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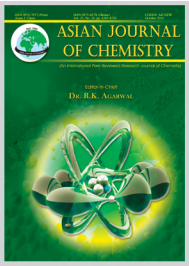

Effects of Thermal Treatment on Chemical Transformation of Short Bamboo-Fibers†

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This study was performed to investigate the influence of the thermal treatment on the chemical transformation of short bamboo-fibers. Results showed that cleavage of acetyl groups of the hemicellulose occurred at elevated temperature and completed beyond 190 ºC for more than 3 h, resulting a noticeable increase of cellulose content at up to 190-205 ºC during 3 h and a significant mass loss at elevated temperature beyond 205 ºC for 3 h. The possible effects of chemical changes on the reduction of hygroscopicity have been discussed.

Key Words: Bamboo-fibers, Thermal treatment, Chemical transformation, Hygroscopicity.

INTRODUCTION

Thermal-treatment has been established as a new effective method by which the hygroscopicity of wood is reduced substantially, resulting in a product with essentially improved durability and dimensional stability[1]. However, this kind of research is still limited in the field of modification of wood. In this paper, we have investigated the influence of the thermal-treatment on the chemical transformation and associated improved hygroscopicity of short bamboo-fibers. As reported[2], the high content of hydroxyl group of short cellulose fiber is the main cause responsible for poor compatibility between reinforced cellulose fibers and the polymers used as matrix. In this work, thermal treatment process is carried out to investigate the effects of the treatment on chemical changes of bamboo-fibers.

EXPERIMENTAL

Pre-dried short bamboo-fibers (BF) from bamboo residues/wastes were grinded into powder of 60-80 mesh and placed in a vacuum oven under -0.09 MPa and thermally treated for 1-5 h at variable temperatures between 160 to 220 ºC and then slowly cooled to room temperature. The deacetylation of hemicelluloses in the samples were determined by infrared spectroscopy recorded with Nicolet 380. The cellulose content was determined by the method of nitric acid-ethyl alcohol. The concentration of accessible hydroxyl groups in the resulting samples were measured by determining the degree of acetylation after treatment with acetic anhydride and confirmed by infrared spectroscopy indicating strong carbonyl absorptions in 1740-1256 cm^{-1} region[3].

RESULTS AND DISCUSSION

Deacetylation of hemicellulose: As shown in FTIR spectra (Fig. 1) of thermally-treated bamboo-fibers with variable temperature (between 160 to 220 ºC) and time, the intensity of carbonic(acetyl group) peak in the 1740-1265 cm^{-1} region decreased with elevated heat-treatment temperature and also decreasing with the increase of holding time, which is most likely due to the cleavage of the acetyl groups of hemicellulose during thermolysis[4] and approximately all the accessible acetyl groups were cleaved at temperature beyond 190 ºC for more than 3 h. When further comparing the spectra of the treated bamboo-fibers with the heat-treated bamboo-fibers with that of fully treated at 220 for 4 h, a noticeable intensity increase observed attributable to the carbonyl peak. This intensity increase can be commonly explained by polycondensation of lignin, which have been similarly reported by Tjeerdsma[4].

Analysis of cellulose content: Compared with the content of controlled bamboo-fibers sample (44.82 %), cellulose content of treated bamboo-fibers increased slightly at temperature between 160 and 190 ºC for 3 h and then increased rapidly up to 54.88 % at high temperature of 205 ºC (Fig. 2), while cellulose content of treated bamboo-fibers increased steadily from 52.61-53.80, 55.87, 57.37 and 62.73 %, respectively for 1, 2, 3, 4 and 5 h at 220 ºC (Fig. 2). According to these experimental results, it was obvious that the temperature played a more important role than time during thermal

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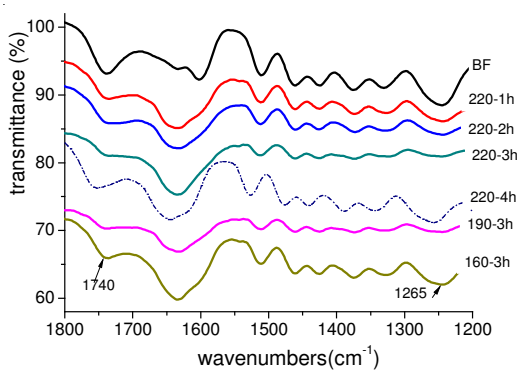

Fig. 1. FTIR spectra of treated samples with variable temperature and time

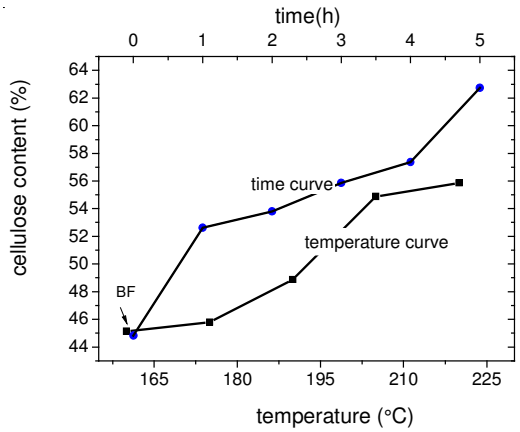

Fig. 2. Cellulose content of treated bamboo-fibers with variable temperature and time

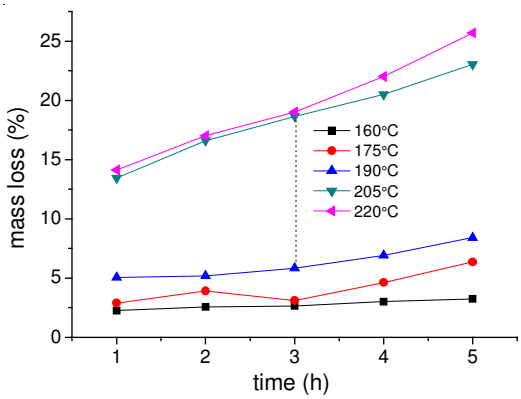

Fig. 3. Mass loss of treated bamboo-fibers with variable temperature and time

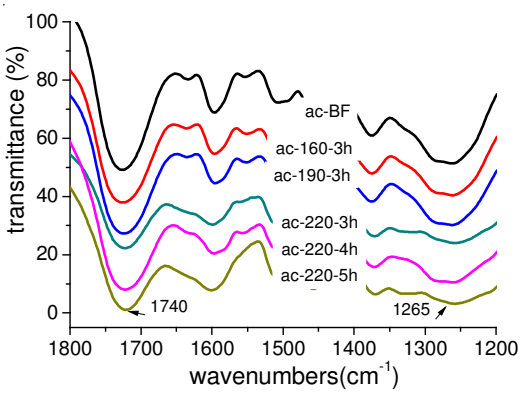

Fig. 4. Esterification degree of treated bamboo-fibers with variable temperature and time

treatment process; for treated samples at higher temperature at 220 ºC, treated samples with 1 h holding time, the cellulose content increased about 10 % more than treated bamboo-fibers at 160 ºC for 3 h. As indicated by researchers this increase of the cellulose content was mostly attributed to the degradation of hemicelluloses in bamboo-fibers.

Analysis of mass loss: A noticeable mass evolution was observed in Fig. 3 for treated-bamboo-fibers at temperatures between 160 and 220 ºC. It showed that samples treated at 160 and 175 ºC exhibit negligible change of mass loss with the time extending, while, a slight increase was observed at temperature of 190 ºC. When the temperature was further elevated to 205 ºC mass loss increased significantly from 6 % at 190 ºC to 19 % at 205 ºC for 3 h, comparison of data corresponding to mass losses with increasing cellulose shows some similarities.

Accessible hydroxyl groups: Hygroscopicity is highly correlated with the accessible hydroxyl groups in wood or natural fibers[1]. It was found that noticeable carbonyl peaks in the 1740 and 1256 cm^{-1} region were observed in Fig. 4. after an acetic anhydride treatment due to esterification reaction of free hydroxyl groups into acetyl groups. Compared with non-treated bamboo-fibers sample, this peak clearly decreased with increased temperature and a substantially reduction of carbonyl groups was presented in treated bamboo-fibers at 220 ºC for 3 h, indicating improved hygroscopghicity due to thermal treatment at high temperature; while the peak continued to increase at temperature of 220 ºC for more than 4 h, which can be generally explained by condensation reaction of lignin.

Conclusion

Thermal treatment changes the chemical composition of treated bamboo-fibers, where both degree of deacetylation and content of cellulose are proportional to the observed mass losses with elevated temperature and delayed time, resulting in the significant reduction of accessible hydroxyl groups in bamboo-fibers after treated at high temperature beyond 220 ºC for 3 h. It is concluded that thermal treatment has been confirmed as a new effective method to improve the hygroscopicity of natural bamboo fibers. It could be expected that treated bamboo-fibers in this work shows potential for use as reinforced fiber contributable to high durability and dimensional stability for composite.

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