MICROWAVE HEATING
A Potential Pretreating Method for Bamboo Fiber Extraction

by

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Microwave heating is proposed as a kind of pretreating methods for bamboo fiber extraction. Effect of various processing parameters, e. g. microwave initial-setting power, reaction temperature, irradiation time, and bath ratio (bamboo to water) on bamboo powders was studied. Analysis of chemical components indicates that microwave assisted extraction is a mild treating method without obvious change of main constitutes of bamboo. The removal of polysaccharide by microwave treating resulted in loosening the structure and thus benefits hydrolysis of bamboo in subsequent.

Key words: *bamboo, microwave heating, total sugar*

Introduction

Bamboo timber possesses extra-compacted structure in nature, which hinders the penetration of degumming chemicals and reduces the efficiency for fiber extraction. In this case, the pre-removal of partial substances in bamboo is necessary to loosen the structure and enhance the degumming efficiency in subsequence.

Microwave has been recognized as a unique and novel technology in terms of the rapid heating enhancement resulting from three major mechanism viz., dipolar momentum, ionic conduction and interfacial polarization (a combination of ionic conduction and dipolar momentum) [1]. Microwave assisted extraction is a process employing microwave energy, together with solvent, to separate target compounds from raw materials. It shows advantages in reducing energy requirements for processing and presents the capability for a uniform and selective treating [2]. Water is one of the most environmentally friendly and readily available solvents in the world. It is by far the most widely used medium in terms of microwave assistant extraction of components from vegetable materials.

In the present study, microwave assistant extraction was applied to pretreat bamboo powders. Electromagnetic effect generated by microwaves might interact with bamboo pow-

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ders and water to speed up the recovering of water-soluble substances from bamboo. The influence of main processing parameters was investigated.

Materials and methods

Five year old Moso bamboo was selected and its hard epidermis was removed prior to slicing and grinding process. Bamboo powders passing through a No. 100 mesh sieve were collected and subsequently extracted with a 1:2 (v:v) mixture of benzene and alcohol for three hours. The resulting bamboo powders were then boiled and rinsed thoroughly with deionized water, and air-dried for further use. All the other chemicals of reagent grade were purchased from J&K Chemical Ltd., Shanghai, China.

The microwave assisted extraction was conducted in an ultrasonic-microwave combined reactor system (XO-SM50 type; Nanjing Xianou Instrument Manufacturing, Nanjing, China). The effect of microwave initial-setting power, reaction temperature, reaction time, and bath ratio was investigated by single factor experiment. Reaction liquid was collected and centrifuged at 10000 rpm for 10 minutes. The supernatant was used for total sugar analysis through a modified sulphuric acid-phenol colorimetric method with glucose as the reference [3]. A volume of supernatant (1.0 ml) was mixed with 0.5 ml of 6% (w/w) aqueous solution of phenol and 2.5 ml of concentrated sulphuric acid in a glass tube. The tube was fully shaken and then allowed to stand for 35 min at room temperature. Spectrophotometric measurements were performed by means of a UV-9600 UV/visible spectrophotometer produced by Beijing Beifen-Ruili Analytical Instrument (Group) Co., Ltd., Beijing. The absorption spectra was measured at 490 nm against a spectrophotometric blank containing 1.0 ml of deionized water, 0.5 ml of 6% phenol and 2.5 ml of concentrated sulphuric acid. The absorbance value viz., optical density (OD) value was compared to analyze the suitable microwave assisted extraction condition.

The chemical components of original bamboo powders as well as microwave-pretreated bamboo powders were analyzed by Fourier transform infrared (FTIR) spectrophotometer (IS5, USA) and spectra were recorded in reflection mode at 2 cm^{-1} interval over the wavelength range, 4000-500 cm^{-1}.

Results and discussion

Effect of microwave initial-setting power on yield of total sugar from bamboo

Microwave initial-setting power is the key factor greatly influencing the total sugar yield from bamboo. In the present study, microwave initial-setting power was varied from 290 to 490 W, while keeping temperature, irradiation time and bath ration at 50 °C, 23 minutes, and 1:20, respectively. The change of OD value obtained from the spectrometer corresponded to the variation of the yield of total sugar. As can been seen in fig. 1, there was a rising trend in the OD value from 290 to 440 W. This increase is due to the fact that a rise in microwave power enhances dipole reactions and causes rapid heating of mixture to improve the solubility of bamboo [4]. Meanwhile, fast heating of the intracellular water may cause the cell wall breakage [5]. More polysaccharides in bamboo would flow out and dissolve in the extraction medium, thus enhanced the yield of total sugar. However, a downward trend of OD value was observed after 440 W. Since polysaccharide structure is easily destroyed during the process, it seems that the denaturation of polysaccharide happened at excessive power and led

to the inhibition of total sugar yield [6]. The highest total sugar yield was obtained at 440 W of microwave initial-setting power level.

Effect of reaction temperature on yield of total sugar from bamboo

To evaluate its effect on yield of total sugar, reaction temperature was varied from 35 to 55 °C, maintaining microwave initial-setting power, extraction time and bath ratio at 440 W, 23 minutes, and 1:20, respectively. An increase in yield of total sugar (OD value) was observed with an increase in temperature from 35 °C to 40 °C, as presented in fig. 2. And then, the yield of total sugar decreased. It seems that appropriate temperature can accelerate the release of the extractant. The electromagnetic field generated by microwave could speed up the diffusion rate of molecules of polysaccharide in bamboo from the internal solid phase to the solid-liquid interface. However, excess reaction temperature would lower the efficiency of microwave assisted extraction due to the restriction of external condition.

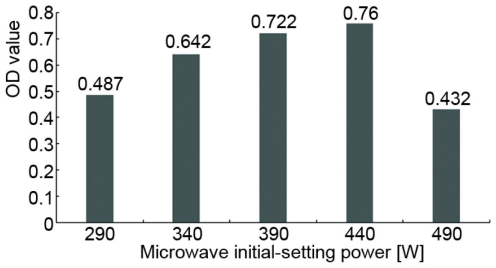

Figure 1. Effect of microwave initial-setting power on the yield of total sugar

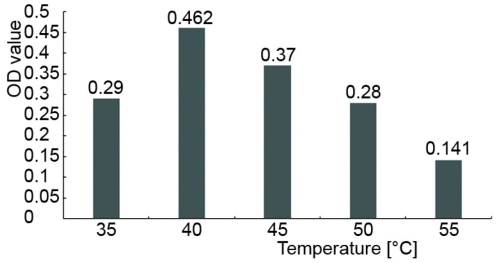

Figure 2. Effect of reaction temperature on the yield of total sugar

Effect of irradiation time on yield of total sugar from bamboo

To analyze the effect of irradiation time on yield of total sugar from bamboo, experiments were launched at 440 W, 40 °C, and bath ratio of 1:20 with a variety of irradiation time from 13 to 33 minutes. It is shown in fig. 3 that there was a slight fluctuation on the OD value (representing the yield of total sugar) at the beginning stage. After 23 minutes, a decrease in the yield of total sugar with an increase in irradiation time was observed. The time of continuous irradiation should be controlled since the long-time irradiation might cause the solvent boiling and thus result in the serious squander of solvent and the loss of the target products [7]. It is found the prolonging of microwave radiation time helped to improve extraction efficiency at the beginning. After a certain period of time, extraction efficiency was inhibited. Therefore, radiation time should not be too long. Highest OD value was observed at 23 minutes, indicating the highest yield of total sugar could be obtained from bamboo under this condition.

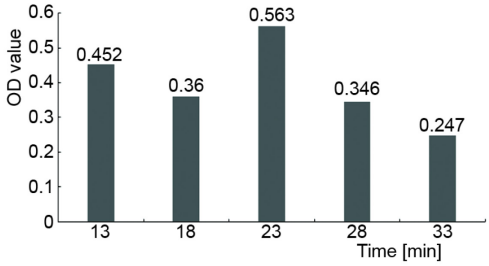

Figure 3. Effect of microwave treating time on the yield of total sugar

Effect of bath ratio (bamboo to water) on yield of total sugar from bamboo

The bath ratio of bamboo to water (w:v) varied from 1:10 to 1:30, keeping the microwave power, reaction temperature, and irradiation time at 440 W, 40 °C, and 23 minutes,

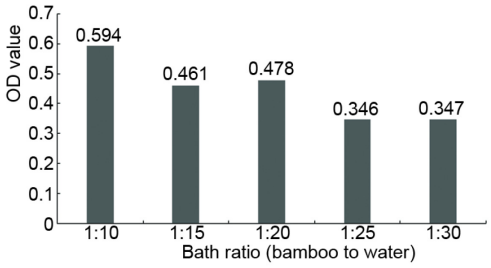

Figure 4. Effect of bath ratio on the yield of total sugar

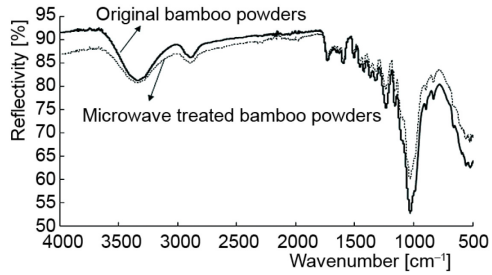

Figure 5. The FTIR-ATR spectra of bamboo samples

respectively. The weight of bamboo powers was fixed to 0.5 g, while the volume of water changed from 5 to 15 ml. It is indicated in fig 4. that a fluctuation in OD value was found when the bath ratio changed from 1:10 to 1:20. Afterwards, a decrease in OD value was found at bath ratio of 1:25 and limited variation in OD value was observed between bath ratio of 1:25 and 1:30. Microwave radiation greatly affects the polar compounds. Certain amount of water was required to ensure that the bamboo powers were being soaked and can be swelled during the extraction. Under microwave irradiation, water molecule would turn from high rotational state into excited state and presented an unstable status. Under this circumstances, water molecule might evaporate to strengthen the driving force for the extraction, or it might release the excess energy and return to the ground state. The released energy transfers to bamboo might speed up the molecular movement and shorten the diffusion time of extract and finally results in the increase of total sugar yield. However, when the amount of water exceeds a certain value, polar molecule in water might absorb a significant portion of microwaves, thus, decreases the penetration depth for microwave irradiation and results in a loss of extraction efficiency towards bamboo substances. Highest OD value was obtained at a bath ratio of 1:10, indicating highest yield of total sugar could be achieved under this condition.

Chemical components analysis

The FTIR-ATR spectra of original bamboo powders and microwave treated bamboo powders were presented in fig. 5. The two profiles showed the similarity in shape, indicating that the main components for microwave pretreated bamboo powders were almost the same as original bamboo powders consisting of cellulose, lignin, and hemicellulose. Thus, microwave assisted extraction is a mild and gentle pretreating method.

Conclusion

Microwave initial-setting power, reaction temperature, irradiation time, and bath ratio (bamboo to water) were regarded as the main parameters in microwave assisted extraction of bamboo. The preferred treating condition were: 440 W, 40 °C, 23 minutes, and 1:10. Under this condition, more yield of total sugar could be achieved. Analysis of chemical components revealed that there was no obvious change between original bamboo powders and microwave-treated bamboo powders, indicating that microwave assisted extraction is a gentle and mild method. It is concluded that the microwave assisted extraction shows the possibility in pretreating bamboo substances to reduce the burden of degumming in subsequent.

Acknowledgment

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