Effect of Heating Time to Density, Hardness, and Resistivity Against Fungus of Yellow Bamboo (Bambusa Vulgaris Var Schard. Vitata)

A.H. Dawam Abdullah¹, Saukani Nasution²
¹Research Unit for Clean Technology, Indonesian Institute of Sciences, Bandung, Indonesia
²Department of Physics, UIN Sunan Gunung Djati, Bandung, Indonesia

Abstract. It has been studied the influence of heating process to the density, hardness and resistivity against fungus of Yellow bamboo (Bambusa Vulgaris Var Schard. Vitata). Structure of bamboo is identified by optical microscope. Bamboo is heated at 100 °C with variation of heating time: 0, 1, 2, 3 and 4 hours. Density of bamboo is measured by using pycnometer, whereas hardness is measured by using a Rockwell Hardness Type- R (HRR). Resistivity against fungus is observed by naked eye. OM image shows that bamboo consist of hollow structures wherein the water is stored. The diameter of vascular at inner part (~ 150 µm) is quite larger than outer part (~50 µm). Heating time of one hour caused density decrease by about 39%, whereas heating four hours will decrease by 52%. The longer heating time, the hardness of bamboo is increased. For the longitudinal side, two hours heating increased hardness up to 31%. For tangential side, four hours heating time increased hardness until 82%. Furthermore, heating time 3-4 hours will persist bamboo from fungus attack more than 14 days.

Keywords: bamboo, density, hardness, fungus

1. Introduction
Bamboo is one of the plant that easily to be cultivated in Indonesia and has been widely used for various purposes like traditional houses, furniture, or musical instrument. The price of bamboo is relatively cheap compare with previous commodities such as wood, because the quantity of bamboo is so abundant. It’s due to growth-time of bamboo is fairly quick, in a matter of 4 years bamboo is ready to be harvested. Moreover, time processing to become finished goods is relatively short, so it made bamboo more attracted in industrial manufacture.

Yellow bamboo (Bambusa Vulgaris Var Schard. Vitata) is one type of bamboo that has a cylindrical shape, hard-walled culm, light, and good mechanical strength. Yellow bamboo is easy to breed because it has fast growth. Some potential of yellow bamboo are as decoration in yard and furniture. However, the properties of Yellow bamboo mostly will be determined by its water content [1] Generally, the less water content in the bamboo, the better bamboo properties [2].

Bamboo culm consist of cells, fibers and parenchyma with a percentage of 10%, 40%, and 50% respectively [2]. Beside that, bamboo’s culm also contain an empty space called vascular. Chemistry of bamboo culm consist of lignin, pentose, and holoselulosa with a percentage of 20-25%, 30%, and 50-70% [3]. Combination of these structure and chemistry caused water likely to be stored in bamboo’s culm (hidrophilic). Those maybe caused a drawback in mechanical properties of bamboo. Moreover, high water content could accelerate growth of fungus that can initiate the destruction of bamboo culm. So this researched is aimed to enhance mechanical properties of bamboo by address the heating for
reducing water content where evaluation of density, hardness, and fungus growth has not been done before.

2. Materials and methods

2.1 Materials

Yellow Bamboo that was studied is obtained from Bandung area, West Java, Indonesia (Figure 1). The age of bamboo is around 3 years. Sample for experiment is taken from the bottom part.

2.2 Morphology analysis

Bamboo’s morphology is identified by using optical microscope (MeijiTechno MT6000). Observations were made on the cross section of bamboo. Bamboo is being cut and sliced bamboo is observed. Identification of bamboo is conducted in the 3 area the inner, middle, and outside areas.

2.3 Density test

Bamboo was cut with dimension of 2 x 0.5 x 0.5 cm. Then bamboo was heated 100°C by oven with five variations time: 0, 1, 2, 3, and 4 hours. For each bamboo, the density was measured by using pycnometer with principle similar to the Archimides. Density test for each specimen is performed three times.

2.4 Hardness test

Yellow bamboo is being cut into two categories: 3 x 3 x 3 cm and 3 x 3 x 2 cm as presented in Fig.2. The former category is for tangential side measurement, and the rest is for longitudinal side measurement. After cut then bamboo is heated with variation: 0, 1, 2, 3, and 4 hours. And Then bamboo is measured by using rockwell hardness tester type R (HRR). Hardness for each sample is measured five times repetition.

2.5 Resistivity against fungus

Slicing of bamboo by heating time variation is observed by naked eye. Initial time for fungus growth is recorded. All sequence of experiment including morphology analysis, density measurement, hardness test and resistivity against fungi are presented in Figure 2.
3 Result and discussion

3.1 Morfology of Bamboo

Morfology of bamboo is presented in Figure 3. Figure 3 shows a cross section of bamboo culm. The vascular of bamboo is marked by white circular area which are represent the hollow structure in culm. The area surrounding vascular consist of fiber and parenchyma which is represented by orange color area [4]. The image shows that diameter of vascular at inner part (~150 µm) is quite larger than outer part (~50 µm). The vascular is the most water storaged because it is a water channel from bottom to top bamboo. So Inner part will the more water than outer part so that the inner side of bamboo will be softer than outer side.

![Figure 3 Morfology of Bamboo](image)

3.2 Bamboo’s Density

The density of bamboo corresponding to heating time is presented in Figure 4. It could be seen that the bamboo density decreases with increasing heating time. Heating for one hour caused the bamboo density decreased by about 39%. Heating up to 4 hours caused bamboo density decreased by 52%. This condition reflected that the highest evaporation occurs in the first hour period. So it could be estimated that evaporation in the first hour is occured in the vascular area where the water is mostly stored. However, after one hour, water evaporated mostly occured from the area which contain low water such as parenchyma and fiber area.

![Figure 4 Density vs Heating time](image)
3.3 Hardness of bamboo

In the Figures 5 and 6 both hardness in the longitudinal and tangential sides show the same tendency. The longer heating time, the hardness of bamboo is increased. For the longitudinal side, by heating time for two hours, the hardness increased by 31%, whereas for additional two hours (heating time 4 hours) the hardness only increased by additional 10%. However, slightly different is shown in the measurement of hardness in the tangential plane. The hardness indicates continuous increase up until up to 82% upon 4 hours heating time. Principally, the longer heating time, the less water content in the bamboo, so it will make the bamboo's harder [5]. Certainly, beside the water content the properties of bamboo is also determined by the ingredients contents [6].

![Figure 5](image5.png)

**Figure 5** Hardness vs Heating time (longitudinal side)

![Figure 6](image6.png)

**Figure 6** Hardness vs Heating time (tangential side)
3.4 Resistivity against fungi
The resistivity of bamboo against fungus is resumed in Table 1.

| Heating time (hours) | 0   | 1   | 2   | 3   | 4   |
|----------------------|-----|-----|-----|-----|-----|
| Fungus appeared      | 3   | 3   | 6   | >14 | >14 |
| (day)                |     |     |     |     |     |

Table 1 shows that bamboo with 0 and 1 hour heating time will be attacked by fungus after 3 days. Bamboo with longer heating time (2 hours) are able to survive from fungus attack until 6 days. While bamboo with heating time of 3 and 4 hours can survive from fungus attack up to more than 14 days. The more heating time causes water content in the bamboo is decreased. This respectively causes the growth of fungi is low. In contrarily, the short heating time still result a high water content which results in relatively rapid growth of fungi. Thus, heating time up to 3 hours is quite optimum in keeping the bamboo from the fungus attack.

4. Conclusions
The bamboo’ culm structure contains many cavities (hollow) caused a lot of water stored. An efforts to reduce the water content of bamboo is successfully done with heating at 100°C. Through evaluation of bamboo’s density, water decreases significantly after 1 hour heating. However, in order to improve mechanical properties (hardness), the heating process should be extend up to 2-3 hours. While, for enhancing the resistivity against fungus attack, bamboo should be heated until 3-4 hours.

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