Preparation and Characterization of Biochar from Palm Kernel Shells as an Activated Carbon Precursors with the Pyrolysis Method

Ratni Dewi[1,3], Harry Agusnar[2*], Zul Alfian[2] and Tamrin[2]

[1]*Postgraduate Chemistry Study Program, Faculty of Mathematics and Natural Sciences, Universitas Sumatera Utara, Jl. Bioteknologi No. 1 Kampus USU, Medan, Indonesia*

[2]*Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Sumatera Utara, Jl. Bioteknologi No. 1, Medan 20155, Indonesia*

[3]*Chemical Engineering Department, Lhokseumawe State Polytechnic, Lhokseumawe, Indonesia*

Keywords: Activated Carbon, Biochar, Precursor, Palm Kernel Shell, Pyrolysis.

Abstract: In this study the preparation of biochar from palm kernel shells was carried out by the pyrolysis method. Characterization of biochar is done by using FTIR, XRD, SEM EDX, and DSC / TGA. Based on the results of measurements with FTIR, functional group stretching vibration of O-H and C-C stretching was obtained. The surface of biochar looks rough with irregular pore diameter size. From the SEM analysis, it was obtained that the pore diameter ranged from 625.3 nm - 870.9 nm, while the EDX results showed the carbon content at biochar was 84.93%. The results of the TGA / DSC analysis show that biochar loses weight due to the release of water during heating and in the carbon decomposition phase. From the results of the characterization, it can be concluded that biochar derived from the results of the pyrolysis process with the raw material of palm kernel shell is very good to be used as an activated carbon precursor.

1 INTRODUCTION

Indonesia and Malaysia are the largest palm oil producing countries in the world, followed by Thailand Colombia and Nigeria (Bentivoglio, 2018). In 2016, the area of oil palm plantations in Indonesia reached 11.6 million ha and is predicted to increase to 14.6 million ha in 2019 (Agriculture, 2016). Palm oil processing plant more and more built up and ultimately have an impact on the resulting waste, mainly liquid waste and solid waste. In one ton of fresh fruit bunches (FFB) there are 15% of mesocarpes (MF), 6% of palm kernel shells (PKS), and 23% of empty fruit bunches (Liew, 2018) where PKS and MF are solid waste that is most produced.

During this time the use of PKS in palm oil processing industry is limited as the boiler fuel, so a lot of the PKS left and into a pile of biomass (Okoroigwe, 2013). Biomass can generally be described as all organic matter or compounds that are either produced from plants, forest products or marine life (Awalludin, 2015). Palm kernel shells are solid waste from palm oil mills which account for 60% of palm oil production. Palm shells has a fairly high carbon content of 46% (Okoroigwe,n 2014) and potentially as a precursor for activated carbon is indispensable in industrial water treatment, food and cosmetics. Palm kernel shell has advantages as a precursor because the surface is porous, mechanical strength and high chemical stability and no solution in water (Rashidi, 2017).

Therefore, the reuse of PKS as a carbon source will be economically and environmentally beneficial (Hidayu, 2016). Palm kernel shells contain lignocellulose (Ikumapayi, 2018) which can be converted to biochar, one of them by the pyrolysis method.

Pyrolysis is a process of thermal decomposition of organic matter in the absence of oxygen or with very limited oxygen. This process can be applied to process solid waste, especially waste with high organic content that are environmentally friendly (Lam, 2016). Direct burning of waste can release large amounts of CO_2, while the pyrolysis method can limit the production of greenhouse gases (CO_2) and decompose waste to produce useful products

Dewi, R., Agusnar, H., Alfian, Z. and Tamrin, .
Preparation and Characterization of Biochar from Palm Kernel Shells as an Activated Carbon Precursors with the Pyrolysis Method.
DOI: 10.5220/0008863101520155
In *Proceedings of the 1st International Conference on Chemical Science and Technology Innovation (ICOCSTI 2019)*, pages 152-155
ISBN: 978-989-758-415-2

such as solid biochar, liquid bio-oil and biogas. Biochar is a product of the pyrolysis process with temperatures below 700^{0}C and the utilization of biochar is currently widely used as a soil enrichment material and activated carbon precursor.

This study aims to examine the quality of biochar from the pyrolysis process with PKS as raw material, through characterization using XRD, FTIR, SEM EDX and TGA / DSC. The utilization of PKS as biochar can increase the benefits of the biomass, in addition to its abundant availability and can reduce environmental pollution.

2 MATERIALS AND METHODS

2.1 Apparatus and Materials

The equipment used in this study was FTIR spectrophotometer (Shimadzu FTIR - 4200 type A), XRD (Shimadzu XRD-6000), SEM EDX (JEOL JSM-5500), DSC / TGA, glass set (Pyrex), filter 80 mesh Retsch, and biochar.

2.2 Preparation of Biochar

Palm kernel shell was obtained from Oil Palm plantation, PTP. Nusantara I, Cot Girek, North Aceh, Indonesia. Palm kernel shell is cleaned of dirt and oil by washing using deionized water, then dried in an oven at 100ºC for 2 hours. The carbonation process was carried out at 400ºC for 3 hours in the pyrolysis reactor. Carbonized materials or biochar is ground into fine particles and sieved to 80 mesh particle size. Biochar is then further characterized by using XRD, SEM EDX, TGA/DSC, and FTIR.

3 RESULT AND DISCUSSION

3.1 Fourier Transform Infrared Analysis

Absorption of FTIR spectra from biochar showed in Figure 1, a sharp peak uptake at 3591-3336 cm^{-1} which represented the stretching vibration of O-H in the hydroxyl group (shamsuddin, 2016). Characteristic band at 1662-1631 cm^{-1} assigned to C=C stretching indicate the methyl and methylene group. Bands at 1265 cm^{-1} attributed to C-O stretching vibration.

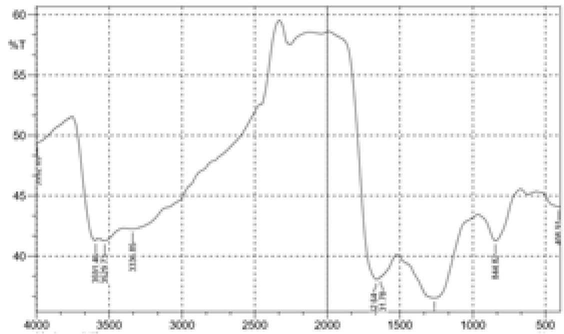


Figure 1: The FTIR Spectra of Biochar.

The results of absorption of FTIR spectra from biochar are shown in Table 1.

Table 1: Functional Groups and The Classification of Compounds Identified in Biochar by FTIR.

Wavenumber (cm^{-1})	Functional groups	Classification compounds (Liew et al, 2017)
3336	OH stretching	Alcohol, phenol, carboxylic acid
1662	C=C stretching	Alkene, aromatic ring

3.2 Structural Analysis and Surface Morphology (SEM EDX)

The SEM observations were carried out on a typical fracture surface of the manufactured biochar. Biochar surface as shown in Figure 2 looks rough with irregular pore size and begins to form due to loss of volatile substances after carbonization at 400ºC. The remaining non-volatile components are then transformed into biochar with pores of various shapes and sizes observed on the surface (Liew, 2018). Based on SEM analysis obtained pore diameters ranging from 625.3 nm - 870.9 nm.

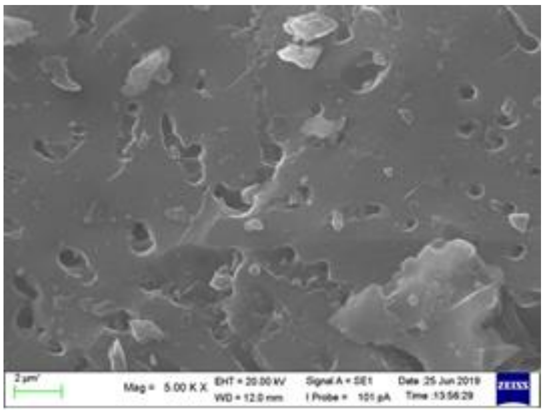
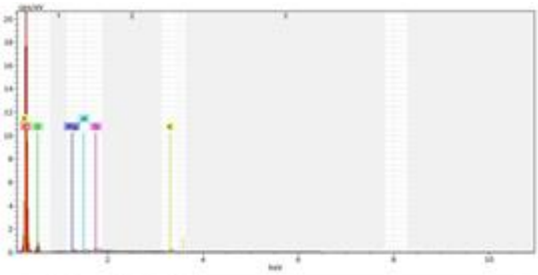


Figure 2: Morphology of Biochar.

The EDX analysis of biochar (Figure 3) shows that the composition of carbon in biochar reached 84.93% while oxygen, magnesium, aluminum, silicon and potassium were only 14%, 0.11%, 0.18%, 0.26% and 0.46%.



Spectrum: Acquisition

Element	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error (1 Sigma) [wt.%]
Carbon	K-series	84.93	84.93	88.58	10.58
Oxygen	K-series	14.06	14.06	11.01	3.00
Magnesium	K-series	0.11	0.11	0.06	0.04
Aluminium	K-series	0.18	0.18	0.08	0.04
Silicon	K-series	0.26	0.26	0.12	0.04
Potassium	K-series	0.46	0.46	0.15	0.05
	Total:	100.00	100.00	100.00	

Figure 3: EDX of Biochar.

3.3 X-ray Diffraction Analysis

The XRD pattern for biochar resulting from the pyrolysis process is shown in Figure. 4. Based on the peak position of diffraction intensity (2θ) biochar, absorption peaks appear at 2θ pada (°) = 22.3, 26.5 and 64.4. This reveals the presence of irregular amorphous structures stacked by carbon rings.

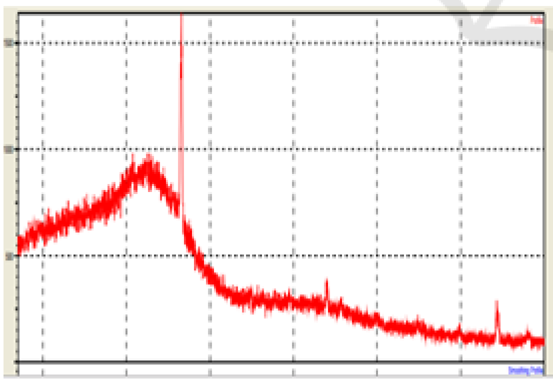


Figure 4: X-ray Diffractogram of Biochar.

3.4 Tga/Dsc Analysis

Figure 5 shows the thermal decomposition of biochar, significant weight loss (reaching 97%) occurs below 100ºC which can be attributed to evaporation of water bound inside the biochar pores. This condition slowly decreases to 600ºC, which at this temperature can be associated with the carbon decomposition phase.

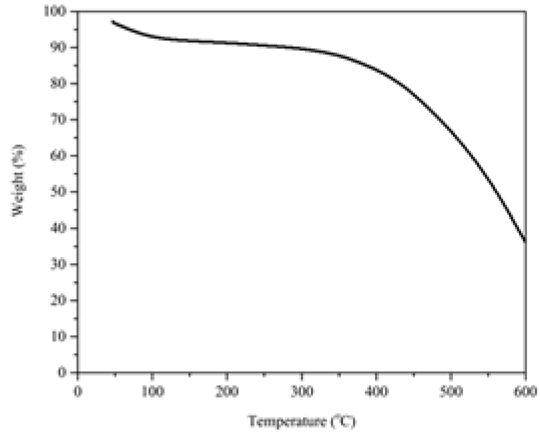


Figure 5: TGA Analysis of Biochar.

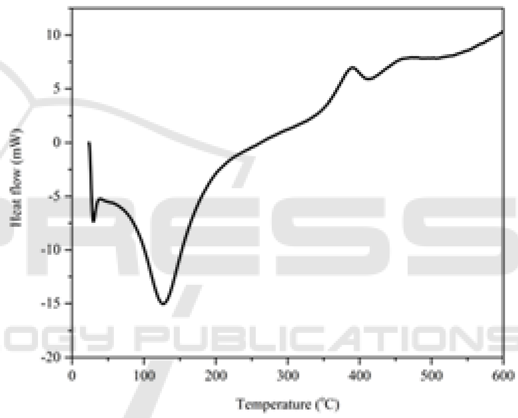


Figure 6: DSC Analysis of Biochar.

The transformation of the biochar phase in the temperature range of 20-600°C was studied using differential thermal analysis. The biochar derivatogram is shown in Figure 6. The endothermic effect on the biochar DSC curve at a temperature of 15ºC – 30ºC is a sharp peak (endothermic peak) that occurs due to hygroscopic water removal or water evaporation. This evaporation process requires heat ΔH = 151.44 J/g or ΔH = 36.18 cal/g. At a temperature of 127ºC, there is an endothermic curve which is quite wide due to the release of bonds of water molecules.

4 CONCLUSIONS

Biochar is a solid residue produced from the pyrolysis process. Biochar characterization has been done using FTIR analysis, SEM EDX, XRD and TGA / DSC. Based on the results of measurements with FTIR, functional group stretching vibration of O-H and C-C stretching was obtained. The surface of biochar looks rough with irregular pore diameter size. From the SEM analysis, it was obtained that the pore diameter ranged from 625.3 nm - 870.9 nm, while the EDX results showed the carbon content at biochar was 84.93%. The results of the TGA / DSC analysis show that biochar loses weight due to the release of water during heating and in the carbon decomposition phase. Based on the results of the above characterization, it can be concluded that biochar derived from the results of the pyrolysis process with the raw material of palm kernal shell is very good to be used as an activated carbon precursor.

ACKNOWLEDGEMENTS

The author would like to thank RistekDIKTI the financial support to complete this study and all lecturer in the Department of Chemistry Universitas Sumatra Utara.

REFERENCES

Awalludin, M. F., Sulaiman, O., Hashim, R., & Nadhari, W. N. A. W. (2015). An overview of the oil palm industry in Malaysia and its waste utilization through thermochemical conversion, specifically via liquefaction. *Renewable and Sustainable Energy Reviews*, *50*, 1469–1484.

Bentivoglio, D., Finco, A., & Bucci, G. (2018). Factors affecting the indonesian palm oil market in food and fuel industry: Evidence from a time series analysis. *International Journal of Energy Economics and Policy*, *8*(5), 49–57.

Hidayu, A. R., & Muda, N. (2016). Preparation and characterization of impregnated activated carbon from palm kernel shell and coconut shell for CO2 capture. *Procedia Engineering*, *148*, 106–113.

Ikumapayi, O. M., & Akinlabi, E. T. (2018). Composition, Characteristics and Socioeconomic Benefits of Palm Kernel Shell Exploitation-An Overview. *Journal of Environmental Science and Technology*, *11*, 220–232.

Lam, S. S., Liew, R. K., Jusoh, A., Chong, C. T., Ani, F. N., & Chase, H. A. (2016). Progress in waste oil to sustainable energy, with emphasis on pyrolysis techniques. *Renewable and Sustainable Energy Reviews*, *53*, 741–753.

Liew, R. K., Nam, W. L., Chong, M. Y., Phang, X. Y., Su, M. H., Yek, P. N. Y., … Lam, S. S. (2018). Oil palm waste: an abundant and promising feedstock for microwave pyrolysis conversion into good quality biochar with potential multi-applications. *Process Safety and Environmental Protection*, *115*, 57–69.

Okoroigwe, E. C., Ofomatah, A. C., Oparaku, N. F., & Unachukwu, G. O. (2013). Production and evaluation of activated carbon from palm kernel shells (PKS) for economic and environmental sustainability. *Int. J. Phys. Sci*, *8*, 1036.

Okoroigwe, E. C., Saffron, C. M., & Kamdem, P. D. (2014). Characterization of palm kernel shell for materials reinforcement and water treatment. *Journal of Chemical Engineering and Materials Science*, *5*(1), 1–6.

Agriculture, K. (2016). Palm oil outlook. Center for Data and Agricultural Information Systems: Jakarta

Rashidi, N. A., & Yusup, S. (2017). Potential of palm kernel shell as activated carbon precursors through single stage activation technique for carbon dioxide adsorption. *Journal of Cleaner Production*, *168*, 474–486.

Shamsuddin, M. S., Yusoff, N. R. N., & Sulaiman, M. A. (2016). Synthesis and characterization of activated carbon produced from kenaf core fiber using H3PO4 activation. *Procedia Chemistry*, *19*, 558–565.