

Selected Properties of Beech Wood Modified by Citric Acid

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ABSTRACT

The Anti Swelling Efficiency (ASE) and biological durability against brown rot fungus *Poria placenta* of beech wood modified by Citric Acid (CA) was measured and results are presented. Modification was performed by impregnation with 7.0 % CA and 6.5 % sodium-hypophosphite water solution and 10 hours curing at 140 and 160 °C. In addition, the influence of leaching after modification on ASE and on durability was researched. Weight Percentage Gain (WPG) caused by modification, maximum swelling and mass loss of wood after fungal decay were measured. At increasing curing temperature WPG of modified beech wood decreases. Results showed increased dimensional stability of modified wood for more than 40 % and durability of modified wood to be more than 9 times greater than durability of non-modified wood. Improved durability remained unchanged after leaching, while dimensional stability decreased to 30 % after leaching. Results indicate modification by CA as a promising method, but further research on modification parameters optimisation is needed towards improvement of desired wood properties.

INTRODUCTION

Research on the wood modification mostly deal with improvement of the wood properties i.e. elimination or reduction of limitations of wood as a raw material. Modified wood is expected to be more dimensionally stable, more durable against bluestain and rot fungi, more resistant to UV radiation in comparison to unmodified wood. Mechanical properties should be unchanged. Ecological-economic justification of modification processes and chemicals is also requested. Thermal modification is a process where wood cell wall polymers (especially hemicellulose, less lignin) are destructed to the radicals that repolymerise with OH groups of wood cell wall compounds only by heating. In contrary, chemical modification implicates etherification, esterification or acetylation between some chemical and OH groups of wood. One of reactants often applied is DMDHEU (1,3-dimethylol 4,5-dihydroxy ethylene urea). Modification by DMDHEU has a problem with releasing formaldehyde from N-methylol bonds by hydrolytic destruction at higher modification temperatures. Because of this problem, scientists are introducing new non-formaldehyde chemicals.

One group of such chemicals is polycarboxylic acids (PCA). The possibility of bonding PCA anhydride with OH groups of lignocelluloses ensures cross-link reaction, good bond stability and durability (Fang *et al.* 1999). Cross-linking reaction between

cellulose and PCA is esterification. Citric acid (CA) is widely spread in the nature and it completely satisfies nowadays strict ecological-economic requirements. Bischof *et al.* (2006) have modified fir wood and beech wood by CA. Wood modified by CA and cured by temperature or by microwaves had improved dimensional stability, while micro-tensile strength decreased. Hasan *et al.* (2007) and Despot *et al.* (2008) reported multiple increasing in biological durability of pine sapwood and beech wood modified by CA against some rot fungi. Both of these chemical modifications have the same goal – to improve dimensional stability and biological durability with unchanged mechanical properties. Results on the weight percentage gain (*WPG*), improvement of dimensional stability and biological durability in laboratory conditions of beech wood modified by CA are presented.

EXPERIMENTAL

Air-dried and afterwards kiln-dried beech planks (*Fagus sylvatica L.*) were used for this research. Lattices were sawn from the region close to bark, and specimens were cut, successively axially selected, marked and prepared according to DIN 52 184 (1979) and EN 113 (1996). Experiment was performed according to Table 1.

Table 1: Type of test, type of modification and number of specimens

Type of test	Type of modification	Number of specimens	
		Leached	Non Leached
Dimensional stability	CA 140 °C / 10h	10	10
	CA 160 °C / 10h	10	10
	Control 103°C	10	10
Biological durability against	CA 140 °C / 10h	7	7
	CA 160 °C / 10h	7	7
	AHT 140 °C / 10h	7	7
	AHT 160 °C / 10h	7	7
	Control	56	

Chemicals, solutions, modification and leaching procedures

Water solution of 7.0 % citric acid (CA) and 6.5 % sodium hypophosphite (SHP) as catalyst was prepared for the modification. The impregnation and modification procedure was performed as described in previous article (Katović *et al.*, 2004). Group of specimens was only air heat treated (AHT) at the thermo-condensation temperatures and used as a control of possible influence of temperature on biological durability. Specimens prepared for leaching were conditioned at standard climate, and then leached (vacuum impregnated) with distilled water and allowed to soak for 24 hours and then again air- and oven-dried to constant mass.

WPG, Dimensional stability, MC and Durability determination

WPG of modified specimens was calculated as a ratio of difference of oven-dried mass after modification (m_2) and oven-dried mass before modification (m_1) and m_1 (1).

$$WPG = \frac{m_2 - m_1}{m_1} \times 100[\%] \quad (1)$$

Dimensional stability of leached and non-leached specimens was quantified by comparing the volumetric swelling coefficients (α_v) of treated and control specimens. After modification and air-drying all specimens including controls were oven dried at 103 °C to a constant mass and then vacuum impregnated with distilled water following atmospheric soak for 24 hours. The volumetric anti-swelling efficiency (ASE) was calculated according to (2):

$$\alpha_v = \frac{(V_s - V_o)}{V_o} * 100[\%] \quad ASE = \frac{(\alpha_{VC} - \alpha_{VT})}{\alpha_{VC}} * 100[\%] \quad (2)$$

where: **V** is the volume, **S** represents saturated, **O** oven dried at 103 °C, **C** control, **T** - treated. Determination of biological durability of CA modified wood was done according to EN 113 (1996). Brown rot, fungus *Poria placenta* (Fries) Coke sensu J.Erikson was chosen. Mass loss (ML) caused by leaching was calculated by dividing the difference of oven-dried mass of specimens after leaching (m_2) and starting mass (m_1) with starting mass (3). Mass loss caused by fungal decay (dm) was calculated by dividing the difference of oven-dried mass of specimens after decay (m_4) and starting mass (m_2) with starting mass (4).

$$ML = \frac{m_1 - m_2}{m_1} * 100[\%] \quad (3) \quad dm = \frac{m_2 - m_4}{m_2} * 100[\%] \quad (4)$$

This mass loss percentage dm [%] is the unit which shows the durability: smaller dm means more durable wood.

RESULTS AND DISCUSSION

WPG of specimens cured at 140 °C is significantly higher than of those cured at 160 °C. This can be explained by greater catalyst evaporation at higher temperature. Accordingly ML of specimens cured at 140 °C is greater than ML of those cured at 160 °C probably because more catalyst was leached (Fig. 1).

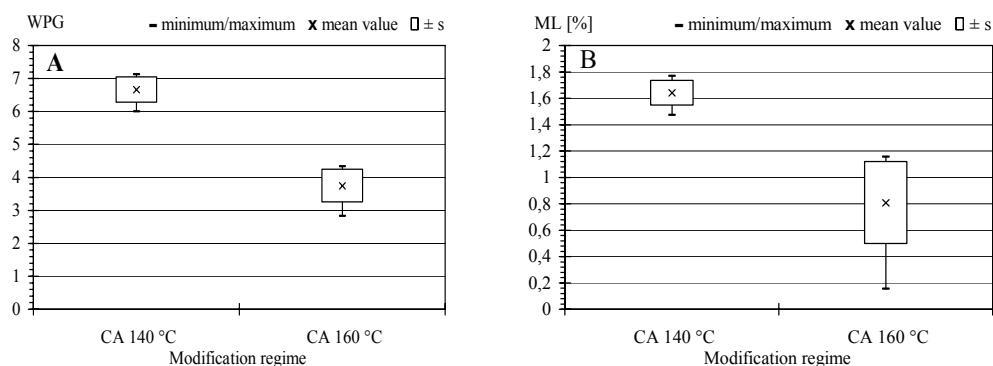


Figure 1: A) Weight Percentage Gain (WPG) of differently modified specimens; B) Mass loss (ML) of differently modified specimens after leaching ($n = 14$).

The effect of modification by CA on dimensional stabilisation was almost equal using either of curing regimes. The value of ASE was around 43 %. After leaching with distilled water ASE decreased to value of 30 % (Fig. 2). Results confirmed no

significant difference in biological durability between AHT and control specimens. These results indicate that significant increase of biological durability of CA specimens against *Poria placenta* was exclusively the result of ester bonds between CA and beech wood. Results also showed no significant difference in durability between leached and non-leached specimens. It leads to the conclusion that majority of CA esterified OH groups of wood and that ester bonds were resistant to fungal decay and to leaching (Fig. 3 and 1B).

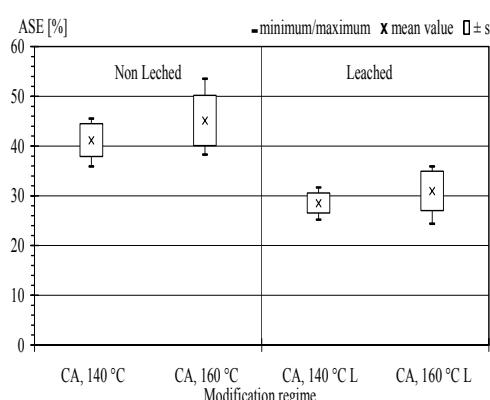


Figure 2: AntiSwelling Efficiency (ASE) non leached and leached specimens (n=10)

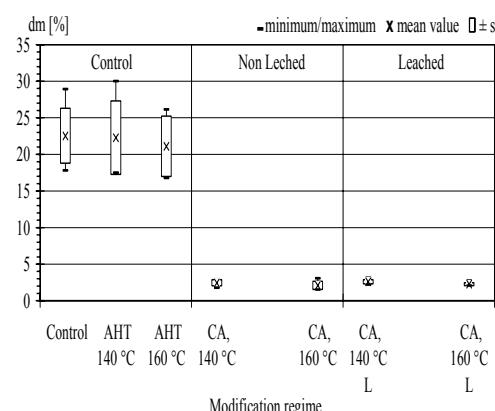


Figure 3: Mass loss (dm) of differently modified specimens after 16 weeks of exposure to Poria placenta (n = 56 for controls, n = 7 for other treatments).

CONCLUSIONS

Application of CA using SHP as catalyst resulted in increasing of dimensional stability and biological durability. Increased biological durability against *P. placenta* remained unchanged after leaching while improved dimensional stability decreased to ASE of around 30%. Further intention is to additionally test the strength of ester bonds to wood with more leaching cycles.

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