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Róbert Németh, Christian Hansmann, Holger Militz, Miklós Bak, Mátyás Báder

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Examination of the durability of beeswax-impregnated wood

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ABSTRACT

Within the framework of this research, the biological durability of two different wood species (*Pinus sylvestris* and *Fagus sylvatica*), impregnated with beeswax was investigated. The durability was tested according to the standard EN 113, and with a laboratory-scale soil contact test, based on the standard ENV 807, using modified parameters. The aim of the tests was to increase the biological durability of the samples treated with beeswax by impregnation. Test specimens modified in this way do not have any toxic effect on the environment. Unimpregnated beech and Scots pine samples showed high decomposition during both decay tests. The damage of the impregnated samples was markedly lower. Beside mass loss, this was confirmed by the visual inspection of the samples after soil exposure under laboratory conditions. Impregnated samples showed low degradation level compared to the controls.. SEM imaging showed that beeswax filled the lumens and separated most of the cell walls from the hyphae, which slowed the spreading of the fungi in the wood.

INTRODUCTION

The advantage of beeswax is its biological origin and its nontoxic nature. However, natural waxes are generally not biologically stable (Schmidt 2006). Nonetheless, they can delay the decay of wood because waxes are water repellent, and with the impregnation method, the cell lumens can be filled with wax (Bak et al. 2015). As a result of the hydrophobic properties of beeswax and the lumen filling, the decay of wood by fungi is slowed. Waxes have the effect of reducing termite damage as well, but they cannot protect wood completely (Scholz et al. 2010a). Another advantage of wax impregnation of wood is the improvement in wood's mechanical properties. For example, the hardness can be increased in beech wood up to 86 to 189% in the longitudinal and lateral directions, respectively (Scholz et al. 2010b). Different waxes, including beeswax, are often used as conservation agents for wooden artifacts (Timar et al. 2010; Timar et al. 2011). This shows that under appropriate conditions, beeswax is suitable for wood protection. Chemical composition of beeswax presents a huge diversity of components because of its lipid nature. Beeswax is mostly composed of a mixture of hydrocarbons, free fatty acids, monoesters, diesters, triesters, hydroxy monoesters, hydroxy polyesters, fatty acid polyesters, and some unidentified compounds. Each class of compounds consists of a series of homologues differing in chain length by two carbon atoms (Maia and Nunes 2013).

During the outdoor utilization of wood, the hazard class of soil contact is ranked very high among the exposure classes (use class 4, according to EN 335 (2013)). For use in soil contact, very effective protection and/or durable wood species are needed. The aim of the tests was to increase the biological durability of the samples treated with beeswax by impregnation.

MATERIALS AND METHODS

Scots pine (*Pinus sylvestris*) and beech (*Fagus sylvatica*) samples were impregnated with beeswax and exposed to fungi under laboratory conditions. Unimpregnated samples were used as the control. Wood pores were completely filled with wax, or at least their surface was coated with wax as a result of the impregnation, depending on the degree of impregnation. Beeswax was melted at 80 °C in a closed chamber, and the dry samples (moisture content: 0%) were put into the melted beeswax. After that, the pressure was decreased in the chamber to 150 mbar for 4 h. Following the vacuum period, the pressure was increased to 6 bar and the temperature of the beeswax (with the samples) was kept at 80 °C for 24 h. Weight percent gain (WPG) was calculated according to the initial dry weight of wood (m_0) and the beeswax impregnated wood (m_i) (Eq. 1):

$$WPG = \frac{m_0 - m_i}{m_0} \times 100\ [\%] \quad (1)$$

The presence and distribution of beeswax in the structure of wood was tested with scanning electron microscopy (SEM) imaging, using a Hitachi S-3400N device.
The effect of beeswax impregnation on the durability was tested under laboratory conditions using two methods. One method was the EN113 (2020) standard method, where 15×25×50mm wooden blocks were exposed to a white rot *Trametes versicolor* and a brown rot *Coniophora puteana*, 10 pieces of each variation. The other method was based on the ENV807 standard method, but no fungi culture was added to the soil used. The fertile soil was taken from the Botanical Garden of the University of Sopron, with its original decaying organisms. Thus, the decaying organisms were unknown in this case. The moisture content of the soil in plastic containers was kept at 95% of its water holding capacity to ensure constant conditions during the test. Samples with dimensions of 5×10×150 mm were used. The incubation time was 32 weeks. Mass losses (ML) were calculated according to the initial dry weight (m_0) and the decayed dry weight of wood (m_{0d}) (Eq. 2):

$$ML = \frac{m_0 - m_{0d}}{m_0} \times 100\ [\%] \quad (2)$$

RESULTS AND DISCUSSION

Weight percent gain

WPG of both beech and Scots pine was considered as high after the impregnation process, which indicates high efficiency of the treatment. However, wood species showed different WPGs, which is contributed to their different pore volume (Fig. 1).

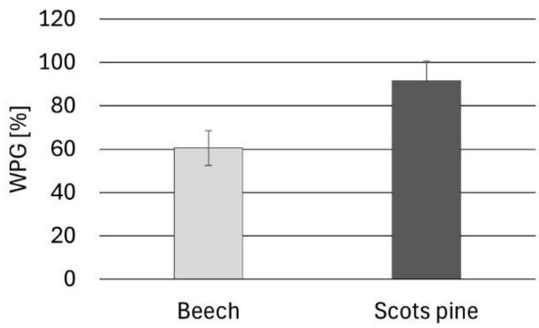

Figure 1: WPG of beech and Scots pine samples as a result of beeswax impregnation. Bars indicating standard deviation

Microscopic imaging

SEM imaging supported the results of WPG, as it showed that most of the cell lumens were entirely filled with beeswax. Only a slight amount of cell lumens was detected as empty or partly filled. Generally, the cell walls in the lumens partly filled were covered by the beeswax entirely. Besides, a low ratio of lumens without any beeswax were detected as well (Fig. 2). This is considered as a weak point of the method, as the protection mechanism of this treatment is the blocking of the lumens and excluding of the hyphae in order to slower the fungal decomposition of the wood without using fungicides. However, the impregnation efficiency could be improved by the alteration of the impregnation parameters in order to increase the amount of beeswax in the wood structure. This might further improve the protective effect of the treatment. Beside the lumen filling, it is expected that the beeswax impregnation decreases the moisture absorption of wood, which is contributing to the protection efficiency of the method.

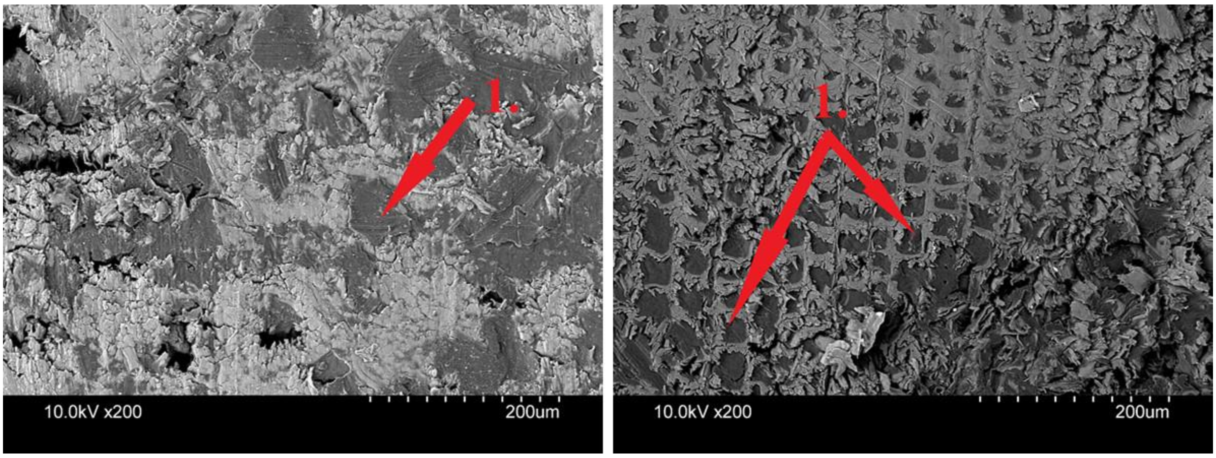

Figure 2: SEM images of beeswax impregnated beech (left) and Scots pine (right). Arrows indicating filled lumens

Durability test according to EN 113

The durability test after 16 weeks of incubation time showed a significant improvement in the durability of the impregnated wood. In *Trametes versicolor* the average ML decreased by 44.93% and 76.24% for beech and pine respectively, as a result of the beeswax impregnation (Fig. 3a). In *Coniophora puteana* the average ML decreased by 59.05% and 46.96% for beech and pine respectively, as a result of the beeswax impregnation (Fig. 3b). These results indicate that it is not possible to reach full protection to wood using beeswax, even at high impregnation levels.

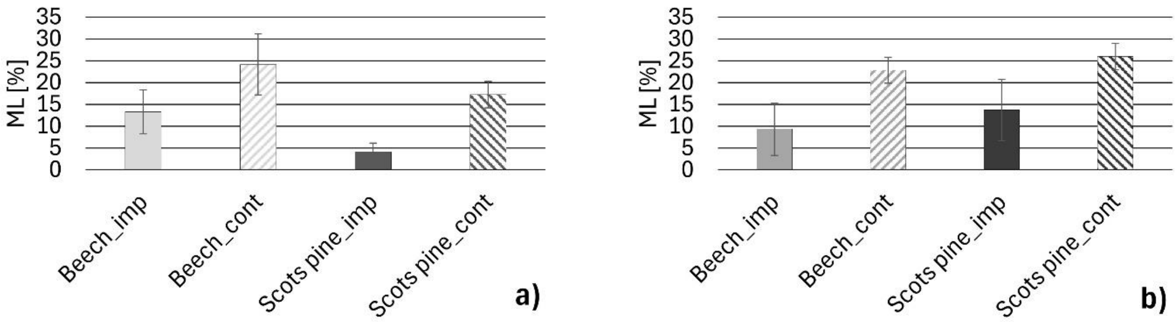

Figure 3: Mass loss of beeswax impregnated (_imp) and control (_cont) beech and Scots pine samples after EN 113 decay test, using the white rot Trametes versicolor (a) and the brown rot Coniophora puteana (b) as test fungi. Bars indicating standard deviation

Durability test according to ENV 807

The durability test after 32 weeks of incubation time showed a significant improvement in the durability of the impregnated wood in this case as well. The average ML decreased by 53.04% and 37.03% for beech and pine respectively, as a result of the beeswax impregnation (Fig. 4). These results also underline the conclusion taken according to the EN 113 test method that it is not possible to reach full protection to wood using beeswax, even at high impregnation levels. However, the results indicate that this wood modification method might be a considerable alternative solution for wood protection under less harsh conditions than soil contact.

The ML results were supported by the visual inspection. Control samples showed in some cases total decomposition (ML=100%, beech control), or at least high level of erosion with a remarkable loss in the cross section and/or the length (Scots pine control). Despite that, beeswax impregnated samples were found less affected by decay in their cross-sectional dimensions (Fig. 5). However, mass loss was high in their case as well.

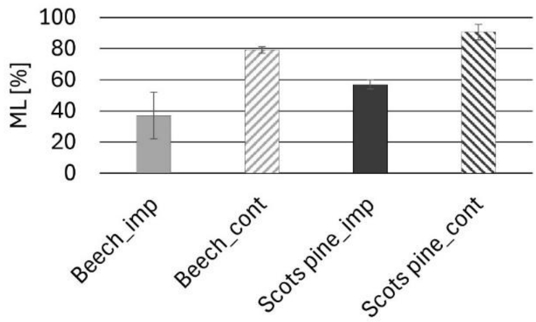

Figure 4: Mass loss of beeswax impregnated (_imp) and control (_cont) beech and Scots pine samples in soil contact after the modified ENV 807 decay test. Bars indicating standard deviation

Figure 5: Visual inspection of beeswax impregnated (_imp) and control (_cont) beech and Scots pine samples in 32 weeks of soil contact after the modified ENV 807 decay test

CONCLUSIONS

Beeswax impregnation of beech and Scots pine wood improved the decay resistance significantly. Unimpregnated beech and pine samples showed high decomposition during both decay tests compared to the beeswax impregnated ones. The damage of the impregnated samples was markedly lower. Beside mass loss, this was confirmed by the visual inspection of the samples after soil exposure under laboratory conditions. Impregnated samples showed low degradation level compared to the controls. SEM imaging showed that beeswax filled the lumens and separated most of the cell walls from the hyphae, which slowed the spreading of the fungi in the wood. However, the beeswax could not provide full protection to wood, it could only slower the decomposition. Nevertheless, the decay resistance was improved by a biomaterial, without using any biocides. Even if it is not expected to provide adequate protection in soil contact, but the results show that under certain conditions (use classes lower than 4) the beeswax impregnation might provide effective protection to wood.

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REFERENCES

EN 113 (2020) Durability of wood and wood-based products - Test method against wood destroying basidiomycetes. European Committee for Standardization, Brussels, Belgium.

EN 335 (2013) Durability of wood and wood-based products. Use classes: Definitions, application to solid wood and wood-based products. European Committee for Standardization, Brussels, Belgium.

ENV 807 (2001) Wood preservatives - Determination of the effectiveness against soft rotting micro-fungi and other soil inhabiting micro-organisms. European Committee for Standardization, Brussels, Belgium.

Maia M, Nunes F M (2013) Authentication of beeswax (*Apis mellifera*) by high-temperature gas chromatography and chemometric analysis. FOOD CHEM 136(2):961-968. https://doi.org/10.1016/j.foodchem.2012.09.003

Németh R, Tsalagkas D, Bak M (2015) Effect of soil contact on the modulus of elasticity of beeswax-impregnated wood. BIORESOURCES 10(1):1574-1586. https://doi.org/10.15376/biores.10.1.1574-1586

Schmidt O (2006) Damage to structural timber indoors. in: D. Czeschlik (ed) Wood and Tree Fungi, Springer, Berlin, Germany, pp. 207-237. https://doi.org/10.1007/3-540-32139-X

Scholz G, Militz H, Gascón-Garrido P, Ibiza-Palacios M S, Oliver-Villanueva J V, Peters B C, Fitzgerald C J (2010a) Improved termite resistance of wood by wax impregnation. INT BIODETER BIODEGR 64(8): 688-693. https://doi.org/10.1016/j.ibiod.2010.05.012

Scholz G, Krause A, Militz, H. (2010b) Beeinflussung der Holzfestigkeit durch Wachstränkung. Holztechnologie 51(1):30-35.

Timar M. C., Tuduce, T. A., Porojan, M., and Lidia, G. (2010). "An investigation of consolidants penetration in wood. Part 1: General methodology and microscopy," Pro Ligno 6(4), 13-27.

Timar, M C, Tuduce T A, Pałachia S, Croitoru C (2011) An investigation of consolidants penetration in wood. Part 2: FTIR spectroscopy. Pro Ligno 7(1):25-38.