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Characterizations of Activated Carbon Produced from Bagasse and Banana Stem using H_3PO_4 as Activating Agent

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Abstract: Bagasse and banana stem are such potential materials as activated carbon precursor. Both are agricultural wastes and are generally available in Indonesia. This study aimed to investigate the effects of temperature of carbonization on the characteristics of activated carbon produced from bagasse and banana stem using H_3PO_4 as the activator. Each sample was impregnated for 24 h at room temperature in activator solution and carbonized at 400°, 500° and 600°C for 15 min. This treatment showed good results of activated carbon. The yields of activated carbon were in the range of 43-60.43% with high content of carbon as high 97.06%. The SEM images demonstrated more porous were formed with irregular structures of the produced activated carbon.

Key words: Activated carbon, bagasse, banana stem, H_3PO_4 activator, investigate, precursor

INTRODUCTION

Activated carbon is principally referred as carbonaceous material with high mechanical strength, stability in physicochemical properties, degree of surface reactivity, pore volume and adsorptive capacity. It is also characterized with very large surface area up to 2000 m^2/g (Yahya *et al*., 2015; Gupta *et al*., 2016). Activated carbon has been utilized in many areas including water treatment, chemical and petroleum industries, separation, purification, catalysis, energy storage, batteries, fuel cells, nuclear power stations, electrodes for electric double layer capacitors, pharmaceutical, hydrometallurgy and others (Yahya *et al*., 2015). Due to its wide applications, the research on activated carbon has been attracted many researchers.

Activated carbon can be produced from a variety of raw materials by both naturally occurring and synthetic of carbonaceous resources. Raw materials from animal, mineral and vegetables have been studied as the solid precursors (Yahya *et al*., 2015). Recently, lignocellulosic materials from agricultural wastes have been widely used as precursors for activated carbon production. The use of agricultural wastes has many advantages such as inexpensive, easy to find, utilizing waste into valuable product and primarily are renewable resources (Yahya *et al*., 2015).

Ba Gasse (BG) and Banana Stem (BS), actually is banana pseudo stem-are such raw materials that potentially utilized as activated carbon precursor. Both are generally available and abundant materials in Indonesia but have not been utilized optimally. Bagasse contains 42.16% cellulose, 36.0% hemicellulose and 19.30% lignin (Chen *et al*., 2012) whereas banana stem contains 43.3% cellulose, 20.6% hemicellulose and 27.8% lignin (Noeline *et al*., 2005). Those components are very important in producing activated carbon by pyrolysis process.

There are many factors that influence the characterization of produced activated carbon. Besides the starting material, the use of activating agents (types, time of impregnation, ratio of raw material to activator) and carbonization conditions (time, temperature) also play important role (Yahya *et al*., 2015). The chemicals that widely used as activating agents are $ZnCl_2$ and H_3PO_4 for lignocellulosic materials. However, H_3PO_4 is more preferred than $ZnCl_2$ due to the toxicity and its impact to environment. The use of H_3PO_4 also provides easier way to recover the carbon product thus gives higher yield of activated carbon (Yahya *et al*., 2015). In this study, the effects of temperature of carbonization on the characteristics of activated carbon produced from BG and BS using H_3PO_4 as the activator were investigated.

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MATERIALS AND METHODS

Experimental procedure

Activated carbon preparation: Ba Gasse (BG) and Banana Stem (BS) were washed several times to eliminate the surface impurities. The samples were dried under sun light and continued by oven drying at 105°C. The dried samples were ground and sieved to 32 mesh sizes. Each sample was impregnated in H_3PO_4 solution at room temperature for 24 h. The mass ratio of sample to activating agent was 1:1.

The solution was filtered and dried. The dried sample then was carbonized at 400°, 500° and 600°C for 15 min using reactor with equipped with N_2 flow. The product was washed several times with warm distilled water until neutral solution was achieved. The constant weight of dried Activated Carbon produced from Ba Gasse (ACBG) and Banana Stem (ACBS) were sieved and used for all the experiments.

Raw material and activated carbon characterizations: The yield of the samples was calculated by comparing the mass of the produced activated carbon to the mass of raw material used. The product underwent the proximate analysis to determine the ash and volatile matters content. The morphological structures of each raw materials and activated carbons were analyzed by scanning electron microscope images after gold sputter coating.

The ultimate analysis was carried out using Energy Dispersive X-ray (EDX). The specific surface area of each sample was calculated using the Brunauer-Emmett-Teller (BET) method. The Barrett-Joyner-Halenda (BJH) method was utilized to determine the pore size distribution that was derived from the adsorption branch of the corresponding isotherm. The total pore volume was estimated from the amount adsorbed at a relative pressure of $P/P_0 = 0.99$.

RESULTS AND DISCUSSION

Yield and proximate and ultimate analysis: Ba Gasse (BG) and Banana Stem (BS) have high water content so that a very small amount of dried sample can be obtained. The yield of dried BG was 11.46% whereas of dried BP was 21.67%. Meanwhile the yield of activated carbon was in the range of 43-60.43%. The yield of ACBGs was slight higher than of ACBSs. However, based on the proximate analysis, the ash and volatile matters content were quite higher for all products. The high content of volatile matters can affect the porous structure of produced activated carbon. Overall, the higher temperature resulted in higher yield of produced activated carbon but smaller ash and volatile matters content.

The ultimate analysis showed that both activated carbons had carbon content in immense amount in the range of 86.27-97.06%. The large amount of carbon was attributed to the activating agent. H_3PO_4 serves as dehydrating agents that influenced the pyrolytic decomposition and prevented the formation of ash, thus increasing the carbon yield. The content of carbon in this study is in accordance with (Gupta *et al*., 2016) that this content is in the range of 80-95% for activated carbon. Moreover, the products contained no element of N and S, with a varied amount of O. Other elements (Si, P, Zr, Ca and Na) were found in a small amount which might origin from its raw components. The large amount of carbon demonstrated both materials are appropriate lignocellulosic sources in activated carbon precursor. The summary of the proximate and ultimate analysis is presented in Table 1.

The yield and the carbon content of ACBGs and ACBPs resulted in this study are larger than activated carbon of pruning mulberry shoot. From the previous study as Wang *et al*. (2010), the maximum yield of activated carbon of pruning mulberry shoot was 38.12% with carbon content was 44.8%.

Surface morphology: Figure 1 presents the comparison of SEM micrographs of raw materials and produced activated carbons. BG (Fig. 1a) presents long and organized surface while the ACGB (Fig. 1b) presents a more irregular shape with more pores. The impregnation with activator and operating conditions of pyrolysis were able to open the raw fibers as expected (Fig. 1b). These results were in accordance to Alves *et al*. (2016). Similar images were also obtained for BS (Fig. 1c) and ACBS (Fig. 1d). More porous and irregular structures were found at the surface of ACBS compared to of BS.

Table 1: Proximate and ultimate analysis for produced activated carbon

		Proximate analysis (% w/w)		Ultimate analysis (% w/w)						
Activated carbon (°C)	Yield (%)	Ash	Volatiles	C	O	Si	P	Zr	Ca	Na
ACBG 400	45.76	10.33	49.88	91.18	8.15	0.11	0.56	-	-	-
ACBG 500	53.22	8.49	76.81	86.27	12.15	0.26	0.68	-	-	0.64
ACBG 600	60.43	7.00	52.00	97.06	1.27	0.29	0.48	0.91	-	-
ACBS 400	45.53	12.95	63.48	90.70	8.13	-	1.16	-	-	-
ACBS 500	43.00	13.70	48.05	87.36	10.83	0.75	1.06	-	-	-
ACBS 600	50.16	9.00	48.00	93.22	3.03	0.74	1.20	1.67	0.14	-

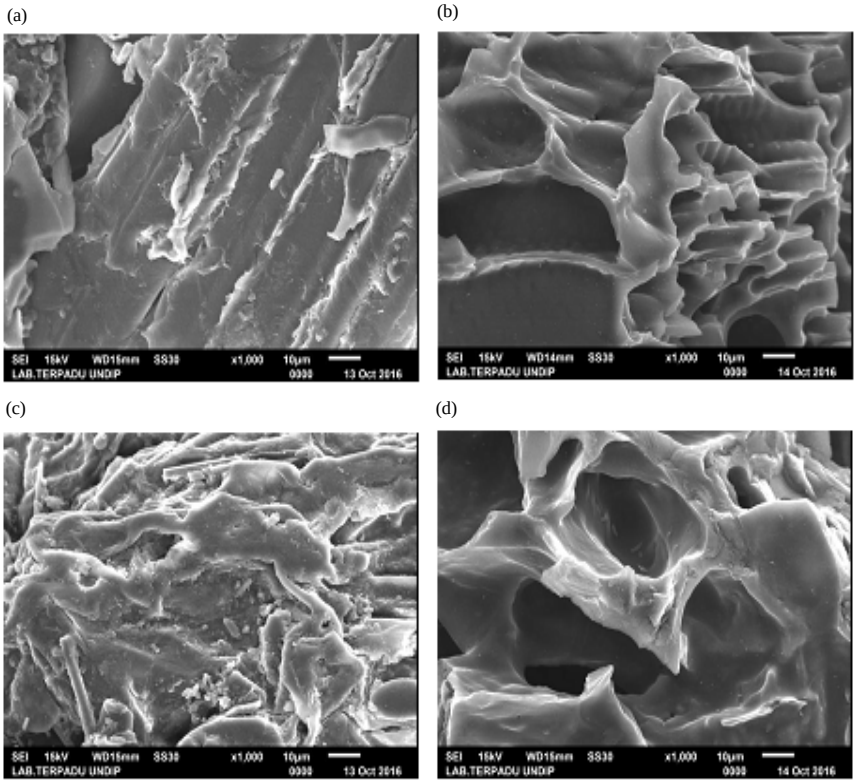

Fig. 1: Left: Scanning electron micrographs of raw material of: a) BG; b) BP. Right: Scanning electron micrographs of activated carbon produced at 600°C of; c) ACBG and d) ACBP

Table 2: Surface area and pore volume of raw materials and produced activated carbons

Samples	Pore volume (cc/g)	Pore radius (nm)	BET surface area (m^2/g)	Micropore area (m^2/g)
BG	0.008	2.6917	0.000	0.000
ACBG 400°C	0.464	2.7288	1,069.997	313.469
ACBG 500°C	0.959	1.7100	785.500	477.900
ACBG 600°C	3.084	1.7050	501.000	0.000
BS	0.021	2.7365	22.421	6.622
ACBS 400°C	0.464	2.7288	862.215	475.351
ACBS 500°C	0.383	2.0130	559.958	346.700
ACBS 600°C	0.464	2.7288	457.729	0.000

Porous structure: Table 2 summarizes the BET surface area, pore volume and average pore size on the samples under study. The results revealed that the total surface area on ACBGs and ACBSs increased due to the impregnation in activator and pyrolysis process. These results were consistent with the more porous formed as mentioned by SEM image. However, the incresed of temperature caused the decreased of surface are.

CONCLUSION

The use of H_3PO_4 as activating agent attributed to the large amount of carbon content and increased the yield of produced activated carbon. The higher the temperature, resulting the higher yield and carbon content. In contrary, higher temperatur affected to the decreased of total surface area. The best performance was achieved at the use of bagasse as activated carbon precursor at temperature of carbonization of 400°C.

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