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Physical and Mechanical Properties of Coarse Bamboo Fibers Extracted by Different Techniques ⋆

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Abstract

Bamboo fiber extraction methods include mechanical, stem explosion, water retting, enzymatic, and chemical methods. Each extraction method has drawbacks in terms of fiber quality, cost, efficiency, and environmental impact. The combined technique of fiber extraction was developed by combining two or more extraction methods in order to minimize the disadvantages of separate methods. This study developed and tested alternative combined fiber extraction procedures for the extraction of fibers from bamboo culms, with the goal of minimizing the drawbacks of separate extraction methods by using an environmentally friendly enzyme solution developed by a research group at Chengdu Textile College. The fundamental physical and mechanical properties of bamboo fibers were also investigated. The bamboo species studied were Dendrocalamus membranaceus (S-1), Neosinocalamus affinis (S-2), Phyllostachys heterocycle (S-3), and Phyllostachys bambusoides (S-4). Bamboo fibers with 6.6-56.37 cm fiber length, 5.12-95.02 tex linear density, 100-1446 cN breaking strength, 1.2-146.5 cN/tex breaking tenacity, 0.26-3.43% breaking elongation, and 1.44-173.56 cN/tex breaking modulus values were extracted. The coarsest bamboo fibers were extracted using a combined chemical (boiling alkali)-mechanical (rolling) technique, whereas the bamboo fibers with the lowest average length, fineness, and breaking modulus values were extracted using a combined enzymatic-chemical (alkali)-mechanical (rolling) technique. Bamboo fibers extracted using a combined chemical (alkali at room temperature)-enzymatic (by stacking)-mechanical (rolling) technique had the lowest average breaking strength, tenacity, and elongation values but the highest average length. Bamboo fibers with the highest average breaking strength, tenacity, and modulus values were extracted using a combined chemical (alkali at room temperature)-enzymatic (in solution)-mechanical (rolling) technique. The extracted bamboo fibers exhibited variations in fundamental properties, as is typical of plant fibers. The fibers extracted using a combination of enzymatic-chemical (alkali)-mechanical (rolling) methods showed the least variation.

Keywords: Bamboo fiber extraction; Physical properties of bamboo fibers; Mechanical properties of bamboo fibers; Comparison of bamboo extraction methods

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1 Introduction

Natural fibers are renewable and environmentally friendly materials as they have low density, low price, and acceptable mechanical properties and are replacing synthetic fibers in composite structures. Hence, many scientists are interested in replacing them with synthetic materials to conserve the environment (John and Thomas, 2008).

Bamboo is a new kind of natural fiber from plant sources. In recent years, bamboo fiber is getting more attention from scientists and is in the frontier of bamboo timber processing, new composite, and textile research field (Qiang et al, 2018). Bamboo in comparison with other natural fibers has some attributes which make it the most important plant fiber (Loretta et al, 2008; Abdul Khali et al, 2012). It is an abundant, naturally growing (Mohammed et al, 2013) and extremely fast-growing plant. The fastest known bamboo grows vertically two inches per hour and in some Moso bamboo species, a height of 60 feet is achieved in 3 months, thus the cutting down of this substitute wood would not affect the ecological balance at all. It is grown on various continents of the world (Maxim et al, 2017) and can grow in low water or poor soil ecologies and is sometimes used in wasteland reclamation (Hofer et al, 2010). It is known as the world's "second largest forest resource" widely distributed in Asia (Kazuya et al, 2010). More than 1000 varieties of bamboo and approximately 70 genera grow in the natural conditions in diverse climatic conditions, having a specific plentiful amount in Asia and South America (Abdul et al, 2012).

The properties of bamboo such as lightweight, high strength, stiffness, biodegradability (Janssen, 2000) low cost, and fast growth rate (Osorio et al, 2011) caused it to be used traditionally for manufacturing living tools (Janssen, 2000). Besides the massive utilization of bamboo in building construction and living tools, it also can be used as reinforced composite materials based on extracting appropriate fibers in a controlled manner (Shin et al, 1989). Recently, the use of bamboo fibers as reinforced polymer composite materials has increased. Based on its properties, bamboo fiber can be compared with glass fiber for applications in composite materials (Abdul et al, 2012).

A better understanding of bamboo constituents is the key to establishing the extraction process and achieving the final fibre products that meet requirements. The chemical composition of bamboo is similar to other bast materials. The chemical composition of bamboo fiber constitutes mainly of cellulose, hemicelluloses, and lignin. These components make up about 90% the of the total weight of bamboo fiber (Wang et al, 2010). The amount of the constitute differs in various bamboo species (Phong et al, 2011). Usually, the chemical content of bamboo changes with the age of the bamboo (Ashish et al, 2016). Lignin and hemicellulose matrix held cellulose fibrils together (Jawed and Abdul, 2011). Degumming is a process to remove the natural amorphous substances such as hemicellulose and lignin and obtain fiber (Akin et al, 2001). Chemical, mechanical, and a combination of mechanical and chemical processes have been used to extract bamboo fibers based on their application in the industries (Phong et al, 2012; Kim et al, 2013). Biotechnology has also attracted wide attention due to its important role in the development of environmental-friendly technologies (Gübitz et al, 2006). Mechanical fiber extraction methods can take the form of different procedures such as a steam explosion or heat steaming, crushing, grinding, and rolling in a mill (Shao et al, 2008). In the mechanical method longer fibers could be extracted (Osorio et al, 2010). Moreover, the mechanical process is more eco-friendly than the chemical method (Rao and Rao, 2007). However, all mechanical methods have some advantages and disadvantages (Nugroho and Ando, 2001). In chemical procedure alkali or acid retting and chemical-assisted natural retting are used to remove the amorphous regions and reduce the lignin content of the