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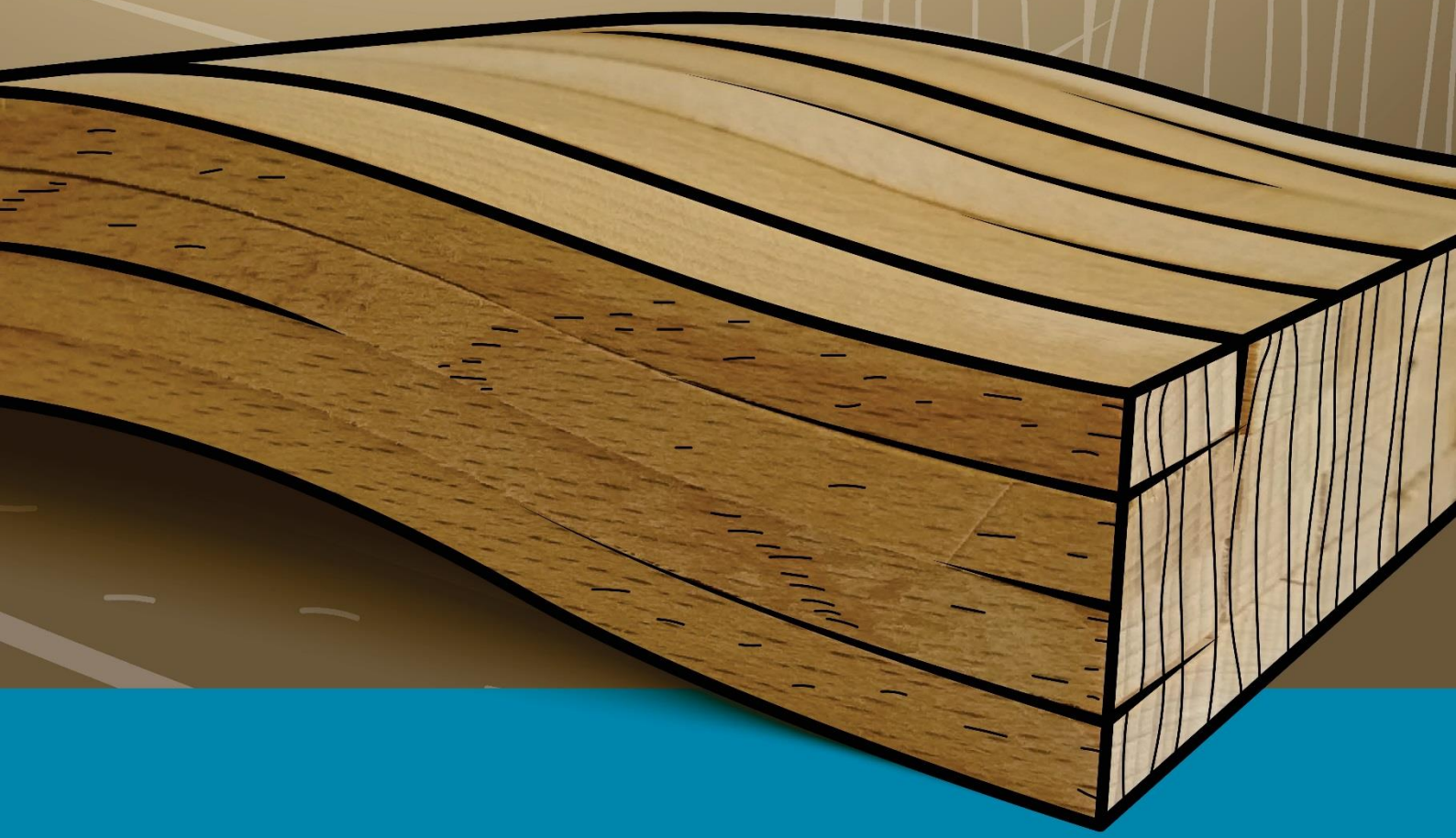

WOOD KPLUS

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10TH HARDWOOD CONFERENCE PROCEEDINGS

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Cover image based on the beech specimens of Radim Rousek and Mátyás Báder by Miklós Bak, 2021

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Fungal resistance of *Fagus sylvatica* after different wood modification processes

Fruzsina Horváth[1], Miklós Bak[1], Mátyás Báder[1*]

[1] University of Sopron, 9400 Bajcsy-Zs. Str. 4, Sopron, Hungary

E-mail: fruzsi.horvath99@gmail.com; bak.miklos@uni-sopron.hu; bader.matyas@uni-sopron.hu

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ABSTRACT

The paper describes the resistance of longitudinally compressed (pleated), heat-treated and impregnated beech wood (*Fagus sylvatica*) to white rot fungi (Turkey Tail, *Trametes versicolor*). White rot fungi degrades all constituents of wood with enzymes. Pleating is a chemical-free thermo-hydro-mechanical process, whose primary purpose is to obtain a better bendable, more flexible material. Due to the increased density and decreased cell lumina diameter resulting from pleating, it was assumed that a more fungal-resistant wood would be obtained. For pleating, higher density wood species are suitable, therefore we used beech, which is widespread in Hungary and used worldwide. Part of the compression process may be a fixation period (held the specimen in compressed state for a while). Two different fixation periods were used: 1 minute and 3 hours. In addition to pleating, our aim was to test environmentally friendly wood modification methods that may be resistant to fungi and can replace various harmful preservative treatments. We also used the long-known heat treatment at 180 °C in aerob conditions, which improves the resistance of the wood to biotic damages due to the chemical changes that take place during the treatment. We also tested samples impregnated with lactic acid by a vacuum treatment, with a positive effect on thermal and dimensional stability. Fungal decay was determined according to the standard EN 113 based on mass losses, and scanning electron microscopy was used to examine fungal mycelium penetration to wood. The longer fixation time after compression has a negative effect on the fungal resistance. Pleated beech samples impregnated with lactic acid proved to be the most resistant. Heat-treated samples as well as non-compressed samples impregnated with lactic acid showed greater fungal resistance to Turkey Tail than the untreated ones.

INTRODUCTION

The resistance of wood to biotic degradation is an important issue during use. Our aim was to investigate the effect of various environmentally friendly wood modification procedures on fungal decay resistance. Longitudinal compression (aka. pleating) is a thermo-hydromechanical process. After fibre softening, wood is exposed to pressure parallel to the axis of fibres, so that the cells can slide relative to each other, and their cell walls fold like an accordion (Báder and Németh 2020, Navi and Girardet 2000). At the end of the modification process, we get an environmentally friendly material with increased density, which can be bent more easily and to a greater extent in all directions (Báder 2015). For a broader overview, pleated samples were heat treated and impregnated with lactic acid (*LA*) as well. As a result of heat treatment, the resistance of wood to biotic degradation improves due to the chemical changes that take place during the treatment (Navi and Girardet 2000). After impregnation with *LA*, the dimensional and thermal stability of the wood improve (Grosse et al. 2019, Noël et al. 2015). These treatments are also considered as environmentally friendly procedures. The fungal decay resistance tests were carried out with a white rot fungus, Turkey tail (*Trametes versicolor*), which degrades all constituents of wood with enzymes. This fungus can be found on forest stumps, logs and built-in timber (Gyarmati et al. 1975).

EXPERIMENTAL METHODS

Hardwood species with higher density are suitable for pleating (Báder 2015). Common beech (*Fagus sylvatica* L.) was used for the experiment, which is popular in the wood industry. All specimens were made from the same log for 200 × 20 × 30 mm^3 (longitudinal direction × radial direction × tangential direction; L × R × T) determined by the laboratory-scale compressing equipment. The process requires high-quality raw material with uniform density, free of fibre slope, fissures and knots.

The specimens were stored in a freezer at a temperature of -30 °C until compression to preserve their moisture content. After steaming in saturated steam for 45 minutes, they were placed in the heated laboratory compression equipment, where they were compressed in the fibre direction with a rate of 50 mm/minute provided by the Instron 4208 (Instron Corporation, USA) universal material testing machine by 20% of their original length. The compression was followed by the fixation process (holding the specimen in compressed state, at a constant size), during which the stresses occurring in the wood gradually decreased. Two different fixation periods were used: the more economical 1 minute long and 3 hours long, which results in reduced spring-back of the specimen and even better pliability after cooling (Báder and Németh 2020). In both cases, the specimen remained in the equipment during the fixation period. After compression and fixation, the specimens were placed in a climate chamber with a temperature of 20 °C and a humidity of 65%.

Both untreated and compressed-fixated for 1 minute specimens were conditioned then heat treated at 180 °C in atmospheric conditions. During heat treatment, we first heated the equipment to 40 °C, then the temperature was increased to 180 °C at a heating rate of 0.1 °C/min, where the heat treatment was done for 10 hours. The cooling rate was 0.25 °C/min.

A 90% aqueous solution of L(+)-lactic acid was dehydrated using a magnetic stirrer at a rate of 175 RPM for 75 minutes in a vacuum chamber under a vacuum of 150 mbar at 75 °C temperature. Afterwards, the *LA* monomers were oligomerized in two steps using the same vacuum and stirrer rotation rate, first at 100 °C for 100 minutes, then at 130 °C for 160 minutes. For impregnation, both untreated and compressed-fixated for 1 minute specimens were placed in the *LA* oligomer, weighed that they were covered everywhere by the oligomer, then kept them under a vacuum of 100 mbar at 90 °C for 60 minutes. The specimens have been then removed from the oligomer, wiped, wrapped in aluminium foil, and placed in a drying chamber at a temperature of 120 °C for 360 minutes, to polymerizes the *LA* in the wood.

After the treatments, the specimens were conditioned at 20 °C and 65% humidity. We have been examined the following beech samples (in addition to untreated samples): compressed and fixated for 1 minute; compressed and fixated for 3 hours; heat treated; compressed and fixated for 1 minute and heat treated; impregnated with *LA*; compressed and fixated for 1 minute and impregnated with *LA*. Using the originally 200×30×20 mm^3 (L × R × T), pleated and non-pleated samples, 3 specimens of 50 × 15 × 25 mm^3 (L × R × T) were created in accordance with the standard EN 113. The initial cross-section of the specimens treated with *LA* did not meet the requirements of the standard as a result of previous treatments. In this case, we tried to create the largest possible specimens (36×12×20 mm^3; L × R × T). Fungal decay resistance tests with a time interval of 16 weeks were carried out according to standard EN 113 using Turkey tail (*Trametes versicolor* (L.) Lloyd). In all cases, the specimens were disinfected at a temperature of 103 °C before the test, and their weight was measured. A treated and an untreated specimen were placed on glass sticks in kolle flasks filled with fungal mycelium grown on the microbiological agar. The flasks prepared in this way were placed in an incubator (22 °C, 70% relative humidity) until the end of the test, when drying and mass measurement followed again. The degree of fungal decay was obtained as a percentage of mass loss (m/m%) based on standard EN 113.

After fungal decay resistance tests, the arrangement of the fungal hypha entering the wood was examined with a Hitachi S-3400N scanning electron microscope (Hitachi, Japan). The version of the Hitachi software was 1.24 (serial number: 340632-01), the resolution of the images was 2560×1920 pixels. The applied vacuum was 60 mbar, and the accelerating voltage of the electron beam was 8 kV. The specimens were examined with a detector distance of 10 mm. We used automatic contrast as well as brightness and focus before recording the images, with occasional manual adjustments to further improve the image quality.

RESULTS AND DISCUSSION

The values of the mass loss of differently treated beech wood due to the Turkey tail decay are shown in Fig. 1. The average weight losses of the specimens heat-treated; impregnated with *LA*; compressed and impregnated with *LA* are lower than the weight loss of their untreated counterparts, so they are more resistant to Turkey tail decay.

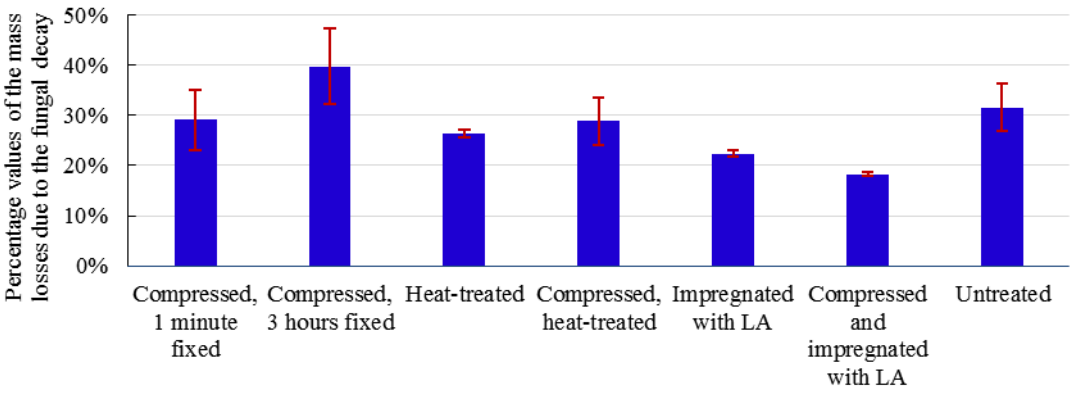

Figure 1: Mass loss of beech specimens after Turkey tail decay

At the examination with electron microscope both compressed and fixated for 1 minute and compressed and fixated for 3 hours specimens showed a similar amount of mycelium to their untreated specimen counterparts. In the heat-treated samples only in few places, small quantity, while in the samples treated with *LA* no mycelium has been found (Fig. 2).

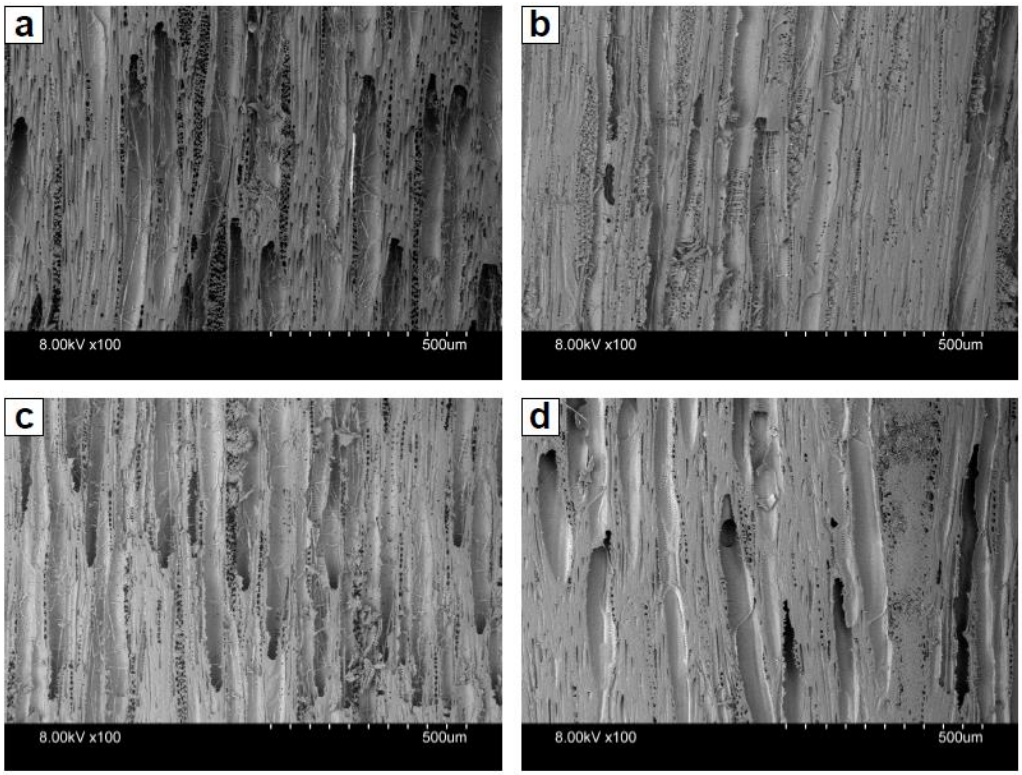

Figure 2: Scanning electron microscope image of untreated (a), compressed and fixated for 1 minute (b), compressed and heat-treated (c) and compressed and impregnated with lactic acid (d) beech samples on the radial-fibre direction surface, taken after Turkey tail decay

The moisture content of every specimen impregnated with *LA* was above that specified in the standard (94.95%). The *LA* has not been entirely polymerized (Báder and Németh 2019), thus highly hydrophilic monomers/oligomers remained in the specimens. 2-4 weeks after placing the specimens on the Turkey tail, a yellowish condensate left them, covering the surface of the mycelium in patches, which was later absorbed. The resistance of the specimens impregnated with *LA* to fungal decay increased because moisture optimum of the Turkey tail was significantly exceeded, which is also indicated by the moisture leaving the specimens. In the incubated environment inside the flask, however, the Turkey tail was able to expand better on the untreated wood, causing a mass loss of 36.36%, well above the average (Fig. 1). The compressed and fixated for 3 hours specimens were the least resistant to the decay, although their mass loss did not differ significantly from the untreated specimens. The reason may be the large amount of microcracks created by the pleating and the increased cell lumen-surface ratio, which could also be found in the electron microscope images in some places.

CONCLUSIONS

Fungal resistance of beech wood modified with environmentally friendly processes to white rot fungi has been tested. Our goal was to assess the impact of modification procedures that change mechanical and physical properties of wood on resistance to fungal decay (longitudinal compression, heat treatment and impregnation with lactic acid).
Compressed and impregnated beech samples are significantly more resistant to white rot fungal decay (fungal decay ratio: 18.31%) than their un-compressed counterparts (fungal decay ratio: 31.62%). Heat-treated (26.36%) and impregnated with lactic acid (22.36%) beech also proved to be more resistant than untreated beech. Due to its hydrophilic molecules, specimens impregnated with lactic acid bind a significant amount of moisture (94.95%), which exceeds the moisture optimum of fungus, thus inhibiting its spread. A longer fixation time after compression has a negative effect on the fungal decay resistance.

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