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Moisture Resistance of Sugarcane Bagasse Cellulose Filled Tapioca Starch Biocomposites: Effect of Cellulose Loading

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Abstract - Biodegradable plastic-based starch is become one of alternative to substitute the synthetic plastic. In this study, the biodegradable plastic was made by tapioca starch and cellulose fiber from sugarcane bagasse. The production of bioplastic was casting method. Moisture resistance was observed by moisture absorption testing. The result shows that 4% sugarcane bagasse cellulose fiber (SBC) filled tapioca starch has good moisture resistance. It was indicated by lower moisture absorption for 28.3% at 22.5 hours condition. This result was supported by FTIR analysis which indicates a shift in the OH functional groups wavenumber in around 3500-3000 cm^{-1}. This shift resulting in the new formation of hydrogen bonding.

Keywords - Tapioca Starch, Sugarcane Bagasse Cellulose, Moisture Resistance, FTIR, Functional Group Analysis.

I. Introduction

Plastic waste is a major problem in many countries, especially in Indonesia. Until now, Indonesia has become the second largest producer of plastic waste after China. This phenomenon has an impact on several problems such as flooding and air pollution [1]. One way to overcome this problem is the replacement of plastic materials with biodegradable materials. One of the materials that can be converted into plastic is biodegradable starch [2-3].

Starch can be obtained from the extraction of tubers such as cassava, potatoes, corn, and yam. Cassava is the main commodity in Indonesia. In Indonesia, cassava is called tapioca. Tapioca starch is widely traded at the local market. Generally, tapioca starch contains amylose and amylopectin by 15 and 85%, respectively [4-5]. The content is very influential on the mechanical, thermal and moisture absorption properties of the thermoplastic starch film [6].

However, thermoplastic starch films have several disadvantages, namely low moisture resistance. Therefore, one way to improve the moisture resistance properties is by adding cellulose fibers to the starch matrix. According to previous research, the addition of fiber into the matrix can improve mechanical properties, thermal stability, and moisture resistance [7-9].

In this study, we examine biocomposites based tapioca starch matrix reinforced by sugarcane bagasse cellulose fiber. Moisture absorption and Fourier transform infra-red (FTIR) were observed to determine the moisture resistance and chemical functional groups of all biocomposite tested.

II. Materials and Methods

A. Materials

Tapioca starch was purchased from local market in Jember, Indonesia. Tapioca starch content was approximately 15%. Sugarcane bagasse was obtained from sugarcane ice seller from Jember. NaOH was purchased from Aneka Chemical store, Jember.

B. Preparation of Sugarcane Bagasse Cellulose Fiber

Sugarcane bagasse was dried for 3 days under the sun. The cellulose fiber extraction process begins with in several steps below:

1. Dried sugarcane bagasse was cut for 1 cm long
2. 10 grams of dried sugarcane bagasse was processed by alkalization using 15% NaOH. The alkalization was carried out at 60 ºC for 4 h and 300 rpm.
3. Sugarcane bagasse fiber was washed by distilled water until neutral pH.
4. Sugarcane bagasse fiber was processed mechanically using an ice blender for 5 min until it becomes pulp. Sugarcane bagasse fiber pulp has a water content of 98-99%.

C. Fabrication of Biocomposite

Biocomposites were made using the solution casting method. As much as 100 ml of distilled water was mixed with 10 grams tapioca starch. The mixture was stirred at 500 rpm for 5 min. 2 ml of glycerol was added slowly to the mixture. Sugarcane bagasse fibers with different variations namely 0, 2, 4 and 8% (from the dry weight of starch) were added to the biocomposite mixture. It was heated at 60 ºC, 500 rpm for 30 min. After gelatinization, the biocomposite mixture was molded into 15 cm diameter petri dish. It was dried using a drying oven at 50 ºC for 20 h.

D. Moisture Absorption Testing

The biocomposite sample was shaped in rectangular form (1 x 1.5 cm). It was dried to constant weight conditions. The moisture absorption test was carried out in tupperware boxes with 70% relative humidity and 25 ºC. The technique of weighing sample according to previous researchers with W_t as the final weight and W_o as the initial weight. The calculation of moisture absorption using the formula below:

$$Moisture\ Absorption\ (\%) = \frac{(W_t - W_o)}{W_o} x100$$

E. FTIR

Perkin-Elmer Frontier with a range of 4000-600 cm^{-1} at a resolution of 4 cm^{-1} was used as instrument of FTIR. This test aims to determine the chemical functional groups of all biocomposite samples tested.

III. RESULTS AND DISCUSSIONS

A. Moisture Resistance

Figure 1 shows the percentage of moisture absorption from all biocomposites tested. The test was carried out for 21 h with an interval measurement of 0.5 h. It was seen that biocomposites without the addition SBC (control) had the highest percentage of moisture absorption among other samples. Starting from point 0.5 hours, the moisture absorption from control sample is higher 2.3%, 1.5%, 2.1% from 2%SBC, 4%SBC, 8%SBC, respectively. This is due to the absence of SBC into starch matrix resulting in easier movement of moisture absorption pathway to diffuse into a starch matrix system [10]. In addition, the hydrophilic nature of starch is a factor in the rapid moisture absorption rate into the matrix system.

This phenomenon is different when SBC is added to the starch matrix. The percentage of moisture absorption from of biocomposite with the addition of 2%, 4%, 8% of SBC were 22.4%, 21.8%, 20.5%, at the condition of 3 hours. This proves that the addition of SBC to the matrix reduces the moisture absorption. This is because the function of SBC become barrier agent of moisture. Another reason is the good dispersion of SBC into the matrix. The good dispersion minimizes the void fraction in matrix [11].

A. Functional Group Analysis

Functional group of all biocomposite samples was tested by FTIR. Figure 2 shows the spectrum of all samples tested. There are several peaks formed along the 4000-600 cm^{-1} wavenumber. Some of these peaks are O-H (3600-3100 cm^{-1}), C-H (2960-2850 cm^{-1}) and presence of water (1740-1600 cm^{-1}).

O-H stretching shows the stretching of tapioca starch and sugarcane bagasse cellulose components [12]. The wavenumber value of tapioca starch film shift to the right (value decreases) after the addition cellulose. For example, the tapioca starch film (control) has 3429 cm^{-1} in wavenumber. After the addition of cellulose 2, 4 and 8%, the wavenumber shifted to 3410, 3371, 3375 cm^{-1}, respectively. This indicates that the presence of cellulose in the tapioca starch matrix resulting in new hydrogen bonding formation [13].

The formation of C-H stretching appears in the range of 2960-2800 cm^{-1} wavenumber. This indicates the existence of aliphatic saturated components in all samples. For water absorption groups indicated by wavenumber at around 1650-1600 cm^{-1} [14]. The wavenumber values of tapioca starch, TS/2%SBC, TS/4%SBC, TS/8%SBC are 1637, 1635, 1629 and 1624 cm^{-1}. The reducing wavenumber due to the different ability of water absorption of each sample. This is confirmed by the moisture resistance value in Figure 1.

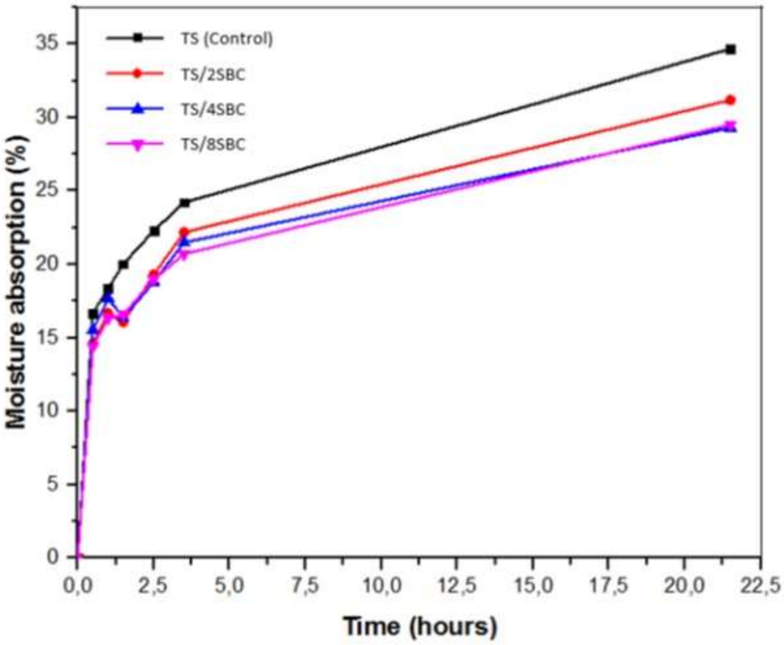

Figure 1. The percentage of moisture absorption from all samples tested

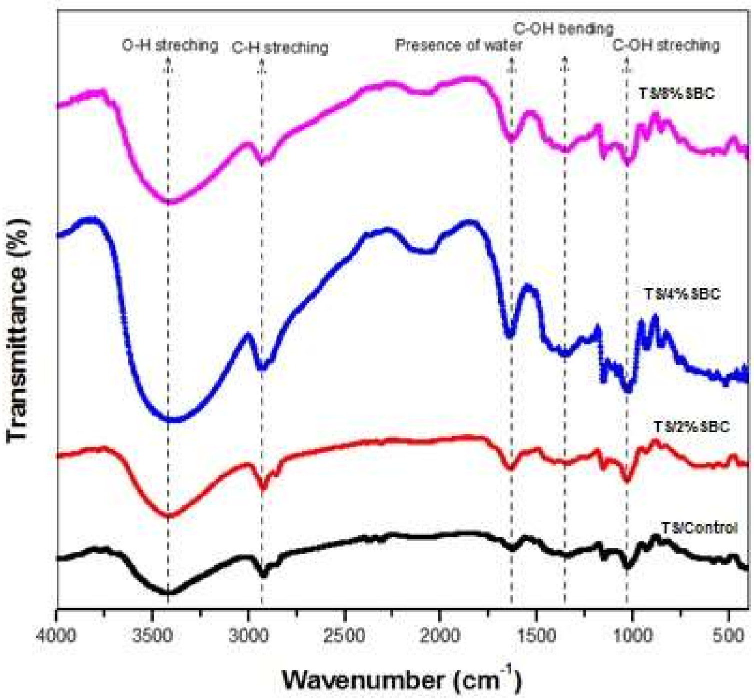

Figure 2. The functional group spectrum of all samples tested

IV. Conclusions

The starch bioplastic-based tapioca starch and cellulose sugarcane bagasse fiber was successfully made through solution casting. The addition of cellulose fiber in starch matrix improved moisture resistance. Functional group analysis indicated that there is a shifting to the higher wavenumber indicated new formation hydrogen bonding. Cellulose fiber has an important function as reinforcement in thermoplastic based starch matrix. This thermoplastic starch probably uses as packaging application.

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