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## Chemical Properties of Heat-Treated Rubberwood

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### ABSTRACT

The usage of chemical preservative lead to environmental concerns regarding the process of treating, the loss of chemicals in service and the disposal of the treated wood at the end of its service life. Thus, heat treatment using steam is an alternative method to increase the durability of wood against fungus and termite, reduce the hygroscopicity and improve dimensional stability. The present study is undertaken to determine the effect of pressure and treatment schedule on chemical properties of rubberwood. The heat treatments were done at pressures, 30, 60, 90 and 120 psi and durations, 30, 60, 90 and 120 min. The chemical analysis of the heat-treated rubberwood for all treatments showed there were variations on the percentage of holocellulose,  $\alpha$ -cellulose, lignin and extractives content compared with the untreated rubberwood. The percentages of holocellulose and lignin decreased as the pressures and durations increased and they were lower compared with the untreated sample. The 120 psi-treated samples gave the highest percentage of ethanol-toluene, extractives compared with the other treated and untreated samples.

**Keywords:** heat treatment, rubberwood, chemical properties

### Introduction

Biological deterioration is one of the obvious threats or advantages to wood use. Given the right circumstances, they can break down and consume the cellulose, lignin and other components of wood. Wood preservatives are used to withstand fungal decay and insect damage as to produce a high quality wood product. However these chemical preservatives are also potentially dangerous towards wood treater's health and the environment. Three widely used preservatives are creosote, inorganic arsenic and pentachlorophenol (PCP) which are highly toxic. They have been linked to cause cancer in human and lab animals.

Studies on heat treatment on wood have been intensively carried out since 1920's. Several studies on alternative heat-treatment processes were conducted in France (Kandem *et al.* 2000; Bourgois *et al.* 1989), the Netherlands (Tjeerdsma *et al.* 1998) and Japan (Momohara *et al.* 2003). Heat treatment has the effect of modifying wood properties. The treatment consists of heating wood to temperatures exceeding its spontaneous combustion temperature with water vapour having a protective function. Heat treatment can be used to modify wood properties according to the needs of the intended application. Varying temperatures, varying treatment duration and varying drying techniques impart new properties to the treated wood. Wood properties are enhanced in regard to dimensional and form stability, thermal insulation, decay resistance and the flexibility of wood in adopting different shapes and forms. Thermally treated wood are utilized in interior and exterior claddings, garden furniture, flooring and sauna furnishing (Metsa-Kortelainen 2004).

Thus, this study was conducted to ascertain the effect of heat treatment toward chemical properties of rubberwood. A basic knowledge of the chemical modifications is vital for the optimization of processes to produce wood tailored for specific purposes. The objective of this study is to determine changes of chemical properties during the heat treatment process.

### Methodology

The 25-year-old rubberwood was obtained from Malaysian Rubber Board plantation in Sungai Buloh. The rubberwood logs were cut into small blocks (20 x 5 x 3.5 cm) before being heat-treated in an autoclave at pressures, 30, 60, 90 and 120 psi and durations, 30, 60, 90 and 120 min. Table 1 shows the temperatures obtained for each pressure used during the treatment.

Table 1: Temperature obtained for pressures used during the treatment.

Pressure (psi)	Temperature (°C)
30	120 ± 5
60	130 ± 5
90	140 ± 5
120	160 ± 5

For the analysis of chemical components, the treated wood blocks were then reduced to wood meal using a Wiley Mill. Then the portion, which passed through a BS 40 mesh size (425 µm) and retained on a BS 60 mesh size (250 µm) was collected and used to determine the chemical components. The chemical analyses were carried out according to the methods as summarized in Table 1.

Table 2: Standard methods used in chemical analysis

Method	TYPE OF ANALYSIS
T246-om	Determination of moisture content
T204 om-88	Alcohol benzene solubility in wood
Method of Wise et al (1946)	Holocellulose in wood
T203 om-93	Determination of a,b and g in wood
T222 om-88	Acid insoluble lignin in wood and pulp

## Results and Discussions

The percentages of ethanol-toluene extractives are shown in Figure 1. The results show that the 120/120 sample (treated at 120 psi and 120 min) gave the highest percentage of extractives compared with the untreated and other treated samples. With the increasing of the pressures and durations, the percentage of ethanol-toluene extractives also increased. As the pressures increased, so did the temperature. Some minor changes can occur at temperature above 50 °C, such as elimination of water and release of volatile components. Extractives were not structural components in wood, thus most of the volatile component evaporated easily during the heat treatment. For non-volatile components such as wood resin, the migration of it onto the surface of the wood has been observed at low temperature 120 -160 °C (Nuoponen *et al.* 2003). The increase in ethanol-toluene extractives also could probably be due to the considerable amount of partly hydrolysed hemicelluloses and pectin extracted even though they are not considered as extractives.

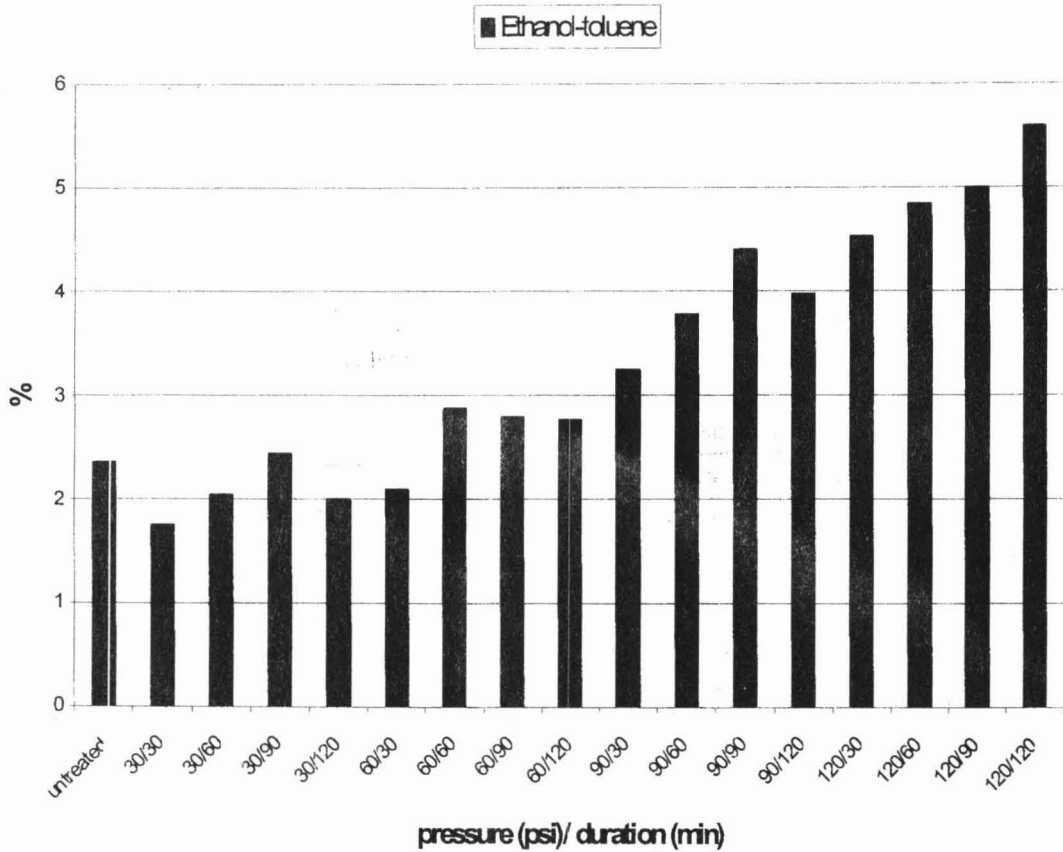


Fig. 1: The percentage of ethanol-toluene extractives for untreated and treated rubberwood samples at different treatment durations and pressures.

The results in Figure 2 show that the percentages of holocellulose decreased as the pressures and durations increased and they were lower compared with the untreated sample. Holocellulose consists of hemicelluloses and  $\alpha$ -cellulose. As for the  $\alpha$ -cellulose content, the percentage was slightly decreased as the pressures and durations increased (Figure 3). These were because at 150°C, the changes for hemicelluloses and cellulose was more obvious as the mass losses started to accelerate (Sundqvist 2002). However,  $\alpha$ -cellulose degraded more slowly and at higher temperatures than hemicelluloses. Hemicelluloses were the most vulnerable to thermal degradation. The degradation rates of hemicelluloses have been reported to be four times higher at 150 °C than that of wood or for  $\alpha$ -cellulose (Stamm 1956).

Upon heating, degradation of hemicelluloses started with the liberation of acetic acid. It was suggested that the volatile organic acid formed was trapped in the process and promoted the degradation rate. The released acid served as a catalyst in the hydrolysis of hemicelluloses to soluble sugars and hydrolysed the bonds joining the units of glucose, breaking cellulose into shorter chains. With the degrading of the hemicelluloses, the amount of fungi susceptible material decreased thus improved the resistance of heat-treated wood to fungal decay. This will have to be supported by an actual fungus testing investigation which will be the subject of another paper to be reported later.

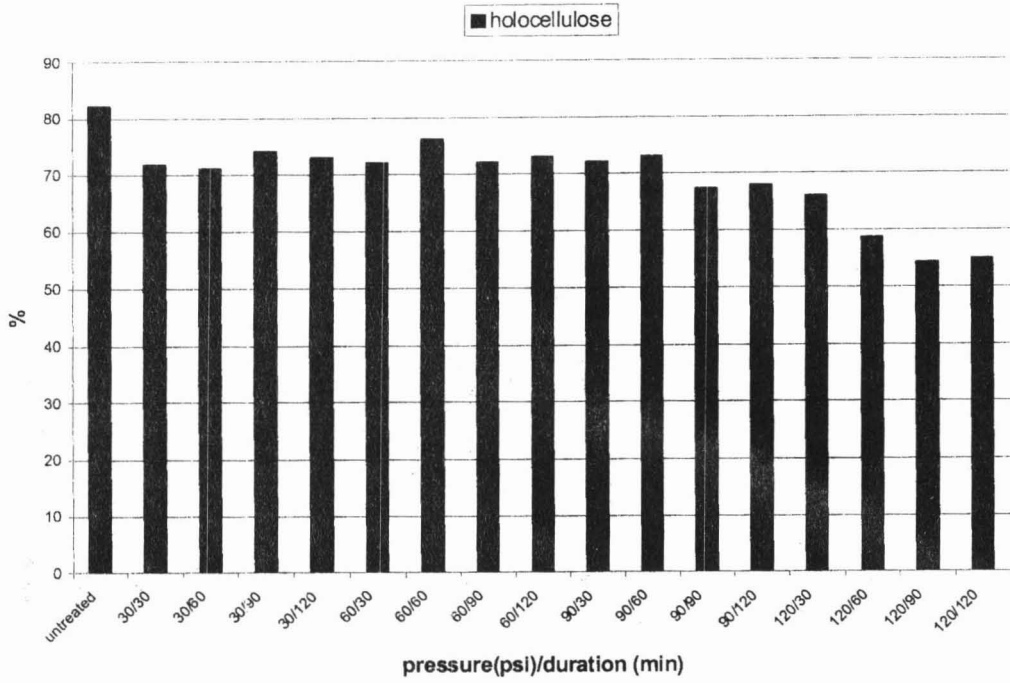


Fig. 2: The percentage of holocellulose for untreated and treated rubberwood samples at different treatment durations and pressures.

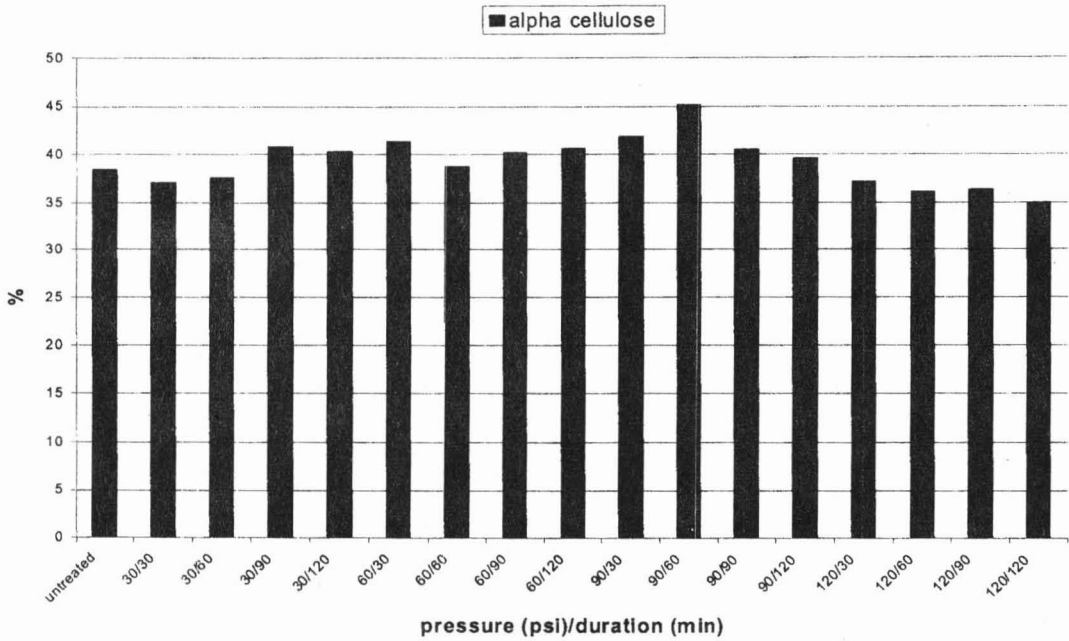


Fig. 3: The percentage of alpha cellulose for untreated and treated rubberwood samples at different treatment durations and pressures.

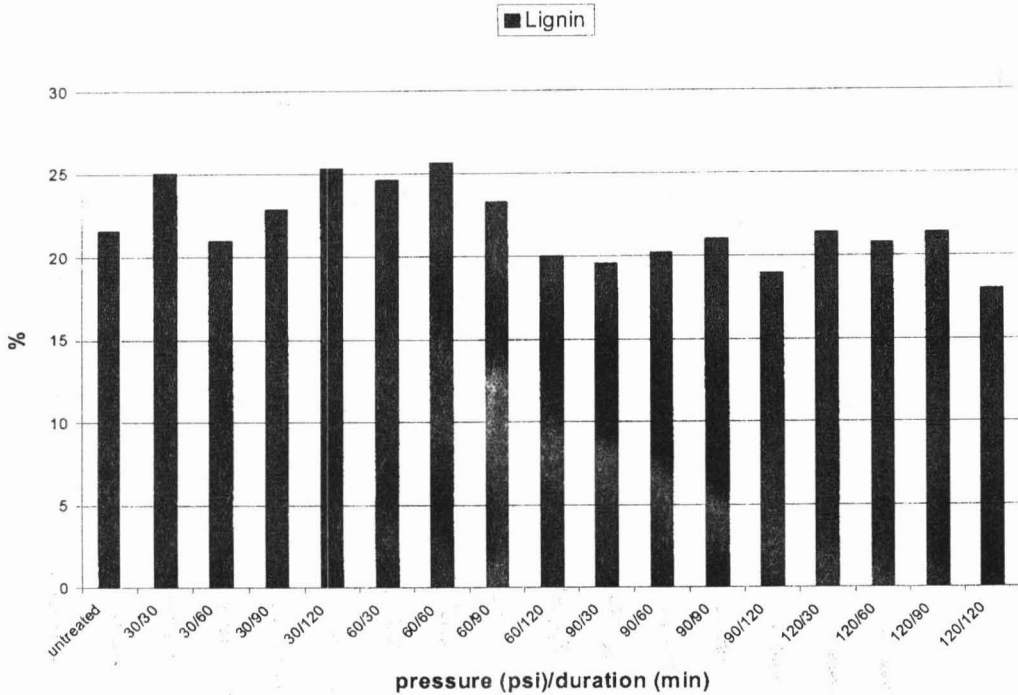


Fig. 4: The percentage of lignin for untreated and treated rubberwood samples at different treatment durations and pressures.

The result in Figure 4 shows that the percentages of lignin decreased as the pressures and durations increased and they were lower compared with the untreated sample. The amount of lignin in wood ranged from 20 – 40% and was often considered to be the glue of the wood structure. The lignin of the wood was affected at 150°C, which considered being plasticisation temperature of wood. Lignin is not changed as much as the hemicelluloses when subjected to hydrolytic conditions below 200 °C. Mild acidic hydrolysis of lignin was proposed to be the result of breaking of cyclic  $\alpha$ -aryl ether bonds giving various lignin fragments such as lignols (Lai 1991).

### Conclusion

Heat treatment permanently changed several of the chemical properties of wood. The change in chemical properties was mainly caused by thermic degrading of hemicelluloses. Desired changes started to appear at about 150 °C and the changes continued as the temperature and duration increased. With the degrading of the hemicelluloses, the amount of fungi susceptible material decreased thus improved the resistance of heat-treated wood to fungal decay. However, this will have to be supported by an actual fungus testing investigation which will be the subject of another paper to be reported later

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### References

- Bourgois, J., Bartholin, M.C & Guyounet, R. (1998). Thermal treatment of wood: Analysis of the obtained product. *Wood Sci. Technol.* 23: 303 – 320.
- Fengel, D. & Wegener, G. (1989). *Wood: Chemistry ultra structure reactions*. Berlin: Walter de Gruyter & Co.

- Kamden, D.P., Pizzi, A. & Tribulout, M.C. (2000). Heat-treated Timber: Potentially toxic byproducts preserve and extent of wood cell wall degradation. *Holz Roh Werks.*, 58: 253- 257.
- Lai, Y.Z. (1991). Chemical degradation. In: Wood and cellulosic chemistry. Eds. Hons, D.N.S and Shiraishi N., Marcel Dekker, Inc., New York pp. 455 – 524.
- Metsa-Kortelainen, S. (2004). Water absorption of heat-treated Pine and spruce. *Proceeding of 8<sup>th</sup> World Conference on Timber Engineering*: 441-444.
- Momohara, I., Ohmura, W., Kato, H. & Kubojima, Y. (2003). Effect of high temperature treatment on wood durability against the brown-rot fungus, *Fomitopsis palustris* and the termite (*Optotermus formosanus*) *8<sup>th</sup> International IUFRO Wood Drying Conference*: 284 – 287.
- Nuoponen, M., Vuorinen, T., Viitaniemi, P. & Jamsa, S. (2003). Effects of heat treatment on the behaviour of extractives in softwood studied by FTIR spectroscopic methods. *Wood Sci. Technol.*, 37: 109-115.
- Rowell, R.M. (1994). *Kimia Kayu Padu*. Kuala Lumpur: Dewan Bahasa dan Pustaka.
- Stamm, A.J. (1956). Thermal degradation of wood and cellulose. *Ind. Eng. Chem.* 48: 413-417
- Sundqvist, B. (2002). Color response Scots pine (*Pinus sylvestris*). Norway spruce (*Picea abies*) and birch (*Betula pubescens*) subjected to heat treatment in capillary phase. *Holz-als Roh –und Werkstoff*. 60:106-114.
- Tjeerdsma, B.F., Boonstra, M., Pizzi, A. Tekely, P. & Miltz, H. (1995). Characterisation of the thermally modified wood: Molecular reasons for wood performance improvements *Holz Roh Werks.* 56: 149-153.

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