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The vacuum-assisted microwave drying of round bamboos: Drying kinetics, color and mechanical property

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ABSTRACT

Round bamboos hold great promise for replacing wood as structural materials due to their easy large-scale cultivation, rapid growth, high strength and high toughness. However, rapid drying of round bamboo with good quality remains a key challenge. Here, vacuum-assisted microwave drying (VMD) technology is firstly applied to dry round bamboo. It only takes ~150 min to reduce the moisture content of bamboo to ~10%. The resulting dried bamboos not only have a smooth surface, superior gloss, uniform golden color and few striking defects, but also show good mechanical performance. Moreover, few splitting, cracking, even "Firecrackers" occur during the drying process, which could not be avoided by conventional drying method. Thus, VMD technology shows a great potential application in drying round bamboo in industry.

1. Introduction

Bamboo is considered as the most abundant natural resources available in China and has a huge impact on the application of structural material [1], because of its excellent advantages such as easy large-scale cultivation, rapid growth, high yield, high strength and high toughness. In the utilization of bamboo as engineered structural material, pristine round bamboo culm is most widely used, which is composed of hollow cylindrical shoot separated by solid transversal diaphragms at the nodes. The smart structure of bamboo endows it beautiful appearance, high strength and bending modulus, so it is a better alternative to engineered wood from the aspects of function, ecology and economy. As fresh bamboo has a high moisture content (45%–90%), it needs immediate drying to avoid microbial damage and mold, making it ready for further storage, transport, processing and utilization. To date, the mass use of round bamboo as a structural material is limited by the lack of scale production of well-treated raw materials, semi-finished products and standardized parts. Notably, drying technology is a key step in the industrial use. The current common drying (COM) technology (e.g. air drying, kiln drying) usually requires high energy and time-consuming process (about 6–12 weeks for air drying and 3-6 weeks for kiln drying) [2]. Moreover, it also brings poor guarantee quality for dried bamboo. Hence, a simple, fast and efficient drying technology for round bamboo is greatly important for the extensive industrial processing and utilization.

Round bamboo is a typical heterogeneous structure, which consists of hollow cylindrical shoot divided into sections by nodes, and the external wall is composed of bamboo green, bamboo yellow and bamboo membrane from exterior to interior. The complex heterostructure brings about different diffusion rate of water molecules in different parts of bamboo, resulting in uneven shrinkage during the drying process. In addition, the bamboo wall contains abundant highly hygroscopic parenchyma cells, which make bamboo begin shrinking above the fiber saturation point (~17–25%) [2]. All these factors increase the difficulty to dry round bamboo with high quality. And for that reason, although timbers or split bamboos could be dried well by traditional air-drying or kiln-drying methods without difficulty, there remain some problems to dry round bamboo effectively with the same methods [3–5]. Besides that, it also frequently suffers from crack and collapse in round bamboos with common drying techniques and causes many defects due to undue and non-uniform shrinkage. The poor drying technology has become one of main factors restricting the large-scale use of round bamboo as structure materials. However, the work on the drying technique for round bamboo is still in its

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infancy. Therefore, rapid drying of round bamboo under the premise of quality assurance remains a key challenge.

Considering the limitation of traditional drying methods in low efficiency and poor quality control, we used vacuum-assisted microwave drying (VMD) method to dry round bamboo by using the representative bamboo species, *Phyllostachys iridescens* C.Y. Yao and S.Y. Chen. Previous report demonstrated that microwave drying method was effective in drying food products with a short time and good rehydration characteristics [6]. Encouraged by these results, VMD method was applied firstly to dry round bamboo to reduce drying time and optimize product quality. The impact of vacuum microwave drying on the quality of round bamboo, the optical and mechanical properties of dried bamboo were investigated in this work.

2. Results and discussions

Fig. 1 shows schematic illustration for drying round bamboo by using VMD method. Briefly, the bamboo samples were gathered, cut into bamboo culm (~1 m length) and dried at 80 °C in the microwave drier under vacuum. The bamboo samples were found to be dried effectively, and the color of bamboo changed from green to golden. It only took ~150 min to dry round bamboo by this method. In the drying process, when the samples are exposed to an electromagnetic field with microwave radiation, the dipole water molecules in the bamboo begin to swing and generated lots of heat, thus increasing the temperature of the samples uniformly in a short time. As bamboo culm is composed of hollow cylindrical and separated by solid transversal diaphragms at the nodes, most of water molecules are expelled through diffusion from axial direction by vessels, while some water molecules in the chamber between adjacent internodes would diffuse from bamboo yellow into the internodes, and only a small part of water molecules are expelled from horizontal direction by bamboo green. It is easy to expel the water molecules along axial direction of bamboo through vessels, and the process could be accelerated under vacuum condition. As the chamber between adjacent internodes is a relatively sealed space, the water molecules inside internodes are difficult to move out, especially by common drying method. When the

Fig. 1. Schematic illustration for drying round bamboo by VMD method.

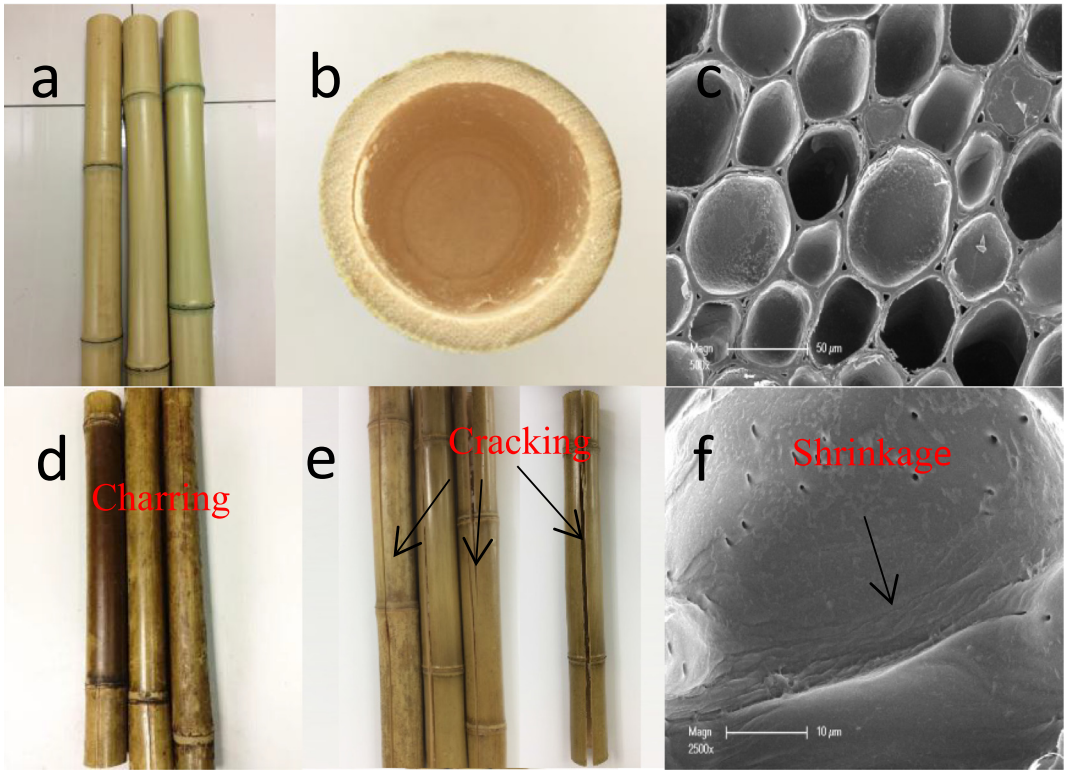

Fig. 2. The bamboo samples dried by different drying method (a-c, VMD; d-f, COM).