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Preparation and Characterization of Activated Carbon from *Cocos nucifera L.* (coconut) Shell and Sugarcane Bagasse

Muhammad Zharif JASNI[2,a], Nor Hakimin ABDULLAH[1,b*], Suhaiza ABDULLAH[1,c], Mohammad Khairul Azhar ABDUL RAZAB[1,d], An'amt MOHAMED NOOR[1,e], Mazlan MOHAMED[1,f], Nik Alnur Auli NIK YUSUF[1,g], Mohamad Asyraf MOHD AMIN[3,h], Mohd Sukhairi MAT RASAT[1,i] and Mohamad Faiz MOHD AMIN[2,j]

[1]Advanced Material Research Cluster, Faculty of Bioengineering and Technology, Universiti Malaysia Kelantan Kampus Jeli, Locked Bag 100,17600 Jeli, Kelantan.

[2]Faculty of Earth Science, Universiti Malaysia Kelantan Kampus Jeli, Locked Bag 100,17600 Jeli, Kelantan.

[3]Facultyof Electrical Engineering and Automation,Terengganu Advanced Technical Institute College University, 24000 Telok Kalong, Kemaman, Terengganu.

[a]zharifjasni.93@gmail.com, [b]norhakimin@umk.edu.my, [c]suhaizaabdullah@ymail.com, [d]azhar@umk.edu.my, [e]anamt@umk.edu.my, [f]mazlan.m@umk.edu.my,[g]alnurauli@umk.edu.my,[h]asyrafamin@tatiuc.edu.my, [i]sukhairi@umk.edu.my, [j]mohamadfaiz@umk.edu.my

ABSTRACT. The aim of this study is to synthesis and characterize activated carbon from *Cocos nucifera L.* (coconut) shell and sugarcane bagasse by carbonization and activation process. The samples were carbonized and activated at 300°C in a furnace. As the concentration of activating agent increased, the percentage of weight loss also increased due to more volatiles in samples that were released. Addition of phosphoric acid (H_3PO_4) and potassium hydroxide (KOH) resulting more porous structure in the activated carbon. The result indicated that the activated carbon derived from coconut shell has higher carbon content compared to sugarcane bagasse. Besides, the elements that contained in the samples were analysed using X-ray Diffraction (XRD) and surface chemical was characterized using Fourier Transformation Infrared-Attenuated Total Reflection (FTIR-ATR). It was concluded that production of activated carbon from coconut shell and sugarcane bagasse can be used in a lot of applications like dye absorbent for waste water treatment.

Keywords: *Activated carbon, Agriculture waste, Activating agent;*

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1. INTRODUCTION

In recent years, activated carbon is very popular among the researchers because they are focusing on recycling the agricultural waste into beneficial usage [1-2]. This green approach is aimed to reduce the impact of waste to the environment [3-4]. Furthermore, application of waste to wealth concept would allow the agricultural byproducts which do not have any economic value to be commercialized into a new high value product [5-7].

Activated carbon is commonly derived from carbonaceous materials such as egg shells, coffee husks, coconut shells and husksas well as sugarcane bagasse [8]. For the production process, at the beginning, the carbonaceous sources are carbonized and followed by physical or chemical treatment.The surface modification process which occurs at the molecular level allows the carbon to be fully functionalized into

activated carbon [9] .High degree of porosity that exists in activated carbon is well known to be an excellent candidate for adsorption process such as dye removal in waste water or air filter [10].

In this research, activated carbon was produced from coconut shell and sugarcane bagasse. Both of them are available all year around and have advantage properties like high carbon content, low ash content, high yield, mechanical strength and resistance to attrition [11]. Activating agents namely phosphoric acid (H_3PO_4) and potassium hydroxide (KOH) were used for chemical activation purpose. Weight loss of the synthesized activated carbons was recorded and characterizations of physical properties were conducted by using XRD and FTIR-ATR.

2. MATERIALS AND METHODS

The coconut shells were collected from local market nearby in Jeli, Kelantan, Malaysia. KOH(ACS reagent) with purity ~ 85% and H_3PO_4(ACS reagent) with purity ~ 85% were purchased from Sigma–Aldrich. Distilled water was also used to remove any impurities.

2.1 Preparation of Activated carbon. The coconut shells were crashed into smaller pieces using hammer. The smaller pieces of coconut shells then washed with distilled water to remove any impurities. Next, they were grinded using grinder before dried in an oven at 105°C for overnight to remove the moisture. Then, the grinded coconut shells were blended to get the sample in powder form. To make sure the powder in similar size, the powder samples were sieved in 250 µm.

For the sugarcane bagasse sample, firstly, it was washed with distilled water to remove any impurities. Then, the sugarcane bagasse was dried in oven at 105°C for overnight. After that, it was cut into smaller size before blending process.The grinded coconut shells and sugarcane bagasse were filled in the crucible before putting in the furnace at temperature of 300°C for pre-carbonization process.

The samples then added with activating agents, H_3PO_4 and KOH. These activating agents solution then mixed with the activated carbon using impregnation ratio which was 1:3. The 5, 10 and 15% different concentrations for H_3PO_4 and KOH were applied for the activation process. For the carbonization process, the samples were placed in furnace at 300°C for another 2 hours. Then, the samples were distilled with deionized water until the pH of water became neutral. Finally, the samples were dried in oven for several hours to remove the moisture.

2.2 Determination of Percentage of Weight Loss. The coconut shell and sugarcane bagasse samples before carbonization and the final product (activated carbon produced after chemical activation) weighed using an electronic weighing balance. The shell samples carbonized in a furnace for durations of 1, 2 and 3 hours to measure the percentage weight decrease or weight loss of the materials during preparation from the original weight of the raw materials. The mathematical expression as shownin Eq. 1.

$$Percentage\ of\ weight\ loss\ (\%) = \frac{W_i - W_f}{W_i} \times 100 \quad (1)$$

where W_i is the initial weight of the raw material and W_f is the final weight of the product.

XRD was conducted for determination of phase identification of activated carbon using Bruker D2 Phaser instrument. DIFFRAC.EVA software was used for qualitative analysis as well as the elemental analysis of the charcoal and activated carbon. In addition, the powder of XRD pattern was analyzed to investigate the crystallographic structures changes during activation process.

FTIR-ATR is a nondestructive analysis that can identify chemicals either organic or inorganic. FTIR-ATR analysis was used to study the surface organic structures and functional group presence at the surface of

activated carbon by Perkin Elmer Spectrum™ 400 FTIR-ATR Spectrometer. The samples were put into the FTIR-ATR spectrometer sample holder and the spectra were recorded between 400 and 4000 cm^{-1}.

3. RESULTS AND DISCUSSION

Weight loss of the prepared activated carbon from coconut shell and sugarcane bagasse for different concentration of H_3PO_4 and KOH (before and after activation processs) as shown in Figs. 1 and 2, respectively. Fig. 1 illustrated the weight loss of activated carbon from both coconut shell and sugarcane bagasse in different concentration of H_3PO_4 and KOH. It can be seen from Fig. 1(a) that approximately 30, 22 and 21% the weight loss occurred for coconut shell activated carbon while for sugarcane bagasse it was about 43, 38 and 32%.The weight loss of coconut shell after impregnation with KOH was about 49, 60 and 26% while for sugarcane bagasse was about 38, 47 and 32% as shown in Fig. 1(b). Weight loss increased in Fig. 1(b) due to the high excess of potassium hydroxide that promote gasification of char which caused the increased total weight loss of carbon.

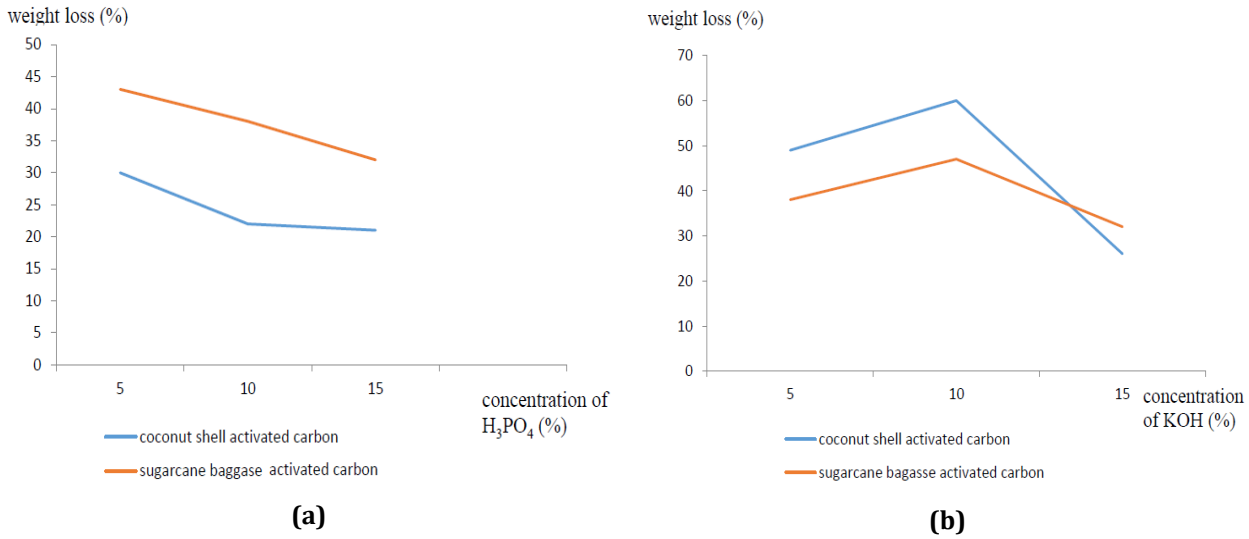

Fig.1 Weight loss of activated carbon from both coconut shell and sugarcane bagasse in different concentration(a) H_3PO_4, (b) KOH

XRD analysis of coconut shell and sugarcane bagasse activated carbon as depicted in Fig. 2. The XRD spectra of native carbon and the activated carbon indicated that all those chars are amorphous. This was denoted by the existence of two peaks at the 2Θ = 25° and 2Θ = 45° for the samples from all figures [12]. The peak at the 2Θ = 45° in all figures became stronger after impregnation process with KOH and H_3PO_4 which explained that the carbon have a tendency to crystallize at an elevated temperature [5].

Surface chemistry of the synthesized activated carbon was characterized by using FTIR-ATR. All figure in Fig. 3 showed that the first peak was around 3420-3440 cm^{-1} which corresponded to as O-H stretching mode of hydroxyl groups and absorbed water [13]. For Fig. 3 (c) that shows sugarcane bagasse activated carbon impregnated with 5, 10 and 15% of KOH, the results showed the aromatic phenone compound. It was due to C=O stretching vibration that the most intense in the spectrum. For Fig. 3 (b), result showed that the 10% $H_3PO_4$was resulted as aliphatic isothiocyanates compound and 15% H_3PO_4 showed as primary aliphatic alcohols. Primary aliphatic alcohol had one other carbon atom that attached to the oxygen bound carbon. For the primary alcohols, -C-O stretching and -OH deformation vibrations were at 1050 cm^{-1} [14].

Fig. 3 (d) showed the C-O stretching at 1200-1180 cm^{-1} and -C-O-C- stretching absorption at 1270-1230 cm^{-1} [15]. According to Yakout & El-Deen [13], the most important changes revealed in this characterization were the development of C-H vibration which might happen due to disappearance of oxygen at the surface of the carbon material [8].

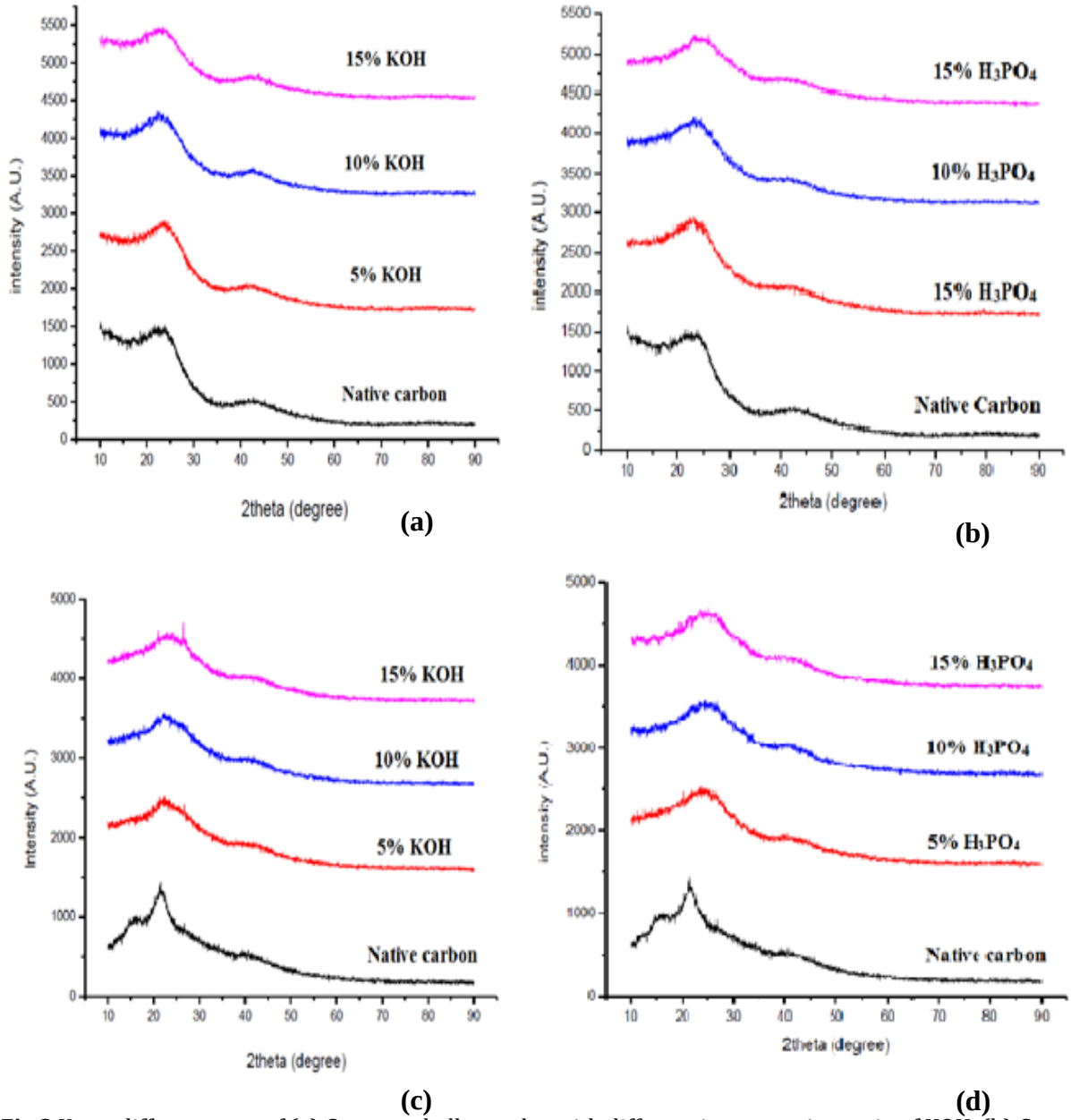

Fig.2 X-ray diffractogram of (a) Coconut shell samples with different impregnation ratio of KOH, (b) Coconut shell samples with different impregnation ratio H_3PO_4, (c) Sugarcane bagasse samples with different impregnation ratio of KOH, and (d) Sugarcane bagasse samples with different impregnation ratio of H_3PO_4

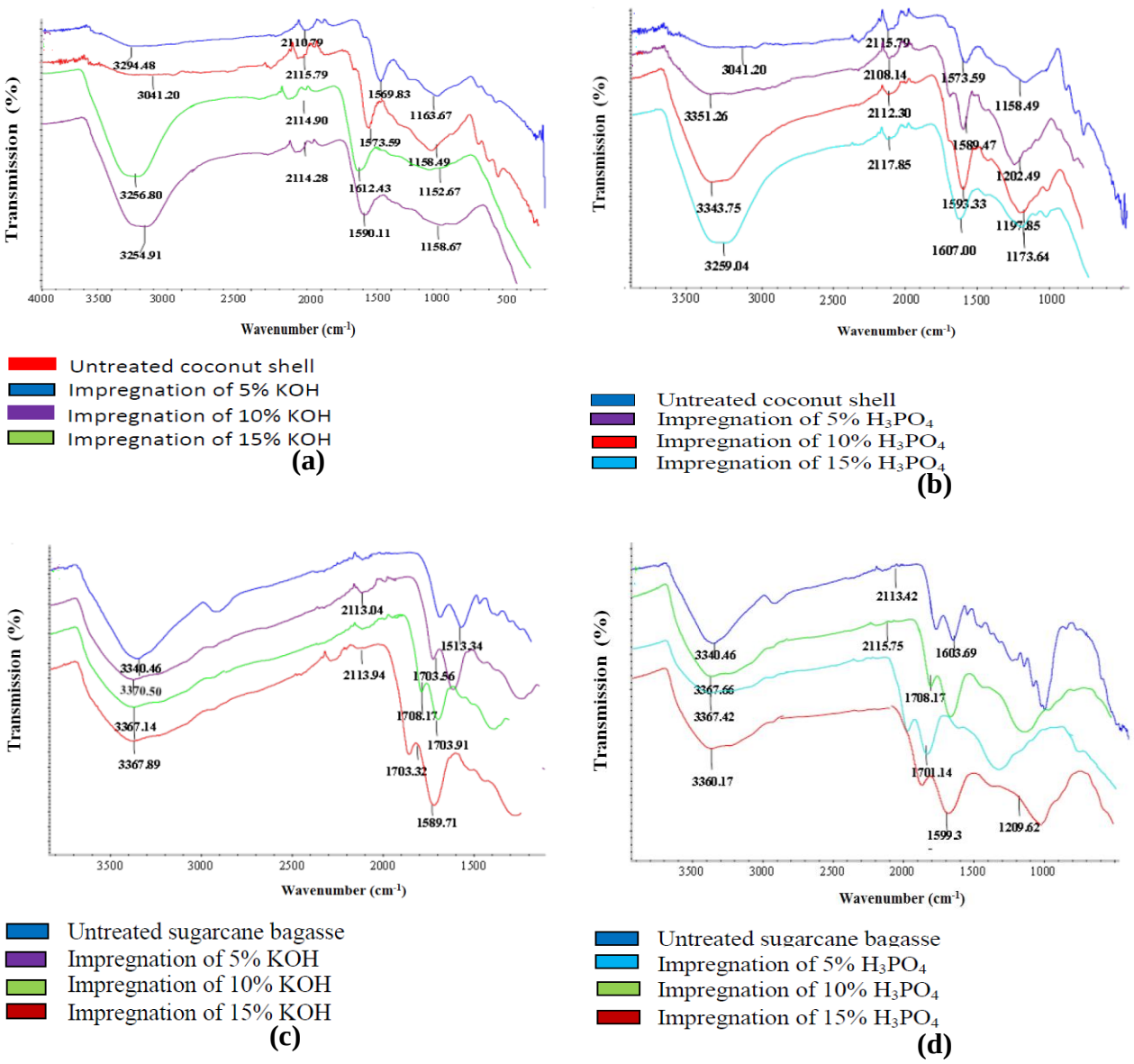

Fig.3 Coconut shell impregnation with (a) KOH and (b)H_3PO_4, Sugarcane bagasse impregnation with (c) KOH and (d) H_3PO_4

4. SUMMARY

In this study, activated carbon was prepared from coconut shell and sugarcane bagasse. Addition of H_3PO_4 and KOH gave rise to more porous structure in the activated carbon. The results indicated that the activated carbon derived from coconut shell has higher carbon content compared to sugarcane bagasse. XRDresults depicted that the activated carbon samples are amorphous. Surface chemistry analysis by FTIR-ATR revealed the surface functional groups that related to synthesized activated carbonfrom coconut shell and sugarcane bagasse.

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