

DECAY RESISTANCE AGAINST *BASIDIOMYCETES* FUNGI OF HEAT-TREATED *PINUS ROXBURGHII* AND *MANGIFERA INDICA* WOOD

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TRIPATHI S, PANT H & KASHYAP AK. 2014. Decay resistance against *Basidiomycetes* fungi of heat-treated *Pinus roxburghii* and *Mangifera indica* wood. Heat treatment of wood is an effective method to improve biological durability of wood without using non-environmentally-friendly conventional preservatives. This study was performed to investigate the effects of the heat treatment on the resistance of wood against fungal attack. Softwood (*Pinus roxburghii*) and hardwood (*Mangifera indica*) species were heat treated at different temperatures for different durations. The decay resistance of heat-treated wood specimens was examined by soil block bioassay method. The specimens were exposed to wood-rotting fungi (*Oligoporus placentus* and *Trametes versicolor*) for 14 weeks and the weight loss was assessed. This study revealed that the decay resistance of *P. roxburghii* and *M. indica* wood against fungal attack could be improved with heat treatment.

Keywords: Heat treatment, hardwood, *Oligoporus placentus*, softwood, *Trametes versicolor*

INTRODUCTION

The use of conventional preservatives has been restricted following environmental concerns. Efforts have been made to develop non-chemical and environmentally-friendly techniques for wood preservation. Heat treatment of wood is an effective method to improve biological durability of wood without using harmful conventional preservatives. There are five heat treatment processes commonly used in the industry, namely, ThermoWood, Plato process, retification, Le Bois Perdure and oil heat treatment method.

Heat treatment at relatively high temperatures (over 150 °C) is an effective method to improve the biological durability of wood (Weiland & Guyonnet 2003). Wood provides abundant nutrition to the fungi. Thiamine is one of the essential nutrients for most wood-decaying fungi. Wood has been proven to be free of decay when thiamine is extracted from it (Shen 1993). The resistance of heat-treated wood against fungal decay depends upon wood species and conditions of heat treatment. Heat treatment at temperatures higher than 220 °C and duration longer than 3 hours improves the biological resistance of wood due to chemical degradation and formation of new compounds in wood (Jamsa & Viitaniemi 2001). Heat treatment improves wood physical properties by reducing hygroscopicity and

improving dimensional stability (Santos 2000). However, heat-treated wood is not suitable for ground contact applications (Jamsa & Viitaniemi 2001). The effects of heat treatment in nitrogen (N₂) gas on bending strength and fungal resistance properties of *Styrax tonkinensis* were examined by Phuong et al. (2007). It was reported that heat treatment showed positive effect on the resistance of wood against white-rot and brown-rot fungi at 200 °C and for more than 8 hours (Hill 2006). However, the study also reported that heat treatment decreased the strength of wood to as much as 40%. The decrease in hemicelluloses is thought to contribute to the improvement in durability. In another study, it was observed that heat treatment modified the durability of beech wood from non-resistant to moderately resistant or resistant depending on the fungus (Kamdem et al. 2002). Quebec wood species, jack pine (*Pinus banksiana*) and aspen (*Populus tremuloides*), were thermally treated in an industrial furnace using Bois Perdure technology. The effects of thermal modification on resistance against soft and brown rot fungi of sapwood and heartwood of Scots pine and Norway spruce were investigated using laboratory test methods by Kortelainen and Viitanen (2009). Results revealed that thermal modification increased

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the biological durability of all samples. The effect of thermal modification seemed to be most effective within pine heartwood. However, thermal modification above 230 °C was needed to achieve resistance against decay comparable with the durability classes of ‘durable’ or ‘very durable’ in the soft-rot test. Brown-rot test gave slightly better durability classes than the soft-rot test.

Hardwood species are more susceptible to thermal degradation compared with softwood (Chaouch 2012). Chemical composition is directly connected to per cent weight loss due to thermo degradation, allowing the use of chemical composition to predict fungi durability. Carbon and oxygen contents and/or oxygen to carbon ratio of heat-treated wood can be therefore used as valuable markers to develop quality control assessment of heat-treated wood.

The aim of this paper was to study the effects of heat treatment on decay resistance of chir pine (*Pinus roxburghii*) and mango (*Mangifera indica*) against wood decaying fungi.

MATERIALS AND METHODS

Chir pine (*P. roxburghii*) and mango (*M. indica*) in green condition were collected from the Forest Research Institute campus, New Forest, Dehradun (30° 19' N and 78° 04' E). The specimens were subjected to heat treatment in a vacuum oven. Heat treatment was done in nitrogenous atmosphere and heat-treated and control specimens were tested against brown (*Oligoporus placentus*) and white rot fungi (*Trametes versicolor*) through soil block bioassay IS 4873 (IS 2008).

Determination of moisture content

Samples of size 50 mm × 50 mm × 270 mm were prepared from defect-free sapwood planks of both wood and weighed. Before heat treatment the samples were kept in an oven at 103 ± 2 °C for 24 hours or more until constant weight was achieved. Moisture content of green wood was recorded (IS 1991).

Moisture content was calculated for green condition wood using the formula

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{W_2} \times 100$$

where W_1 = initial weight of sample and W_2 = oven-dry weight of sample.

Heat treatment

After oven-drying, samples were placed in a vacuum oven. Vacuum (400 mm of Hg) was created in the oven with the help of vacuum pump after which N_2 gas from a cylinder was introduced. Oven temperature was increased subsequently from ambient to the desired operating temperature. Heat treatment was carried out at 160, 190 and 210 °C at intervals of 4, 8 and 12 hours. After completion of the process, the temperature of the oven was set at 20 °C. When temperature reached 20 °C, samples were removed from the oven, weighed (W_3) and placed in desiccators.

Soil block bioassay

Fungal strains

Test fungi selected for the present study were received from the Forest Pathology Division, Forest Research Institute, Dehradun, India. *Trametes versicolor* (for non-conifers) was collected from oak stem at the Senji forest area, Mussorie (Forest Research Institute Herbarium No. 7437) and *O. placentus* (for conifers) was received from the Forest Products Research Laboratory, Princess Risborough, England (No. 304-A). Fungi were maintained at 25 ± 2 °C on 2% (w/v) malt agar until inoculation (IS 2008).

Preparation and sanitisation of test blocks

Heat-treated samples were converted into sample size of 19 mm × 19 mm × 19 mm with a 0.32-mm central hole on the tangential face along the length of grain and weighed (W_4). Six replicates were used for each temperature and time interval as well as for control (untreated). For sanitisation the test blocks were steamed at 100 °C for about 20 min at atmospheric pressure in an autoclave in tightly closed bottles (IS 2008).

Preparation of soil culture bottles

Sieved, air-dried garden soil amounting to 125 g with pH between 5 and 7 was filled in screw capped bottles. Distilled water (44 mL) was added to the bottles so as to obtain 130%

of water-holding capacity of soil. Feeder blocks of size 4 mm × 19 mm × 35 mm were prepared from sapwood of *Bombax ceiba*. Two feeder blocks were placed directly on the surface of the soil. The prepared bottles with caps loosened were sterilised and autoclaved for 30 min.

Preparation of test culture

Fungal inocula (10 mm × 10 mm) were taken from the outer edge of mycelium of 2-week-old fungal colonies and placed on the edge of the feeder blocks in sterilised culture bottles. The inoculated bottles with slightly loosened lids were incubated in an incubator maintained at $25 \pm 2^\circ\text{C}$ and $70 \pm 4\%$ relative humidity for approximately 3 weeks or until the mycelia mat had covered the feeder blocks.

Introduction and incubation of test blocks in culture bottles

Two blocks with cross-section face down were placed on feeder blocks in contact with mycelium in each culture bottle. The bottles containing test blocks were incubated for 14 weeks in the incubator maintained at $25 \pm 2^\circ\text{C}$ and relative humidity of $70 \pm 4\%$ (IS 2008). After 14 weeks, the test blocks were removed from the culture bottles and adhering mycelium was cleaned off taking care not to remove splinters of the wood. The blocks were dried at room temperature for 3 to 4 days and then in hot air oven and weighed till constant weight (W_5) was obtained. The extent of fungal attack was determined by weight loss. The ratings for classification of wood into various resistance classes were based on per cent weight loss caused by the test fungi (Table 1) (Kumar & Dev 1993).

$$\text{Weight loss (\%)} = \left(\frac{W_4 - W_5}{W_4} \right) \times 100$$

Table 1 Classification of wood into various resistance classes on the basis of weight loss caused by fungi

Weight loss (%) in wood	Resistance class
0–10	Very durable
11–24	Durable
25–44	Moderately durable
> 44	Not durable

where W_4 = conditioned weight of the blocks before test, W_5 = conditioned weight of the blocks after test. Weight loss caused by test fungi was statistically analysed using SPSS package (17.0 version).

RESULTS AND DISCUSSION

Weight loss data of *P. roxburghii* and *M. indica* due to decay caused by fungi *O. placentus* and *T. versicolor* in soil block bioassay test are presented in Table 2. In this study, control treatments of both wood with weight loss of more than 55%, were classified as non-resistant because the weight loss was over 44% (Kumar & Dev 1993).

Pinus roxburghii wood specimens heat treated at 160°C for 4 hours, showed 30.8% weight loss when exposed to *O. placentus* thus improving the wood decay resistance from non-durable to moderately durable class. However, in the case of *T. versicolor* only 18.6% wood weight loss was observed leading it to durable class. Heat treatment at 160°C for 8 and 12 hours, 190°C for 4, 8 and 12 hours and 210°C for 4 and 8 hours improved decay resistance of wood to durable against both the decay fungi, showing less than 25% weight loss. The decay resistance of *P. roxburghii* was enhanced to very durable class when heat treatment was at 210°C for 12 hours showing less than 10% weight loss. (8.63% weight loss in specimens exposed to *O. placentus* and 9.87% when exposed to *T. versicolor*).

In *M. indica*, heat treatment for 160, 190 and 210°C for 4 hours was not effective in improving decay resistance, showing more than 44% weight loss against both the test fungi. Heat treatment at 160 and 190°C for 8 hours against *T. versicolor* was also ineffective in improving resistance. Heat treatment of *M. indica* at 210°C for 12 hours increased decay resistance of wood against *O. placentus* showing only 17.9% weight loss (i.e. durable) and against *T. versicolor*, 34.2% weight loss (moderately durable). Decay resistance of heat-treated specimens increased with increase in temperature and duration of treatment (Table 2). Statistical analysis of data at 5% significance level revealed that all treatments were significantly different from one another.

Results of this study showed that heat treatment was more effective against *T. versicolor* compared with *O. placentus* in *P. roxburghii*. Contrary to this in *M. indica*, heat treatment was found more

Table 2 Mean weight loss (%) of heat-treated wood due to decaying fungi

Temperature (°C)	Time (hours)	Wood			
		<i>Pinus roxburghii</i>		<i>Mangifera indica</i>	
		<i>Oligoporus placentus</i>	<i>Trametes versicolor</i>	<i>Oligoporus placentus</i>	<i>Trametes versicolor</i>
Control		60.2	55.7	63.5	66.4
160	4	30.8	18.6	58.1	61.2
	8	21.2	15.7	39.2	47.2
	12	16.3	12.5	25.2	38.6
190	4	16.3	15.7	53.2	56.2
	8	12.0	13.3	35.6	44.9
	12	10.5	10.5	18.2	37.9
210	4	12.4	14.2	45.4	49.0
	8	9.5	11.3	28.9	40.0
	12	8.6	9.8	17.9	34.2
Mean (wood)			14.4		40.6
Mean (fungi)			25.5 (<i>Oligoporus placentus</i>)		29.5 (<i>Trametes versicolor</i>)

Critical difference _(0.05) of wood = 0.2, fungi = 0.2, temperature = 0.3, time = 0.3

effective against *O. placentus* compared with *T. versicolor*. All treatments were more effective against brown rot compared with white rot (Table 2). Heat treatment was best at 210 °C as less weight loss was recorded against both decaying fungi. Heat treatment at 210 °C for 12 hours was the best treatment compared with the rest of the treatments as least weight loss was recorded. Results also revealed that heat treatment was less effective in *M. indica*, i.e. showing more weight loss compared with *P. roxburghii*.

Similar findings have been reported by Boonstra et al. (2007). It was reported that heat treatment of wood at relatively high temperatures (between 150 and 280 °C) was effective in improving biological durability of wood. Increase in durability conferred by thermal treatment is generally explained by these hypotheses (Hakkou et al. 2006), namely (1) low affinity of heat-treated wood to water and (2) generation of toxic compound during heating, which provides protection to heat-treated wood against wood degrading agencies. It was also reported that chemical modification of the main wood polymers affected the durability of heat-treated wood. Degradation of hemicelluloses also occurred, which contributed to resistance. However, heat treatments showed positive effect on the resistance of the wood against white-rot and brown-rot fungi at 200 °C and for more than 8 hours but decreased its strength to as much as 40% (Phuong et al. 2007).

CONCLUSIONS

Heat treatment of *P. roxburghii* revealed a clear improvement in resistance against both the test fungi but the effect on the resistance in *M. indica* wood was rather limited. The decay resistance of *P. roxburghii* against both wood-rotting fungi was improved from non-resistant to highly resistant after being treated at 210 °C for 12 hours. Heat treatment of *M. indica* wood at this temperature improved its decay resistance to durable and moderately durable against *O. placentus* and *T. versicolor* respectively.

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