Bioincised Wood as Substrate for Surface Modifications

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ABSTRACT

The aspiration of bordered pits during drying of wood is the most important reason for a limited impregnability of Norway spruce (*Picea abies* (L.) Karst.). Incubation of this wood species with the white rot fungus *Physisporinus vitreus* for a period of 6 weeks (Bioincising) improves significantly the subsequent uptake of liquid modification substances. There is evidence that the enhanced permeability is caused by a selective degradation of bordered pit membranes during the initial period of substrate colonization. It is suggested that the bioincised material can be impregnated more efficiently with surface modification substances. For a successful upscaling to industrial application, a uniform colonization of the substrate and controlled fungal activity must be achieved to ensure a homogenous distribution of wood modification substances. The present paper identifies the influence of Bioincising on the uptake of liquid modification substances. As example, preliminary results from flame resistance tests are presented that showed a negative effect of Bioincising on the target property. A better understanding of fungus growth in wood and the optimization of the Bioincising process is needed to improve the treatability of Norway spruce with *surface* modification substances.

INTRODUCTION

The limited impregnability of Norway spruce (*Picea abies* (L.) Karst.) is mainly caused by the aspiration of bordered pits during wood drying. The bordered pits represent the interconnecting pathways for liquids between adjacent tracheids. To reopen the wood structure for a subsequent treatment with wood preservatives or wood modification substances, various incising techniques have been developed (Hansmann *et al.* 2002). Earlier work based on biotechnological concepts such as fungi pre-treatment (Messner *et al.* 2003) or technical enzymes (Militz 1990) showed a positive effect on impregnability of spruce sapwood. Despite first promising results, transfer to industrial application was not achieved. Moreover, the effect on spruce heartwood was comparably low. In contrast, the inoculation of coniferous wood with the white rot fungus *Physisporinus vitreus* induces a selective degradation of bordered pits in sapwood and heartwood during early stages of colonization. As a consequence, incubation of Norway spruce heartwood with P. *vitreus* for a period of 6 weeks resulted in a significant enhanced uptake of water, while impact bending strength was reduced only negligibly (Schwarze et al. 2006). Hence, the so called Bioincising process could be a promising approach to improve the uptake of preservatives and wood modification substances into the heartwood of refractory species, such as Norway spruce.

Biotechnological parameters

Based on promising findings from previous laboratory investigations (Schwarze *et al.* 2006) an industry cooperation project was launched with the objective of scaling up the Bioincising process to industrial scale. For this purpose, detailed knowledge about the biotechnological parameters and their sensitive control during incubation determine the optimization of the inoculation with *P. vitreus*. In this context, Schubert *et al.* (2009) conducted a parameter analysis using the Response Surface Methodology (RSM) and found a strong influence of substrate humidity (water activity a_w) on the growth of *P. vitreus*. Moreover, the study showed that *P. vitreus* is highly susceptible to contaminations during the initial growth phase of substrate colonization. This has a negative influence on the homogeneity of colonization. To reduce the contamination rate the incubation of wood in bioreactors after sterilisation is currently being evaluated. Anyhow, for industrial applications a feasible and cost efficient technology has to be developed.

Surface modification on bioincised wood

In addition to the investigation of the biotechnological principles, the biologically modified wood is presently being characterized as a substrate and possible applications for *surface* modification on this new material are evaluated. Depending on the target property to be improved, certain penetration depths and a high uniformity of treatment have to be achieved. In the present paper, the influence of Bioincising on subsequent substance uptake and average penetration depth is discussed. Additionally, on base of preliminary flame resistance tests the interaction between the bioincised wood and wood *surface* modification substances is presented.

EVALUATION OF THE BIOINCISED MATERIAL

Material and methods

Wood samples (30 x 40 x 15 mm, length x width x height) of Norway spruce (*Picea abies*) were incubated for 6 weeks and then (as well as control samples) treated with a range of wood modification substances to improve hydrophobicity and fire resistance. The aqueous substances were applied to the material by brushing, dipping (30 minutes) and vacuum impregnation (20 min, 7 mBar). Five hydrophobisation agents and three flame retardants were used, all of them commercial products. To avoid major capillary uptake, the endgrain surfaces were sealed with a polyurethane coating prior to treatment. All substances were stained with fluorescence dye Rhodamin for microscopic analysis. The total substance uptake of the samples was measured gravimetrically directly after treatment. For a better comparability of the results, the uptake data were recalculated to kg/m³. For the evaluation of the penetration depth, the samples were cut in transverse sections that then were planed with a microtome knife. Fluorescence photographs were taken at 2.5x magnification under a microscope. Fire resistance was measured by exposing the treated samples horizontally to a propane flame for 3 min. After removing the char, mass loss was determined gravimetrically. Results for uptake and penetration of hydrophobisation substance. After brushing and dipping no or little effect of Bioincising on the uptake was observed, whereas a significantly higher retention was apparent when the samples were impregnated in a vacuum chamber (Figure 1). The bioincised material revealed a much higher variance.

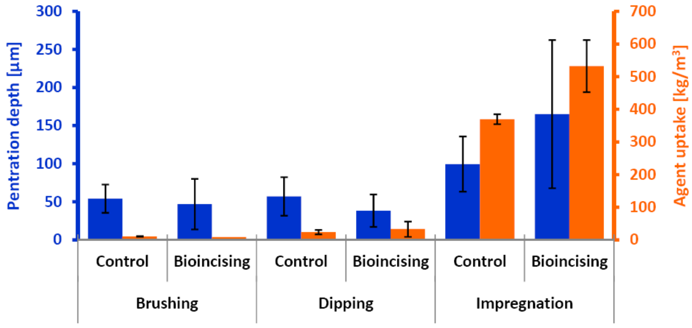
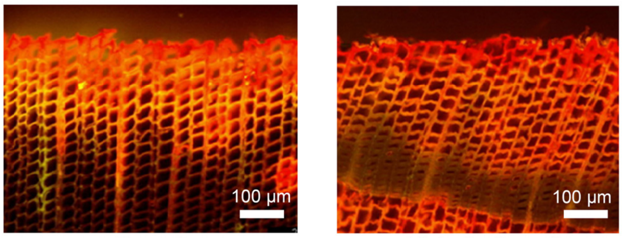


Figure 1: Liquid substance uptake and average penetration depth in bioincised material

Brushed and dipped samples showed a substance penetration into the sub-surface of only two or three cell rows (40-60 µm). In contrast, impregnation resulted in a deeper penetration, which was even more pronounced in bioincised wood (Figure 2). Local distribution and penetration depth of the applied substances varied strongly for all application methods, especially for the bioincised samples.



Control *bioincised wood*

Figure 2: Microscopic photographs of impregnated samples (commercial hydrophobisation substance)

Results for flame resistance of bioincised and fire protected wood

Preliminary tests for flame resistance revealed that a higher uptake of substances in bioincised wood did not automatically result in an improvement of wood surface properties (Figure 3).

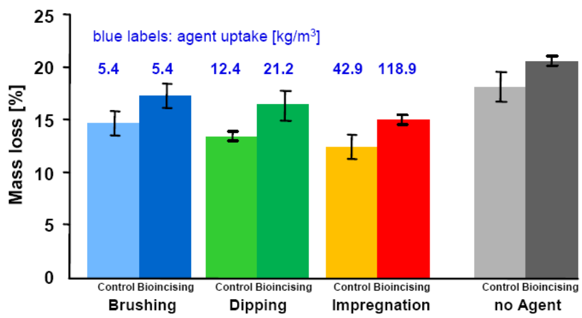


Figure 3: Mass loss during 3 min burning test of fire protected wood

The uptake of flame retardants by the bioincised material was significantly improved for dipping and impregnation. But despite of that fact, a significantly higher mass loss was measured for all treated, bioincised samples. Anyhow, comparison with the untreated controls showed significantly, that the flame retardant performed well. Most probably the Bioincising process affected the cell wall structure in a manner that promotes flammability. Possible reasons could be a change in the chemical composition of the cell wall by *P. vitreus* and hence a reduction of density and a delignification of the inner secondary wall. Another hypothesis is that the reopened bordered pits promote the faster distribution of hot gases within the cellular system. Further work is in progress to reveal the exact reasons.

CONCLUSIONS

Bioincising of Norway spruce wood for 6 weeks resulted in an enhanced uptake of liquid substances after vacuum impregnation. The selective degradation of bordered pits by *Physisporinus vitreus* activity is regarded as reason for this effect. Due to the heterogeneous colonization of the substrate, substance uptake and penetration depths varied strongly. Preliminary tests on bioincised wood showed a negative effect for a subsequent modification of selected properties, such as flame resistance. Most probably, fungus activity has not only degraded the bordered pits but also delignified the inner secondary wall. These possible negative effects of fungal degradation on the cell wall will be subject of future work. Furthermore the ingress of the wood modification substances through cellular system is currently being elucidated. The optimization of the Bioincising process is still in progress; therefore, the present results are indicative. A profound understanding of wood-fungus-interactions on wood permeability will help to optimize the treatment of the bioincised wood with surface modification substances.

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