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The effect of acetylation of alder, beech, birch and poplar wood on decay caused by *Coniophora puteana* fungus

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Abstract: *The effect of acetylation of alder, beech, birch and poplar wood on decay caused by Coniophora puteana fungus*. Many European hardwood species belong to materials of relatively low resistance to degradation caused by *Basidiomycetes* fungi. *Coniophora puteana* fungus is a fungus which very easy attacks wood causing brown rot of wood. Impregnation of wood with fungicides as well as modification of chemical constituents of wood may increase resistance of wood to decay. Birch, beech, poplar and alder wood was acetylated in quasi technical conditions to improve its physical and mechanical properties and biological durability. The resistance of the acetylated wood to *Coniophora puteana* fungus was tested without leaching and after leaching with water. The resistance of all tested wood increased significantly as a result of acetylation. The natural wood of all tested wood species was classified as class 5 – not durable, when the durability of acetylated wood of those species ranged from class 1 – very durable to class 3 – moderately durable for majority of the tested wood, even after leaching the wood with water.

Keywords: hardwood, acetylation, decay, resistance to fungi, *Basidiomycetes*

INTRODUCTION

During service in higher use classes wood elements are often exposed to risk caused by destructive abiotic and biotic factors, particularly to fungi attack [Fojutowski *et al.* 2009, PN-EN 335-1, PN-EN335-2, Ważny 2003]. A lot of European hardwood species of economic significance belong to species of relatively low biological durability. The resistance of wood to degradation by fungi is low to medium. Wood often belongs to durability classes 3 – moderately durable to 5 – not durable. *Basidomycetes* fungi are responsible for causing significant mass losses and a decrease in mechanical properties of wood over very short time. *Coniophora puteana* fungus is a fungus which very quickly decays wood, causing degradation of building elements. Wood elements intended for use in moist conditions should therefore be treated with wood preservatives of fungicidal and/or insecticidal properties or modified [Kollmann 1936, PN-EN 152-1, PN-EN 599-1, Ważny 2003]. However, according to Biocidal Products Directive [DIRECTIVE 98/8/EC…1998] nowadays the use of chemical substances with biocidal properties is limited due to environmental and health concerns. Therefore, alternative methods are studied and tested. Fungal decay, oxidative degradation and processes of water absorption and desorption by wood depend, among others things, on the amount of hydroxyl groups of cellulose and hemicelluloses in wood. Thermo treatment and/or acetylation are the methods for improving some physical properties of wood, such as hygroscopicity (decrease), dimensional stability (increase) and resistance to fungi, due to the reduction of the amount of hydroxyl groups [Kollman 1936, Mazela *et al*. 2004, Militz 2002, Militz i Callum 2005, Rep *et al*. 2004, Schwarze and Spycher 2005, Skyba *et al*. 2008, Welzbacher *et al*. 2006, Zaman *et al*. 2000]. In the course of our own research we have tried to obtain improved wood by using acetylation method. In terms of ecology, the method for modification of natural wood properties by acetylation with anhydride of some organic acids is considered a more friendly method of enhancing wood resistance to fungi than the methods based on chemical substances, i.e. biocides.

The aim of this research was to identify the resistance of acetylated wood to brown rot-causing fungus *Coniophora puteana* belonging to *Basidiomycotina* group.

MATERIALS

Samples of the dimensions of 15Radial(R)×25Tangential(T)×50L(Length) cut out of beech (*Fagus sylvatica* L.), birch (*Betula pendula* Ehrh.), poplar (*Populus nigra* L.), and alder (*Alnus glutinosa* (L.) Gaertn.) control and acetylated with acetic anhydride wood strips of the dimensions of 25(R)×100(T)×450Lmm were the main materials for tests. The acetylation process was carried out in quasi technical conditions using vaccum-pressure method followed by final drying at 140°C. The results of acetylation were characterized by anhydride net absorption of 476 kg m^{-3} for beech wood, 416 kg m^{-3} for birch wood, 330 kg m^{-3} for poplar wood, and 506 kg m^{-3} for alder wood. Density of the control wood samples of beech wood was approx. 710 kg m^{-3}, of birch wood 650 kg m^{-3}, of poplar wood 480 kg m^{-3}, of alder wood 605 kg m^{-3}, and of acetylated wood similar (maximum difference ± 10%, mostly less than 5%). The samples were conditioned for testing in laboratory conditions (20°C/65%RH) and sterilized with steam before the test with *Coniophora puteana=Cp* (Schum. ex Fr.) Karst. (BAM Ebw.15) fungus. Wood resistance to the fungus was tested using a method based on EN 113 Standard [EN113]. For 16 weeks the wood samples were exposed to the action of *Coniophora puteana* (Schumacher ex Fries) Karsten (BAM Ebw. 15). The samples were used as test specimens – U_t, as well as control and virulence control specimens – U_k (two Scots pine sapwood specimens in one Kolle flask, six specimens in total). One test specimen of natural or acetylated beech, birch, poplar or alder wood and one control wood specimen (Scots pine sapwood) were kept together in one Kolle flask. For calculation of the correction values check test specimens of wood, kept in a sterile (uninoculated) culture medium in conditions similar to the conditions in which samples were exposed to fungi, were used (two specimens in one Kolle flask). 10 wood specimens were tested for each natural or acetylated wood species. The tests were conducted on wood specimens not subjected to ageing and after accelerated ageing: leaching according to EN 84. The wood durability class, in terms of its resistance to *Basidiomycotina* fungi, was evaluated according to EN 350-1 (Eq. 1) based on the results of determination of the wood resistance to *Coniophora puteana*:

$$x=U_t/U_k \quad (1)$$

x – durability coefficient,

U_t – mean corrected mass loss of wood modified by acetylation,

U_k - mean corrected mass loss of control wood,

where durability classes are defined as follows: class 1, $x<0.15$ – very durable; class 2, $0.15<x\leq0.30$ – durable; class 3, $0.30<x\leq0.60$ – moderately durable; class 4, $0.60<x\leq0.90$ – low durable; class 5, $x>0.90$ – not durable.

RESULTS

The results of the tests of acetylated wood resistance to *Basidiomycotina* fungi with the example of *Coniophora puteana* fungus are shown in table 1 – wood not subjected to leaching, table 2 – wood after leaching, and table 3 – durability classes of wood. The mass loss of Scots pine wood, used as virulence control, caused by *Coniophora puteana* fungus (table 1 and table 2) shows that the virulence activity of the fungus was high, because the mass losses exceeded 30% in the test without leaching and were close to 30% in the test after wood leaching. The minimum mass loss for *Coniophora puteana* on Scots pine required for validity of the test is 20%. The mass losses of natural birch, beech, poplar and alder wood were higher than that observed for the control Scots pine sapwood for all the tested wood species both not subjected to leaching and after wood leaching. In contrast to the results for natural wood, the mass losses of acetylated birch, beech, poplar and alder wood were lower than that observed for control Scots pine sapwood and lower than those determined for natural wood of the same species. The mass losses of acetylated alder and beech wood were a little higher (approx. 14% and 19% respectively, not subjected to and after leaching) than those observed for acetylated birch and poplar wood (approx. 5% and 10% respectively not subjected to leaching, and approx. 11% for both of the species after leaching). The mass loss of acetylated poplar wood not subjected to leaching was the smallest (approx. 5%) among the treated wood samples. Artificial ageing (leaching) of acetylated birch, beech and alder wood did not reduce the resistance of the modified wood to *Coniophora puteana* fungus, except for acetylated poplar, which, however, remained resistant to brown rot caused by the fungus. It is very important in terms of external use of building elements made of modified wood. We also observed decreased moisture content of acetylated wood after the test with fungi in comparison to natural wood of the same species. This demonstrates that acetylation of wood increases hydrophobation (or resistance of wood to water) in comparison to natural wood. Acetylation of poplar wood increases its durability class from class 5 – not durable to class 1 – very durable, while acetylation of birch wood raises its durability to class 2 – durable. After acetylation beech and alder wood, which belongs to durability class 5 – not durable, demonstrates properties which allows its classification as class 3 – moderately durable.

Tab. 1 The results of determination of the resistance of natural and acetylated birch, beech, poplar and alder wood to *Coniophora puteana* – wood not subjected to ageing

Wood	**Correction value**	**Loss of mass (U_t)**	**Moisture content**	**Loss of mass of control Scots pine sapwood**	**Moisture content of control Scots pine sapwood**
	%				
Acetylated poplar	0.7	5.2	*49.5*	45.8	*61.4*
Natural poplar	0.3	37.8	*65.9*	35.0	*65.1*
Acetylated birch	0.8	10.0	*37.2*	44.5	*66.0*
Natural birch	0.4	39.9	*71.6*	35.3	*64.7*
Acetylated alder	0.6	14.5	*30.9*	40.2	*53.8*
Natural alder	0.0	43.4	*60.6*	34.4	*57.1*
Acetylated beech	0.9	19.9	*41.3*	41.4	*62.6*
Natural beech	0.2	42.2	*64.4*	38.4	*64.3*
Scots pine sapwood, virulence control	-	-	-	37.2	*53.2*

Tab. 2 The results of determination of the resistance of natural and acetylated birch, beech, poplar and alder wood to *Coniophora puteana* – wood after leaching according to EN 84

Wood	**Correction value**	**Loss of mass**	**Moisture content**	**Loss of mass of control Scots pine sapwood**	**Moisture content of control Scots pine sapwood**
	%				
Acetylated poplar	0.7	11.3	*28.1*	34.7	*50.6*
Natural poplar	0.6	32.6	*52.3*	30.3	*51.3*
Acetylated birch	1.5	11.1	*38.6*	33.8	*58.4*
Natural birch	1.1	34.9	*66.9*	29.9	*57.0*
Acetylated alder	0.5	14.0	*35.4*	33.1	*59.1*
Natural alder	1.3	38.0	*59.6*	31.5	*55.3*
Acetylated beech	0.7	19.0	*45.3*	31.4	*61.0*
Natural beech	1.3	37.8	*65.4*	31.0	*60.6*
Scots pine sapwood, virulence control	-	-	-	29.5	*43.7*

Tab. 3 The assessment of durability of natural and acetylated beech, birch, poplar and alder wood in terms of its resistance to *Coniophora puteana* fungus

Wood	Acetylated poplar	Natural poplar	Acetylated birch	Natural birch	Acetylated alder	Natural alder	Acetylated beech	Natural beech
x *	0.14	1.02	0.27	1.07	0.39	1.17	0.53	1.13
Durability class	1	5	2	5	3	5	3	5

* $x=U_t/U_w$, where (U_t) mean corrected loss of mass of acetylated wood; (U_w) mean corrected loss of mass of reference samples,

** durability classes: 1 – very durable, 2 – durable, 3 – moderately durable, 4 – low durable, 5 – not durable

CONCLUSIONS

1. In relation to natural wood, the wood of beech, birch, poplar and alder acetylated with acetic anhydride demonstrates enhanced resistance to *Coniophora puteana* fungus, which cause brown rot of wood.
2. The enhanced resistance of acetylated beech, birch and alder wood to *Coniophora puteana* fungus does not decrease as a result of leaching by water, which is an advantage in terms of direct exposure to outdoor factors. The mass loss of poplar wood after leaching was admittedly higher than when not subjected to leaching (5% to approx. 11%), but the wood was still resistant to brown rot.
3. Modification of wood by acetylation enhanced the durability of the tested wood to *Basidiomycotina* fungi from class 5 – *not durable* to class 3 – *moderately durable* for alder and beech wood, to class 2 – *durable* for birch wood, and to class 1 – *very durable* for poplar wood.

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Streszczenie: *Wpływ acetylacji drewna olchy, buka, brzozy i topoli na rozkład powodowany przez grzyb Coniophora puteana.* Wiele europejskich gatunków drewna liściastego należy do materiałów o stosunkowo małej odporności na degradację powodowaną przez grzyby podstawczaki *Basidiomycetes*. Grzyb *Coniophora puteana* jest jednym z grzybów bardzo łatwo atakujących drewno powodując jego brunatny rozkład. Impregnacja drewna fungicydami, jak również modyfikacja chemicznych składników drewna mogą zwiększać odporność drewna na rozkład. Drewno brzozy, buka, topoli i olchy acetylowano w warunkach ćwierćtechnicznych dla polepszenia jego właściwości fizycznych i mechanicznych oraz odporności biologicznej. Odporność acetylowanego drewna na działanie grzyba *Coniophora puteana* badano bez wymywania próbek wodą i po wymywaniu. Odporność wszystkich gatunków badanego drewna znacząco zwiększyła się w wyniku acetylacji. Drewno naturalne wszystkich badanych gatunków zaliczono do klasy 5 - nietrwałe, podczas gdy trwałość acetylowanych gatunków drewna wynosiła od klasy 1 – bardzo trwałe do klasy 3 – średnio trwałe dla większości badanego drewna, nawet po wymywaniu próbek wodą.

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