Effect of Carbonization Temperature Variations and Activator Agent Types on Activated Carbon Characteristics of Sengon Wood Waste (*Paraserianthes falcataria (L.) Nielsen*)

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Abstract. The need for Sengon wood is increasing every year. The waste produced by Sengon wood is also high. Sengon wood waste contains lignin by 26.50%. This high lignin content makes Sengon wood waste very potential to be used as activated carbon. Activated carbon is a porous solid containing 85 - 95% carbon. Activated carbon is produced from carbon-containing materials with high temperature heating. The process of making activated carbon consists of dehydration, carbonization, and activation. Chemical activation is carried out using certain chemicals to be mixed with carbon. The purpose of this study is to analyse the effect of carbonization temperature on the quality and characteristics of activated carbon from Sengon wood. The temperatures used are 400, 500 and 600 °C and the types of activator agents used are ZnCl₂, CaCl₂, and CH₃COOH. Tests carried out are water content testing, iodine absorption test and surface area calculation. In this study, the results of carbonization temperature were obtained and the type of activator agent significantly affected the character of the activated carbon produced. The best results are shown by carbon with a carbonization temperature of 600 °C with CaCl₂ activator agent which is a water content of 1.46%, iodine absorption of 1089.5598 mg/g and a surface area of 1201.5688 m²/g.

Keywords: activator agent, activated carbon, carbonization temperature, Sengon wood

1. Introduction

Every year the demand for wood is very high and continues to increase. The need for Sengon wood reaches more than 500000 m³ per year. Sengon wood is a plant that can grow quickly if planted in fertile soil and suitable climate [1]. Sengon wood is widely used for crates, baffle boards, cement foundry in industries, industrial matches, pencils, plywood, woodworking and so on [2]. With the high demand for Sengon wood, the volume of waste produced is also quite high both from logging and waste from the wood processing industry. The utilization of wood waste is also not optimal. One of the uses of Sengon wood waste is activated carbon. The lignin content makes Sengon wood can be used as activated carbon [3]. The need for active carbon continues to increase every year. Demand for domestic and foreign markets for activated carbon is quite large. Activated carbon production in Indonesia is around 200 tons...
per month. This is because activated carbon is widely used in the chemical industry [4]. Activated carbon is a porous solid containing 85-95% carbon. Activated carbon is produced from carbon-containing materials with high temperature heating [5-7]. Stages in making activated carbon from Sengon wood include dehydration, carbonization and activation [8]. Activation can be done chemically with the addition of certain chemicals. According to Ma [9] the quality of activated carbon is determined by several factors including activation time, activation temperature, type of activating material, concentration of activating ingredients and how to activate.

Carbonization causes decomposition of organic material in raw materials and impurities can be removed. This release of volatile elements will create a pore structure. The carbonization process is stopped if it no longer emits smoke. The addition of temperature can be done to speed up the reaction but temperatures that are too high like above 1000 °C can also result in the amount of ash that can close the pore. Surest et al. [10] used a temperature of 300 °C, 400 °C, and 500 °C in the manufacture of activated carbon. The results showed a carbonization temperature of 500 °C and 24-hour activation time was the best treatment. Esterlita and Herlina [11] used 400 °C and 500 °C temperatures for carbonization of activated charcoal from palm fronds and obtained the best treatment at a temperature of 500 °C. A temperature of 400 °C was chosen because at this temperature there was depolymerisation and breaking of C-O and C-C bonds. At this temperature the cellulose will be degenerated, lignin begins to decompose to produce tar, pyrolignite solution and gas CO, CH\textsubscript{4}, and H\textsubscript{2} increase. While at a temperature of 500 °C was chosen because at this temperature there will be decomposition of lignin and the formation of an aromatic layer [12].

Activation can be done physically or chemically. Chemical activation is done by adding chemicals during the activation process. Activators are chemicals that are added to the activation process in making activated carbon. Activators can be either acidic or basic. The addition of chemicals can be in the form of alkali metal hydroxides, carbonate salts, chlorides, sulfates, phosphates from alkali metals and organic acids. Esterlita and Herlina [11] use activator ZnCl\textsubscript{2} in the manufacture of activated carbon from palm fronds. Surest et al. [10] using activator CaCl\textsubscript{2} in making activated carbon from candlenut shell. Suhendra and Gunawan [13] using activator CH\textsubscript{3}COOH in the manufacture of activated carbon from corn stalks.

Based on Indonesia’s national standards, carbon quality can be seen from water content, ability to absorb iodine, and Brunauer-Emmet-Teller (BET) surface area. The purpose of this study was to analyse the effect of carbonization temperature on the quality and characteristics of activated carbon from Sengon wood, analyse the effect of activator on the quality and characteristics of activated carbon from Sengon wood and analyse the surface of activated carbon from Sengon wood with different activation temperatures and activator types using SEM-EDX. From the background above, research will be conducted on the characterization of activated carbon from Sengon wood waste with variations in activation temperature and type of activator agent to be in accordance with the expected Indonesian national standards.

2. Materials and Methods

The materials used in the study include solid waste in the form of Sengon wood from Malang, East Java, activator agent in the form of ZnCl\textsubscript{2}, CaCl\textsubscript{2} and CH\textsubscript{3}COOH, aquades, analysis material in the form of iodine, starch, sodium thiosulfate and standardization solution K\textsubscript{2}Cr\textsubscript{2}O\textsubscript{7}, litmus paper, and filter paper. Tools used in the study include furnaces, ovens, SEM-EDX (TM3000, Hitachi, Japan), analytical scales, 100 mesh screens, porcelain exchange rate, mortar, desiccator, erlenmeyer, glass cupper, measuring pipette and drop pipette, and titration tools. The process of making activated carbon includes several stages [14], namely: (1) the preparation stage of the sample, the raw material is collected and taken for cleaning from dirt and cut to a smaller size; (2) dehydration stage, the process of evaporation of water content contained in the sample using a temperature of 100 °C for 4 hours; (3) the carbonization step is carried out by inserting the sample into the furnace using a temperature of 400 °C, 500 °C and 600 °C for 2 hours. The sample was mashed using mortar and sieved using a 100 mesh sieve, and the sample was stored in plastic clips and glass bottles. Activation process of activated carbon includes several steps.
as follows [15]: (1) carbon soaked using 3 types of chemical activators (ZnCl$_2$, CaCl$_2$ and CH$_3$COOH) with 10% concentration for 24 hours; (2) then the carbon is washed with distilled water until the neutral pH is 7 and the carbon is separated from the solution by filtering it using filter paper, the sample is produced in the form of paste; (3) the activated carbon paste that has been obtained is then dried using a furnace with a temperature of 300 °C for 1 hour. Activated carbon obtained by testing includes: (1) water content; (2) iodine solution absorption; (3) calculation of active carbon surface area; and (4) Scanning electron microscopes-energy dispersive X-Ray (SEM-EDX) imaging [16; 17].

3. Results and Discussion

Moisture content is one of the parameters measured to characterize activated carbon. The activated carbon water content is influenced by the carbonization temperature and the type of activator agent used. In this study the water content produced ranged from 1.46 - 10.24% as shown in figure 1. The lowest water content was found in the treatment of 600 °C carbonization temperature with CaCl$_2$ agent activator which was 1.46%. While the highest water content at 400 °C carbonization temperature without activator agent is 10.24%. This value is in accordance with Indonesia's national standard requirements where the maximum value of water content for powder is 15%. Of the three temperatures, carbon water content without activation has the greatest value compared to the water content that is activated using an activator agent. This indicates that the activator agent is successful in binding to the water molecules contained in the material and the release of the free and bound water content contained in the raw material during the carbonization process [18]. In the carbon produced, the value of water content also decreases with increasing temperature. The higher the carbonization temperature, the more water that is lost during the carbonization process. The low water content shows the free water content and the water bound in the material has evaporated during the carbonization process [19].

![Figure 1](image-url)  
**Figure 1.** Water content of Sengon wood activated carbon with carbonization temperature and differences in activator agent.

Iodine absorption is an important parameter for the characterization of activated carbon. The absorption capacity of iodine shows the ability of carbon to absorb impurities and dyes in the form of solutions. The size of the molecule that is absorbed is smaller than 10 Å. In addition, iodine absorption can give an indication of the number of pores with a diameter of 10-15 Å [20]. The value of iodine absorption in this study ranged from 345.275 – 1089.560 mg/g. The lowest iodine absorption value was found at 400 °C carbonization temperature treatment without activation, which was 345.275 mg/g. The highest iodine absorption value was found at 600 °C carbonization temperature treatment with CaCl$_2$ activator agent which was equal to 1089 mg/g. Activator agents play a role in removing impurities that adhere and cover carbon pores by oxidizing carbon [21; 22]. The pores formed on carbon without activation are only formed in the carbonization process and there is no pore enlargement. This makes
carbon without activation have a lower iodine absorption value. CaCl$_2$ activator is hygroscopic. With its hygroscopic nature, CaCl$_2$ is better able to reduce the moisture content of materials compared to other activators. Moisture will affect the iodine absorption value. Low water content values will make the iodine absorption value produced large. The absorption capacity of iodine produced will be directly proportional to the carbon surface area produced where the greater the absorption capacity of iodine, the greater the surface area of the activated carbon. Absorption of activated carbon iodine of Sengon wood generally increases with the increase of carbonization temperature. According to Wang [4] with rising temperatures the number of iodine increases. Carbonization temperature will have a significant effect on the formation of active carbon pore structure [6].

According to Wang [23] the surface area of activated carbon characterized by BET and using iodine numbers is not much different so that the iodine number method can present surface area. Surface area is an important parameter in determining the quality of activated carbon. The adsorption power of activated carbon itself is closely related to its absorption of iodine solution. The greater the value of iodine absorption, the better the activated carbon will be for adsorption. The surface area of activated carbon produced ranged from 380.77 to 1201.57 m$^2$/g as shown in figure 2. The value of the carbon surface area increases with increasing carbonization temperature and increases occur in each activator agent. The value of the surface area is greater with increasing carbonization temperature. The increase also occurs for each activator agent. The smallest surface area value is found at 400 °C carbonization temperature without activation, which is 380.77 m$^2$/g. The biggest surface area value is found at 600 °C carbonization temperature with CaCl$_2$ activator agent which is 1201.569 m$^2$/g.

**Figure 2.** Surface area of Sengon wood activated carbon with carbonization temperature and different activator agent.

SEM test results will show the surface structure of activated carbon. SEM analysis was carried out in the best treatment and compared with controls (without activation). The carbonization temperature of 600 °C without activator which is the control can be seen in figure 3 (a), (b), (c) and for the best treatment the carbonization temperature of 600 °C with CaCl$_2$ agent activator is shown in figure 3 (d), (e), (f). In Figure 3 (a), (b), (c) shows the activated carbon structure of the 600 °C carbonization temperature control treatment which has a hollow and porous structure but is covered by impurities. Whereas in figure 3 (d), (e), (f) shows the structure of the activated carbon from the treatment of the carbonization temperature of 600 °C with CaCl$_2$ activator agent which shows the pores formed are larger and are not covered by impurities. The pores that are formed can be linked to the absorption of carbon produced. The activated carbon from the 600 °C carbonization temperature control has a lower iodine absorption value than the 600 °C carbonization temperature iodine absorption value with CaCl$_2$ activator. The presence of impurities that still cover the pores causes this to happen.

The result of sengon wood activated carbon will also be tested for composition using SEM-EDX. The carbon tested was a 600 °C carbonization temperature treatment with CaCl$_2$ activator agent and
600 °C carbonization temperature activated carbon without activator agent. The percentage of carbon atoms can be seen in Table 1. The percentage of activated carbon atomic components with a carbonization temperature of 600 °C consists of 90.593% carbon, 8.608% oxygen, and 0.799% calcium. While the percentage of activated carbon atoms with a carbonization temperature of 600 °C with activator CaCl$_2$ consists of 77.289% carbon and 22.711% oxygen. The difference in components shows that the activator agent plays a role in removing other components in carbon. The high carbon content in the control treatment indicates that the carbonization process has been going well where the raw material of sengon wood has broken down into carbon. Decreased carbon content after activation and drying using a furnace at 300 °C for 1 hour due to the reaction of carbon with water vapor so that the remaining carbon decreases. According to Pari [24] if the speed of reaction between carbon and water vapor increases, the amount of carbon remaining will be less. The value of oxygen produced increases from before the activation process and after the activation process. This is because of the activation process that forms functional groups. The functional group is formed because of the interaction of free radicals on the carbon surface with atoms such as oxygen and nitrogen. Much oxygen is chemically bound to the functional group. In addition, functional groups are also affected by the raw material from making carbon itself. Wood is one of the materials that contain a lot of oxygen [25].

![Figure 3. SEM structural imaging of sengon wood activated carbon with 600 °C carbonization temperature (a) 500x magnification (b) 1500x magnification (c) 2000x magnification; and activated carbon with a carbonization temperature of 600 °C with CaCl$_2$ activator agent (d) magnification of 500x (e) 1500x magnification (f) 2000x magnification.](image)

**Table 1.** Percentage of atomic components of activated carbon with carbonization temperature 600 °C

| Atom Components | Control | Activator CaCl$_2$ |
|-----------------|---------|--------------------|
| Carbon (% weight) | 90.593  | 77.289             |
| Oxygen (% weight) | 8.608  | 22.711             |
| Calcium (% weight) | 0.799  | -                  |

4. Conclusions

Sengon active carbon has a characteristic of water content between 1.46 - 10.24%, iodine absorption between 345.275 - 1089.560 mg/g, and active carbon surface area between 380.77 - 1201.57 m$^2$/g. The best treatment was indicated by the value of iodine and the largest surface area of carbon with 600 °C carbonization temperature and CaCl$_2$ activator. The iodine value produced was 1089.5598 mg/g. Carbonized carbon structure temperature of 600 °C and without activator has smaller pores and is covered by impurities. As for the activated carbon temperature of 600 °C and activator CaCl$_2$ have larger pores and fewer impurities. The development of activated carbon from wood waste can support the environmental sustainability.

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