Characteristics of Microactive Carbon from Bamboo Var. Petung as Adsorbent

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Abstract. Bamboo has unique characteristics, such as in the carbonization process at a temperature of 500°C, the carbon characteristics is homogeneous. The characteristics of bamboo have great potential as a future bio-energy resource. Apart from being a bio-energy source of bamboo can also be used as an adsorbent material in the form of activated carbon. Activated carbon is the most inexpensive and easy to produce adsorbent material. One of the activated carbons of bamboo materials used is the micro-activated carbon from bamboo. Microactivated carbon bamboo has a pore structure which is good for adsorption because of its surface area being much better than the other adsorbent, mainly on mesopore and micropore pore size. The purpose of this research is to make micro-activated carbon adsorbent bamboo var. petung and to analyze their characteristics. The characteristic of microactive carbon was analyzed by SEM EDS and Iod number. The result showed a variation in pore size from 1µm to 11.157µm. The surface area of micro-active carbon of 200 mesh and 80 mesh is 1954.95 m² g⁻¹ and 1516.34 m² g⁻¹.

1. Introduction

Charcoal and activated carbon made from bamboo is a very promising product. Bamboo charcoal and bamboo activated carbon is a good product for moisture control because it has a specific surface area and large pore volume. Bamboo is composed of cellulose and lignin. Cellulose in petung bamboo has a homogeneous fiber and its lignin is a pore matrix. The characteristics of this bamboo have great potential as a future bio-energy resource in China [1]. The carbon characteristics of petung bamboo is homogeneous and the highest calorific value produced on bamboo petung by using argon gas at carbonation process with a temperature of 500°C are 10924 Cal g⁻¹[2].

Activated charcoal is an amorphous carbon material having a very large surface area of 200 to 2000 m² g⁻¹. Activated charcoal has better absorption and surface area than other adsorbents. The pore structure of the active charcoal causes the ability to absorb water [3]. The activated charcoal consists of two types: the activated charcoal of the liquid phase and the gas phase. The liquid phase activated charcoal is usually a very fine powder, whereas gas phase one is usually granular or hard pelleted. The main characteristic that distinguishes these two types of adsorbents is the distribution and size of the pores. The liquid phase carbon has a surface area almost equal to the gas phase but the liquid phase carbon has larger number of pores in the transition area (mesopore), with the pore volume between 0.2-10 mL g⁻¹ while in the gas phase is 0.15-0.5 mL g⁻¹ (micropore) [4]. The materials typically used
commercially for liquid phase carbon are charcoal, sawdust, lignite and fly ash. The active bamboo charcoal pore structure looks like figure 1[5].

![Figure 1. Activecharcoal pore structure](image)

Most of the pores in activated charcoal in the form of pellet or granular pore structure are macro pore while they in the form of powder structure are usually mesopore and micropore. The activated charcoal pore structure of macropore is not well used in alcohol purification because of its small surface area and relatively short contact time. The process of carbonation and activation greatly affects the quality of activated carbon produced [4]. The purpose of this research is to study the making and characteristic of activated charcoal bamboo charcoal with carbonation and activation temperatures of 300°C and 600°C, respectively.

2. Materials and Methods

2.1. Materials
The material used in this study was bamboo petung.

2.2. Preparation of charcoal
The bamboo was cut into 1-cm cubes, placed on a porcelain plate and then put into the furnace with temperature of 300°C for 3 hours. Subsequently, the charcoal produced was washed by aquades and then dried in drying oven at temperature of 110°C for 1 hour.

2.3. Activation of charcoal
Activated charcoal making consists of three stages of process, namely pretreatment, carbonation and activation [6]. The purpose of activation is to enlarge the size of the active charcoal pore and the wider surface area so that the absorption improves. The activation process was performed at an atmospheric fixed bed reactor. The reactor is equipped with N₂ gas inlet and heater. The reactor schematic is shown in figure 2.

![Figure 2. Atmospheric fixed bed reactor](image)
2.4. Scanning electron microscopy (SEM)
Structure and area of pore diameter of adsorbent using scanning electron microscope (JEOL, Ltd, Japan, Model JSM 6510LA). The active charcoal sample will be scanned in the form of active charcoal powder. Sample is inserted into vacuum tube with voltage 20kV with distance of 10 mm. For SEM that has a vacuum condition, the resulting image contrast depends on the topography; by varying the orientation of the specimen to the signal detector a dark light effect can be produced to form a three-dimensional image.

2.5. Iod-Number Test
The surface area is measured by iodometric titration method. The principle of this titration is the number of milligrams of iodine adsorbed by one gram of activated charcoal. The absorption of activated charcoal against iod indicates the ability of activated charcoal to adsorb low molecular weight components [7]. The resulting iod number is a representation of the surface area of the activated charcoal. The correlation of the linear regression equation refers to ASTM D-4607-94[8] with the following equation:

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\text{activated charcoal surface area} = \frac{\text{Iod number} - 174.34}{0.6366}
\]

The process of the carbonization and activation process to the analysis phase is shown in figure 3.

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**Figure 3.** Carbonization and activation charcoal bamboo process
3. Results and Discussion

3.1. Carbonization and activation
The process of carbonizing bamboo samples was performed at 300°C for 3 hours. Bamboo charcoal product averages 30% of the sample's initial weight. This mass loss occurs due to several factors such as moisture content and ash content of the samples used in the process of carbonization in the furnace. The mass loss increases with increasing carbonization temperature [4]. The carbonized bamboo is then washed with purified water and then dried in 110°C oven for 1 hour. Subsequently, they are crushed and sieved manually by using 80 and 200 mesh sievers. A sample of 10 g of each charcoal powder was put into the reactor. Then, for activation process the procedure described in table 1 was performed.

| Temperature (°C) | Time (minute) | Action | Observation |
|------------------|---------------|--------|-------------|
| 30               | 5             | N\(_2\) started to flow into the reactor with a rate of 140mL min\(^{-1}\) | - |
| 30-200           | 10            | Heater was turned on with a rate of 10°C min\(^{-1}\) | water vapor started to come out marked by the exit of smoke smoke came out increased |
| 200-400          | 20            | Heating rate of 10°C min\(^{-1}\) | more smoke and stopped at temperature of 600°C |
| 400-600          | 20            | Heating rate of 10°C min\(^{-1}\) | |
| 600              | 60            | Keeping the temperature at 600°C for 1 hour | No smoke |
| 600-200          | 30            | Turning off the heater and constantly draining nitrogen gas | Temperature decreased |
| 200-30           | 30            | Turning off the reactor and discharging sample | No smoke |

Table 2 shows the mass reduction due to activation process. The mass reduction was related to the volatile substances which was still exist despite experienced the carbonization process. The washing process after activation process was suspected to influence the mass reduction, since the dirt occupying the pores was removed in this process.

| Size(mesh) | Mass before activation(g) | Mass after activation(g) | Mass reduction (%) |
|------------|----------------------------|--------------------------|--------------------|
| 80         | 10.0                       | 7.5                      | 25                 |
| 200        | 10.0                       | 4.0                      | 60                 |

3.2. Surface area
The surface area of activated charcoal as an adsorbent is very important. Activated charcoal is said to be a good adsorbent when it has a large surface area. The surface area is measured using the iodine number method. The calculation result obtained by the amount of iod from the active charcoal size 80 and 200 mesh was 1139.64 mg g\(^{-1}\) and 1418.86 mg g\(^{-1}\). The surface area of activated charcoal is calculated by referring to the linear regression equation in ASTM D-4607-94[8]. The surface area of each sample size is 1516.34 m\(^2\) g\(^{-1}\) and 1954.95 m\(^2\) g\(^{-1}\)[9,10]. Activated carbon that has high absorbency to iodine means having a large surface area and a larger micropore and mesopore structure [11]. The carbon content of the sample used is quite high, between 86.1 to 95.4% with diameters between 1μm to 11 μm. The pore structure image and carbon element content by SEM test are presented in figure 4.
The sample obtained was mostly rich in carbon followed by oxygen, which indicates that pyrolysis enriches the carbon content by eliminating non-carbon species [10].

4. Conclusions
This study demonstrated that bamboo var. petung may be used to prepare micro-active carbon via pyrolysis and activation. Optimum conditions for preparing micro-active carbon from char include activation temperature of 600° C activation time of 60 min. This conditioning can produce a high carbon micro-active surface area of 1954.95 m² g⁻¹. Subsequent activation at 600°C for 60 min is recommended.

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