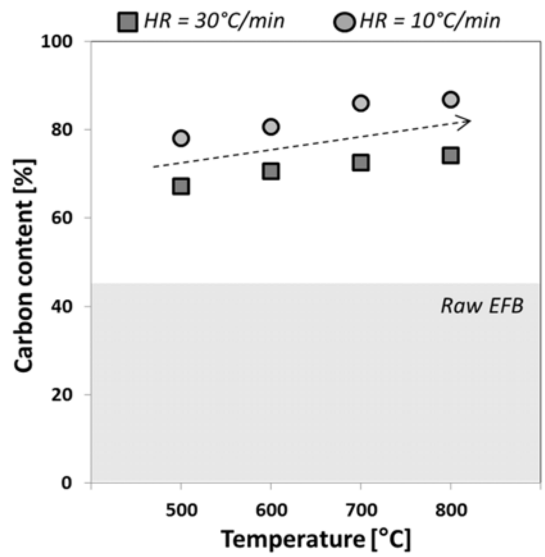

Figure-2. Carbon contents of biochar produced from slow pyrolysis of raw EFB at 500-800°C with heating rates of 10 and 30°C/min.

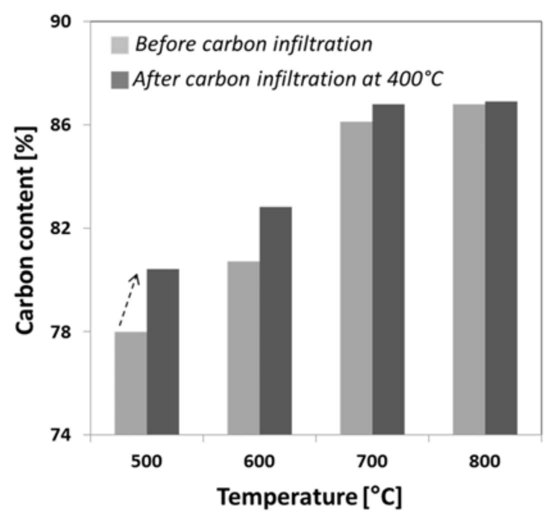

Figure-3. Carbon contents of biochars produced at 500-800°C before and after carbon infiltration at 400°C.

temperatures selected for fast pyrolysis and carbonization process were increased from 400 to 450 and 500°C. The carbon content results are showed in Figure-4. From 400 to 450°C, the carbon deposition within biochar increased from 2.4 to 5.2 mass % of carbon, but as the temperature increased further to 500°C, the carbon deposition obtained reduced to 4.3 mass %. This may be attributed to the deposition rate and gasification process. As the temperature increased to 450°C, the deposition rate of carbon was also increased. However, as the pyrolysis temperature increased to 500°C, gasification process has started to occur [8] to produce non-condensable gases such as hydrogen. This caused a decrease in the amount of condensable pyrolysis vapor, reducing the amount of carbon deposit within the biochar substrate.

Figure-5 depicts the overall utilization of EFB to produce a value-added EFB-derived pyrolysis product. EFB-derived biochar was first prepared by slow pyrolysis process to be used as the substrate and/or medium for carbon deposition, whereby the pyrolysis vapor from fast pyrolysis of EFB was captured by CVI method, through secondary decomposition of this biomass product.

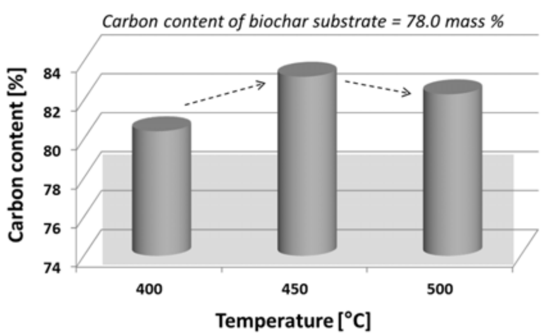

Figure-4. Carbon contents of biochar produced at 500°C after carbon infiltration at 400, 450 and 500°C.

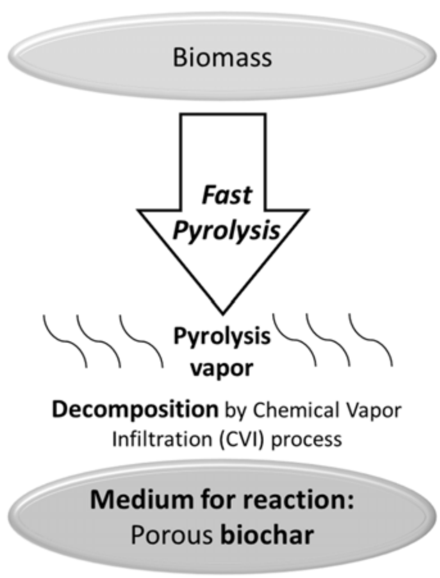

Figure-5. Utilization of raw EFB as a carbon source to be infiltrated within EFB-derived biochar to increase its total carbon content.

The reaction mechanism of this developed process to decompose pyrolysis vapor into secondary char and gases by chemical vapor infiltration (CVI) method is illustrated in Figure-6. Pyrolysis vapor infiltrated within biochar pore and came in contact with the pore surface where decomposition into secondary char and gases took place. The secondary char deposited on the pore surface, increases the total carbon content within the carbon-infiltrated biochar. With an increase in carbon content, this resultant product is able to be used as an alternative energy source, especially in steel industry to partially substitute coke breeze which has environmental issue, and is currently facing depletion.

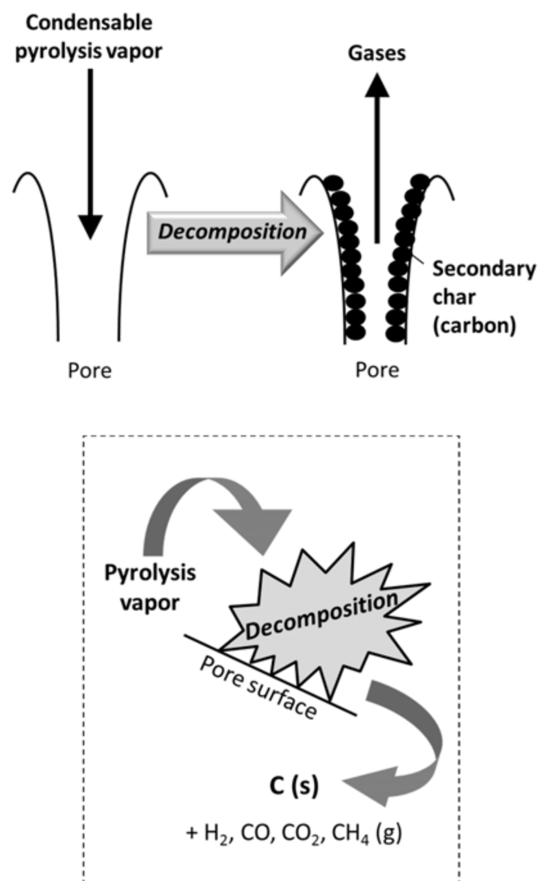

Figure-6. Reaction mechanism to decompose pyrolysis vapor into secondary char and gases by chemical vapor infiltration (CVI) method.

CONCLUSIONS

In conclusion, EFB-derived biochar was successfully used as the substrate and/or medium for carbon deposition from decomposition of pyrolysis vapor. Pyrolysis vapor was produced by fast pyrolysis and subsequently decomposed into secondary char and gases when it came in contact with pore surface within biochar, by chemical vapor infiltration method. The secondary char was deposited on the pore surface after the decomposition process, increasing the total amount of carbon within the resultant carbon-infiltrated biochar. The total carbon content was found increased from 78.0 to 83.2 mass % after carbon deposition at 450°C within biochar substrate produced at 500°C. This material has a potential to be further developed as a substitute to coke breeze in sintering plants in steelworks.

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