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DETERMINATION OF DECAY RESISTANCE AGAINST *Pleurotus ostreatus* AND *Coniophora puteana* FUNGUS OF HEAT-TREATED SCOTCH PINE, OAK AND BEECH WOOD SPECIES

Umit Ayata[1], Caglar Akcay[2,♣], Bruno Esteves[3]

ABSTRACT

The objective of this study, to investigate decay resistance against *Pleurotus ostreatus* and *Coniophora puteana* fungus of heat-treated (ThermoWood method) Scotch pine, oak and beech wood species. Scotch pine (*Pinus sylvestris*), oak (*Quercus petreae*) and beech (*Fagus orientalis*) wood species were heat treated at 190°C for 2 h, 212°C for 1 h and 2 h by the ThermoWood® method. Untreated and heat-treated specimens were exposed to white-rot fungus (*Pleurotus ostreatus*) and brown-rot fungus (*Coniophora puteana*) for 12 weeks according to procedures defined in JIS K 1571 standard. After weight losses of all specimens were calculated. According to the results, least weight loss was determined on heat treated at 212°C for 2 h. Heat treatment can be used effectively against fungal attack for Scotch pine, oak and beech wood species.

Keywords: Brown rot, *Fagus orientalis*, heat modification, *Pinus sylvestris*, *Quercus petreae,* ThermoWood, white rot.

INTRODUCTION

Heat treatments have proven to be effective in the reduction of the decay promoted by rot fungus. One of the first works was done by Dirol and Guyonnet (1993) that studied the effects of the rectification process on the improved resistance to a white rot (*Trametes versicolor* and two brown rot, *Gloeophyllum trabeum*, and *Coniophora puteana*. These authors reported that for wood treated at temperatures between 200ºC and 260ºC it was possible to reduce the mass loss of treated wood to less than 1% for all of the species studied (spruce, fir, and poplar). Several work has been done with different heat treatments like Thermowood (Viitanen *et al.* 1994), Plato (Tjeerdsma *et al.* 2000), OHT (Sailer *et al.* 2000) and Retification (Kamdem *et al.* 2002) but all presented similar results. Welzbacher and Rapp (2002) compared the improved biological resistance of the main heat treatment processes against *Trametes versicolor* and concluded that the best improvement was obtained for Thermowood (Finland) with a mass loss under 1%, followed by Plato and OHT (3%), and finally Rectified wood (12%). Nevertheless all of the treatments significantly improved wood resistance in relation to untreated wood,

[1]Forestry and Forest Products, Oltu Vocation School, Ataturk University, Oltu, Erzurum, Turkey.
[2]Department of Forest Products Engineering, Faculty of Forestry, Duzce University, Duzce, Turkey.
[3]Superior School of Technology Polytechnic Institute of Viseu, Portugal.
♣Corresponding author: caglarakcay@duzce.edu.tr
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since mass losses of untreated spruce and Scotch pine were respectively 67% and 60%. In accordance to Hakkou *et al.* (2006) temperature of treatment is a key factor to improve fungal durability. Only for temperatures over 200ºC significant improvement on resistance to rot can be achieved. Similar results were presented by Esteves *et al.* (2014) with heat treated pine (*Pinus pinaster*) that reported that although a significant increase in durability against *Rhodonia placenta* found for both heartwood and sapwood at the higher temperature (200 ºC), at the lower temperature (190 ºC) only heartwood showed good results.

Even though heat treatments improve the resistance against all kinds or rot the results for white rot are usually worse. Boonstra *et al.* 2007 reported that heat treatment of radiata pine (*Pinus radiata*) wood by the Plato process did not improve significantly the resistance against *Trametes versicolor*. Similar results were recently presented by Sivrikaya *et al.* (2015) that reported that even for a treatment at 210ºC the mass loss of heat treated Spruce and Ash due to the white rot *Trametes versicolor* was higher than 5% while the mass loss due to *Coniophora puteana* was lower than 2%. The same was presented by Tjeerdsma *et al.* (2000) who studied the increase of the resistance to soft rot, white rot (*Trametes versicolor*), and brown rot (*Coniophora puteana*) of heat treated *Pinus sylvestris*, *Picea abies*, *Pinus radiata*, and *Pseudotsuga menziesii* and concluded that the best performance was achieved for brown rot. Leithoff and Peek (2001) compared the treatment necessary to significantly improve the resistance to rot and concluded that to resist the attack of *Trametes versicolor* wood needed a treatment for 120 min at 220ºC, while 60 min at 200ºC were enough for *Coniophora puteana*.

Numerous explications have been given for the improved durability. The most mentioned is the decrease in equilibrium moisture content (Tjeerdsma *et al.* 2002). (Weiland and Guyonnet 2003) associated the increased durability to the reticulation of lignin with some compounds obtained during the heat treatment such as furfural, leading to a difficult for the fungus to recognize the substratum. Another reason given was the probable esterification of cellulose due to the acetic acid released by the degradation of hemicelluloses. A different explanation was proposed by Boonstra *et al.* (2007). These authors stated that the increased resistance against fungal attack is derived from the changes on the external conditions affecting the micro-environment, like pH and chemical growth factors, the blocking of reactions of non-enzymatic oxidizing agents and substrate changes that affected the decay mechanism of heat-treated wood. The increase in resistance also increased with an increasing duration of heat treatment at the higher temperatures. Yalcin and Ibrahim (2015) found good correlations between the reduction in mass loss due to fungal attack and the decrease in equilibrium moisture content and changes in the wood's chemical composition due to heat treatment.

The improved resistance to rot attributed by the heat treatment does not work when wood is in contact with soil. Kamdem *et al.* (2002) studied the durability of pine (*Pinus pinaster)* treated at temperatures between 200ºC and 260ºC in ground contact. Results showed that mass loss due to brown rot (*G. trabeum*) decreased from 57% to 11% but for *Rhodonia placenta* the decreased was only from 54% to 47% and for *Irpex lacteus*, from 35% to 28%.

This work intended to study the improvements by heat treatment on the decay by two common fungus in Turkey, a white rot (*Pleurotus ostreatus*) and a brown rot (*Coniophora puteana*) on heat treated Scotch pine (*Pinus sylvestris*), oak (*Quercus petreae*) and beech (*Fagus orientalis*).

MATERIALS AND METHODS

Wood material

Randomly selected first grade Scotch pine (*Pinus sylvestris* L.), oak (*Quercus petreae* L.) and beech (*Fagus orientalis* L.) wood species were obtained from the industrial region of Duzce in Turkey. A total of 144 specimens were prepared (48 from each species).

Heat Treatment Process

Heat treatment was performed according to the ThermoWood® process and conducted at 190°C for 2 h, 212°C for 1 h and 2 h in a private commercial Novawood Factory in Gerede - Bolu, Turkey. All heat treated and untreated wood samples were conditioned before biodegradation tests in a climatic chamber at 20 ± 2 °C and 65 ± 5% RH (relative humidity) until about 12% MC (moisture content) was reached (ISO 554 1976).

Untreated and heat treated Scotch pine (*Pinus sylvestris*), oak (*Quercus petreae*) and beech (*Fagus orientalis*) wood specimens measuring 20 mm x 20 mm x10 mm (radial, tangential, longitudinal) were cut for decay tests.

Decay Resistance Test

The decay resistance of untreated and heat-treated Scotch pine (*Pinus sylvestris*), oak (*Quercus petreae*) and beech (*Fagus orientalis*) wood specimens against white rot (*Pleurotus ostreatus*) and brown rot (*Coniophora puteana*) was done in accordance to JIS K 1571 standards. Decay resistance tests were conducted in the Forest Biology and Wood Preservation Laboratory of Duzce University. *P. Ostreatus* was purchased from Agromar™ Denizli, Turkey. *Coniophora puteana* was kindly provided by Forest Products Laboratory, Madison, Wisconsin, USA. *P. ostreatus and C. puteana* were grown on 3,7% malt extract agar (MEA) medium. The media was sterilized using steam at 121°C and 1,1 A for 20 min before being transferred to the pre sterilized petri dishes. After inoculation of the test fungi, the petri dishes were kept at 26°C and 70% relative humidity until the media surfaces were completely colonized by the fungi. Treated and untreated wood samples were sterilized before being placed on the surface of the inoculated test fungi petri dishes. Subsequently, samples were kept in contact with the fungus for 12 weeks at 26°C and 70% relative humidity in an incubator chamber. After 12 weeks exposure, the wood samples were weighed once the surface mycelium on wood samples was cleaned. The mass loss of all samples was determined by the difference between the dry weight of each specimen before and after the decay test.

Statistical Analysis

Statistical analysis using SPSS software package (17.0 version) (IBM, USA) was performed for the weight loss caused by *P. ostreatus* and *C. puteana* fungus of Scotch pine (*Pinus sylvestris*), oak (*Quercus petreae*) and beech (*Fagus orientalis*) heat treated at 190°C for 2 h, 212°C for 1 and 2 h according to the ThermoWood® process.

RESULTS AND DISCUSSION

Decay Test

The weight loss of untreated and heat treated woods due to white rot and brown rot decay is presented on table 1. Results show that all of the treatments improved the resistance of wood to decay since the weight loss of the untreated samples was higher than for heat treated samples for the three species studied. For untreated Scotch pine and Beech the weight loss was similar for white and brown rot. Although the weight loss is slightly higher for brown rot the statistical analysis shows that there is no significant difference between them. In relation to Oak the losses due to white rot are higher than for brown rot. Nevertheless for untreated wood the standard deviations of weight loss due to brown rot are very high. The heat treatment presents better results for brown rot. For instance: the treatment at 190ºC for 2 h was enough to decrease the mass loss to values lower than 5% for all of the studied species. Similar results were presented before by Tjeerdsma *et al.* (2000) who studied the increase of the resistance to soft rot, white rot (*Trametes versicolor*), and brown rot (*Coniophora puteana*) for heat treated *Pinus sylvestris, Picea abies, Pinus radiata,* and *Pseudotsuga menziesii* and concluded that the best performance was achieved for brown rot.

The treatments with higher intensity have lower mass loss. For example the mass loss due to brown rot was only 0,10; 0,67 and 0,38% for respectively Scotch pine, beech and oak heat treated at 212ºC for 2 h. Even though the mass loss decrease is smaller for white rot there is a direct relation between the intensity of the heat treatment and the mass loss decrease as stated before (Leithoff and Peek 2001).

A treatment at 212ºC for 2h is necessary to attain mass losses lower than 7% for all of the studied species. Only for oak it was possible to achieve a mass loss lower than 5%. The results show that a treatment at higher temperature or during a longer time will certainly allow the reduction of the mass loss due to rot to values under 5%. Nevertheless, one of the main problems of using a more severe treatment is the significant strength loss that makes treated wood unfitted for some applications. For example Esteves *et al.* (2006) stated that heat treated pine at 210ºC with mass loss around 7% had a 30% reduction on bending strength. Therefore a good combination between the increase in rot durability and the decrease in mechanical properties has to be achieved in accordance to the final destination of treated wood. Several studies have proven that some other mechanical properties are also affected by the treatment. Compression strength parallel to grain decreased for heat-treated Scots pine wood (Korkut *et al.* 2008) or for heat-treated Turkish river red gum (Unsal and Ayrilmis 2005). Static and impact bending strength are however considered to be the properties with the largest negative impact.

The statistical analysis shows that the white rot behaves similarly for all of the untreated wood samples and that the differences between the studied species are not significant. The only significant difference is with brown rot. There is a significant difference in mass loss due to fungal attack between Scots Pine and Beech in one side and Oak in the other. The differences between each control and treated wood are clearly significant, both with white rot and brown rot even for the lowest temperature (190ºC) showing that the treatment improves the biodegradation resistance against these types of rot. The decrease observed on the mass loss due to white rot in pine and beech is similar and lower than the attained for oak species. This is probably due to the better performance of the initial material.

Table 1. Weight Loss of Untreated and Heat Treatment, Scotch pine (*Pinus sylvestris*), Beech (*Fagus orientalis*) and Oak (*Quercus petraea*).

Wood type	Temperature (°C)	White rot (*P. ostreatus*)		Brown rot (*C. puteana*)	
		Mean	HG	Mean	HG
Scotch pine (*Pinus sylvestris*)	Control	23,04 (1,46)	a	25,48 (10,54)	a
	190°C for 2 h	11,66 (2,75)	b	1,90 (1,04)	efgh
	212°C for 1 h	8,93 (5,23)	bc	0,72 (0,23)	fgh
	212°C for 2 h	6,74 (2,28)	bcde	0,10 (0,72)	h
Beech (*Fagus orientalis*)	Control	22,87 (3,25)	a	23,74 (10,16)	a
	190°C for 2 h	11,38 (4,32)	b	2,18 (2,41)	defgh
	212°C for 1 h	6,02 (1,35)	bcdefg	1,19 (0,35)	efgh
	212°C for 2 h	6,37 (2,71)	bcdef	0,67 (0,03)	gh
Oak (*Quercus petreae*)	Control	21,54 (5,07)	a	11,20 (7,57)	b
	190°C for 2 h	8,59 (4,56)	bc	3,95 (1,56)	cdefgh
	212°C for 1 h	7,58 (3,33)	bcd	1,67 (0,85)	efgh
	212°C for 2 h	4,74 (2,36)	cdefgh	0,38 (0,33)	gh

Values in parentheses are standard deviations. HG: Homogeneous Group.

Figures 1,2 and 3 present the petri dishes with wood exposed to white and brown rot fungi for untreated and heat treated Scotch pine, Beech and Oak respectively. The results clearly show that both rot fungi covered untreated control groups of the three wood species studied and that for heat treated wood with the increasing heat treatment temperature and time, fungi density decreased for the three wood species. The results also show that heat treatment can be used successfully against brown rot and white rot fungi (*Coniophora puteana*) and (*Pleurotus ostreatus*) attacks. Nevertheless it has to be taken into account that the tests that were made were soil free bioassays. The results only prove that the treatment is effective in improving the resistance to rot biodegradation without ground contact. Several work has shown that for ground contact tests the durability of heat treated wood is much lower. For example Brischke and Meyer-Veltrup (2016) performed field tests with heat treated wood for 14 years and concluded that it decayed rapidly when exposed to ground contact. Even though heat treated wood decayed less during the first 1-2 years, it catch up afterwards. The difference between durability classification based on laboratory and field test does not happen only in heat treated wood as reported before (Brischke *et al.* 2009).

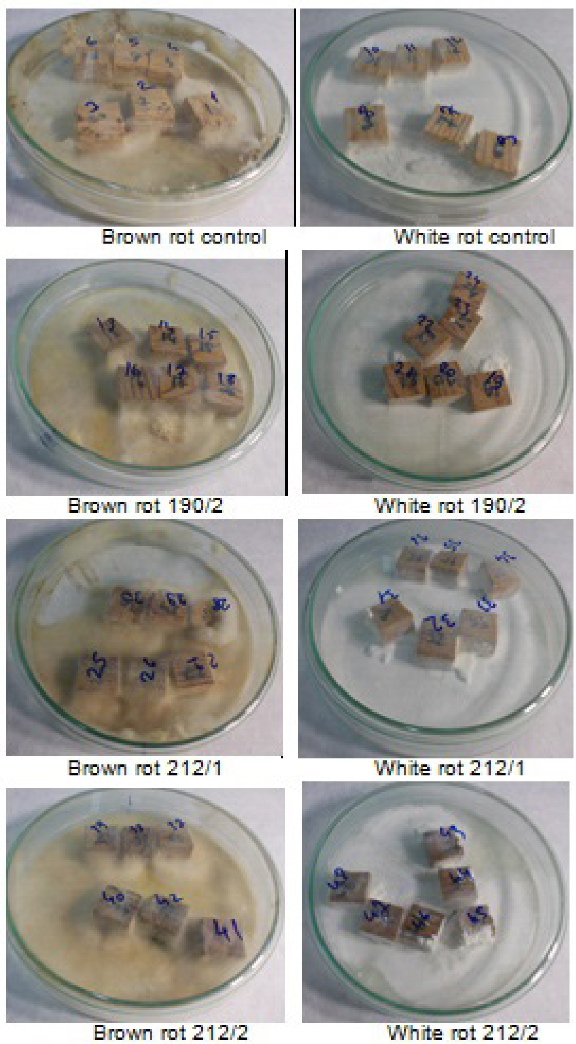

Figure 1. Heat treated Scotch pine (*Pinus sylvestris*) wood exposed to white and brown rot fungi.

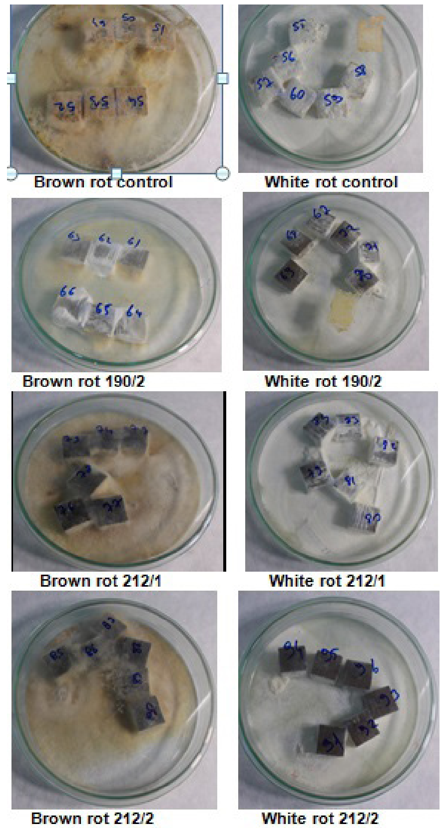

Figure 2. Heat treated oak (*Quercus petreae*) wood exposed to white and brown rot fungi.

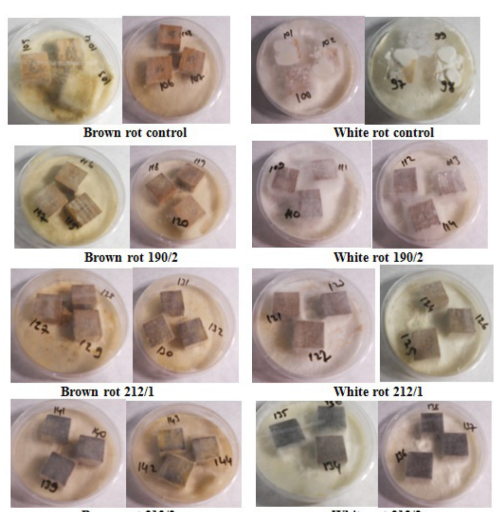

Figure 3. Heat treated beech (*Fagus orientalis*) wood exposed to white and brown rot fungi.

CONCLUSIONS

Overall heat treatment improves the durability of Scotch pine (*Pinus sylvestris*), oak (*Quercus petreae*) and beech (*Fagus orientalis*) wood.

With higher intensity of the heat treatment, mass losses are lower.

Heat treatment is more efficient on the reduction of brown rot decay.

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