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Activated carbon production from bagasse and banana stem at various times of carbonization

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Abstract. The utilization of bagasse and banana stem as activated carbon precursors has been conducted. In this study, the dried samples were impregnated using phosphoric acid (H_3PO_4) solution as the activator at a ratio of sample to the activator (w/w) was 1:1. The impregnation was conducted at room temperature for 24 hours. The samples then carbonized at 400 °C for 30, 45 and 60 minutes and finally washed and dried to obtain the activated carbon. The research aimed to investigate the effects of time of carbonization on the characteristics of activated carbon produced from bagasse and banana stem. The result showed that yield of activated carbon was in the range of 40.03 – 46.73 % with a high content of carbon as high 90.33 %. The result of BET analysis showed that the highest surface area reached1130.465 m^2/g.

1. Introduction

Activated carbons are materials containing the large surface area, well-developed porosity and rich surface group [1]. The beneficial properties of activated carbon have been recognized since ancient times. Today, activated carbons are very useful in wide variety of applications such as decolorization, decontamination, respirators for protection against toxic gases, as desiccants and or medicinal agents in detoxification [2].

The factors such as the nature of raw materials, the activation method, the activating agent and the condition of process affect the textural and chemical characteristic of the activated carbons. In recent years, activated carbon is being produced from a large number of easily available and low-cost materials such as agricultural products like coconut shells, reedy grass leaves, fire wood, and marigold straw [3].

Bagasse and banana stem are very potential to be used as raw material to produce activated carbon due to its components. The content of bagasse is 42.16 % cellulose, 36.0 % hemicellulose, and 19.30 % lignin [4], whereas banana stem contains 43.3% cellulose, 20.6% hemicellulose and 27.8% lignin [5].

In chemical activation, the precursor is mixed with a certain amount of active agents such as KOH, NaOH, $ZnCl_2$, and H_3PO_4, which lead to the development of porous structures in the material. Among the various dehydrating agents used for chemical activation, phosphoric acid is preferred recently due to environmental and economic concerns. Moreover, the carbon obtained by using zinc chloride as an

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activating agent cannot be used in pharmaceutical and food industries [3]. In this study, we investigatedthe effects of carbonization time on the characteristics of activated carbon produced from bagasse and banana stem using H_3PO_4 as the activator.

2. Experimental Procedure

2.1. Activated Carbon Preparation

The preparation of activated carbon from precursors of bagasse and banana stem was conducted with the same procedure as published before [6]. The raw material that has been washed was then dried under sun light and continued by oven drying at 105°C. The samples were then sieved using sieve size of 32 mesh. Particles that pass the sieve of 32 mesh was mixed with H_3PO_4solution at an impregnation ratio of 1:1 and impregnation time of 24 h. The filtered sample was then carbonized at 400 °C for 30, 45 and 60 minutes under nitrogen (N_2) flow. The product was washed several times with warm distilled water until neutral solution was achieved. Finally, the sample was dried until the mass was constant.

2.2. Activated Carbon Characterizations

The yield of activated carbon was calculated by dividing the mass of the resultant activated carbon by the initial mass of the raw material used. Proximate analysis was conducted to determine the moisture content, ash content and volatile matter content. The SEM-EDX analysis was used to get the surface morphology image and the composition of elements of sample. The Brunauer-Emmett-Teller (BET) surface area of sample was determined by applying the standard BET method to the nitrogen adsorption.

3. Result and Discussion

3.1. Yield of Activated Carbon

Yield of activated carbon was in the range of 40.03-46.73% as shown in Figure 1. The yield of activated carbon from banana stem was slight higher than activated carbon from bagasse. The longer the carbonization time, the lower the yield of activated carbon produced. This was due to more water and volatile matters removed from the sample thus less amount of the obtained product. The best result was achieved when banana stem was carbonized for 30 minutes.

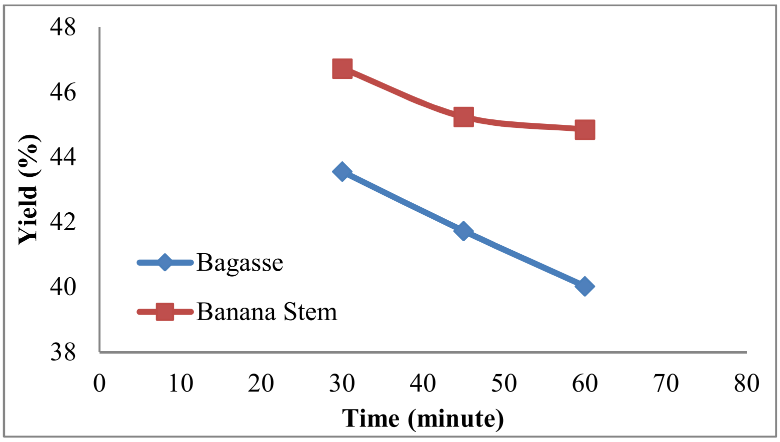

Figure 1. Yield of activated carbon produced from bagasse and banana stem at various time of carbonization

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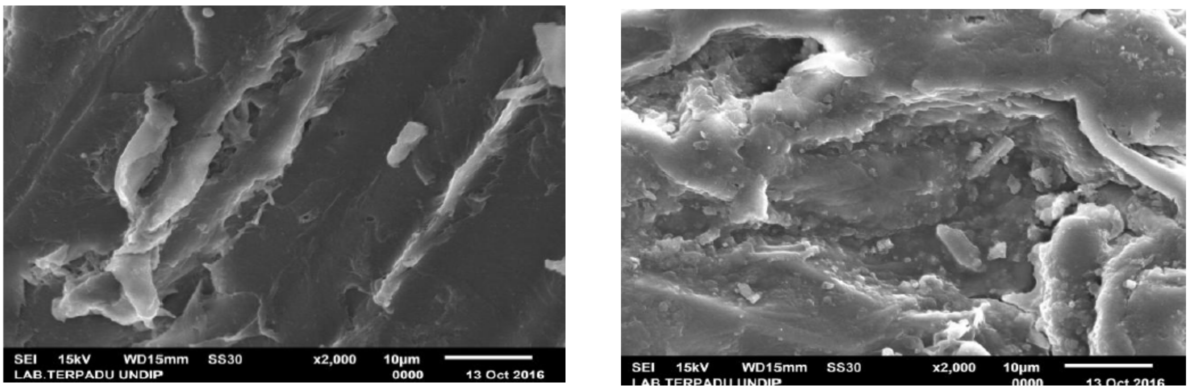
3.2. Proximate and Ultimate Analysis
The proximate and ultimate analysis of the activated carbon produced by carbonization and activation of the material (bagasse and banana stem) is presented in Table 1. The moisture, ash and volatile matter content were quite higher for all products. However, the longer time of carbonization caused the decrease of moisture, ash and volatile matter content; thus increasing the carbon content of the activated carbon.

The carbon content of both activated carbons was in the range of 84.21-90.33%. The large amount of carbon in this study was suitable for activated carbon requirement as stated in [7] that carbon content should be in the range of 80-95%. This result indicated that both materials are potential as activated carbon precursor.

Table 1. Proximate and Ultimate Analysis for Produced Activated Carbon

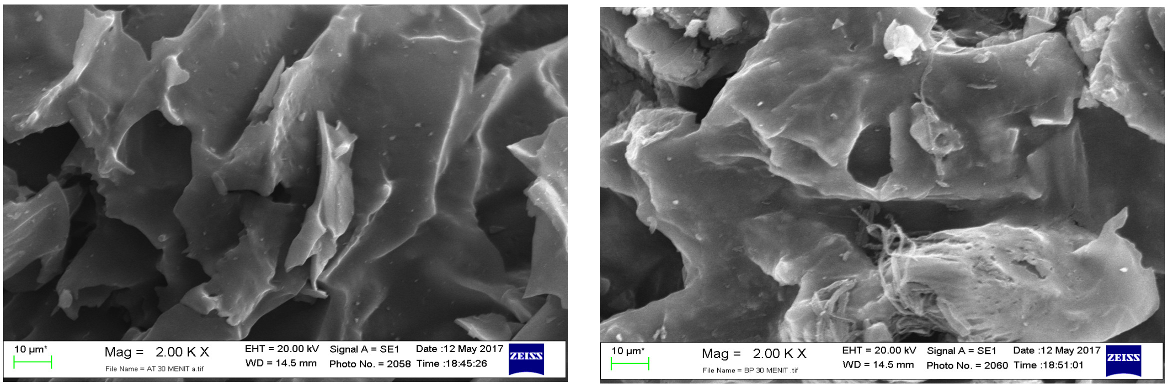
Activated Carbon	**Proximate Analysis (% w/w)**			**Ultimate Analysis (% w/w)**						
	Moisture	**Ash**	**Volatile Matter**	**C**	**O**	**Si**	**P**	**F**	**Ca**	**Na**
Bagasse 30 min	5.13	9.61	68.58	84.21	13.88	0.56	0.57	0.87	-	-
Bagasse 45 min	4.08	8.76	57.46	84.96	9.37	-	4.14	0.89	-	0.64
Bagasse 60 min	7.31	8.28	55.35	87.70	9.75	1.04	0.48	0.89	0.20	-
Banana Stem 30 min	8.02	12.80	73.12	84.55	13.20	0.24	0.83	1.02	-	0.07
Banana Stem 45 min	6.15	9.00	72.69	85.38	12.02	1.06	0.41	1.13	-	-
Banana Stem 60 min	5.32	8.49	63.14	90.33	7.71	0.74	1.20	1.67	0.14	-

3.3. Surface Morphology
The surface morphology of the dried bagasse and banana stem and activated carbon was studied by SEM image. Fig. 2a and 2b show the SEM micrographs of dried bagasse and banana stem. The surface of dried bagasse and banana stem appeared to be covered with thick foreign embodiment. Upon H_3PO_4 activation, more porous structures begin to appear which can be attributed to the dehydration effect of H_3PO_4 and the oxidation of organic compounds in the carbonization step (Fig. 3a and 3b). Concentration of H_3PO_4 used in activation was expected to increase volume due its dehydrating effect, thus providing larger surface area.



(a) (b)

Figure 2. Scanning electron micrographs of dried (a) bagasse and (b) banana stem



(a) (b)

Figure 3. Scanning electron micrographs of (a) bagasse and (b) banana stem activated carbon produced at 400 °C and carbonization time of 30 minutes

3.4. Porous Structure

Analysis results of surface area, pore volume, and average pore size using BET are presented in Table 2. It demonstrated that activated carbons have much larger surface area than the raw materials. Principally, based on its pore diameter, activated carbons are classified into three groups by IUPAC: micropore (diameter < 2 nm), mesopore (2-50 nm) and macropore (> 50 nm) [8]. All activated carbons exhibited the presence of micropore but not more than 32.85%. The highest portion of micropore was obtained at carbonization of banana stem for 30 minutes. The longer carbonization time increased the surface area of activated carbon.

Table 2. Porous Structure of Raw Materials and Produced Activated Carbons

Sample	Pore Volume (cc/g)	Pore radius (nm)	BET Surface Area (m^2/g)	Micropore Area (m^2/g)
Bagasse	0.008	2.6917	0	0
Bagasse 30 min	0.186	1.8193	952.611	164.913
Bagasse 45 min	0.188	1.7785	1062.206	154.426
Bagasse 60 min	0.476	1.7925	1130.465	328.588
Banana Stem	0.021	2.7365	22.421	6.622
Banana Stem 30 min	0.486	1.8112	846.531	278.085
Banana Stem 45 min	0.462	1.8183	849.387	273.187
Banana Stem 60 min	0.450	1.7889	876.590	268.619

4. Conclusion

The longer the carbonization time then the higher the yield, carbon content and total surface area. The achieved yield and carbon content of activated carbon from banana stem was slightly higher than that of activated carbon from bagasse. However, activated carbon from bagasse had higher total surface area. The highest yield was 46.73%, carbon content was 90.33% and surface area was 1130.465 m^2/g. All activated carbons exhibited the presence of micropore but not more than 32.85%. Both raw materials of bagasse and banana stem are potential to be utilized as activated carbon precursor.

Acknowledgement
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