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Effects of Combined Lewis Acid and Ultrasonic Pretreatment on the Physicochemical Properties of Heat-Treated Moso Bamboo

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Abstract : Moso bamboo is a common non-wood forest resource in Asia that is widely used in construction, furniture, and other fields. Influenced by the heterogeneous structure and various hygroscopic groups of bamboo, the deformation occurs as moisture absorption and desorption when the environment temperature and humidity conditions change. Thermal modification is a well-established commercial technology for improving the dimensional stability of bamboo. However, the higher energy consumption and carbon emissions limit its further development. Previous studies have indicated that inorganic salt-assisted thermal modification could lead to significant reductions in moisture absorption and energy consumption. Represented by metal chlorides, it could show Lewis acid properties when dissolved in water, generating metal ion ligand complexes. In addition, ultrasonic treatment, as an efficient and environmentally friendly physical treatment method, improved the accessibility of pretreatment chemical impregnation agents and intensified mass and heat transfer during reactions. To save energy and reduce deformation, this study elucidates the influence of zinc chloride-ultrasonic treatment on the physicochemical properties of heat-treated bamboo, and the details of the bamboo deformation mechanism with Lewis acid are explained. Three sets of parameters (inorganic salt concentration, ultrasonic frequency and heat treatment temperature) were designed, and an optimized process was proposed to clarify this scientific question, that is: 5% (w/w) zinc chloride solution, 40 kHz ultrasonic waves and heat treatment at 160 °C. The samples were characterized by different means to analyze changes in their macroscopic features, pore structure, chemical structure and chemical composition. The results suggested that the maximum weight loss rate was reduced by at least 19.75%. The maximum thermal degradation peak of hemicellulose was significantly shifted forward. The hygroscopicity was reduced by 10.15%, the relative crystallinity was increased by 4.4%, the surface contact angle was increased by 25.2%, and the color change was increased by 23.60 in the optimal condition. From the electron microscope observation, the treated surface became rougher, and cracks appeared in some weaker areas, accelerating starch loss and removing granular attachments around the pits. By ion diffusion, zinc ions diffused into hemicellulose and a partial amorphous region of cellulose. Parts of the cell wall structure were subjected to swelling and degradation, leading to the broken state of parenchyma cells. From the Raman spectrum, compared to conventional thermal modifications, hemicellulose thermal degradation and lignin migration is promoted by Lewis acid under dilute acid-thermal condition. As shown in this work, the combined Lewis acid and ultrasonic pretreatment as an environmentally friendly, safe, and efficient physic-chemical combined pretreatment method improved the dimensional stability of Moso bamboo and lowered the thermal degradation conditions. This method has great potential for development in the field of bamboo heat treatment, and it might provide some guidance for making dark bamboo flooring.

Keywords : Moso bamboo, Lewis acid, ultrasound, heat treatment
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