Technical Note

Antimold Effect of Ultrasonic Treatment on Chinese Moso Bamboo

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Abstract

This study examined the antimold effect of ultrasonic treatment on Moso bamboo. Six different ultrasonic processes were conducted, and mold development was observed after 4-week high-humidity conditioning. The results showed that the mold rate of bamboo decreased after ultrasonic treatment, which was inversely proportional to the power and duration of treatment time. Scanning electron microscopic analysis revealed that the starch granules largely disappeared after ultrasonic treatment, which likely occurred because the ultrasonic wave broke or gelatinized the starch and widened the pits of the cell wall so that the starch could easily flow out resulting in slightly reduced mold growth.

Bamboo has been widely used in various fields due to its fast rate of growth and excellent tensile strength. In China, many engineered bamboo products, such as carriage floors and container flooring, have been developed and manufactured as well as exported all over the world (Zhang 1995). However, bamboo culm contains many nutrients, such as starch in parenchyma, that are vulnerable to attack by fungi (Liese 1998). When bamboo products are used and stored at appropriate temperatures and humidity, mold will occur on the surface of the bamboo and change the appearance and properties of its products. Therefore, the antifungal treatment of bamboo is highly critical for bamboo product storage and marketing.

It has been reported that the compound of chitosan-copper complex (CCC) and propiconazole responded best against all of the test fungi, even at low concentrations, and showed a strong synergistic effect on bamboo (Sun 2012). However, the above method was dependent on inhibitors' effective penetration into the bamboo, and its disadvantage was that the starch in parenchyma was not removed before treatment. Bamboo penetration treatment is difficult because of the shortage of conductive tissue in a horizontal direction; therefore, we wanted to find a way to increase the potential of penetration and at the same time remove as much starch as possible, as starch can be a mold food source.

Ultrasonic treatment is widely used to reduce processing time and increase efficiency in food processing treatments such as sterilization, extraction, and filtration (Mason et al. 1996). Ultrasonic cavitation was shown to significantly increase the longitudinal permeability of the more permeable sugar maple by Chen and Simpson (1992), while Avramidis (1998) reported that ultrasound enhanced the absorption of chromated copper arsenate and pentachlorophenol in small sapwood specimens under atmospheric pressure. Recently, it was reported that ultrasonic treatment increased the specific permeability coefficient in both radial and tangential directions of Douglas-fir heartwood (Tanaka et al. 2010). However, the use of ultrasonic treatment on bamboo has been little reported. This research thus aimed to conduct ultrasonic treatment on bamboo in order to evaluate the antimold results and observe its effect on the microstructure and removal of starch.

Materials and Methods

Materials

Processed moso bamboo (*Phyllostachys pubescens*) chips, without green and yellow skins, measuring 21 by 5 by 1,200 mm (width by thickness by length), and aged 6 years, were used in the study. The bamboo was supplied by a bamboo factory in Anji, Zhejiang, China.

Ultrasonic processes

Raw materials were sawed into 21 by 21 by 5-mm samples, put into distilled water, and treated with ultrasonic

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parameters, as shown in Table 1. To compare the effect of the ultrasonic process on bamboo, control groups of bamboo were dipped into cold distilled water simultaneously for 60 minutes.

Mass loss was calculated according to the following formula:

$$\text{Mass loss (\%)} = \frac{m_1}{m_0} \times 100 \quad (1)$$

where m_1 is the dry mass of bamboo samples after ultrasound and cold-water treatment and m_0 is the dry mass before treatment.

Molding conditions

All ultrasonic-treated samples and control groups were placed under the same conditions with a temperature of 30°C ± 2°C and relative humidity of 95% ± 5% for a period of 4 weeks in order to observe the molding situations on the bamboo surface on a daily basis. The moldy sections (21 by 21 mm) of the bamboo samples were pictured and analyzed in the last 2 weeks when the mold rate of the control group reached 100 percent by the graphic analysis software Motic Image Advanced 3.2. The mold rates were calculated according to the following formula (Zhou et al. 2012):

$$\text{Mold rate (\%)} = \frac{s_1}{s_0} \times 100 \quad (2)$$

where s_1 is the total moldy area of the observed surface and s_0 is the total area.

Results and Discussion

Mass loss

Mass loss in the control and ultrasonic groups with different powers and durations are shown in Figure 1. This figure illustrates that mass loss by ultrasonic treatment was three times greater than by cold-water extraction. Mass loss was proportional to ultrasonic power and duration time, although the amount of the increase in the power was small. This indicated that with the increase in ultrasonic power and duration, mass loss rose simultaneously. Furthermore, the effect of ultrasonic duration on mass loss was slightly more evident than with that of ultrasonic power. In the group treated with an ultrasonic power at 1,600 W, an ultrasonic duration of 3 seconds corresponded to the greatest mass loss. Therefore, it is presumed that some of the bamboo nutrients such as starch that are usually removed in cold-water extraction must have been largely dissolved in the water after ultrasonic treatments.

Table 1.—Ultrasonic processes.

No.	Ultrasonic time (s)	Interval time (s)	Total time (min)	Ultrasonic power (W)
a	1	4	60	800
b	2	3	60	800
c	3	2	60	800
d	1	4	60	1,600
e	2	3	60	1,600
f	3	2	60	1,600

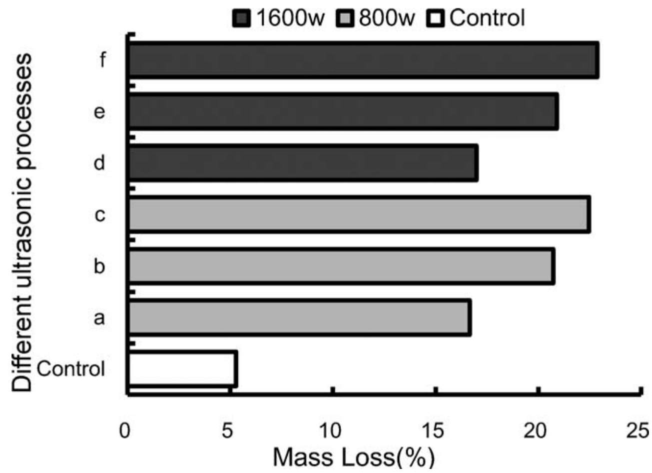

Figure 1.—Mass losses in the control and ultrasonic groups.

Mold rate

Mold rate analysis of the bamboo based on different ultrasonic process group results was compared with that of the control group. According to Figure 2, the mold rates of the control group reached 100 percent, but all the mold rates of ultrasonic-treated groups were lower than those of the control group, with an average value of 80 to 90 percent. On the whole, the mold rate was inversely proportional to ultrasonic power, while ultrasonic duration had little influence on mold rates. There were obvious differences among the results in the ultrasonic groups of 1,600 W. In the samples treated with an ultrasonic power of 1,600 W, an ultrasonic duration of 3 seconds corresponded to the lowest mold rate (Fig. 2, group f). The decrease in the mold rate was not as high as expected, probably because the ultrasonic treatment removed starch grains and changed the pit structure to some extent.

Microstructure analysis

Scanning electron microscopic (SEM) photographs (×400) of longitudinal sections are shown in Figure 3. According to Figure 3a, many parenchyma cells in the

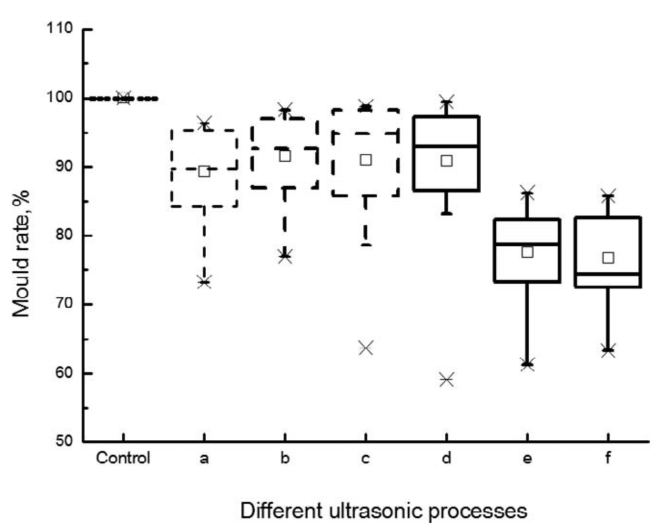

Figure 2.—Mold rates of bamboo cross sections after different ultrasonic processes.

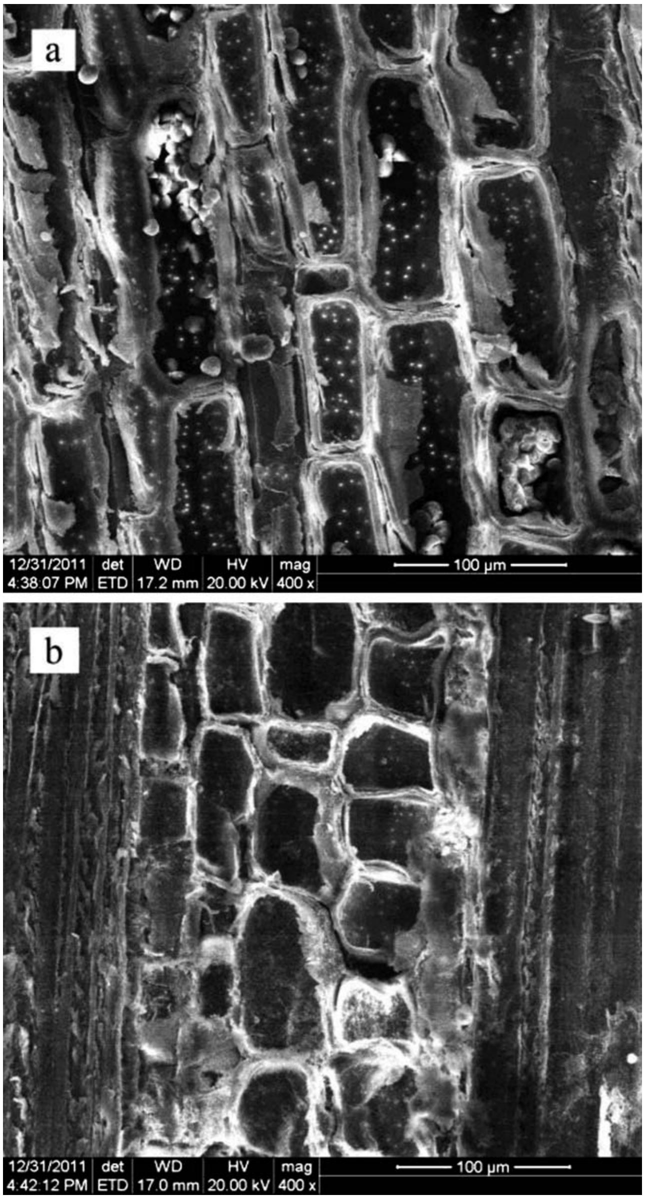

Figure 3.—Scanning electron microscopic micrographs of the longitudinal section before (a) and after (b) ultrasonic treatment (×400).

control group were full of starch granules, but there were hardly any starch granules in parenchyma cells (Fig. 3b) after ultrasonic treatment. A possible explanation may be that the ultrasonic wave broke or gelatinized starch grains and simultaneously caused pit breakdown so that the starch could easily flow out from the pits of the cell wall. This illustrated the mass loss of bamboo after ultrasonic treatment and was attributed mainly to the disappearance of large amounts of starch granules. This implied that the reduction of starch in bamboo inhibited the spread of fungi to a certain extent.

The SEM diagram (×1,600) with an ultrasonic duration of 3 seconds is provided in Figure 4. Massive cracks existed in region A of Figure 4. It was inferred that ultrasonic waves broke or gelatinized starch grains, causing the starch to partly leave the pit, while other particles adhered to the cell wall. The bamboo cell walls were suddenly reduced in size when the SEM sample was dried, which subsequently led to cracking in the starch crust layer close to the cell wall. Starch granules were partly gelatinized in region B of Figure 4, but had not been crusted. This condition showed that gelatinized starch existed in the parenchyma cells in the form of floccules. The results showed that ultrasonic treatment could reduce the starch and allow it flow out easily and decrease the mold rate of bamboo to some extent.

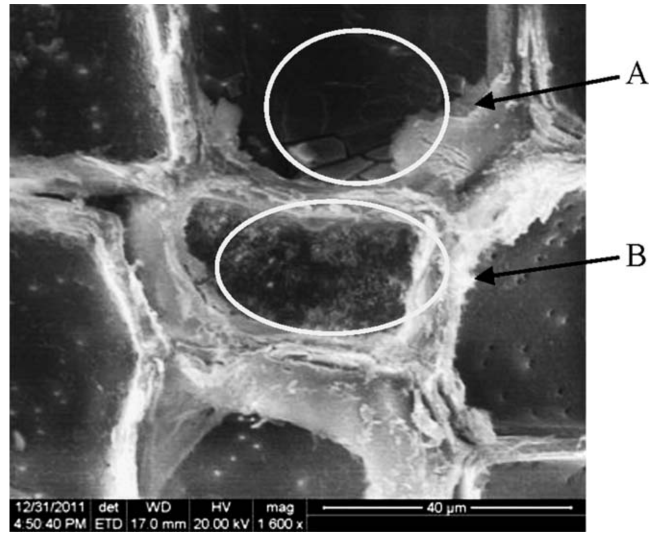

Figure 4.—Parenchyma cells after ultrasonic power of 1,600 W and ultrasonic duration of 3 seconds (×1,600). Massive cracks are shown in area A; partly gelatinized starch granules are shown in area B.

Conclusions

The results indicated that the mass loss was increased with the increasing ultrasonic power and duration and that the mold rate decreased accordingly. SEM analysis showed that large amounts of starch granules disappeared after ultrasonic treatment while there was a tendency of cracking on some inner cell walls. The possible reason was that the ultrasound wave broke or gelatinized large starch grains so that the starch could easily flow out from the pits of the cell wall. Therefore, it is supposed that ultrasonic treatment could act as a pretreatment or assistance method used with preservatives to control molding in bamboo. The extent of the effect of ultrasonic treatment on bamboo should be researched in the future in order to make further improvements and achieve successful practical applications.

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