Bamboo: A Multifunctional "Green" Fibre

Tarannum Afrin, Takuya Tsuzuki, Rupinder K. Kanwar, Xungai Wang
Centre for Material and Fibre Innovation, Deakin University, Australia
taf@deakin.edu.au

OBJECTIVE

This study explores the scope of bamboo as an emerging "green" multifunctional natural fibre in the textile sector.

INTRODUCTION

Bamboo plant is well recognized for its multifunctionality as food, medicine, constructions material and so on, serving the daily needs of billions of people over centuries [1-2]. Bamboo has amazingly fast growth rates with no or very little needs for pesticides and irrigation. The carbon sequestration activity of each acre of bamboo is much higher than trees [3]. As such, bamboo is recognized as one of the most eco-friendly crops and the 'green' properties of bamboo have started to attract consumers in the textile market.

However, most of the manufacturers are currently using regenerated viscose production method to process bamboo plants into fibres, using a large amount of toxic chemicals. Therefore, it is questionable to use the term "green" on the current bamboo textile products [4]. Hence, there is a great need for developing an eco-friendly method to produce bamboo fibres. In this research, an Australian grown bamboo plant *(phyllostachys pubescens)* is processed into fibres in a natural and eco-friendly manufacturing method without losing the unique properties of bamboo plants. This research also describes the origin of the ultra violet (UV) absorbing and antibacterial activity of bamboo.

APPROACH

Several characterization methods are used to explore the morphology and chemical components of raw bamboo and processed fibres such as scanning electron microscope (SEM), X-ray diffraction (XRD) and Fourier transform infrared (FT-IR) spectroscopy. For investigating the origin of UV blocking property, several extractions of raw bamboo were carried out using polar and non polar solvents. Raw bamboo was crushed into powder with sizes of around 5-6 μm by using mechanical milling. The extraction was performed with 10g of powder in 300 ml of solvents for 72 hours at room temperature with continuous stirring. A mixture of non polar and polar solvents (dioxane: water= 9:1), which is the Björkman solvent for lignin extraction, was also used [5].

The antibacterial study was carried out against gram negative bacteria *E. coli* with bamboo extracts in three solvents, namely, water, Dimethyl Sulfoxide, DMSO (a typical plant solvent) and 90% aqueous dioxane. After extraction in 90% aqueous dioxane, dioxane was removed from the solution by evaporation in order to eliminate the effect of dioxane on the antimicrobial activity. The extract in DMSO was diluted down to 20% to optimize the observation conditions of E-coli colonies on agar plates.

Bamboo plant is processed into fibres with the aid of mechanical (such as ultra sonication) and mild chemical treatment (such as enzymes and hydrogen peroxide).

RESULTS AND DISCUSSION

Under SEM, raw bamboo showed a highly porous structure with grooves like capillaries in its cross section (*Figure 1a*). XRD confirmed the cellulose I crystalline structure. FT-IR spectroscopy revealed the presence of aromatic and carbonyl groups in the raw bamboo. The lignin content in the raw bamboo was identified to be 28 wt% by using GB5889-86 standard method (*Figure 1b*).

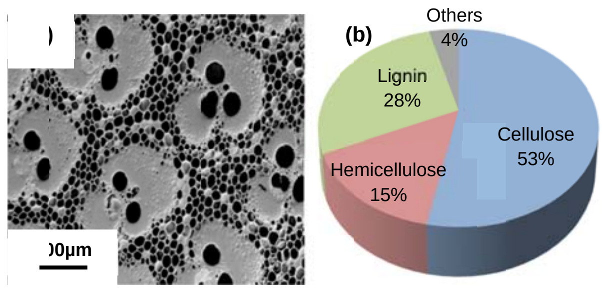

FIGURE 1. (a) SEM micrograph of the cross section of raw bamboo *(phyllostachys pubescens)*; (b) Chemical constituents analysis of raw bamboo according to GB5889-86.

Raw bamboo extracts in protic solvents such as water and ethanol (*Figure 2a*) showed UV absorbing ability, but the extracts in polar aprotic solvents did not. Interestingly, a non polar solvent, hexane, extracted the UV absorbing chemical compound out from raw bamboo (*Figure 2a*).

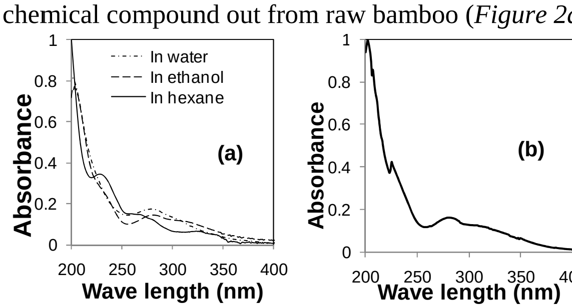

FIGURE 2. UV aborption spectra of bamboo extracts a) in water, ethanol and hexane and b) in 90% aqueous dioxane after removal of dioxane.

The fact that bamboo extracts in both polar and non polar solvents showed UV absorption properties indicates that bamboo has more than one UV responsible chemical components. Since polar protic solvents normally solvate negatively charged ions, the UV absorbing components of bamboo are thought to be positively charged. The extract in the mixture of the non polar and polar solvents (dioxane:water= 9:1) showed a similar UV absorbance spectrum (*Figure 2b*). As this Björkman solvent is a typical lignin extraction solvent, the results indicate that the UV absorption property of raw bamboo lies in the chemical components of lignin.

Bamboo extracts in water showed no antibacterial activity (*Figure 3 a, b*). The extract in 90% aqueous dioxin after removal of dioxane showed 100% antibacterial activity even after diluted 20 times (*Figure 3 c, d*). The DMSO extracts did not show significant antibacterial activity, but the colony size was smaller compared to the control samples (*Figure 3e, f*), indicating that the bamboo extracts in DMSO inhibited bacterial growth but could not kill them thoroughly. Since DMSO is considered as an extraction solvent for hemicellulose [6], that the results suggest that the chemical components in hemicellulose are not strongly antibacterial. The above results of antibacterial test confirm that the antibacterial activity of bamboo mainly stems from the water insoluble chemical components in lignin.

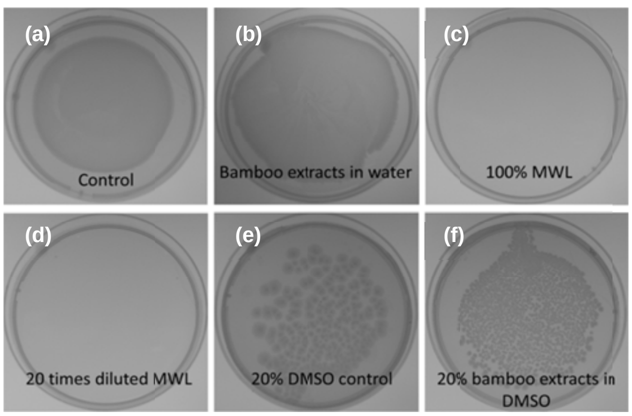

FIGURE 3. The antibacterial characteristics of raw bamboo against *E.coli* in agar plates.

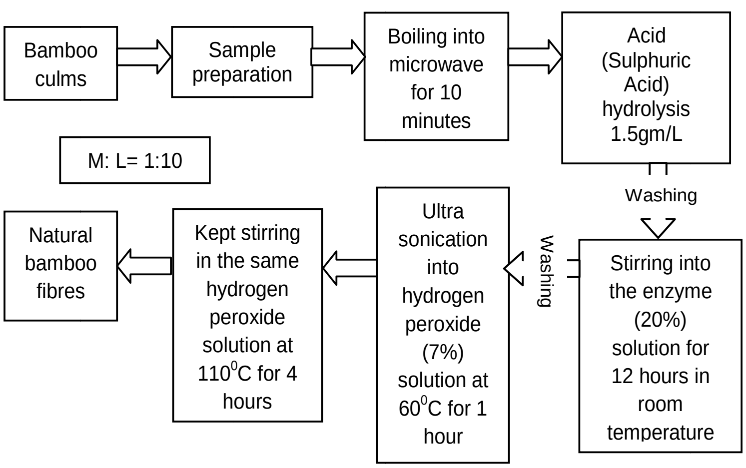

FIGURE 4. Process flow graph of natural bamboo fibre from bamboo plants.

Bamboo plants were processed into fibres according to the flow diagram in Figure 4. Figure 5(a) shows a typical SEM image of the processed fibre. It was found that the raw bamboo and processed bamboo fibres had much higher UV absorption property than cotton that is another cellulose-based common natural fibre (Figure 5b). FT-IR spectroscopy revealed the presence of aromatic and non conjugated carbonyl stretching (1400 -1750 cm $^{-1}$) in raw bamboo and processed bamboo fibre, indicative of the presence of lignin. On the other hand, the FT-IR spectrum of cotton did not suggest the presence of lignin. The results therefore suggest that the UV blocking ability originates from those aromatic and carbonyl groups in lignin

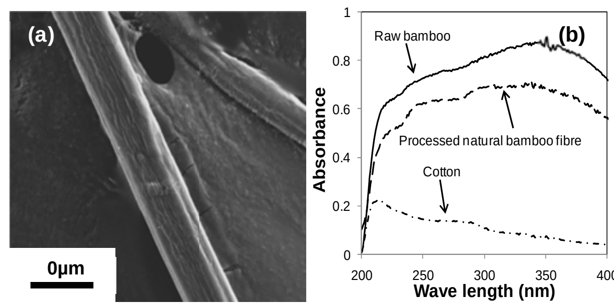

FIGURE 5.(a) SEM micrograph of processed natural bamboo fibre; (b) comparison of the UV absorbance among raw bamboo, cotton and processed natural bamboo fibre.

CONCLUSIONS

The unique multifunctional properties of bamboo, such as UV absorption and antibacterial properties stem from lignin in *phyllostachys pubescens.* The new method to process raw bamboo into fibre successfully retained those unique properties in the fibre. The future works involve the spinning and knitting/weaving of the processed fibres.

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