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Synthesis and Characterization of Activated Carbon from Trembesi Tree Stem Biomass *(Samanea Saman)*

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ABSTRACT

Biomass waste is currently being optimized to increase its use value and selling value on the market and reduce the impact of environmental pollution. Trembesi tree trunks (Samanea Saman) are waste often thrown away after being cut down. For this reason, this research has successfully utilized trembles tree trunk waste as active carbon using a KOH activator. The successful identification of active carbon synthesis was characterized using XRD, which showed an increase in crystal size from 9,902 nm to 14,207 nm. Functional group testing showed a relatively increased formation of carbon functional groups. The morphology of activated carbon shows an increase in pore size from 1537.1317 nm to 1597.3977 nm. The resulting surface area was 807,079 m^2/g with an average pore size of 3.886 x 101 Å. These characterization tests provide important information for applying activated carbon on a wider scale.

1. Introduction

The Trembesi tree, also known as the "rain tree," is native to northern South America and has been naturalized throughout tropical regions worldwide. Its adaptability to various environments has contributed to its widespread distribution across tropical areas [1],[2]. The rain tree (*Samanea saman*) is the most important in the Pacific as a shade tree in small bodies of water, along roadsides, parks, and grasslands with a tree height of 15 to 25 meters. Like all trees, the rain tree absorbs CO_2 from the atmosphere during photosynthesis, converting it into oxygen and glucose. This process helps reduce the concentration of CO_2, a major greenhouse gas, in the atmosphere [4],[5]. The rain tree stores the absorbed CO_2 in its biomass (trunk, branches, leaves, and roots). The larger the tree, the faster it grows and the more CO_2 it can sequester. With a lifespan that can extend for many decades, the rain tree continues to sequester CO_2 throughout its life, contributing to long-term carbon storage [6]. The Trembesi tree's CO_2 gas absorption capacity is 28.5 tonnes of CO_2 gas per year with a canopy diameter of 15 meters, able to reduce air pollution due to increased CO_2 concentrations from various combustion vehicles [7],[8],[9].

Large Trembesi tree trunks usually cover roads and disrupt residents' activities. Therefore, the government often destroys them by cutting them down and then throwing them away or burning them. Researchers have widely used Trembesi tree trunks as active carbon. The selection of raw materials for activated carbon production is based on high carbon content, low organic matter content, availability, cost, shelf life, and the possibility of producing a high percentage of activated carbon so that the ash yield is low. Those raw materials are obtained from plants, animals, and minerals, and production is carried out through physical and chemical activation, depending on the type of raw material. Previous results show that the carbon content in raintrees is relatively high and is a good choice as active carbon [5]. Several studies analyzed the elemental composition of stone fruit before treatment and showed that the carbon content was 56.41%, nitrogen, hydrogen, and oxygen were 1.42% and 8.10–33.11%, respectively. Therefore, Trembesi wood has a great opportunity as a raw material for active carbon production [2].

Activated carbon's increasing popularity is due to its versatility, efficiency, and the simplicity of its production process. Its wide range of applications and cost-effective nature make it a valuable material in many industries. Activated carbon is obtained using chemical activators (e.g., H_2SO_4, KOH, Na_2CO_3, H_3PO_4, $ZnCl_2$, and K_2CO_3) and is widely used in various applications, including water and air purification, medical treatments, industrial processes, and environmental remediation [10],[11]. The properties of the activated carbon, including surface area, pore size distribution, and adsorption capacity, can be substantially influenced by the chemical activator type and the activation procedure. This enables customization to meet the specific requirements of a particular application. The larger the pores and surface area, the greater and wider the range of its application in the industries. Chemical activation of charcoal by using KOH was very effective in expanding pore sizes to micropores and favoring the formation of surface oxygen functional groups [12]. The utilization of Trembesi tree trunks as active carbon is limited so far. This study proposes synthesizing and characterizing active carbon from Trembesi tree trunk waste. The preparation and characterization of Trembesi tree trunk waste are considered to optimize its potential as an active carbon with good specification in terms of morphology, crystallinity, and surface area.

2. Research Methodology

2.1. Materials

The materials used in this research were trembesi tree trunks as a source of active carbon, KOH (Merck, distributor Darmstadt Germany) as an activator, and distilled water used to remove KOH residues in active carbon.

2.2. Procedures

1) Preparation of Raw Materials

The trembesi tree trunk is defended and cut into smaller sizes, then dried in the sun for a while. Next, a carbonization process was carried out at a temperature of 800°C for 3 hours to obtain trembesi charcoal. The carbonized charcoal is ground using a mortar and then sieved using a 200 mesh sieve.

2) Activated Carbon Preparation

Weight 10 grams of trembesi charcoal, then add 150 mL of 3M KOH and soak for 48 hours. After that, filtering was carried out while washing with distilled water until the pH was neutral. The resulting accompaniment was then dried in an oven at 80ºC for 4 hours. The activated carbon obtained is stored at room temperature in a closed and dry place.

3) Activated Carbon Characterization

a) X-Ray Diffraction (XRD)

XRD testing was carried out using a PANalytical for amorphous particles; the XRD peak appears sloping, whereas it will show a sharper peak for crystalline particles.

b) Fourier Transform Infrared Spectroscopy (FTIR)

Samples were tested using an FTIR tool, Thermo Scientific, Nicolet iS10, which aims to determine the functional groups present in the sample. Tests were carried out in the transmission range of 4000-400 cm^{-1}.

c) Scanning Electron Microscopy (SEM)

The surface morphology of the trembesi charcoal and activated carbon samples were carried out using an FEI Inspect S40 type SEM. The results of the interpretation of the electron beam are observed as material microstructure so that they are used in analyzing particle morphology and surface pores.

d) Surface Area Analyzer (SAA)

Physical characteristics in the form of surface area (m^2/g) can be determined through nitrogen adsorption-desorption isothermic analysis at 77 K using the BET (Brunauer-Emmet-Teller) method (Quantachrom type NOVA 1200e), while the BJH method (Barrett, Joyner, and Halenda) is used to determine the pore size distribution.

Fig. 1. Synthesis Activated Carbon

3. Results and Discussion

3.1. Activated Carbon

The carbonization of trembesi tree trunks into trembesi charcoal at high temperatures is a phase that increases the carbon content, removes non-carbon species, and releases volatile compounds from the carbon surface. So, this process will produce large quantities of carbon content [13]. The next step is to activate the trembesi charcoal into active carbon, using chemical activation with the precursor KOH. Overall, the activation process can be shown in the following reaction equation [14], [15], [16]:

$$4KOH + C_f \rightarrow K_2CO_3 + K_2O + 2H_2 \quad (1)$$
$$K_2CO_3 + 2C_f \rightarrow 2K + 3CO \quad (2)$$
$$K_2O + C \rightarrow C - O - H + KOH \quad (3)$$
$$C - O - K + K_2O \rightarrow C - O - H + KOH \quad (4)$$

The stage of forming activated carbon mixed with a chemical solution will cause oxidation, which damages the inside of the carbon, thereby increasing the pore volume, the pores' diameter, and the activated carbon's porosity [13]. During the activation process, in the first stage, the unorganized carbon is removed, thereby exposing the lignin to the action of the activating agent and leading to the development of a microporous structure [17]. In the final phase of the reaction, the existing pores widen or become large. Large pores are formed when the walls between the pores are completely burned. This results in an increase in the transition of pores and macroporosity while the volume of micropores decreases. So, the extent to which the carbon material is burned or the degree of activation is an important measure in producing activated carbon [18]. The resulting activated carbon was then tested for crystallinity using XRD, functional groups using FTIR, morphological analysis using SEM, and surface area testing using the BET method.

3.2. Characterization

1) Crystallinity Analysis

Crystallinity analysis used X-ray diffraction to analyze the crystal structure formed in samples of trembesi charcoal and activated carbon of trembesi. The results of the XRD diffractogram Fig. 2. reveal that trembesi charcoal and activated carbon contain potassium compounds with high crystallinity before and after activation. Overall, the peaks that appeared in trembesi charcoal and trembesi activated carbon did not experience significant differences. This could be because the activation process is carried out only by soaking in KOH without heating. The test results show the presence of hexagonal carbon in trembesi charcoal, namely °2Th = 43.3710 and 48.6206, and active carbon at °2Th = 43.3154; 48.6091; and 64.8727 which corresponds to mp-48. Other peaks also appear for trembesi charcoal and activated carbon at °2Th = 23.2000 and 43.3710 and °2Th = 23.1572 and 43.3154, which show a graphene-like pattern.

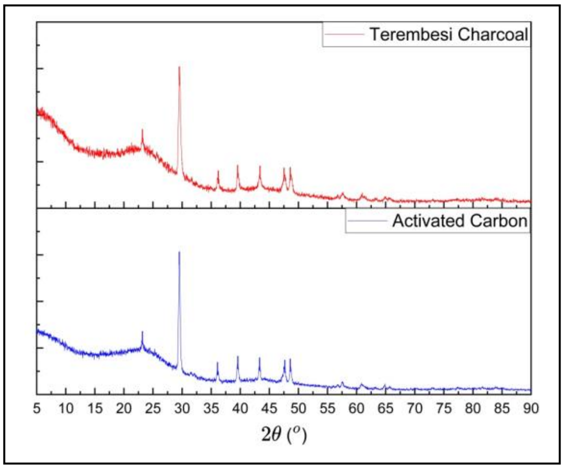


Fig. 2. Results of XRD testing of trembesi charcoal and activated carbon

The average crystal size analysis results show an increase of 9,902 nm to 14,207 nm. In addition, there was an increase in %crystallinity from 19.35 to 21.31. This increase in crystal size shows regularity in the activated carbon material, so it will increase its ability when applied.

2) Functional Group Analysis

Functional group analysis was conducted to determine the changes that occurred during the activation process from trembesi charcoal to activated carbon. The research results showed that peaks appeared for trembesi charcoal at wave numbers (cm^{-1}), respectively 2112.94 (C≡C), 1417.05 (C-O carboxyl group), and 872.55 (C-H aromatic structure). For active carbon, peaks appear in the area 2112.79 (C≡C), 1540.92 (C=C), for the aromatic ring), 868.60 (C-H aromatic structure), and 672.30 (C=C alkene) [14], [19]. From these results, we can see that, after the activation process, new peaks appear at 1540.92 and 672.30, which shows that the amount of carbon formed is greater, which is supported by the disappearance of the C-O group at the wavelength 1417.50 (see Fig. 3.).

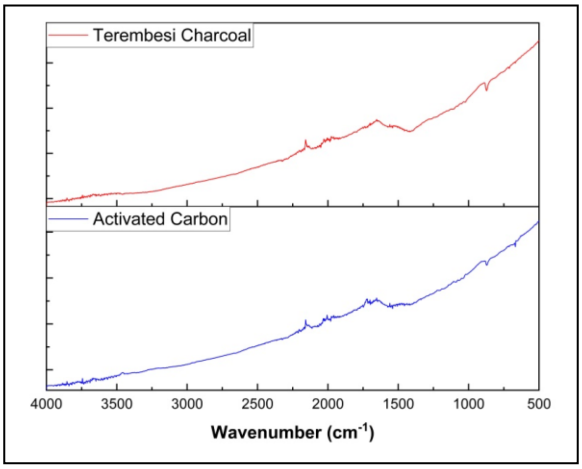
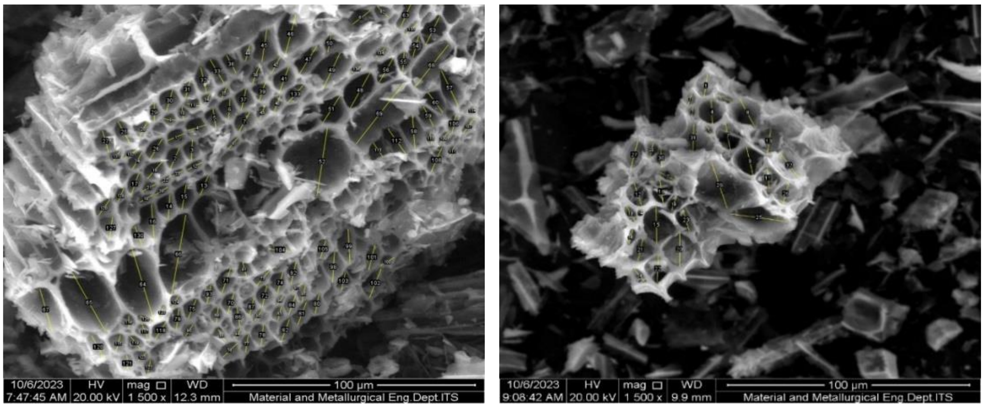


Fig. 3. Results of functional group analysis of trembesi charcoal and activated carbon

3) Morphology Analysis

Morphology testing of trembesi charcoal and activated carbon was carried out to determine the surface shape of trembesi charcoal and activated carbon using Scanning Electron Microscopy. The test results are shown in Fig. 4.



(a) (b)

Fig. 4. Results of morphological testing of (a) Trembesi Charcoal and (b) Activated Carbon

Based on the image above, it can be seen that the morphology of trembesi charcoal already has pores before the activation process occurs. If we look at the morphology of activated carbon from coconut shell charcoal [20], [21], the formation of pores on the surface of the activated carbon from Trembaesi tree trunks has a more uniform shape, with the pores being more clearly visible. This could happen because the trembesi tree has been functioning as a CO_2 absorber from the air, so many pores have been found. For Fig. 4.(a), the trembesi charcoal is lumps with scattered pores with an average diameter of 1537.1317 nm. After the activation process, the activated carbon (Fig. 4.(b)) shows smaller chunks and some of the chunks appear to have been crushed, with an average diameter of 1597.3977 nm. This increase in diameter shows that the activation process can increase the pore size to be applied as a water purifier or composite material [14].

4) Surface Area Analysis

According to previous research [22], activated carbon, which has good absorption capacity for various molecular sizes, must have a large pore surface area. Therefore, it is necessary to test the surface area of activated carbon using a Surface Area Analyzer instrument with the Brenauer Emmet Teller (BET) method to measure a certain surface area. The most common adsorbent used in BET analysis is nitrogen (N2-BET analysis), which is liquid at the boiling temperature of nitrogen (77 K). The test results show that the surface area of activated carbon is 807.079 m^2/g with a pore diameter of 3.886 x 101 Å. Compared with research conducted by previous research [21], the surface area obtained from the research is much smaller; this may be due to the small amount of KOH activator used, so the activation process has not gone well.

4. Conclusion

This research has succeeded in synthesizing active carbon from trembesi tree trunk waste using a KOH activator, supported by XRD, FTIR, SEM, and surface area results. The successful synthesis of activated carbon can be applied as a water purifier, absorbent, water filtration, and composite material.

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