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EFFECT OF MICROWAVE HEATING ON pH AND TERMITE RESISTANCE OF *Pinus roxburghii* WOOD

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In memoriam of Dr. Thomas C. MANNES

ABSTRACT

This study investigated the effect of microwave treatment on wood pH and termite resistance. *Pinus roxburghii* heartwood was exposed to four different microwave intensities at 2450 MHz frequency for 5 minutes. Preservative impregnation, pH variation and termite resistance of microwave-treated and control specimens were studied. Wood pH decreased from 4,6 (C1) to 3,9 (T4) and preservative uptake increased (i.e., 10,4 to 21,6 kg.m^{-3}) with increasing microwave treatment intensities. However, microwave treatment had little effect on termite resistance.

Keywords: Dielectric treatment, durability, impregnation, *Odentotermes obesus*, pine.

INTRODUCTION

Chirpine (*Pinus roxburghii*) is distributed in sub-tropical to temperate regions. *Pinus roxburghii* wood is utilised for construction, packing cases, door and window frames and pulping (Luna 2005). The wood is non-durable and requires supplemental protection when used outdoors.

The heartwood of *P. roxburghii* is easily treated and performs better than many naturally durable heartwood species for variety of uses including cooling towers and marine conditions (Luna 2005). The pH of wood is one of the key chemical properties which affect a number of processes related to its utilisation such as excessive acidic nature of wood can be affect the fixation of preservative salts in wood (Sithole 2005) and may also affect its durability.

Microwave (MW) radiation is an innovative method for improving wood permeability and the drying rate in hardwoods. This method can also be used to produce new composite products and create opportunities for increasing timber durability by impregnation with preservatives (Torgovnikov and Vinden 2009, Dashti *et al.* 2012, Poonia *et al.* 2016). The effects of microwave treatment on pH and durability against termite of *P. roxburghii* wood remain unknown.

The aim of this study was to evaluate the effects of MW treatment of *Pinus roxburghii* wood on pH, receptive to preservative treatment and termite resistance.

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MATERIALS AND METHODS

Preparation of wood specimens

One *Pinus roxburghii* Sarg. tree (90cm girth) was harvested from the grounds of the Forest Research Institute, Dehradun (latitude: 30°19’N and longitude: 78°04’E). The freshly felled log was converted into small clear specimens measuring 3,8cm (Width) × 3,8cm (Thickness) ×15cm (Length). The sawn specimens were randomly selected from heartwood portion of wood. The selected straight grain and defect free specimens were submersed in fresh water to maintain a green condition prior to MW treatment.

Microwave treatment

A 900W microwave oven (model: 30SC3) was used at a frequency of 2450 MHz for the experiment. Details of treatment are as follow:

Intensity of MW treatments: T1 (95,57), T2 (111,50), T3 (127,42), T4 (143,35W/cm^2) and C1: Controls

MW treatment time: 5 Min

Total number of specimens: 90 including controls [Group-I: 30 specimens i.e., subjected to pH studies and Group-II: 60 specimens (30 were Microwave and 30 were MW cum Preservative treated) i.e., subjected for Termite mound test].

Replicates: six in each treatments and controls

Moisture reduction

Percent moisture reduction caused by MW treatment was calculated from the conditioned weight of the blocks before and after MW treatment.

$$Moisture\ reduction\ (\%) = \frac{W_1 - W_2}{W_1}\ x\ 100 \qquad (1)$$

Where, W_1 = Weight of specimens before MW treatment, and
W_2 = Weight of specimens after MW treatment.

Wood pH

Treated and control specimens for pH evaluation were converted into chips and pH of the wood samples was determined using the hot water extraction method described by Sinthole (2005).

Preservative treatment

Microwave treated and controls (C) specimens were subjected to preservative treatment with an aqueous solution of acid copper chromate (ACC) at 4% concentration using a full cell process i.e., an initial vacuum of 75 kPa (25 in Hg) for 30 min followed by pressure 689,47 kPa (100 lbs/in^2) for 1 h. A Final vacuum of 75 kPa (25 in Hg) for 15 min was applied. Controls (C1) received no preservative treatment and served as references for the termite tests.

After treatment, specimens were weighed to determine the preservative retention (IS 401:2001). The amount of preservative solution absorbed by specimen (retention value R in kgm^{-3}) was calculated as:

$$R(kg / cuM) = \frac{G\ x\ C\ x\ 10}{V} \qquad (2)$$

Where; G is the weight of the preservative solution absorbed by the block (W_2-W_1) in gm, C is the concentration of the preservative solution (%) and V is the volume of the test block in cm^3.

Termite mound test

The samples were cut into test specimens (100 × 25 × 6 mm). The test specimens were buried at different places inside a termite mound of Odentotermes obesus (Rambur) in the beginning of month of May. Specimens were removed from the mound in November when activity of termites almost ceases due to fall in temperature. The specimens were visually examined for termite attack and reinstalled next year in month of May so as to have exposure to termites for two successive termite seasons. Specimens were cleaned off mud and debris, and evaluated visually to ascertain damage by termites, according to the following rating scale given in Table 1 (Shukla 1977).

Table 1. Scale used to assess degree of termites damage (Shukla 1977).

Numerical rating	Symbol	Condition of sample
0	N	No attack, sample free from termite attack
0,5	VSw	Trace attack, termite attack area less than 5% of the surface.
1,0	Sw	Light attack, 5-20%
2,0	Mw	Moderate attack, 20- 35%
3,0	Bw	Heavy attack, 35-50%
5,0	Dw	Very heavy attack, >50%

Statistics

Statistical analysis was conducted using SPSS 16 version software. Retention and pH results of *P. roxburghii* at different MW intensities were compared using an analysis of variance (ANOVA) and Duncan's modified significant difference test at $\propto$ =0,05.

RESULTS AND DISCUSSIONS

MW treated samples were compared with untreated samples for any visual defects such as checks or cracks caused by MW treatment. No checks or cracks were observed on MW treated *P. roxburghii* wood.

Moisture reduction

The initial moisture content (MC) of *P. roxburghii* wood before microwave treatment was 40,60% and decreased to 38,40 (T1) and 35,33% (T4) respectively, after microwave treatment (Figure 1).

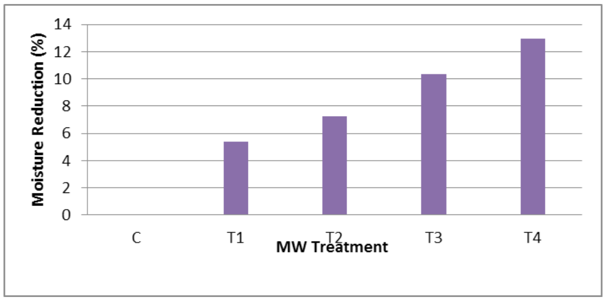

Figure 1. Mean moisture losses percentage in MW treated and untreated specimens of *P. roxburghii* {MSE 3,22 at ($p\leq 0,05$) level}.

Increased MW treatment intensity resulted significant difference ($p\leq 0,05$) in moisture reduction from the initial values. The intensity level of the MW energy had generated steam within the wood cell that resulted removal of MC from wood (Vinden *et al.* 2010). The removal of steam through pores could be seen visually when specimens were removed from microwave assembly.

pH analysis of wood

Wood pH steadily decreased with increasing microwave intensity and differed significantly between T2 (111,50 W/cm^2) and T3 (127,42 W/cm^2) MW treatments (Table 2).

Table 2. Effect of microwave treatment on pH of wood, preservative uptake and resistance to termite attack.

Treatment	pH	Retention (kgm^{-3})	Average Numerical Rating		Final condition of the samples
			Ist Season	IInd Season	
Control (C1)	4,6^a	-	3,20	5	Very heavy attack
T1	4,4^a	-	3,15	5	Very heavy attack
T2	4,1^b	-	3,18	5	Very heavy attack
T3	4,1^b	-	3,12	5	Very heavy attack
T4	3,9^b	-	3,08	5	Very heavy attack
C + ACC		10,41^c	0	0	No attack
T1+ ACC		17,53^d	0	0	No attack
T2+ ACC		19,62^e	0	0	No attack
T3+ ACC		20,16^{e,f}	0	0	No attack
T4+ ACC		21,61^f	0	0	No attack

Mean square Error of pH and retention is 0,06 and 0,88 at ($P\leq 0,05$) level respectively. Different letters denote significantly different groups.

Similar pH reductions have also been reported in *Eucalyptus tereticornis* wood by Poonia and Tripathi (2017) in MW treated wood. Niemz *et al.* (2010) and Chen *et al.* (2012) also found similar results in thermally modified wood. The pH decrease may be explained by the production of organic acids during thermal treatment, mainly by the degradation of hemicelluloses, as acetyl groups split off (Nuopponen *et al.* 2004). Phenolic carboxylic acid and 4-O-methyl-glucuronic and galacturonic acids are also produced as the result of wood hydrolysis adding to the acidity (Windeisen *et al.* 2007).

Retention of preservative

The control (C) specimens had an average retention level of 10,41 kg/m^3, whereas samples treated using different MW intensities exhibited almost 2 fold increase in retentions (i.e. from 17,53 to 21,61 kg/m^3). Preservative retentions increased with increased MW intensity to a maximum of 21,61 kg/m^3 in samples exposed to 143,35 W/cm^2 whereas the lowest retention (17,53 kg/m^3) was found at 95,57 W/cm^2. Similar effects of MW-treatments were also reported by Treu *et al.* (2008) on Norway spruce (*Picea abies*), Ramezanpour *et al.* (2014) on fir wood and Poonia *et al.* (2016) on *P. roxburghii* wood. Thus results reveal that retention of preservative increase with increase in intensity.

Termite mound test

The control (C1) and microwave treated specimens were heavily attacked by termites in the first season. Attack continued and the samples were destroyed after a second season indicating that MW treatment provided no protection against termites. These results are in agreement with the results reported by Poonia and Tripathi (2017): MW treatment did not protect wood from termite attack. Similar results have also been found in thermally modified wood (Metsa-Kortelainen *et al.* 2011 and Duarte *et al.* 2012). The reason behind this non resistivity against termite is may be the change in chemical constituents and wood structure during microwave treatment. Thus, MW treatment attributes no resistance to wood against termite.

The specimens subjected to ACC preservative treatment at 689,47 kPa (100 lbs/in^2) for 1h were sound after two seasons of exposure. Hence, data exhibited significant higher protection when MW treatment was given with ACC at the different intensity. These results corroborate our previous findings (Poonia and Tripathi 2017), suggesting a synergistic effect between chemical and MW treatment for the improvement of termite durability. ACC preservative is effective even when specimens had not received any MW treatment. However, microwave treated wood resulted in remarkably high retention of preservative suggesting end use of wood even in drastic condition.

CONCLUSIONS

Microwave treatment of *P. roxburghii* wood significantly improved impregnation and reduced wood pH, but did not improve termite's resistance. Since, Microwave treatment resulted substantial uptake of preservative in wood, similar experiments without pressure treatment may be conducted to reduce the processing time.

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