Scientia Agraria Paranaensis – Sci. Agrar. Parana.
ISSN: 1983-1471 – Online

DEVELOPMENT OF THE *Trametes versicolor* (L.) C. G. Lloyd. FUNGUS ON THE WOOD OF THERMOREGULATED *Pinus taeda* L.

Luana Maria dos Santos[1*], Érick Martins Nieri[2], Flávia Alves Pereira[3], Sandra Mara Krefta[4], Jéssica Batista da Mata[5]

SAP 23398 Received: 09/10/2019 Accepted: 20/02/2020
Sci. Agrar. Parana., Marechal Cândido Rondon, v. 19, n. 2, apr./jun., p. 112-116, 2020

ABSTRACT - The companies in the forestry sector seek highly durable wood, prioritizing the use of planted forests, and the thermal treatment is a viable alternative to provide quality to these woods. Thus, the objective of the study was to evaluate the resistance of the heat-treated *Pinus taeda* L wood by the attack of white rot fungus *Trametes versicolor* (L.) CG Lloyd. The *P. taeda* L. wood was deployed in joinery to obtain samples with dimensions of 30 x 15 x 2.5 cm (length x width x thickness), being treated at temperatures of 140, 160 and 180ºC. From these, 1.0 x 1.0 x 1.0 cm specimens were obtained and subjected to the fungus for six weeks. The accelerated rot test was carried out in accordance with the ASTM D2017 standard. The experiment was conducted in a completely randomized design with four treatments (T1 = 0; T2 = 140°C; T3 = 160°C and T4 = 180°C) and nine replications. The loss of mass caused by the fungus was less in heat treated wood. On the other hand, the increase in temperature did not provide greater resistance to the material. In conclusion, heat treatment has reduced the degradation caused by the white rot fungus *Trametes versicolor*. Heat treatment at 140°C is indicated to avoid loss of mass in *P. taeda* L. woods submitted to the fungus *T. versicolor.* All treated woods were classified as highly resistant.
Keywords: accelerated decay, wood degradation, loss of mass, heat treatment.

DESENVOLVIMENTO DO FUNGO Trametes versicolor (L.) C. G. Lloyd. SOBRE MADEIRA DE Pinus taeda L. TERMORRETICADA

RESUMO - As empresas do setor florestal buscam madeiras altamente duráveis priorizando a utilização de florestas plantadas, sendo o tratamento térmico alternativa viável para proporcionar qualidade a estas madeiras. Dessa forma, o objetivo do estudo foi avaliar a resistência das madeiras de *Pinus taeda* L., tratadas termicamente, ao ataque do fungo de podridão branca *Trametes versicolor* (L.) C. G. Lloyd. A madeira de *P. taeda* L. foi desdobrada em marcenaria para a obtenção de amostras com dimensões de 30 x 15 x 2,5 cm (comprimento x largura x espessura), sendo tratadas nas temperaturas de 140, 160 e 180ºC. Dessas foram obtidos os corpos de prova com 1,0 x 1,0 x 1,0 cm, que foram submetidos ao fungo por seis semanas. O ensaio de apodrecimento acelerado foi realizado em conformidade com a norma ASTM D2017. O experimento foi conduzido em delineamento inteiramente casualizado com quatro tratamentos (T1 = 0; T2 = 140°C; T3 = 160°C e T4 = 180°C) e nove repetições. A perda de massa causada pelo fungo foi menor nas madeiras tratadas termicamente. Por outro lado, o aumento da temperatura não conferiu maior resistência ao material. Em conclusão, tem-se que o tratamento térmico diminuiu a degradação causada pelo fungo de podridão branca *Trametes versicolor* (L.) C. G. Lloyd. O tratamento térmico a 140°C é indicado para evitar perda de massa em madeiras de *P. taeda* L. submetidas ao fungo *T. versicolor*. Todos as madeiras tratadas foram classificadas como altamente resistentes.
Palavras-chave: apodrecimento acelerado, degradação de madeiras, perda de massa, tratamento térmico.

INTRODUCTION

The wood of native species has high economic value because it has excellent structural and decorative characteristics, which lead to the suppression of these forests in an unsustainable way. In recent years, it is clear that the supply of wood is shifting from native to planted forests, which reduces pressure on native forests (ARAÚJO et al., 2017). However, in general, planted forest species present wood with inferior physical and mechanical properties, as well as, they are less resistant to xylophagous organisms (SOUZA; DEMENIGHI, 2017).

Although reforestation wood iss susceptible to attack by microorganisms under specific conditions, when a preservative treatment is carried out, it becomes a very durable material, being able to obtain effective protection for periods of up to 50 years or more (VIVIAN et al., 2014).

[1]Universidade Federal de Lavras (UFLA), Lavras, Minas Gerais, Brazil. E-mail: luana.dv_@hotmail.com. *Corresponding author.
[2]Universidade Federal do Sul e Sudeste do Pará (Unifesspa), Instituto de Estudos do Xingu, São Félix do Xingu, Pará, Brazil.
[3]Universidade Tecnológica Federal do Paraná (UTFPR), *Campus* Dois Vizinhos, Dois Vizinhos, Paraná, Brazil.
[4]Universidade do Estado de Santa Catarina (UDESC), Lages, Santa Catarina, Brazil.
[5]Universidade Estadual do Centro Oeste (UNICENTRO), *Campus* Irati, Irati, Paraná, Brazil.

The market demands regarding the quality of wood products lead to strategies that minimize or eliminate factors limiting the use of these materials, thus, one of the greatest difficulties of wood science and technology is to find solutions to increase the dimensional stability and natural durability of the wood (SANTOS et al., 2017). The development of wood preservative techniques goes through an important phase, in which the use of products with less potential for damage to the health of organisms is necessary (LAZAROTTO et al., 2016). In this context, heat treatment appears as a feasible alternative to ensure the increase in wood durability to fungi and to promote the dimensional stability of the materials submitted to this technique (MELLO et al., 2014).

The thermal treatment also known as heat-rectification consists of the application of heat to the wood, which promotes the partial thermal decomposition of cellulose, hemicellulose and lignin, usually in the absence of oxygen or air deficiency. This treatment promotes chemical, physical, mechanical and superficial changes in wood, providing advantages for its technological properties (PERTTUZATTI et al., 2016). In order to improve the characteristics of the wood without the impregnation of chemical products, the wood thermorectification has been a widely studied method (CONTE et al., 2014; CADEMARTORI et al., 2014; MISSIO et al., 2015).

This technique is performed by exposing pieces of wood to temperatures between 100 and 250 ° C, obtaining a more resistant product with different characteristics compared to the original wood, and in this type of treatment there is an increase in the proportion of crystalline cellulose and generation of new ones. Extractable compounds, in addition to the increase in cross-linking of the lignin network, these changes reduce the equilibrium moisture and generate new extracts that act as fungicides, modifying the polysaccharides and lignin of the wood, degrading hemicellulose, which is one of the main food sources of the fungi (CADEMARTORE et al., 2014; LAZAROTTO et al., 2016). This treatment can be used, for example, in *Pinus taeda*, as it presents at its core moderate to low resistance to decay while the sapwood is more easily degraded because it has more reserve substances, however, both are susceptible to attack by biodeteriorating agents.

The technology of heat treatment is well advanced in some countries, given the edaphoclimatic conditions in which their planted forests are subjected and the wide demand for wood products, however, the use of this technology is still incipient in Brazil. With this, there is an opportunity to adapt technologies to promote technological innovation aimed at the resistance of materials to biodeteriorating agents that, in some cases, reduce the consumption of these products in the Brazilian market. Thus, the objective of this work was to evaluate the resistance of *Pinus taeda* L. woods, heat treated, to the white rot fungus *Trametes versicolor* (L.) CG Lloyd.

MATERIAL AND METHODS

Pinus taeda L. wood was acquired from a plantation located in Quedas do Iguaçu-PR. This county is located in the third Planalto Paranaense, in the central-west region of Paraná, at a latitude of 25°27’0” South, longitude of 52°54’28” west and an altitude of 630 m. The climate of the municipality, according to the Köppen classification, is *Cfa* type, subtropical humid mesothermal, with hot summers (ALVARES et al., 2013).

Wooden boards from *Pinus taeda* L. were unfolded in joinery and converted into pieces with dimensions 30 x 15 x 2.5 cm (length x thickness x width). Subsequently, nine samples were classified, eliminating those that had defects such as warping, cracking and the incidence of insect attack. These were heat treated in a hydraulic press at the Universidade Estadual do Centro Oeste (Unicentro).

The samples were placed between the press plates, with temperature control, for one hour. The treatment (T0) did not show heating, while to obtain the T1, the samples were arranged for one hour between the press plates at 140ºC. After the stipulated period, the samples were taken and the dish was heated to 160ºC, in order to obtain the T2 treatment. The same process was carried out for T3 at 180ºC.

After the treatments, the specimens removed from the sapwood of individuals aged 10 years old, were produced with dimensions of 1.0 x 1.0 x 1.0 cm (length x width x thickness), sanded and identified. Then, they were placed in greenhouses with forced ventilation at 50 ± 2ºC until constant mass for later determination of mass loss. The accelerated rot test was carried out in accordance with the American Society for Testing Materials (ASTM D-2017, 2005) standard, according to a methodology adapted from Worrall et al. (1997) and Alves et al. (2006).

The fungus used was *Trametes versicolor* (white rot), and its collection and isolation was carried out at the Phytopathology Laboratory of the Universidade Tecnológica Federal do Paraná (UTFPR), *Campus* Dois Vizinhos (PR). The fungus was grown in a 3% liquid malt culture medium and taken to the incubator at 26 ± 1ºC and 70 ± 5% relative humidity, until the mycelium completely covered the surface of the medium (three weeks). At the time of inoculation, the mycelium was fragmented in a domestic blender and subsequently pipetted into the test bottle. The entire procedure for manipulating the fungus, such as peaking, inoculation, fragmentation of the mycelium and introduction of the test cups in the test flasks, were carried out inside a laminar flow hood.

The test was set up in transparent glass flasks, with a large orifice, threadable metallic cap, with a capacity of 500 mL and containing 207 g of soil, which is used as a substrate to provide moisture for the development of the fungus. Horizon B of the dystrophic red latosol was collected at UTFPR, sieved and corrected until reaching pH = 6.0. The soil was moistened with 81 mL of distilled water and a wooden feeding plate of *Pinus taeda* L., with dimensions of 29 x 35 x 3 mm, was added to each jar. These were sterilized in an autoclave at

121 ± 2ºC for 50 min. Each flask was inoculated with 1 ml of culture medium, with fragmented mycelium deposited directly on the support plate. Meanwhile, the specimens were autoclaved at 121 ± 2ºC for 50 min. Each vial received a single specimen. The flasks for the development of fungi in the specimens were conditioned in an incubator with a temperature of 27 ± 2ºC and 70 ± 4% relative humidity, in which the fungus was in contact with the samples for a period of 6 weeks. At the end of the rotting test, the specimens were removed from the flasks and, with a soft brush, the entire mycelium and the portions of soil adhered to them were carefully removed.

To determine the mass loss, the specimens were dried under the same conditions already mentioned and then weighed on an analytical balance with 0.0001 g of precision to determine the final mass. Using the values obtained from the initial mass, before inoculation of the fungus, and final after the rotting test, the loss of mass of the specimens was calculated (Equation 1).

$$PMt = \left(\frac{Mi-Mf}{Mi}\right) x\ 100 \qquad \text{Equation 1}$$

Where:
PMt = total weight loss (%),
Mi = initial mass (g) and
Mf = final mass (g).

According to the final weight loss, the treatments were classified according to the criteria established by the ASTM D-2017 (2005) standard, being:

a) Highly resistant (AR): when the mass loss found is in the range of 0-10%,
b) Resistant (R): when the loss of mass found is in the range of 11-24%,
c) Moderately resistant (MR): when the loss of mass found is in the range of 25-44% and
d) Non-resistant (NR): when the loss of mass found is >45%.

The experiment was conducted in a completely randomized design with four treatments and nine replications. The data were tabulated and when checking for normality, the analysis of variance was performed. When a significant difference was found between treatments (Fisher Test, p<0.01), the averages were compared using the Tukey test, with a 5% probability of error using the SISVAR computer program (FERREIRA, 2011).

RESULTS AND DISCUSSION

Os resultados da análise de variância para a perda de massa da madeira de *Pinus taeda*, tratada em diferentes temperaturas, está disposto na Tabela 1. O tratamento térmico diminuiu a degradação causada pelo fungo de podridão branca e, consequentemente, perda de massa da madeira de *Pinus taeda* durante o ensaio de apodrecimento acelerado (Tabela 2).

TABLE 1 - Analysis of variance for mass loss of *Pinus taeda* L. wood, heat treated, at different temperatures, subjected to the accelerated rot test with the fungus *Trametes versicolor* (L.) CG Lloyd.

Variation sources	Degrees of freedom	Medium squares
Treatment	3	5,6055**
Error	32	0,2643
Coefficient of variation (%)		19,76
Standard deviation		0,52
Number of observations		36
Overall average		2,60

**Significant at 1% probability of error, by Fisher test.

TABLE 2 - Loss of mass of *Pinus taeda* wood, thermally treated, at different temperatures, subjected to the accelerated rot test with the fungus *Trametes versicolor* and classification of treated wood according to ASTM D-2017 (2005).

Treatment temperature	Weight loss (%)	Classification
Control (T0)	3,78 a*	Highly resistant
Thermorectification at 140ºC (T1)	2,27 b	Highly resistant
Thermorectification at 160ºC (T2)	2,13 b	Highly resistant
Thermorectification at 180ºC (T3)	2,23 b	Highly resistant

*Means followed by the same letter do not differ statistically from each other, by the Tukey test, at 5% probability of error.

Samples of *Pinus taeda* woods heat treated in autoclave and greenhouse, submitted to the accelerated rot test with the white rot fungus, *Trametes versicolor*, carried out by Modes et al. (2017), presented greater loss of mass in their witnesses (43.46%), indicating that the thermorectification promotes the increase of the resistance of the wood against the attack of the fungus. This result is similar to that found, since the treatments at 140ºC, 160ºC and 180ºC showed less loss of mass. This is possibly due to the partial degradation of the primary components of wood, which are a source of food for rot fungi.

Heat-treated wood can cause repellency to degrading fungi, due to changes in its chemical composition, especially with regard to food unavailability (hemicelluloses), as there is the production of new molecules that act as fungicides, in addition to cross-linking between lignin and the cellulose polymer partially degraded by treatment (CALONEGO et al., 2013). Another factor that prevents the development of the fungus is the difficulty of the heat-treated wood to absorb moisture, and thus the translocation of enzymes into the wood substrate becomes more restricted. The mass losses caused by the white rot fungus were lower in the heat treated woods, however, the treatments at 140, 160 and 180°C were similar to each other. The T1 treatment is the most suitable to give greater durability to the *Pinus taeda* woods when in contact with white rot fungi, as there were no significant differences between treatments.

Esteves et al. (2008) state that cellulose is esterified by acetic acid during heat treatment. With this, furfural can be linked to the aromatic chains of lignin, forming new compounds and degrading pentosans, which are the nutritive basis for the development of the fungal colony. In this way, conditions are provided that hinder their development.

Przybtsz et al. (2013), proved the improvement in the biological resistance properties of *Pinus oocarpa* wood treated at 220ºC when in contact with xylophagous fungi. Calonego et al. (2013) carried out the accelerated rot test with Eucalyptus grandis term wood treated in contact with the fungus *Gloeophyllum trabeum* (brown rot) and Pycnoporus sanguineus (white rot). This author found that the heat treatment contributed to the wood being less degraded by the studied fungi. The *Pinus taeda* woods were classified according to the resistance to attack by the white rot fungus, according to the criteria established by the ASTM D-2017 (2005) standard (Table 2). All treatments were classified as highly resistant because they had a mass below 10%.

Biodegradable agents with no competence for the degradation of *Pinus taeda* wood in studies carried out demonstrated the significant consumption of the substrate (MODES et al., 2017). Thus, the result obtained is highlighted in that the fungus *T. versicolor* presented degradation of untreated *P. taeda* wood, however the present study proved that this attack is not considered sufficient for the wood to be considered susceptible to the fungus, when to the point that there are big losses.

The tested fungus has no ability to degrade coniferous wood, as all treatments were considered high resistance. Thus, in order to carry out a resistance test in such woods, brown rot fungi should be used, preferably using three fungi. This high strength of *Pinus taeda* wood, according to Mendes et al. (2014), is related to the attack of rot fungi, which feed mainly on hardwoods, although they can also decompose conifers with less intensity.

In general, the heat-treated *Pinus taeda* woods can be considered as highly resistant to the fungus *Trametes versicolor*, whereas the heat treatment reduced the degradation caused by the fungus, with the temperature of 140ºC being the most suitable for the treatment. Future studies can still be carried out, in order to test the efficiency of heat treatment in *P. taeda* wood, preferably using brown rot fungi, which tend to cause greater degradation in coniferous woods.

CONCLUSIONS

The heat treatment reduced the degradation caused by the white rot fungus *Trametes versicolor*.

Heat treatment at 140ºC is indicated to prevent loss of mass in *Pinus taeda* woods submitted to the fungus *Trametes versicolor.*

All treated woods were classified as highly resistant.

REFERENCES

ALVARES, C.A.; STAPE, J.L.; SENTELHAS, P.C.; GONÇALVES, J.L.M.; SPAROVEK, G. Köppen's climate classification map for Brazil. **Meteorologische Zeitschrift**, v.22, n.6, p.711-728, 2013.

ALVES, M.V.S.; COSTA, A.F.; ESPIG, D.S.; VALE, A.T. Resistência natural de seis espécies de madeiras da região amazônica a fungos apodrecedores em ensaios de laboratório. **Ciência Florestal**, v.16, n.1, p.17-26, 2006.

ASTM. AMERICAN SOCIETY FOR TESTING AND MATERIALS. **ASTM D-2017**: Standard method for accelerated laboratory test of natural decay resistance of woods. West Conshohocken: ASTM international, 2005. 5p.

ARAÚJO, V.A.; GARCIA, J.N.; BARBOZA, J.C.; GAVA, M.; SAVI, A.F.; MORALES, E.A.M.; LAHR, F.A.; VANCONCELOS, J.S.; CHRISTOFORO, A.L. Importância da madeira de florestas plantadas para a indústria de manufaturados. **Pesquisa Florestal Brasileira**, v.37, n.90, p.189-200, 2017.

CADEMARTORI, P.H.G.; MISSIO, A.L.; MATTOS, B.D.; SCHNEID, E.; GATTO, D.A. Physical and mechanical properties and colour changes of fastgrowing Gympie messmate wood subjected to two-step steam-heat treatments. **Wood Material Science & Engineering**, v.9, n.1, p.1-9, 2014.

CALONEGO, F.W.; ANDRADE, M.C.N.; NEGRÃO, D.R.; ROCHA, C.D.; MINHONI, M.T.A.; LATORRACA, J.V.; SEVERO, E.T.D. Behavior of the brown-rot fungus *Gloeophyllum trabeum* on thermally-modified *Eucalyptus grandis* Wood. **Floresta e Ambiente**, v.20, n.3, p.417-423, 2013.

CONTE, B.; MISSIO, A.L.; PERTUZZATTI, A.; CADEMARTORI, P.H.G.; GATTO, D.A. Propriedades físicas e colorimétricas da madeira termorretificada de *Pinus elliottii* var. *elliottii*. **Scientia Forestalis**, v.42, n.104, p. 555-563, 2014.

ESTEVES, B.M.; DOMINGOS, I.L.; PEREIRA, H.M. Pine wood modification by heat treatment in air. **BioResources**, v.3, n.1, p.142-154, 2008.

FERREIRA, D. F. Sisvar: a computer statistical analysis system. **Ciência e Agrotecnologia**, v.35, n.6, p.1039-1042, 2011.

LAZAROTTO, M.; CAVA, S.S.; BELTRAME, R.; GATTO, D.A.; MISSIO, A.L.; GOMES, L.G.; MATOSSO, T.R. Resistência biológica e colorimetria da madeira termorretificada de duas espécies de eucalipto. **Revista Árvore**, v.40, n.1, p.135-145, 2016.

MENDES, R.F.; BORTOLETTO JÚNIOR, G.; VIDAL, J.M.; ALMEIDA, N.F.; JANKOWSKY, I.P. Resistência de painéis compensados de *Pinus taeda* tratados com preservantes ao ataque de fungos xilófagos. **Cerne**, v.20, n.1, p.105-112, 2014.

MELLO, R.R.; DALLA LIBERA, L.; STANGERLIN, D.M.; CASTELO, P.A.R. Influence of thermal treatament on dimensional stability and wood durability of *Trattinnickia burseraefolia*. **Ciências Agroambientais**, v.12, n.2, p.101-109, 2014.

MISSIO, A.L.; MATTOS, B.D.; CADEMARTORI, P.H.G; GATTO, D.A. Effects of two-step freezing-heat treatments in Japanese Raisintree (*Hovenia dulcis* Thunb.) wood properties. **Journal of Wood Chemistry and Technology**, v.36, n.1, p.16-26, 2015.

MODES, K.S.; SANTINI, E.J.; VIVIAN, M.A.; GARLET, A. Influência da termorretificação na resistência a degradação biológica das madeiras de *Pinus taeda* e *Eucalyptus grandis*. **Ciência Florestal**, v.27, n.3, p.993-1002, 2017.

PERTTUZZATTI, A.; MISSIO, A.L.; SOUZA, S.C.; SANTINI, E.J.; HASELEIN, C.R. Propriedades físicas da madeira de *Pinus elliottii* var. *elliottii* termorretificada sob diferentes atmosferas. **Ciência da Madeira**, v.7, n.1, p.7-15, 2016.

PRZYBTSZ, M.; MACHADO, G.O.; CHRISTÓFORO, A.L.; DA SILVA, M.R.; CALIL JÚNIOR, C. Resistência biológica a fungos xilófagos da madeira de *Pinus oocarpa* termorretificada. **Madeira:** arquitetura e engenharia, v.14, n.35, p.37-46, 2013.

SANTOS, V.B.; SANTOS, L.C.S.; SANTANA, J.C.S.; CAETANO, M.M.; SILVA, G.C. Propriedades físicas de espécies utilizadas no setor da construção civil em Vitória da Conquista - BA. **Enciclopédia Biosfera**, v.14, n.25, p.1084-1094, 2017.

SOUZA, R.V.; DEMENIGHI, A.L. Tratamentos preservantes naturais de madeiras de floresta plantada para a construção civil. **Mix Sustentável**, v.3, n.1, p.84-92, 2017.

VIVIAN, M.A.; SANTINI, E.J.; MODES, K.S.; CARVALHO, D.E.; MORAIS, W.W.C. Resistência biológica da madeira tratada de duas espécies de *Eucalyptus* em ensaio de campo. **Pesquisa Florestal Brasileira**, v.34, n.80, p.425-433, 2014.

WORRAL, J.J.; ANAGNOST, S.E.; ZABEL, R.A. Comparison of wood decay among diverse lignicolous fungi. **Mycologia**, v.89, n.2, p.199-219, 1997.