Influence of fiber treatment on dimensional stabilities of rattan waste composite boards

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Influence of fiber treatment on dimensional stabilities of rattan waste composite boards

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Abstract. The main drawback of using natural fibers in composite boards is its hydrophilic properties which absorb a high volume of moisture. This results in low dimensional stability of the produced composite boards. Hence, the purpose of this study is to investigate the effects of fibers’ treatment processes of the rattan waste fibers on the dimensional stabilities of composite boards. The collected fibers underwent two types of retting processes, namely a water treatment and alkaline treatment retting processes; where the fibers were soaked in water and a 1% sodium hydroxide (NaOH) solution, respectively. The fibers were dried and mixed with poly(lactic) acid (PLA) pellets with ratio of 30% fibers: 70% matrix; before being fabricated into composite boards via a hot-pressing process and were labelled as RF/PLA, WRF/PLA, CRF/PLA for untreated rattan, rattan treated by water retting, rattan treated by chemical retting, respectively. The produced composite boards were cut and soaked in water for 24 hours for dimensional stability in terms of water absorption and thickness swelling tests. The results showed that WRF/PLA has the lowest water absorption (3.2%), and the CRF/PLA had the highest water absorption (23.2%). The thickness swelling showed a similar trend as water absorption. The presence of void contents and fibers damaged the insides of the boards, which contributed to low dimensional stabilities of the composite boards. It can be concluded that water retting facilitated in improving dimensional stability of the produced composite board.

1. Introduction
The plastic industry dominates a leading industry in the world, with almost 234 million tons of plastic produced in 2013. It contributes towards problems of dumping plastic waste due to the abundant usage of petroleum synthesized polymers in plastic production. This leads to a cost burden and a crisis for waste management [1]. The high awareness towards sustainability of the environment, along with transformation of government regulations for green byproducts, have motivated researchers to find new substitutes for present composite materials with eco-friendlier and biodegradable materials. Biopolymer has a potential to function as bioplastics, where one of the most preferable candidate of biopolymer is poly(lactic acid) (PLA) [2]. PLA is derived from renewable resources such as corn starch or sugar cane, where it works as a thermoplastic which provides environmentally-friendly characteristics, biocompatibility, sustainability, as well as potentially useful physical and mechanical properties. The superior performance of synthetic fibers such as glass fibers or carbon fibers are advantageous for composite materials, yet the safety of these fibers become a threat towards the environment and health. Therefore, researchers have actively explored natural fibers for example sisal, banana and kenaf, where these fibers are non-toxic, biodegradable, lightweight, have superior performance and are cheaper due to their availability [3]. One of the fibers that has high potential as reinforcement in the bio-composites is rattan waste fibers. Rattan waste fibers comprise of cellulose,
hemicelluloses and lignin; where these fibers feature good properties such as low density, flexibility and versatility [4].

The rattan waste fibers and PLA matrices are, however, incompatible with poor interfacial bonding, due to the impurities and hydrophilic properties in rattan compositions, which makes it unsuitable with the hydrophobic nature of PLA. It results in reduction in poor adhesion between fibers and matrix, causing ineffective stress transfer during interfere of composite produced [5]-[6]. The significant of interfacial bonding between fiber and matrices in composite was illustrated in figure 1, that shows the treatment (or environments) on the fiber surface have great effects onto the adhesion between the fibers and matrices.

![Figure 1. Adapted illustration of schematic diagram shows the importance of interfacial bonding in a composite [7].](image)

Based on those factors, the performance of the produced composite can be improved by surface modification of the rattan fibers, through proposed retting processes. Retting is a microbial process that breaks the chemical bonds that hold the stem together and allows separation of the bast fibers from the woody core [8]. The retting process has a good potential to improve the structure of fibers by washing out the impurities on the fibers such pectin, lignin, cellulososes and wax. These impurities are the main factors that reduce the good properties of rattan fibers. There are several common retting processes which are tabulated in table 1, with the advantages and disadvantages of each processes. this study only focused on two processes – water retting and chemical retting. Thus, this study was executed to assess the effects of fiber treatments on rattan waste fibers, effecting dimensional stability of the produced composite boards.

2. Experimental Procedures
The rattan waste fibers was supplied by Rinaat Cane Sdn. Bhd., Perak, Malaysia, in the size of 500μm. The matrix chosen was poly(lactic acid) (PLA) in white crystalline form, purchased from Fuzan Enterprise, Malaysia. The fibers were prepared for two retting processes, which were water retting and chemical retting [9]. The execution of water retting was carried out by fully immersing the fibers in a beaker using tap water at room temperature for 8 days. While, the chemical retting process was conducted by preparing an alkaline solution (1% of NaOH) and the fibers were then soaked in the alkaline solution for 60 minutes before taken out to be washed with tap water to remove the alkali solution from the fiber surface. Both treated fibers were dried in an oven at the temperature of 35°C for 48 hours, and were labelled as WRF and CRF for fibers that underwent water retting and chemical retting processes, respectively.

The Scanning Electron Microscopy, SEM (Jeol JSM-6700F) analysis was done to these treated fibers under 1000x magnification. The fibers were mixed with PLA using an internal mixer (Haake
Polylab System Thermo) machine at a heating temperature of 165ºC, rotor speed of 50 rpm and mixing time of 12 minutes, with fiber:matrix ratio of 30:70. The compound materials were labelled as RF/PLA, WRF/PLA, CRF/PLA, and were grinded using crusher into small pieces before being hot-pressed at pressing parameters of 160ºC, 3 minutes and 147.5kPa. The water absorption and thickness swelling test was performed as per ASTM D7031-04 method. The values of water absorption and thickness swelling were calculated using the following formula of 3.1 and 3.2.

Percentage of water absorption (%) \( \frac{w_2-w_1}{w_1} \times 100 \)  
where \( w_1 \) is initial weigh of specimens and \( w_2 \) is final weight of specimens after being immersed

Percentage of thickness swelling (%) \( \frac{t_2-t_1}{t_1} \times 100 \)  
where \( t_1 \) is initial thickness of specimens and \( t_2 \) is final thickness of specimens after being immersed

Table 1. Types of common retting, adapted from [9].

| Retting Types | Advantages | Disadvantages | Retting Duration |
|---------------|------------|---------------|------------------|
| Dew retting   | - Bacteria easily can removed pectin in the fiber | - Reduced strength  
- Low and inconsistency quality  
- Restriction to certain climatic changes  
- Product contaminated with soil | 2 – 3 weeks |
| Water retting | - Yields greater uniformity and high quality | - High cost  
- Putrid odour, environmental problems  
- Requires high water treatment maintenance  
- Low-grade fiber | 7 – 14 days |
| Enzymatic retting | - Easier refining particularly for pulping purposes  
- Cause a partial degradation of the components separating the cellulosic fiber from non-fiber tissues  
- Faster and cleaner process | - Lower fiber strength | 12 – 24 hours |
| Chemical retting | - Efficient  
- Can produce clean with consistent long and smooth surface bast fiber within a short time. | - Tensile strength of fiber decreases if retted using 1% NaOH  
- Unfavorable color  
- High processing cost. | 1 – 1.5 hours |
Mechanical retting - Produces massive quantities of short fiber in short time - High cost - Low fiber quality

3. Results and Discussion

Figure 2 illustrates the percentage of water absorption and thickness swelling of raw PLA, raw rattan fibers, RF/PLA, WRF/PLA and CRF/PLA after 24 hours of water immersion. The bar chart in figure 2 demonstrates that the raw PLA, with no addition of any fiber content, has the lowest water absorption at 0.8%. This confirms the hydrophobic nature of PLA exhibited the water from absorbed into the polymer chains [2]. On contrary, the raw rattan waste fibers (RF) have the highest water absorption at 47.6%, owing to the hydrophilic characteristic of natural fibers. It is believed that hemicelluloses are responsible for moisture absorption [10], where the removal of hemicellulose produces a less dense and less rigid interfibrillar region.

![Figure 2](image)

**Figure 2.** The percentage of water absorption (bar graph) and thickness swelling (line graph) of the samples.

The RF/PLA composite produced water uptake at 3.7%, resulting from the well-dispersed and mixing between rattan waste fibers and PLA that helped to increase the interfacial bonding of fiber-matrix. The WRF/PLA composite had 3.2% of water uptake, proving that the water retting process had slightly improved the composite compared to other composites. This resulted from the modification of hydrophilicity of rattan fiber filling the voids of cellulosic structure with polymers during the formation of the composite. The CRF/PLA composite had 23.2% of water uptake, due to the presence of void contents inside the composite. The void contents in the composite encouraged the water to diffuse into void spaces, which formed during compounding and the presence of micro-voids between fiber-matrix interfaces [11]. The free hydroxyl groups occurred in the natural fibers attracted water molecules and were absorbed into the composite [12]. Thus, the water absorption led to cell expansion and affected the dimensional change of the composite such as thickness swelling. The thickness swelling of PLA, rattan fibers and composites produced in the line inside figure 2, shows a similar trend as the water absorption graph.

Both retting processes have removed the impurities and surface debris such as lignin, hemicelluloses, pectin from the fiber surface resulting in cleaner vascular bundles and rougher surface
[6], [10], compared to untreated fibers, as can be seen in figure 3. This rough surface facilitates both mechanical interlocking and bonding reaction due to the exposure of the hydroxyl groups to the matrix, thereby increasing the fiber–matrix adhesion, increasing the effective surface area available for contact with the matrix. The processes also disrupted the hydrogen bonding in fiber surfaces. Chemical retting has better efficiency in removing the impurities in fiber surfaces compared to other types of retting, within short duration that changes fiber nature from hydrophilic to hydrophobic [9]. On top of that, this treatment has caused diminished strength of fiber, due to certain factors such as extended treatment time or disproportionate concentration of alkali used [9], [13]. Meanwhile, water treatment did not require any additional chemical for its treatment, except for large treatment scale as mentioned in the table 1. It is easy to handle which required less skills and more environmental-friendly [14].

![Figure 3](image.jpg)

**Figure 3.** Micrographs of fiber surfaces of (a) RF, (b) WRF, (c) CRF.

The micrographs in figure 4 shows the composite board surfaces after a mechanical test, thereby proving that the WRF/PLA boards (in figure 4(b)) had smaller voids compared to RF/PLA and CRF/PLA boards. Similar result obtained by previous study where fiber underwent water retting process gave the highest tensile strength [9], compared to fiber underwent sodium hydroxide and sodium benzoate treatment. A few void spots were noticed on the surfaces of all composite boards indicate that parts of rattan fibers have poor bonding adhesion with the PLA matrix, due to incompatibility of hydrophobic polymer matrix and hydrophilic of natural fiber [7], [15]. figure 4(c) presence greater void occurrence of pulled-out fibers from matrix, which resulted for incoherent in board strength with high water absorption [11], [13], [16]. There are numerous factors that affects boards properties such as fiber types and orientation, processing parts and many more [15].

![Figure 4](image.jpg)

**Figure 4.** Micrographs of surface structures of composite boards (a) RF/PLA, (b) WRF/PLA, (c) CRF/PLA.

Based on the results discussed, water retting has good potential as a surface modification method for rattan fibers which promotes the lowest water absorption and thickness swelling among the samples. It is also recommended to add coupling agents such as maleic anhydride grafted polymers (MAPP) to increase the compatibility between matrix and fibers.

4. Conclusion
The retting process has positive effects on the properties of rattan waste composites. Based on the performance evaluation on the produced composite boards, the water retting process improves
dimensional stability of boards by having lowest water uptake. The CRF/PLA has the highest water uptake due to void presence in composite structures. Meanwhile, the thickness swelling test follows a similar trend with the water absorption test which shows that rattan waste that undergo a chemical retting process are not stable in terms of thickness swelling due to high water uptake. Based on that, the water retting process has improved the performance of composite in terms of its mechanical and physical properties.

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