ABSTRACTS (PH D THESIS)

Investigation of natural adhesive composed of tannin and sucrose for particleboard

(Graduate School of Agriculture, Laboratory of Sustainable material, RISH, Kyoto University)

Zhongyuan Zhao

Wood-based materials are generally used in housing construction and furniture manufacture, and they are frequently present in living environments. In the wood industry, wood adhesives are necessary to obtain satisfactory physical properties of the wood-based materials. Usually, the synthetic resins are used during the manufacture of the wood-based materials, such as formaldehyde-based, polyvinyl acetate (PVAc), isocyanate based resin and so on. These synthetic resins are mostly based on the chemical substances which derived from fossil resources; however, it is believed that the use of the current wood adhesives will be unavoidably restricted in the future due to decreases in the reserves of fossil resources. In this study, tannin and sucrose were chosen as the adhesive component. In the first place, the weight ratio of adhesive compounds, mat moisture content, the effects of hot pressing temperature, hot pressing time and resin content on the physical properties of the particleboard bonded by tannin and sucrose were investigated, based on the results, the optimal manufacture conditions were obtained. Secondly, the thermal analysis, insoluble matter and FT-IR analysis were carried out to study the curing behavior of tannin and sucrose. Finally, based on the results of reaction mechanism of tannin and sucrose, citric acid was added to reduce the reaction temperature of tannin and sucrose.

Results and discussion

(1) Effects of pre-drying treatment, mixture ratio and resin content on physical properties of the particleboard bonded by tannin and sucrose [1]

Tannin and sucrose were used as adhesives to manufacture the particleboard, and we investigated the tannin/sucrose ratio, effects of the drying treatment after spraying and resin content on particleboard properties. As the results, the properties were enhanced when the drying treatment was carried out after the spraying, and when the sucrose ratio increased. Based on the results obtained, the optimum proportion of tannin to sucrose was 25/75, and the optimum resin content was between 30 wt% and 40 wt%. When the particleboards were manufactured under the optimum conditions, the maximum MOR, MOE, and IB are 21.3MPa, 5.0 GPa, and 1.3MPa, respectively. The results showed excellent mechanical properties, higher than those required for JIS A5908 type 18. Based on the results of FT-IR, 5-HMF was formed from the decomposition of sucrose during the heating treatment. In addition, as one kind of the possible reaction mechanism between tannin and sucrose, the dimethylene ether bridges seems to be formed. The possible reaction mechanism was shown in Figure 1.

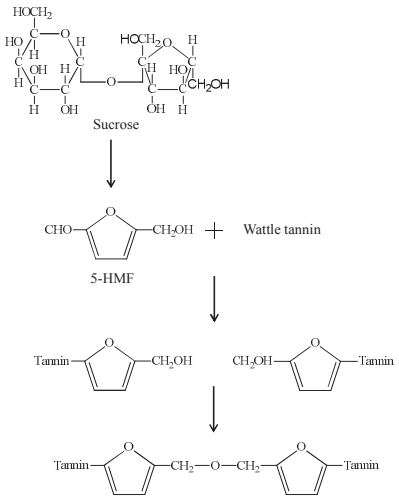

Figure 1. Possible reaction equation between tannin and sucrose.

(2) Effects of pressing temperature and time on particleboard properties, and characterization of tannin-sucrose adhesive [2]

The effects of hot pressing temperature and hot pressing time on the physical properties of the boards were investigated. The mechanical properties and water resistance increased as the hot pressing temperature and time increased. The optimum hot pressing temperature was 220°C, and the optimum hot pressing time was 10min. The MOR, MOE, IB and TS of the board manufactured under the optimum

condition were 23.5MPa, 5.3GPa, 1.6MPa, and 7%, respectively, which were higher than the requirement of the 18 type of JIS A 5908. Thermal analysis showed that the endothermic reaction of the adhesive composed with tannin and sucrose (only the ratio at 25/75) were happened at more than 200°C, this explaining the promotion of the particleboard properties when the hot pressing temperature was increased to 220°C. When the heating time was longer than 10min, insoluble matter was higher than 70wt%. The FT-IR results (Figure 2) showed the existence of the furan ring (1509 and 780 cm^{-1}), carbonyl group (1705 cm^{-1}) and dimethylene ether bridges (1200 cm^{-1}) in the cured adhesives. Comparing the FT-IR spectra of the adhesives heated in different heating time, there was not obviously change of chemical structure in the hot pressing time range of 10-20min.

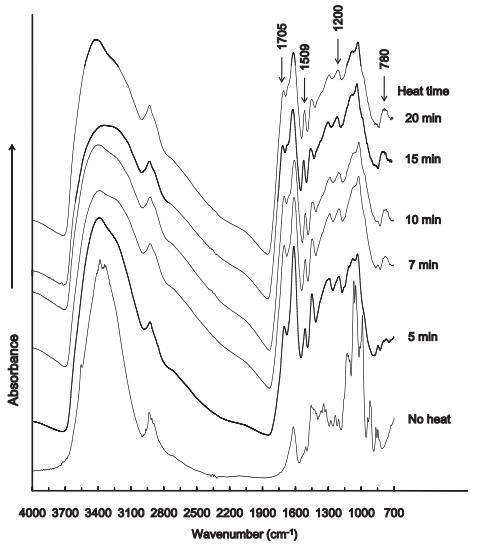

Figure 2. FT-IR curves of the adhesives cured at 220℃.

(3) Effects of addition of citric acid on physical properties of particleboard using tannin sucrose adhesive [3]

To reduce the hot pressing temperature of the particleboard bonded by tannin and sucrose, citric acid was incorporated into a tannin and sucrose adhesive, and the effect of this addition on the hot pressing temperature of particleboard was investigated. The results showed that the addition of citric acid was effective in reducing reaction temperature, and the insoluble matter remaining from 20.0 and 33.3 % citric acid contents adhesives at 200 °C was 2 times higher than for the tannin-sucrose adhesive. In addition, the results of the FT-IR analysis on the adhesives added citric acid and heated at 200°C (Figure 3) showed that the peaks of ester linkage (1731 cm^{-1}) and dimethylene ether bridges (1200 cm^{-1}) increased as the increasing of citric acid content. The physical properties of the particleboards bonded with tannin-sucrose-citric acid adhesive with 20.0 and 33.3 % citric acid contents at more than 200 °C satisfied the requirements of the type 18 standard of JIS A 5908 (2003). Consequently, the addition of citric acid promoted the reaction between tannin and sucrose at a lower temperature, and decreased the hot pressing temperature to 200 °C, while enhancing the bending properties at 220°C.

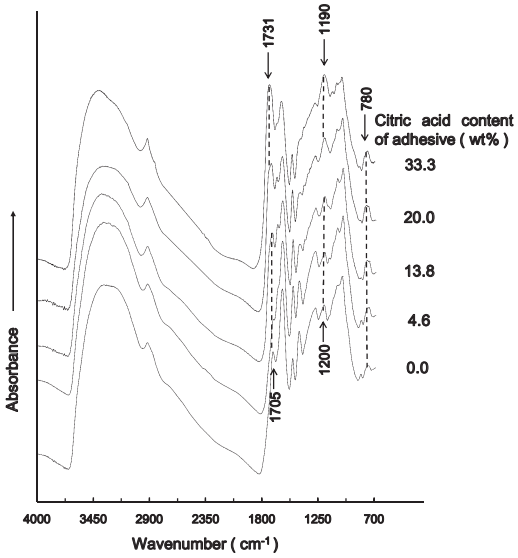

Figure 3. FT-IR curves of the tannin-sucrose adhesives added citric acid and heated at 200℃.

References

[1] Zhao, Z., Umemura, K. Investigation of a new natural particleboard adhesive composed of tannin and sucrose. Journal of Wood Science. 60, 269-277. June 2014.

[2] Zhao, Z., Umemura, K. Investigation of a new natural particleboard adhesive composed of tannin and sucrose 2: Effect of pressing temperature and time on board properties, and characterization of adhesive. BioResources, 10(2), 2444-2460. February 2015.

[3] Zhao, Z., Umemura, K., Kanayama, K. Effects of the addition of citric acid on tannin-sucrose adhesive and physical properties of the particleboard. BioResources, 11(1), 1319-1333. December 2015.