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Effects of Activation Temperature on Characteristics and Microstructure of Coconut Shell-Based Activated Carbon

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Abstract:*Research has been conducted on the effects of activation temperature variations on the characteristics and microstructure of coconut shell-based activated carbon. The purpose of this study was to determine the optimum activation temperature of coconut shell-based activated carbon and its characteristics and to observe the microstructure morphology. The activation process of coconut shell charcoal is carried out at a temperature variation of 500, 600, 700, 800, and 900 °C with a holding time of 1 hour. The results showed that the optimum activation temperature of coconut shell-based activated carbon was 700 °C. Testing in this condition resulted in 4.86% of water content, 10.84% of volatile matter content, 2.04% of ash content, and 87.12% of carbon content (based on Indonesian National Standard (SNI) No. 06-3730-1995). Morphological observations of coconut shell-based activated carbon showed that pore formation had occurred at a temperature of 900 °C.*

Keywords: *Activation temperature, coconut shell-based activated carbon, and microstructure.*

INTRODUCTION

Indonesia is a tropical country that has abundant natural resources such as coconut (Cocos nucifera) whose utilization is still very open for further study and development, so that it can be utilized optimally. Although almost all parts of the coconut fruit have been used, many are still wasted like coconut husk and shell. Coconut shells are most often used as charcoal and water filters. Coconut shell charcoal is usually processed into briquettes and activated carbon for household, business, and industrial purposes. Compared to charcoal materials, activated carbon is more practical, attractive, and clean. The use of activated carbon from coconut shell charcoal has two advantages, namely for water purification and removal of bacteria in water and as one of the solutions to the problem of coconut shell-sourced environmental waste (Panwara, N.L., S.C, Kaushik, Kothari, Surendra., 2011)

Activated carbon produced by heat treatment is usually used to develop the pore structure present in the charcoal so that the surface area becomes larger and to eliminate volatile constituents while removing the production of tar or impure hydrocarbons in the charcoal (H. Marsh, Francisco R.R., 2006).

In this research, coconut shell-based activated carbon was made. This research was carried out by varying the temperature to get the optimum activation temperature. Then, testing of activated carbon is carried out based on Indonesian National Standard (SNI) No. 06-3730-1995. The parameters tested included water content, volatile matter content, ash content, carbon content, water absorption, and activated carbon microstructure.

MATERIAL AND METHOD

The material used in this study is coconut shell. The equipments used are furnace, digital balance sheet, oven, porcelain crucible, 100-mesh sieve, and Scanning Electron Microscope (SEM) EVO MA 10.

Coconut shells are cleaned from the skin and the remaining coconut meat. The shell is then crushed and dried in an oven at 105 °C for 3 hours. The next process is the carbonization of coconut shell using a furnace at a temperature of 250 °C for 5 hours. Carbonized charcoal is crushed and sieved with a 100-mesh screen. The charcoal held on the sieve is then heated at a temperature variation of 500, 600, 700, 800 and 900 °C with a holding time of 1 hour. Furthermore, the coconut shell-based activated carbon produced is cleaned from ash by washing using distilled water and then dried. Finally, testing of activated carbon is carried out based on Indonesian National Standard (SNI) No. 06-3730-1995. The testing parameters are water content, volatile matter content, ash content, carbon content, water absorption, and activated carbon microstructure.

Water Content

The moisture content of the coconut shell determines the quality of the carbon produced. Activated carbon with low water content will have small pores. Determination of activated carbon water content aims to know the amount of water content evaporated on the activated carbon produced after going through the activation process. Calculation of coconut shell activated carbon water content using the SNI standard No. 06-3730-1995 with the formula:

$$\text{Water Content } (\%) = \frac{a - b}{b} \text{ x } 100\% \quad (1)$$

where, a = mass of original sample (gram) b = mass of dried sample (gram)

Volatile Matter Content

The temperature used in the process of making activated carbon affects the level of volatile matter content. The higher the temperature used, the lower the level of volatile matter content in the carbon produced. Determination of the level of volatile matter content aims to know the amount of substances or compounds that have not evaporated in the process of carbonization and activation. Calculation of levels of volatile matter content using the SNI standard No. 06-3730-1995 with the formula:

$$\text{Volatile Matter Content } (\%) = \left[\frac{(a-b)}{a} \text{ x } 100\%\right] \quad (2)$$

where, a = mass of sample before heating (gram) b = mass of sample after heating (gram)

Ash Content

Ash is the material that remains when carbon is heated to a constant mass. Ash content is proportional to the inorganic content in activated carbon. Determination of ash content aims to know the content of metal oxides in activated carbon. The ash content is the rest of the combustion which does not contain carbon at all. The ash content indicates the amount of residue in the form of minerals that are not lost during the combustion process (Mollah, M.Y.A., Morkovsky, P., Gomes, J.A.G., Kesmez, M., Parga, J., Cocke,D.L., 2004). Calculation of activated carbon ash content using the SNI standard No. 06-3730-1995 with the formula:

$$\text{Ash Content } (\%) = \frac{b}{a} \text{ x } 100\% \quad (3)$$ where, a = mass of original sample (gram) b = total ash mass (gram)

Carbon Content

The carbon fraction in activated charcoal is the result of the process of drying other than ash, water, and volatile substances. The type of coconut shell is very influential on the content of carbon in activated charcoal, due to differences in the chemical content in each type of coconut shell. Determination of carbon content aims to know the carbon content after the carbonization and activation process. Calculation of carbon content using the SNI standard No. 06-3730-1995 with the formula:

$$\text{Carbon Content}\ (\%) = 100\% - (\%\ \text{volatile substances} + \%\ \text{ash}) \quad (4)$$

Water Absorption

The percentage of mass of water that can be absorbed by activated carbon in water is called water absorption. The absorption test refers to ASTM C-20-00-2005. Absorption testing is carried out on all types of sample variations. Soaking time in water is 24 hours at room temperature. The initial mass before and after soaking is measured. The value of water absorption can be calculated using the following formula:

$$\text{Water Absorption} = \frac{M_b - M_k}{M_k} \times 100\% \quad (5)$$

where:

Mb = mass of wet sample (gram)

Mk = mass of dry sample (gram)

RESULTS AND DISCUSSION

Characteristics of Carbonated Carbon

The characterization of activated carbon carried out in this study was to find out and analyze activated carbon with varying heating temperatures. The heating temperature will give different characteristics to the activated carbon. The characterization of activated carbon is carried out using the SNI standard No. 06-3730-1995 which includes physical and chemical properties such as water content, volatile matter content, ash content, carbon content, and water absorption.

Water Content

One of the characteristics of activated carbon that affects the quality of activated carbon is water content. The purpose of determining water content is to find out the amount of water that can be evaporated so that it does not cover the pores of the activated carbon. The water content of coconut shell-based activated carbon produced with varying heating temperatures can be seen in Table 1 below.

TABLE 1: Water content of coconut shell-based activated carbon with varying heating temperatures

No.	Temperature (°C)	Water Content (%)	SNI Standard No. 06-3730-1995 (%)
1.	500	1.91	4.5
2.	600	2.62	
3.4.	700	4.86	
5.	800	9.69	
	900	12.15	

Table 1 shows that the water content increases with increasing temperature. This happens because the higher the temperature the greater the amount of evaporated water as seen at 900 °C with a percentage of water content of 12.15%. The non-constant increase in the percentage of water content is due to the influence of air outside the environment on the manual cooling process (in an open room) so that the active carbon absorbs a lot of water vapor.

Quality requirements for water content of activated carbon according to SNI standard No. 06-3730-1995 is 4.5%. The test results showed that the water content for coconut shell based activated carbon whose value was closest to the standard was 4.86% at a temperature of 700 °C.

Volatile Matter Content

Determination of volatile matter content aims to get the amount of substances or compounds that have not evaporated in the process of carbonization and activation. The volatile matter content of coconut shell-based activated carbon can be seen in Table 2.

TABLE 2: Volatile matter content of coconut shell-based activated carbon with varying heating temperatures

No.	Temperature (°C)	Volatile Matter Content (%)	SNI Standard No. 06-3730-1995 (%)
1.	500	2.84	
2.	600	6.12	
3.	700	10.84	15
4.	800	32.80	
5.	900	38.32	

Table 2 shows that the higher the activation temperature the greater the volatile matter content. The value of volatile matter content is due to the presence of non-carbon compounds that attach to the surface of activated carbon, especially O atoms which are strongly bound to C atoms in the form of CO2 and CO. The non-carbon compound is an impurity that covers the pores of activated carbon, thereby reducing its effectiveness in absorbing contaminants in water.

Quality requirements for volatile matter content of activated carbon according to SNI standard No. 06-3730-1995 is 15%. The test results showed that the volatile matter content for coconut shell based activated carbon whose value was closest to the standard was 10.84% at a temperature of 700 °C.

Ash Content

Determination of ash content aims to find out the content of metal oxides in activated carbon. Ash content is the rest of the combustion which has no carbon element at all. The ash content of coconut shell-based activated carbon can be seen in Table 3.

TABLE 3: Ash content of coconut shell-based activated carbon with varying heating temperatures

No.	Temperature (°C)	Ash Content (%)	SNI Standard No. 06-3730-1995 (%)

1.	500	0.56	
2.	600	1.03	
3.		2.04	
4.	700	3.48	2.5
5.	800	7.24	
	900		

Table 3 shows that the higher the heating temperature the greater the ash content. The value of ash content is caused by the contact of activated carbon with air in the cooling process. As a result, there is a further combustion process where the activated carbon turns to ash.

Quality requirements for ash content of activated carbon according to SNI standard No. 06-3730-1995 is a maximum of 2.5%. The test results showed that the ash content for coconut shell based activated carbon whose value was closest to the standard was 2.04% at a temperature of 700 °C.

Carbon Content

Carbon content in a charcoal has an important role in determining the quality of activated carbon. The purpose of determining carbon content is to determine the carbon content after the carbonization and activation process. The carbon content of coconut shell-based activated carbon produced with varying heating temperatures can be seen in Table 4 below.

TABLE 4: Carbon content of coconut shell-based activated carbon with varying heating temperatures

No.	Temperature (°C)	Carbon Content (%)	SNI Standard No. 06-3730-1995 (%)
1.	500	96.60	
2.	600	92.85	
3.		87.12	
4.	700	63.66	80
5.	800	54.44	
	900		

Table 4 shows that the carbon content decreases with increasing temperature. The decreasing carbon content is influenced by the level of volatile matter and ash content. The higher the level of volatile matter and ash content of activated carbon the lower the carbon content.

Quality requirements for carbon content of activated carbon according to SNI standard No. 06-3730-1995 is 80%. The test results showed that the volatile matter content for coconut shell based activated carbon whose value was closest to the standard was 87.12% at a temperature of 700 °C. As for the temperatures of 500 and 600 °C the percentages are 96.6 and 92.85% respectively, also still meet the quality requirements of activated carbon.

Water Absorption

Water absorption is the percentage of mass of water that can be absorbed by activated carbon in water. This absorption test is carried out on all types of sample variations. This absorption test refers to ASTM C-20-00-2005. Water absorption of coconut shell-based activated carbon can be seen in Table 5.

TABLE 5: Water absorption of coconut shell-based activated carbon with varying heating temperatures

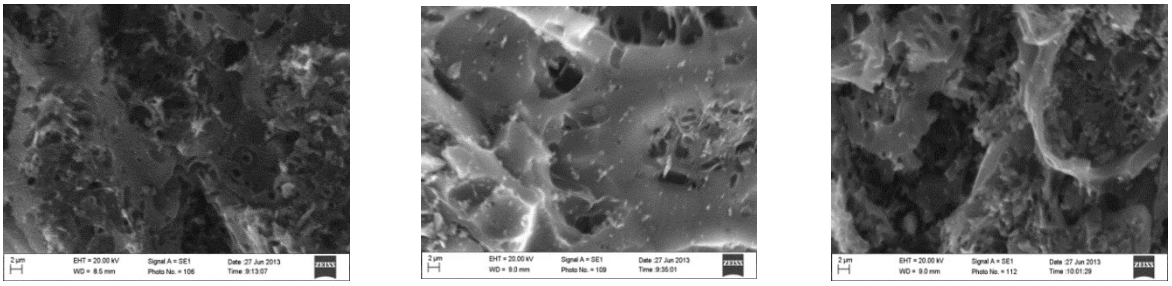
No.	Temperature (°C)	Water Absorption (%)
1.	500	40.56
2.	600	49.25
3.		56.12
4.	700	61.44
5.	800	75.20
	900	

Table 5 shows that the absorption of activated carbon increases with increasing temperature. This is due to the evaporation of impurities on the surface of coconut shell-based activated carbon as a result of the heating process to obtain activated carbon with a high surface area. The greater the surface area, the greater the absorption capacity of coconut shell-based activated carbon. The test results showed that the highest water absorption for coconut shell based activated carbon was 75.20% at a temperature of 900 °C.

Microstructure of Activated Carbon

Characterization of activated carbon microstructure was carried out to observe the surface morphology. Based on the previous results, the parameter values of water content, volatile matter content, ash content, and carbon content that approach the quality requirements of activated carbon according to SNI standard No. 06-3730-1995 is at a temperature of 700 °C. While the highest value of water absorption is at a temperature of 900 °C. Therefore microstructural observations are carried out to get the best activated carbon to be used as a filter in the water purification process. The surface morphology of coconut shell-based activated carbon was observed using Scanning

Electron Microscope (SEM) EVO MA 10 with a magnification of 5000 times. The SEM image can be seen in Figure 1.



(a) (b) (c)

Fig 1: SEM micrographs of coconut shell-based activated carbon with activation temperatures of (a) 500 °C, (b) 700 °C, and (c) 900 °C

The difference in surface morphology of coconut shell-based activated carbon at heating temperatures of 500, 700, and 900 °C is clearly visible. Coconut shell-based activated carbon at heating temperatures of 900 °C shows more distributed pores when compared to activated carbon at heating temperatures of 500 and 700 °C. Large pore size can occur due to the influence of the heating process which causes the decomposition of coconut shell organic compounds. So, the higher the heating temperature, the more pores formed.

CONCLUSION

From the studies that have been done, it can be concluded that the optimum heating temperature of coconut shell activated carbon based on SNI standard No. 06-3730-1995 is 700 °C. This is indicated by the results of testing the water content, the level of volatile substances, ash content, and carbon content. While the optimum water absorption is obtained at 900 °C. Observations on the microstructure of coconut shell-based activated carbon indicate that the formation of distributed pores occurs at a heating temperature of 900 °C.

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