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Improving the Mould and Blue-stain-resistance of Bamboo through Acidic Hydrolysis

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Introduction

Bamboo is much easier to be attacked by fungus compared to wood, resulting in shorter service life and higher loss in storage and transportation. It has been long accepted that the high content of starch and sugars in bamboo is mainly responsible for its low mould resistance. In this paper, acetic acid, propionic acid, oxalic acid and hydrochloric acid were adopted to hydrothermally hydrolyze the starch in bamboo, with the aims to investigate their respective effect on the mould and blue-stain resistance of bamboo. The glucose yields, weight loss and color changes of solid bamboo caused by the different acidic hydrolysis were also compared.

Materials and Methods

Materials

- Moso bamboo (Phyllostachys pubescens Mazel ex H. de Lebaie) strips with regular cross section were purchased from Hangzhou Dazhuang Flooring Co., Ltd. The samples for mould resistance test had dimensions of 50 mm (longitudinal) × 20 mm (tangential) × 5 mm (radial), whereas the ones for both weight loss and color change measurement were 20 mm (longitudinal) × 20 mm (tangential) × 5mm (radial). For each treatment, there are 12 specimens for mould resistance tests and 10 respectively for weight loss and color change tests. Five kinds of common acids, namely acetic acid, propionic acid, oxalic acid, citric acid, and hydrochloric acid were purchased from Beijing Chemicals (Beijing, China). The mould fungus (Aspergillus niger van. Tieghem) and the blue-staining fungus (Botrydiplodia theobromae Pat.) were purchased from the Institute of Forest Ecology Environment and Protection, Chinese Academy of Forestry (Beijing China).

Acidic treatment

- Bamboo specimens were soaked in the aqueous solutions of acetic acid, propionic acid, oxalic acid, citric acid and hydrochloric acid with concentration (W/W) of 2%, 2%, 2%, 2% and 0.7%, respectively for 1 hour at room temperature. Then the samples together with the acidic solutions were transferred to a drying oven, and heated at a temperature of 90℃ for 3 hours. Afterwards, the residual acids in the treated samples were removed by repetitive washing with deionized water. All samples were then oven dried at 105℃.

Mould resistance tests

- The tests of laboratory mould resistance were carried out according to a Chinese national standard GB/T 18261-2000. The treated and control (untreated) blocks were placed in petri dishes containing agar (2% agar) with the selected fungus and incubated for 4 weeks at 25℃ and 85% relative humidity. The change of each sample was photographed and recorded every day. The samples were visually rated for the growth of fungi on the following scale: 0 = no growth, 1 = 25 percent, 2 = 50 percent, 3 = 75 percent, 4 = 100 percent coverage with mold. To evaluate growth of fungi objectively, the infection area on bamboo surface after the test was estimated by Matlab (MathWorks, America, R2011b). The infection degree of bamboo was obtained from ratio of hypha pixels to the whole block pixels.

Soluble sugar content in the hydrolysates

- Ion Chromatography with an ampere detector (850, Metrohm, Switzerland) was used to test the content of glucose in the hydrolysates.

Color change

- The color changes of specimens due to acidic treatments were measured by a portable chromatic aberration meter (6834, BYK-Gardner, Germany).

Results and Discussion

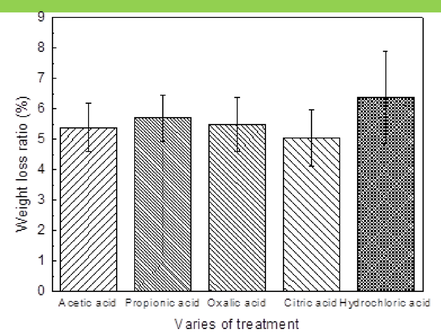

Fig.1 Weight loss of bamboo caused by five different acidic treatments.

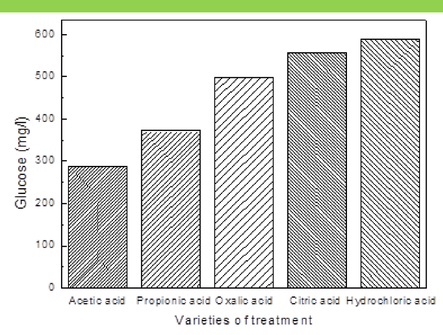

Fig.2 Glucose content in five different acid hydrolysates.

Table 1 Fungus growth rating of bamboo treated with different acids

Varieties of treatment	*A. niger*	*Penicillium citrinum*	*Trichoderma viride*	*B. theobromae*
Control	4	4	4	4
Acetic acid	3	3	3	3
Propionic acid	3	3	3	3
Oxalic acid	3	3	2	2
Citric acid	3	2	2	2
Hydrochloric acid	2	2	2	2

Table 2 Color parameter changes of bamboo due to acid treatments

Parameter	Acetic acid	Propionic acid	Oxalic acid	Citric acid	Hydrochloric acid
ΔL*	-4.329	-2.945	-4.897	-4.979	-6.127
Δa*	0.46	0.249	1.557	0.22	2.214
Δb*	-2.747	-3.578	-2.276	-3.304	-2.061
ΔE*	5.15	4.64	5.62	5.98	6.83

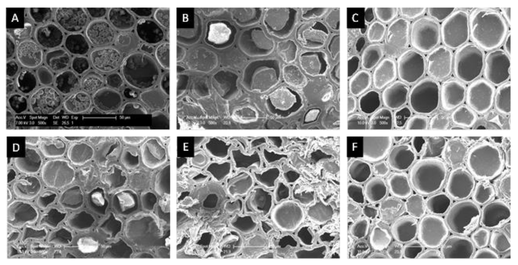

Fig.3 Distribution of starch in bamboo parenchyma cells (A: Control sample, B: Acetic acid treatment sample, C: Propionic acid treatment sample, D: Oxalic acid treatment sample, E: Citric acid treatment sample, and F: Hydrochloric acid treatment sample).

Bamboo infected by *A. niger* and *B. theobromae* respectively were observed periodically.The occurrence and propagation of both fungi on the treated samples were all much later and slower than those on the control samples. This phenomenon was especially obvious during the period of the first 3-5 days. The growth rating of for treated groups ranged between 2 and 3 compared to 4 for control group (Table 1). The general improvement in mould and blue-stain resistance of bamboo after acidic treatments could be to a large extent attributed to the reduction of nutritious components in bamboo, including free sugars and starch particles.

The glucose yields in different hydrolysates were shown in Fig.2. The glucose yields in hydrolysates derived from acetic acid and propionic acid were 288 and 372 mg/l respectively, significantly lower than the 500, 557 and 588 mg/l, respectively from oxalic acid, citric acid and hydrochloric acid. It can be observed that the starch grains in the parenchyma cells disappeared mostly after treated with propionic acid, oxalic acid, citric acid and hydrochloric acid. However, it doesn't mean the whole starch had been hydrolyzed into glucose. Some of it could still exist in bamboo but with the new structure or even smaller sizes that was invisible under SEM.

Conclusions

Bamboo treated with acetic acid, propionic acid, oxalic acid, citric acid and hydrochloric acid in a low concentration could improve their fungus growth rating from 4 of control samples to 2 or 3 resistance. The surface color of bamboo was only slightly influenced by the four different acid treatments with the highest overall color change value (ΔE*) only 6.83 for the hydrochloric acid treatment. The results in this study demonstrate acidic treatment can effectively remove the starch grains in bamboo but only result in limited improvement in fungus resistance. Therefore, the origins of the low mould and blue-stain resistance of bamboo cannot be solely attributed to the existence of starch particles. Other possible mechanism like the content of soluble carbohydrates (glucose, fructose, sucrose) should be further explored.

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