Proximate and morphology properties of swat bamboo activated carbon carburized under different carbonization temperature

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Abstract. Activated carbon (AC) has an important role in many life fields. It has high porosity and very useful for gas mixtures separation and purification of air and water. Every application requires specific properties of AC. Characteristics of AC are strongly influenced by raw material and parameters of manufacturing process. This paper is focused to characterize of activated carbons (ACs) derived from swat bamboo (Gigantochloa verticillata) which is manufactured under different carbonization temperatures. Prepared samples of swat bamboo were carbonized by heating variations of 550, 650 and 750°C and held at such temperature for 1 hour. Char yielded is powdered and meshed to maximum grain size of 250 μm and then physically activated by heating up to 800°C, held for 1 hour by flowing of 150 mL / min nitrogen. The results show that there was an increase in fix carbon and carbon contents from raw material to char and from char to ACs yielded; there were a little bit increase of fix carbon and carbon contents proportional to increasing of carbonization temperature. The maximum fix carbon (74.73%) and C (75.52) were obtained at carbonization temperature of 750°C. SEM observation showed that there has been a change in the morphology microstructure from raw material to activated carbons, wherein the ACs the pores structures clearly can be observed.

1. Introduction
Activated carbon (AC) is material having high adsorption capacity [1] due to its high porosity [2] and very large surface area [3]. Due to its specific characteristics, Activated Carbons (ACs) are widely used to storage of gas [4-8], to purify the various types of pollutants from industrial waste [5] and waste water [9], to separate of heavy metals [10], to be used as supercapacitor cathode material [11] and others. Coal is raw material generally used to produce ACs, however due to it is a non-renewable material make it becoming has relatively expensive price [12]. Today, it has been widely developed ACs from other resources for AC raw material alternative, such as biomass. Some biomass sources have been used as AC such as palm [13], coconut shell [14-15], and bamboo [5, 13, 16-20].

Bamboo is widely studied as a raw material source for production of activated carbon. Bamboo has some advantages as AC source such as very fast growth and matures in three years [18]; it is very easy to be found in a huge volume; and its chemical composition is very suit for AC. Bamboo has lignin, cellulose and hemicellulose contents more than 90% of its total mass. Generally, bamboo contains of 40-50% alpha cellulose and lignin content in the range of 20% to 26% [19]. Elemental analysis show that bamboo has carbon content around 48.64 % and nitrogen, hydrogen and sulphur contents are low 0.14 %, 6.75% and sulphur 0.11 %, respectively [20]. Bamboo can be converted into activated carbon through carbonization and activation processes. The aim of carbonization is to increase carbon content of material by reducing non-carbon elements by use of thermal decomposition [21] and to produce initial porosity in the char [22]. In order to develop advanced and high porosity of activated carbon, the char yielded at the carbonization stage is activated through physical or chemical activation [7]. Parameters of carbonization are one of factor can affect the characteristics of ACs. In this paper, properties of activated carbon prepared from swat bamboo with different carbonization temperatures were investigated. The properties of activated carbon to be observed were the content of ash, volatile, fix carbon, moisture, carbon (C), hydrogen (H), nitrogen (N) and morphology microstructure.
2. Method
The swat bamboo was cut into approximately small pieces of 1 x 1 x 1 cm and dried under the sunshine for 10 days. The samples were then dehydrated by heating in the electric furnace for 1 hour at a temperature of 110°C. Carbonization was carried out by heating up to temperatures of 550, 650 and 750°C and soaking during 1 hour. The char yielded was powdered with maximum grain size 250 μm and physically activated by heating up to 800°C, held for 1 hour by flowing of 150 mL/min nitrogen. The ACs produced were signed as 550F1, 650F1 and 750F1 for carbonization temperatures of 550, 650 and 750°C respectively. Proximate test (TGA 701), elemental analysis (CHN628S), Van Soest Analysis and SEM observation were conducted in order to find out of parameters of proximate test (ash, volatile, fixed carbon, moisture and carbon), elemental contents (C, H, N), chemicals composition of swat bamboo (lignin, hemicellulose, cellulose) and morphology microstructure, respectively.

3. Results and discussion
3.1. Chemical compositions of swat bamboo
Figure 1 presents the chemical composition of swat bamboo. As shown in figure 1, cellulose (44.22 %), lignin (22.99 %) and hemicellulose (14.97 %) are the main chemical contents of swat bamboo. This cellulose content is closed to cellulose content of Japanese bamboo (43.30 %) as reported by Scurlock et al [23] and closed to cellulose content of 4 types of Guadua bamboo (37 – 44 %) [24]. Cellulose and lignin have significant contribution to final carbon content of AC and porosity formed. Cellulose content is associated with producing of AC micropores structure and lignin content is related with formation of AC macropores structure [25].

![Figure 1. Chemical compositions of swat bamboo](image)

3.2. Proximate and elemental analysis
Table 1 and 2 exhibits the proximate and ultimate analysis of sawt bamboo, char and activated carbons produced, respectively. Fix carbon of raw material (1.99 %), as shown in table 1, has improved significantly after carbonization and activation processes. There are an increase of 97.10 % and 97.33 % in average of fix carbon content from swat bamboo to all chars and ACs produced, respectively. The increase of fix carbon is due to conversion process of volatile become fix carbon during carbonization and activation processes [26]. However, the ash content yielded for all ACs produced are relatively high so having potency will produce low porosity and surface area. The highest fix carbon (74.49 %) is obtained when raw material is carbonized at 750°C. Elemental analysis also shows that C content of swat bamboo increases significantly after carbonization and activation, as shown in table 2. This is due to separation of elements such as H, N and O from fix carbon during elemental analysis. The highest C content (75.52%) is also gained at carbonization temperature of 750°C.
Figure 2 illustrates the fix carbon and carbon contents of swat bamboo, chars and ACs produced at variation of carbonization temperature. It can be seen that fix carbon and carbon contents increase proportional to increasing of carbonization temperature although the increase is very small. This is probably due to that pyrolysis process of swat bamboo has completed at 500°C, meanwhile the lowest carbonization temperature applied in this carbonization is 550°C. First decomposition occurs at hemicellulose (200-260°C), followed by cellulose at 240-350°C and next lignin at 280-500°C. However, the uniform of lignin decomposed can be slowly from ambient temperature to 900°C. This gives probability that fix carbon and carbon contents will improve significantly when carbonization temperature used is upper then 750°C. Table 1 also show that increasing of temperature carbonization also affects improving of moisture and ash of char, but decreasing of volatile content. For ACs produced, the higher carbonization temperature the higher fix carbon and carbon contents obtained, the lower moisture yielded and no trend to be found at volatile and ash.

| Samples | Moisture [%] | Volatile [%] | Ash [%] | Fix carbon [%] |
|---------|--------------|--------------|---------|----------------|
| Swat bamboo | 7.86         | 88.32        | 1.85    | 1.99           |
| Char 550 | 5.40         | 14.92        | 12.51   | 67.17          |
| Char 650 | 6.03         | 10.65        | 13.56   | 69.76          |
| Char 750 | 7.86         | 8.58         | 14.33   | 69.23          |
| 550 F1   | 2.86         | 8.36         | 14.33   | 74.45          |
| 650 F1   | 1.96         | 8.6          | 14.95   | 74.49          |
| 750 F1   | 1.61         | 7.75         | 15.92   | 74.73          |

Table 1. Proximate analysis of swat bamboo, chars, and ACs

| Samples | C [%] | H [%] | N [%] |
|---------|-------|-------|-------|
| Char 550 | 71.48 | 2.51  | 1.19  |
| Char 650 | 72.32 | 1.88  | 0.92  |
| Char 750 | 71.21 | 1.27  | 0.77  |
| 550 F1   | 74.70 | 0.56  | 1.09  |
| 650 F1   | 75.31 | 0.34  | 1.08  |
| 750 F1   | 75.52 | 0.37  | 1.01  |

Table 2. Elemental analysis of swat bamboo, chars, and ACs

Figure 2. Comparison of the fixed carbon and C contents of swat bamboo, chars, and ACs
3.3. Morphology microstructure
Morphology microstructure of swat bamboo and ACs produced are illustrated in Figures 3 to Figure 6. Figure 3 shows the surface structure of raw material (swat bamboo) that is no structural porosity can be observed. This is due to the swat bamboo is still containing of original chemical composition that trough pyrolysis such chemical composition will be decomposed so that the porosity start to be formed and will be advanced and expanded during activation process. This is shown in Figure 4, 5 and 6 for 550F1, 650F1 and 750F1 respectively, where all of ACs manufactured have possessed porosity. However, it is not clear can be distinguished the porosity of ACs activated with different carbonization temperature. This due to SEM observation shows the qualitative data. The advance analysis (surface area analyser) is needed to find out the quantitative data such as pore volume, surface area and pore diameter so the difference properties of ACs due to applied of different carbonization temperature can be accurately compared.

![Figure 3. Morphology microstructure of swat bamboo](image1)
![Figure 4. Morphology microstructure AC carbonized at 550°C (550F1)](image2)
![Figure 5. Morphology microstructure AC carbonized at 650°C (650F1)](image3)
![Figure 6. Morphology microstructure AC carbonized at 750°C (750F1)](image4)

4. Conclusion
Carbonization temperatures give different properties of ACs produced. Increasing of carbonization temperature creates higher fix carbon and carbon contents, although for temperatures of 550, 650 and 750°C their increase is very small. On the other hand, in this case, the higher carbonization temperature the lower of moisture obtained. AC requires the high fix carbon and carbon contents so that AC produced at carbonization temperature of 750°C is considered as the best result due to the highest fix carbon (74.73%) and carbon (75.52%) are gained. Observation of morphology microstructure show that clearly can be seen that structural porosity has been formed after
carbonization and activation processes. This porosity is specific property of AC making it having ability to adsorb or absorb a substance.

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