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Utilization of Sustainable Palm Empty Fruit Bunch Sorbents for Carbon dioxide Capture

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Abstract

Sustainable porous carbons have been produced via pyrolysis of palm empty fruit bunch (EFB) and then modified using hydrogen reduction and treatment with phenol for increase in hydrophilic character. The sorbents were tested for CO_2 capture. The EFB based sorbent materials were characterized for morphology and chemical functional groups. Characterization of the porous carbons covered four samples: hydrogen reduced, hydrophilic treated, bio oil impregnated and CO_2 uptake samples. FTIR analysis showed presence of hydroxyl, carbonyl, aliphatic, esters, alcohol, phenol and carboxylic groups on the surfaces of the sorbent materials. Absence of C=O in the hydrophilic treated samples could be traced back to reaction of the phenol and compounds containing carbonyl groups. Absence of C-O stretching for ethers in the carbon captured samples could be related to oxidation of ethers in CO_2.Spectra at 557.5cm^{-1} could be due to adsorption of CO_2 bending stretch.

Keywords: CO_2 capture; palm empty fruit bunch; hydrophilic; pyrolysis; bio-oil substrate

1. Introduction

The control of anthropogenic CO_2 emission is a crucial matter due to assertion that CO_2 gas contribute hugely to global climate change (Servilla et al., 2011). Carbon dioxide, (CO_2) was ranked as one of the major sources of greenhouse gas emission (GHG) and directly contributes to global climate changes and human's health (IPCC, 2007). In addition, penetration of fossil fuels in most parts of human activities which leads to CO_2 generation have aggravates this scenario. The use of sustainable solid waste material such as palm oil, pineapple wastes, rice husk and paddy straw for carbon dioxide (CO_2) capturing is a new approach to reduce excessive amount of CO_2 nowadays. Conventionally, most methods for CO_2 capture are based on different physical and chemical processes such as adsorption, absorption, membranes and cryogenics (Pirez et al., 2011; Wang et al, 2011). Application of a particular technique largely depends upon

the characteristics of the gas stream from which CO_2 needs to be separated, which mainly depends on the power plant technology (Jacobson, 2009). In other hands, the For process of capturing CO_2 emissions from power plants involves the use of toxic materials and requires 20 to 30 percent of the plant's energy output. Consequently, the necessity for zero emission associated with green lifestyle nowadays has boosted the concerted effort to find best solution to achieve it. Due to techno-economic problems associated with the present amine system used in CO_2 capture, researches are devoted to find an alternative. Porous carbons are one of the leading sorbent contenders for CO_2 capture. Their major advantage include low cost, availability, regeneration, low energy requirement, high surface area and easily susceptible to surface and pore modifications. In this work, sustainable solid char was prepared from Empty fruit bunches (EFB) and then treated with hydrophilic phenolic solution to serve as adsorbent for CO_2 capture. Therefore, the aim of this paper is to study the use of reduced empty fruit bunch (EFB) as an adsorbent as well as its modification toward proper capturing of CO_2. Fourier transform infra-red (FTIR) technique was employed to evaluate the adsorption capacity of the porous unmodified and modified reduced EFB and the functional group effects. EFB modified can be a commercial potential source of adsorbent to replace the existing/conventional adsorbents such as amine and activated carbon thereby reducing wastes generation annually as well as improving environmental air quality.

2. Experimental

2.1 Sample Preparation

The raw empty fruit bunch (EFB) used in the experiment was obtained from palm oil plantation, Koperasi Kampung Jawi Johor Bharu Berhad. Initially, the raw EFB was dried in roller oven under temperature condition of 100^{o}C for 24 hours, it's then separated and stored in vacuumed desiccators. The purpose of the drying process was to remove moisture content. The solid charcoal from EFB was obtained at pyrolysis (Figure 1) temperature of 525^{o}C±25^{o}C, supplied with 4.5L/min N_2 and 1.8 psi for 3 hours. The collected products were separated into residue solid and liquids. To ensure the homogeneity in the EFB composition, the EFB was grinded to 250µm size and then used as support material for CO_2 capture.

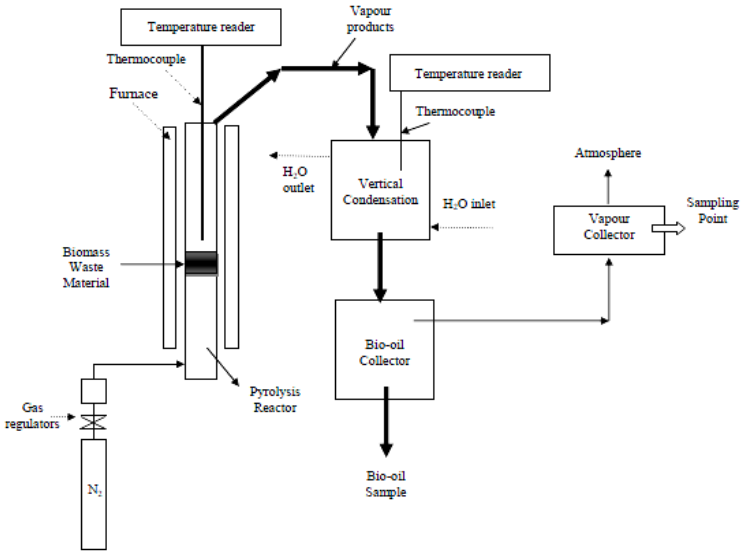


Figure 1. Schematic diagram of EFB pyrolysis batch reactor

The sample was reduced with hydrogen gas for 3 hrs at 120mL/min±10mL/min in a batch reactor as shown in the Figure 2, then 0.4g of EFB reduction was treated in 1.4g phenolic solution as hydrophilic state, prepared by ratio 1.4g phenol to 8g water and 0.03g bio oil substrate from the pyrolysis process. The solution was left for 20 min with occasional gentle stirring 6 rpm and dehydrated in the oven evaporator for 24 hours at 100^{o}C High-purity carbon dioxide was passed over the sample bed at a rate of 100ml/min for 3h for the uptake process of the micro porous element in the sample as in Fig. 2 and then transferred to a desiccator until use.

2.2 Characterization of Sample

2.2.1 Fourier Transform Infrared Spectroscopy (FTIR)

FTIR was used to qualitatively identify the chemical functionality of the samples. PerkinElmer FT-IR spectrometer one series model was used in the tests. The transmission spectra of the samples were recorded using KBr pellets containing 0.1% of carbon. The spectra were recorded from 4000 to 400 cm^{-1}. A blank test was carried out first to eliminate the buoyancy effect as described by Dantas et al. (2011).

2.2.2 Scanning Electron Microscopy (SEM)

Scanning electron microscopy (SEM) was used to observe the microstructure and the surface morphology of EFB and treated EFB chars. The instrument was a Karl Zeiss (EVO50 XVPSEM, Germany) with an acceleration voltage of 15.0 KV. The samples were coated with gold to provide about 200A ˚ gold layer thicknesses using a vacuum sputter coater. Morphology of the samples was examined using magnification of 1000.

2.3 Carbon Dioxide Capturing

CO_2 adsorption studies were conducted by passing CO_2 gas over the adsorbents samples. The flow was maintained at 100mL/min for 3 hours at pressure of 1.6bars under ambient temperature in the range of 35˚C to 65˚C (Zhao et al., 2011).

3.0 Results and Discussion

3.1 FTIR

The FTIR spectra of the treated and untreated EFB derived bio-char samples are shown in Figure 2. The summary of the FTIR analysis with some probable functional groups on the samples are given in Table 1.

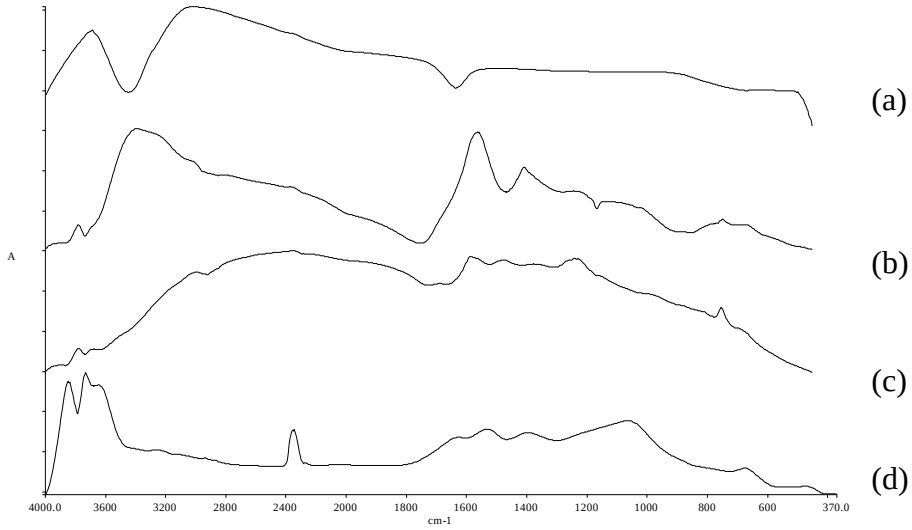


Figure 2. FT-IR spectrum for bio char sieved 250µm (a) CO_2 capture (b) reduced treated hydrophilic impregnation with bio oil (c) reduced treated hydrophilic (d) pyrolysis

Table 1. FTIR functional group composition of EFB derived bio-char

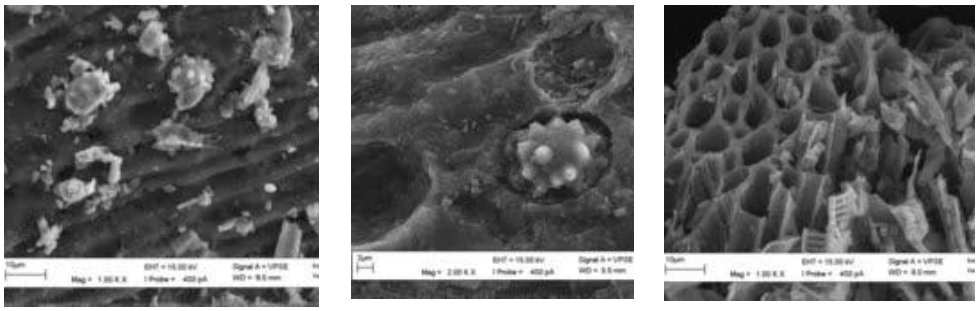
Bonding	**Wave number(cm^{-1})**	**Hydrophilic treated EFB impregnation with bio oil**	**CO_2 capturing EFB sample**	**Class compound**
O-H stretching	3600-3300	3400.0	-	Phenols, alcohols
C-H stretching	3000-2800	-	3033.9	Alkanes
C=O stretching	1750-1650		1717.8	Ketones, Aldehydes, Carboxylic acids, esters
C=C stretching	1675-1575	-	-	Alkenes
C-H stretching	1460-1350	1408.3	-	Alkanes
C-O stretching	1300-950	1223.6,1141.3	-	Primary , secondary and tertiary alcohols, phenols, ester
C-H bending	900-650	746.3	906	Aromatic compounds
CO_2 bending stretch	667-578	669.5	557.5	CO_2 bending
CO_2 stretching	2348	2368.1	-	-

The spectra of all the chars displayed the bands containing OH, C=C and CH stretch. This shows that they contain similar surface functional groups. However, the spectra of the samples show some differences at other points. Absence of C=O (Figure 2) in the

hydrophilic treated samples could be traced back to reaction of the phenol and compounds containing carbonyl groups. Absence of C-O stretching for ethers in the carbon captured samples could be related to oxidation of ethers in CO_2 (Gua et al., 2008). The spectrum of the CO_2 capture sample showed band at 557.5 cm^{-1} which could be due to the adsorption of CO_2 bending stretch.

3.2 Morphology of Samples

The low magnification SEM micrographs (x1000) of the surface of the porous carbon samples (Fig. 3a, b. and c) clearly showed the differences. It can be observed that raw EFB had very little pores available on the surface.



(a) **(b)** **(c)**

Figure 3. EFB bio solid charcoal morphology effect (1000x) on treatment process sieved 250 µm. (a) reduced with hydrogen, (b) reduced and treated with hydrophilic solution, and (c) reduced, treated and impregnated with bio oil substrate.

In Figure 3a, smooth surface of EFB was observed compared to Figure 3c which shows the beginning of fiber separation due to some of the lignin located in middle lamella as cement between fibers (Li et al., 2010). The separation of fiber indicates the destruction of the network of lignin, which is abundant in the middle lamella. Hence, it can probably be concluded that in the presence of bio oil and phenol in the process, brings about chemical attacks on lignin which starts an early decomposition during the impregnation process Initially EFB (Figure 3a.) input consists of a mixture of small particles and large fiber bundles. The majority of this mixture consists of large fiber bundles. The micrographs of treated EFB indicate that the large fiber bundles of EFB change to the small particles in a more uniform size with development of more cavities. As expected, the structure of fiber is disrupted during the reaction process. More uniform pores with little deposits were observed in treated and impregnated samples this could be due to carbonization (Alkhatib et al., 2011) and impregnation of bio-oil.

Conclusions

The experimental resuls indicated that porous carbon with well developed porosity could be prepared from palm waste empty fruit bunches. Effect of impregnation is clearly indicated on the SEMand FTIR results. uniform pores with little deposits on the surface were observed in treated and impregnated samples this could be due to carbonization and bio-oil addition. The spectrum of the CO_2 capture sample showed band at 557.5 cm^{-1}which could be due to the adsorption of CO_2 bending stretch. This indicated that EFB derived chars will be among the the altenatives CO_2 capture adsorbents and in gas-phase adsorption for air pollution control. Futher works will be

carried out to modify the porous carbon for enhanced selectivity towards carbon capture.

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