Moisture absorption of starch based biocomposites reinforced with water hyacinth fibers

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Abstract. Bioplastic based on tapioca starch (TSB) is very sensitive on moisture; meanwhile this substance may be used to replace synthetic plastic. This paper reports effect of Water Hyacinth Fibers (WHF) content on performance moisture absorption of starch based biocomposites. WHF content in the TSB matrix was varied in 1, 3, 5, and 10% respectively. The samples were placed in closed room with high relative humidity (RH) of 99% at 25°C with different duration for 30 and 960 min respectively. The result showed that moisture absorption in the beginning was increased rapidly, and then achieved a level steady state. After that, significant swelling of the sample occurred for further duration in 960 min. Gradient of the swelling was decreased as increasing the fibers content in the TSB matrix.

1. Introduction
Starch based bioplastic has advantages such as low cost, wide availability, and total composability without toxic residues [1]. For this reason, the bioplastic provides a great attention to replace synthetic polymers such as for packaging applications [2]. General procedure for processing a bioplastic involves the granular disruption by the combination of temperature, shear, and a plasticizer, which is usually water and/or glycerol [3][4]. However, weakness of the bioplastic is easy to absorb moisture [5]. Therefore, several techniques have been investigated to minimize the weakness, for example, the bioplastic mixed with fillers [6][7][1]. After adding cellulose as filler in bioplastic, moisture resistance of the biocomposites improved as reported by last work of K. Kaewtatip and J. Thongmee [8].

Cellulose of plants is considered to be one of the most promising renewable resources [9]. As the aquatic weed, water hyacinth plant demonstrated the feasibility of producing cellulose nanofibers, which can have potential applications for reinforcement in the near future [10]. In the present work, WHF in form of pulping has been incorporated in TSB. Moisture absorption characterization of the biocomposite in various WHF content was measured. The originality of this study is to observe the characterisation of moisture absorption in region of steady state achieved.

2. Methods

2.1. Measuring chemical compositions
Chemical composition of WHF tested was respectively hemicellulose, cellulose and lignin. Measuring methods used were ASTM 1104-56, and testing by Technical Association of the Pulp and Paper Industry (TAPPI) standard T9M-54 and TAPPI T13M-54 respectively.
2.2. Manufacture of biocomposites
Extracted WHF was of freshwater hyacinth plant growing in local swamp in Kabupaten 50 Kota, Indonesia. It was cut for 1 cm long, and cleaned with fresh water. Then, it was placed in a close room isolated by plastic under sunlight. The studied samples were dried in the room after 5 days. Next steps was that the dried WHF samples were entered in 25% NaOH solution to be assimilated by digester for 6h at about T=130°C, 2 bar. Finally the pulp was neutralized by water until pH 7, and then blended by mixer for 10 min. The pulp was screened by using screen printing with T61 mesh. The next step was to dry the wet pulp using sunlight.

Tapioca powder was used as material for making bioplastic matrix for this research. The powder was from a commercial product with name “Cap Pak Tani”, bought in local market. Content of water, amyllose, and amylpectin in the powder was 19, 15, and 85%, respectively. TSB was processed as following (i) Aqua of 140 ml was mixed WHF based on volume fraction of 1, 3, 5, and 10%, respectively. The mixing was homogenized for 5 min, then, added by tapioca powder of 10 g. Further steps were homogenizing of the solution while 5 min. Glycerol of 3 ml was added to the solution, then, homogenized for 5 min; (ii) Magnetic stirrer set up at temperature of 150°C, 500 rpm, was used for mixing the solution average 18 min in order to get gelatinization; (iii) The gel was poured into a glass mould making biocomposite film. Drying process of all tested samples was in universal oven (Memmert UN-55) for 20 h at 50°C. The studied samples were released of the mould after 24 h in room temperature.

2.3. Moisture absorption
All tested samples were dried in oven (Universal Oven Memmert UN-55) until achieving constant weight. Then, they were stored in closed chamber in which both relative humidity (RH) and temperature were 99% and 25°C, respectively. Duration of the sample in the chamber was varied, there was 30 min, and even there was 960 min. The samples were taken out from the chamber to be weighted by using precision balance of 0.1mg (Kenko). Percentage of moisture absorption in the sample was calculated by difference between dried weight and wet weight divided by dried weight in % unit [11].

3. Results and analysis
3.1. Chemical composition
Of this research, after digesting and blending for 10 min., chemical compositions content of the studied WHF was measured that hemicellulose, lignin, and cellulose was 3.5, 3.8, and 67.0%, respectively. As it can be seen, content of hemicelluloses and lignin was very low due to the chemical and mechanical treatment. Meanwhile, cellulose content of 67.0% was high enough, and more dominant in the WHF. This result was in good agreement with last studies [12][13].

3.2. Moisture absorption
Figure 1 shows performance of moisture absorption for all studied samples. As control, both pure starch based bioplastic, and 25%NaOH treated digested pulp of WHF were also measured of own moisture absorption behaviour. All samples were stored in closed chamber with very high RH of 99% at temperature of 25°C. Duration of the sample in the closed chamber was varied, both 30 and 960 min. In the beginning, the studied samples exhibited high rate of moisture absorption due to a high different concentration of relative humidity between the inner dry samples and the humid environment of the chamber. For the initial 30 min. in the chamber, it was gauged that moisture absorption of sample TSB composites (1, 3, 5, and 10% WHF), and 100%WHF was 51, 49, 51, 54, 53, and 24 % per h, respectively. It can be seen from the data that the lowest moisture absorption was found in 100%WHF, meanwhile TSB as well as the biocomposites film displayed similar high capacity in absorbing moisture. Hence, existing of the fibers provides an increase resistance of water uptake. Diffusion of water molecules was hindered by the fibers in the matrix. Among 960 min placed in the humid
chamber, the biocomposites show swelling due to nature hydrophilic samples. Highest swelling was observed in pure WHF, and the lowest one was on 10% WHF in TSB.

![Swelling.png](attachment:Swelling.png)

**Figure 1.** Performance of moisture absorption for all studied samples.

For further 30 min observation, the rate was decreased continuously to achieve equilibrium level. As it can be seen in Figure 1, that TSB, started from 90 up to 240 min, displayed the fluctuation of moisture absorption. In this case, moisture content in the tested sample was never in steady state condition. The sample cannot keep an equilibrium point of water content. Moisture was probably diffused and evaporated easily into and from the tested sample. While the sample was stored during 16 h in closed chamber, the result was very surprised that the moisture absorption was still increased continuously, measured additionally of 2%. Then, TSB sample was stored again in closed chamber, and for each 30 min long it was taken out to measure the moisture absorption of the sample. However, the result shows that the moisture absorption was decreased to tend an equilibrium level again. This is due to the fact that amount of moisture was evaporated from the sample. Surprisingly, all studied samples also have exhibited same behaviour that they have very high sensitivity on the moist environment, and cannot keep a constant moisture content in environment with varied relative humidity.

### 3.3. SEM photograph

Figure 2 shows SEM photograph of fracture surface for tensile testing. As shown in Figure 2a, beach marking may due to low crack propagation of starch based thermoplastic. Meanwhile, agglomeration as well as clearance between fibers and matrix may provide possibility to water molecule to enter, thus increasing the moisture absorption of the biocomposite. It is noted that fracture surface of the fiber may inform good adhesion bonding between matrix and fiber.
Figure 2. SEM photograph of fracture surface of, a) TSB matrix, b) 3% WHF in TSB matrix.

4. Conclusion
Variation of WHF in the TSB was 1, 3, 5, and 10%, respectively. Increase in volume fraction of WHF in the TSB matrix improved generally moisture absorption resistance of the biocomposites. In the beginning, all materials absorb water rapidly until achieving a steady state for short duration in humid chamber. After that, swelling of the biocomposites was significantly increased in increasing the duration in humid chamber. It was then slightly lower as further WHF content in the TSB.

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