Mode of action of DMDHEU treatment against wood decay by white and brown rot fungi

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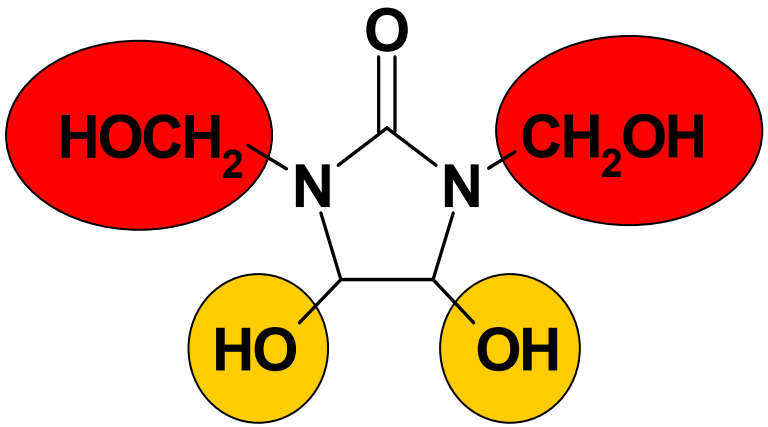
Content

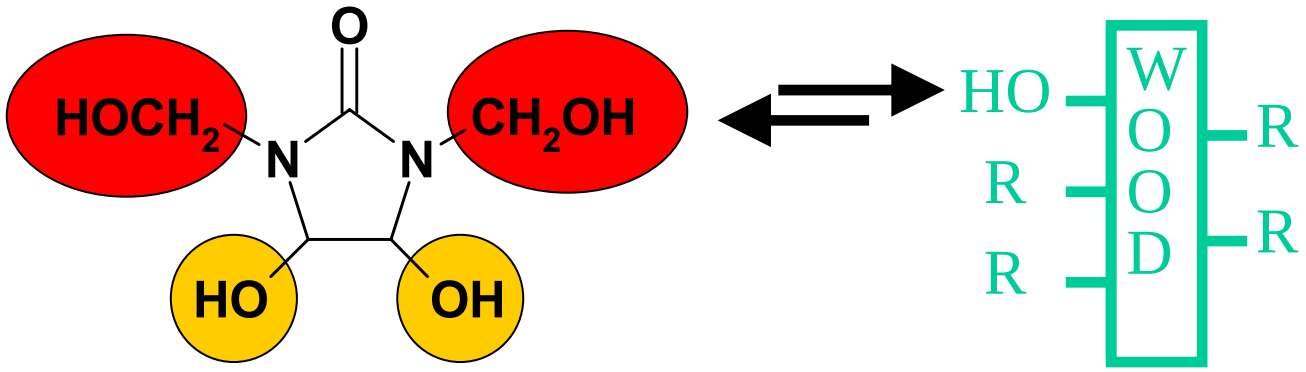
- Fungal colonisation
- Effect of nutrients
- Effect of cell wall bulking
- Effect on hydrolysis by cellulase
- Effect of Fenton‘s reagent



DMDHEU
(1,3-Dimethylol-4,5-dihydroxyethylen urea)

(1,3-Dimethylol-4,5-dihydroxy-Imidazolidinon)

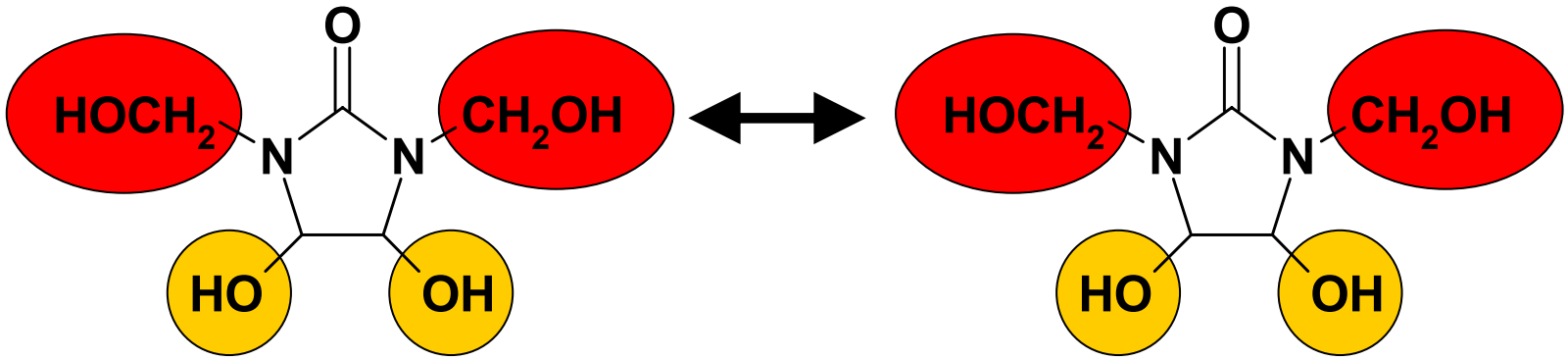
Possible Reactions



Cross-linking:

$R_2NCH_2OH + HO\text{-wood} \rightarrow R_2NCH_2O\text{-wood} + H_2O$

Possible Reactions



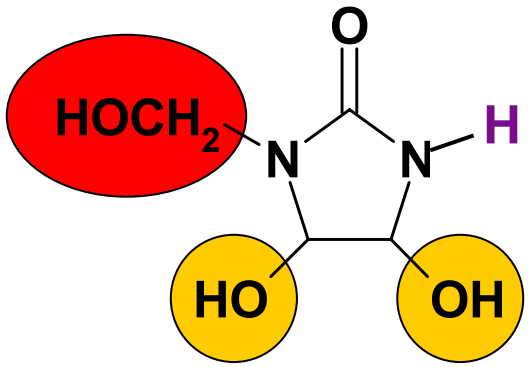
Cross-linking:

$R_2NCH_2OH + HO\text{-wood} \rightarrow R_2NCH_2O\text{-wood} + H_2O$

Polycondensation:

$R_2NCH_2OH + HOCH_2NR_2 \rightarrow R_2NCH_2OCH_2NR_2 + H_2O$

Possible Reactions



+ CH_2O

Cross-linking:

R_2NCH_2OH + HO-wood ⟶ R_2NCH_2O-wood + H_2O

Polycondensation:

$R_2NCH_2OH + HOCH_2NR_2 \longrightarrow R_2NCH_2OCH_2NR_2 + H_2O$

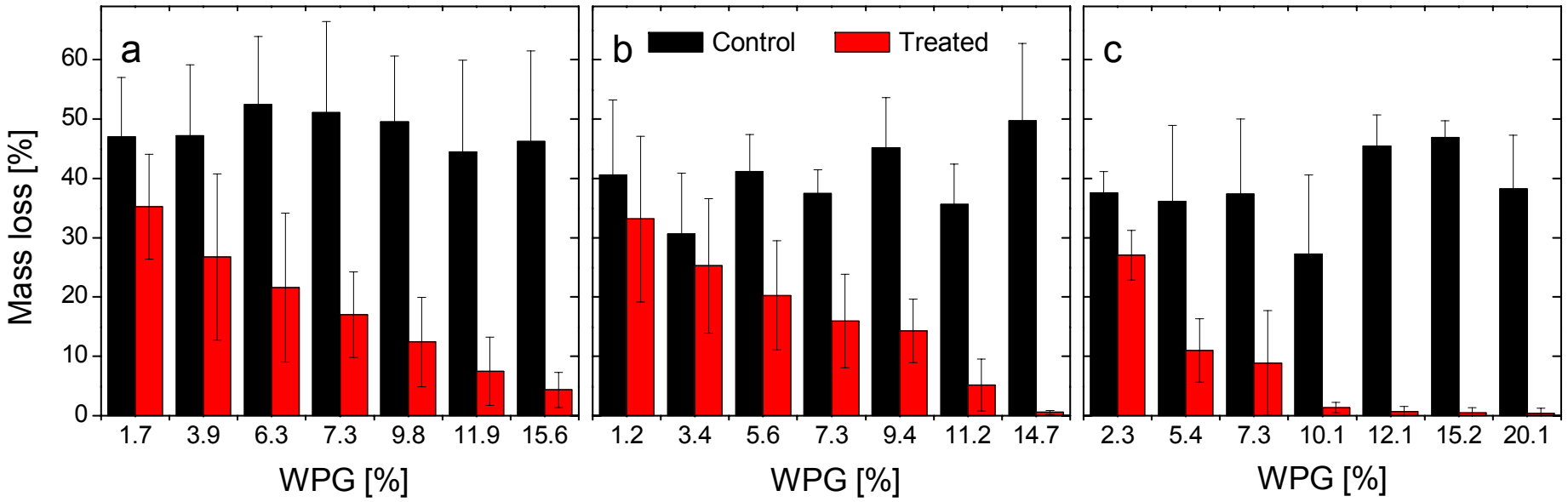
Dissociation:

$R_2NCH_2OH \rightleftharpoons R_2NH + CH_2O$

Basidiomycete-Test (Mini-Block, 12 weeks)

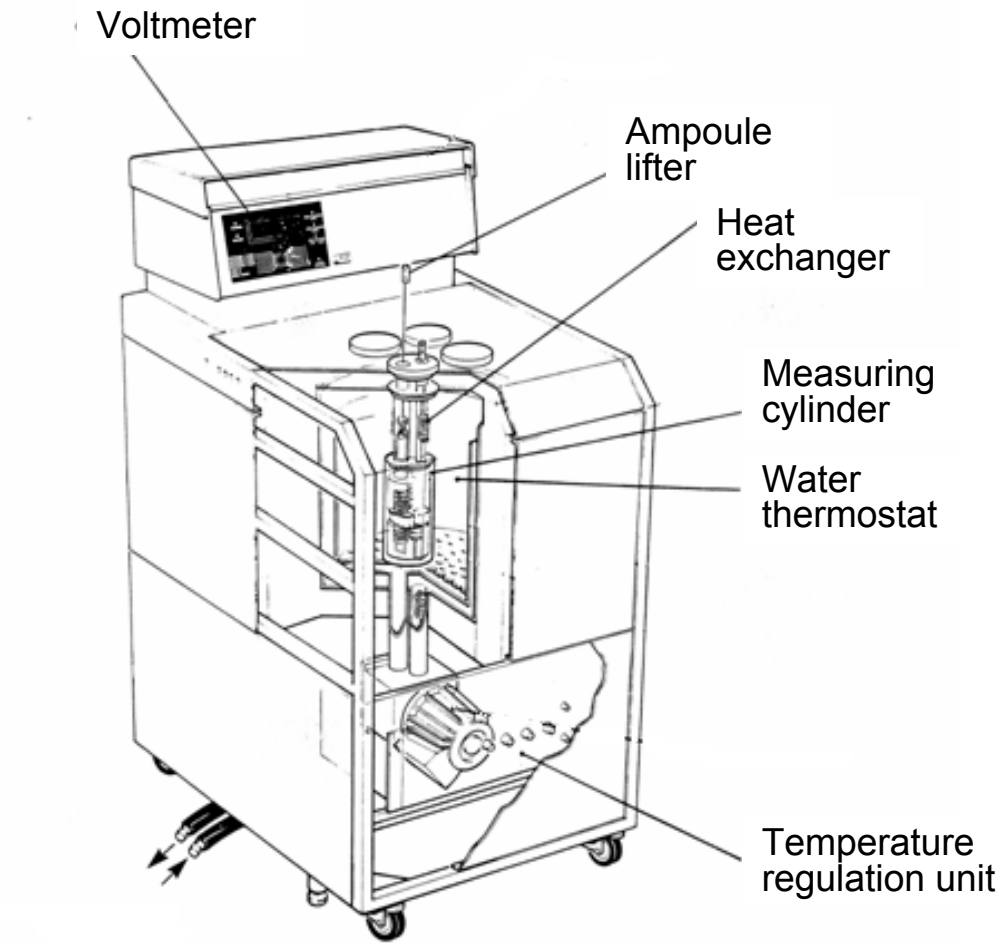
30 [longitudinal] x 10 x 5 mm^3

***T. versicolor*, beech** ***C. puteana*, beech** ***C. puteana*, pine**

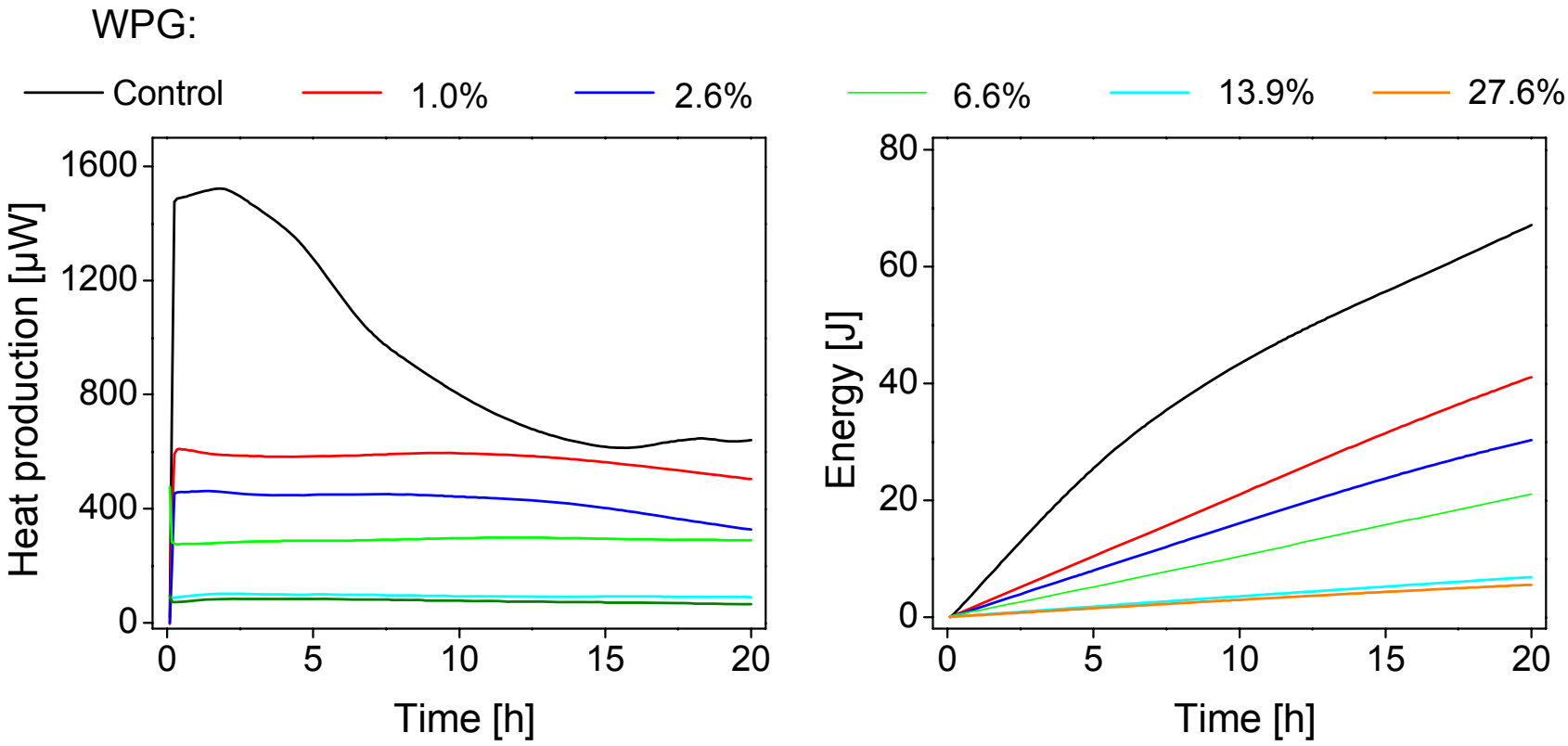


WPG of 10-14 % was necessary to protect the wood!

Fungal Colonisation / Micro-Calorimetry



Micro-Calorimetry (*T. versicolor*, Beech)

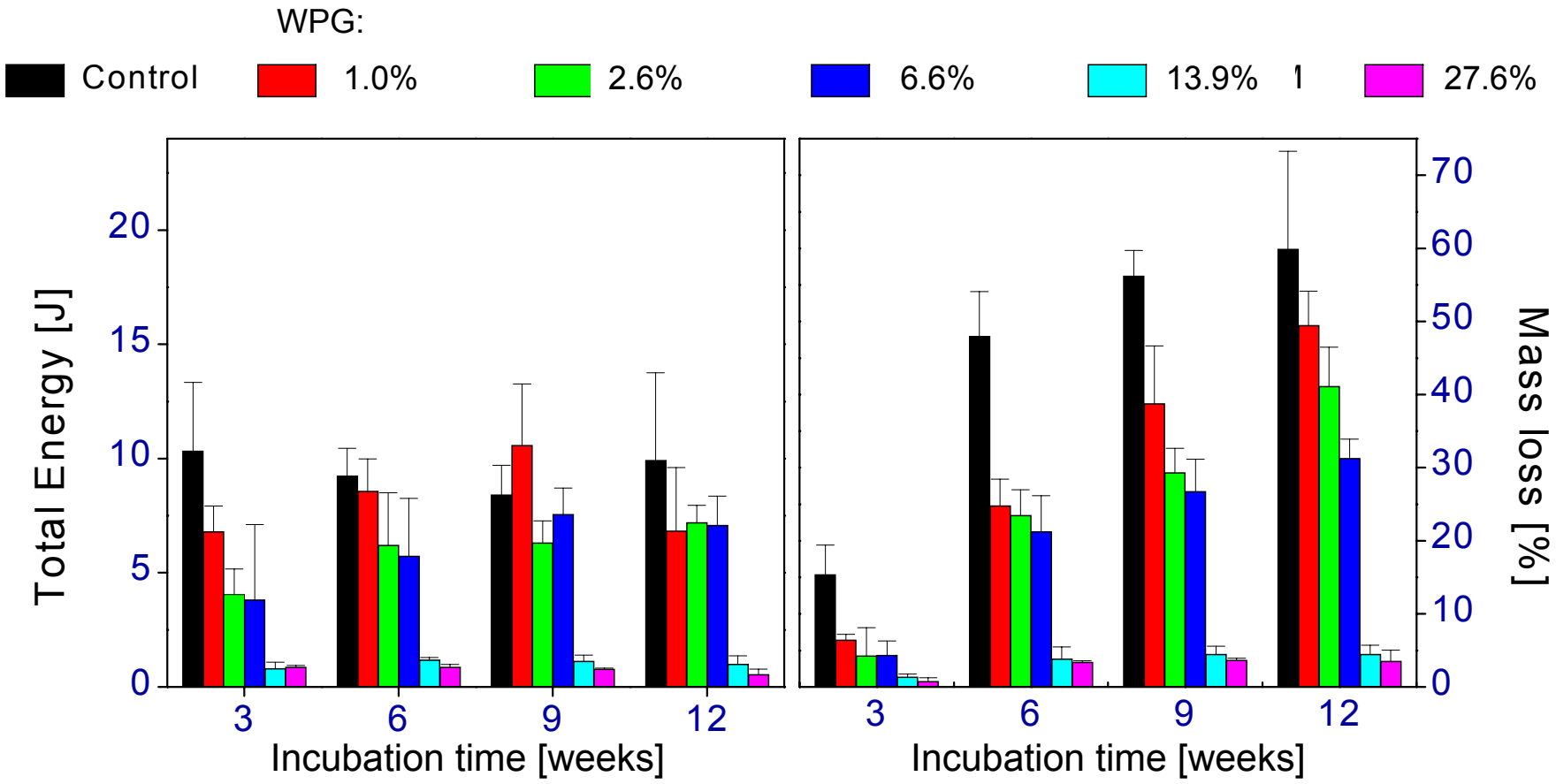


$$E_{total} = \sum_i Q_i \times t$$

Q_i: heat production [W]

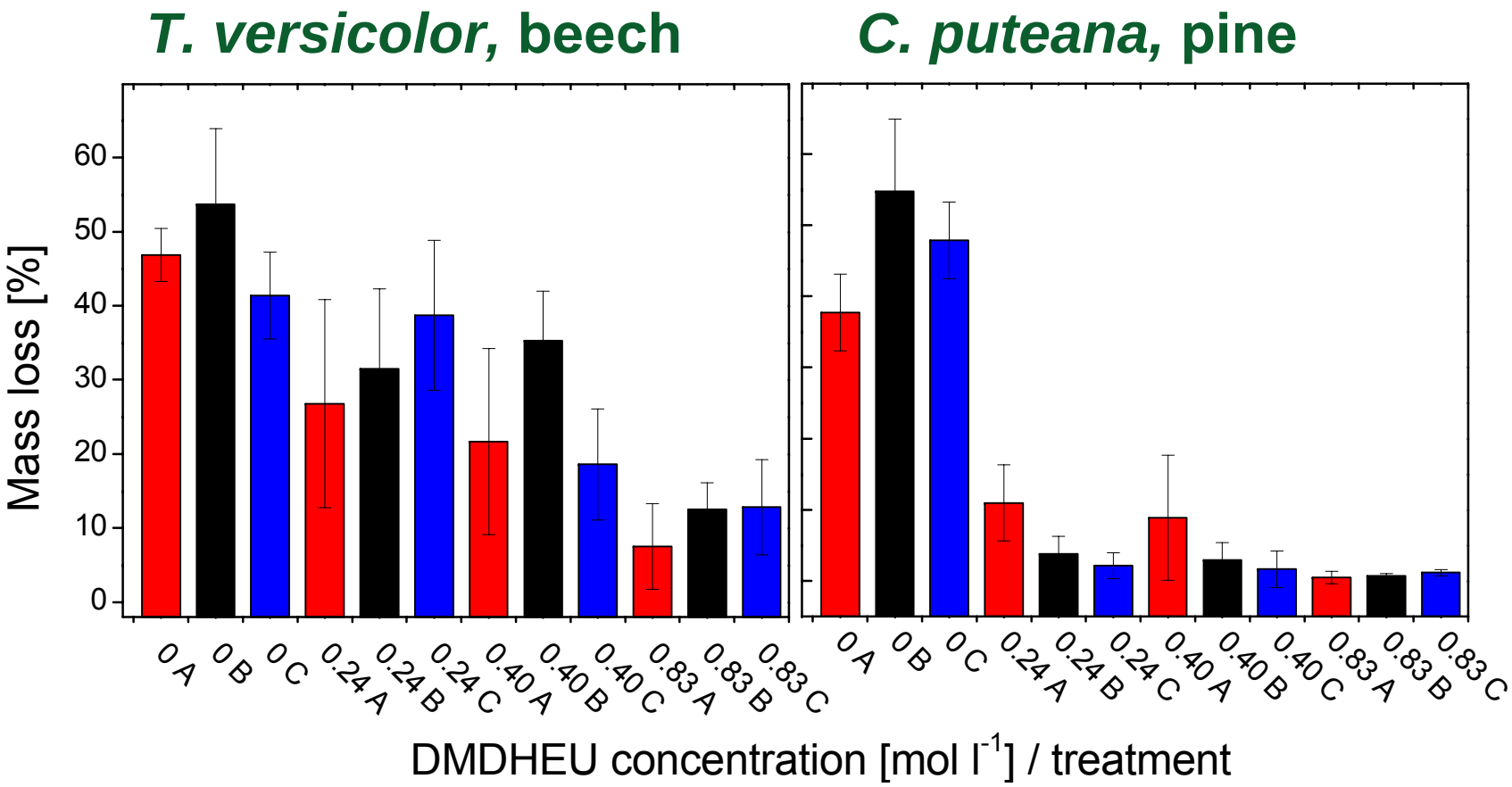
t: time [s]

Micro-Calorimetry (*T. versicolor*, Beech)



Energy production within 3h

Effects of Nutrients on Decay

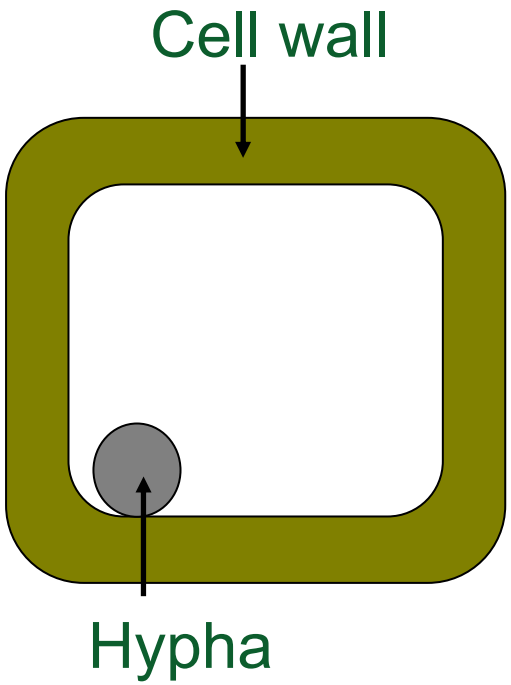


Red (A): without nutrients; black (B): nutrients (without thiamine); blue (C): nutrients and thiamine

Modes of Action of Cell Wall Modification

- Reduction of wood moisture content
- Availability of water in the cell wall
- Cell wall polymers become unrecognizable for enzymes
- Reduction in pore diameters prevent penetration of enzymes

Wood degradation is an extra-cellular process

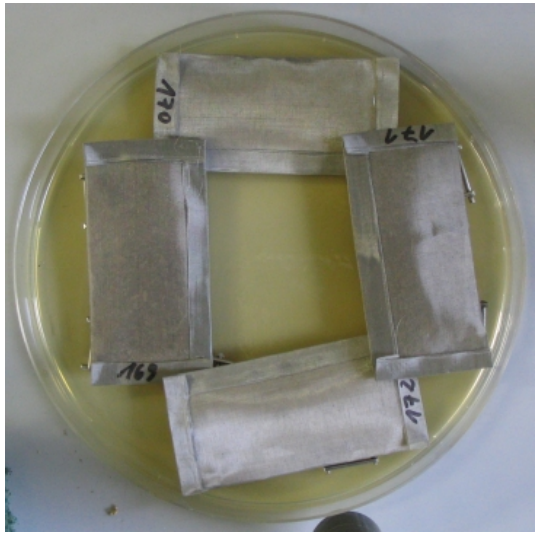


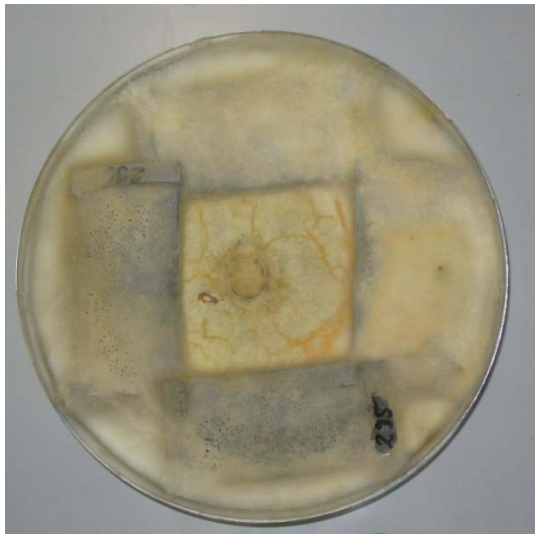
Enzyme Penetration (adopted from C.A.S. Hill)

- The diameter of micro-pores in the cell walls of sound wood **is not greater than 2 nm**
- Lignin-Peroxidase exhibits a diameter of 4.7 nm (spheric) or 4.3 x 6.0 nm (elliptic)
- Cellulases exhibit a diameter of 5.9 nm (spheric) or 3.3 x 20 nm (elliptic)
- Xylanasen exhibit a diameter of approx. 7nm

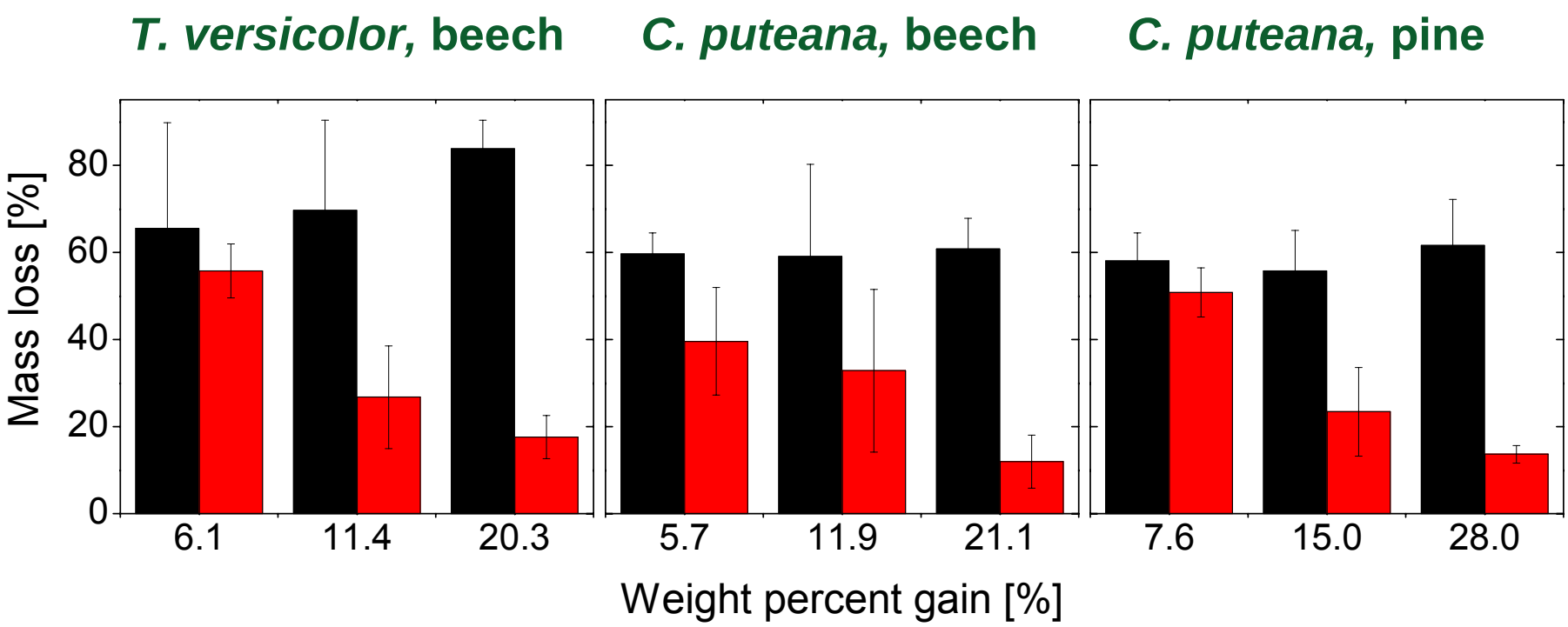
Mass Loss of Wood Flour

- Mini-blocks were treated with DMDHEU
- Blocks were milled to a size of 40-50 µm
- Wood flour was incubated in stainless steel mesh bags for 24 weeks
- Bags had a mesh pore size of 40 µm





Mass Loss of Wood Flour (24 Weeks)



Mass loss at high WPG was mainly due to leaching of DMDHEU

Decay Studies on Cellulose and Wood Flour

- **Cellulase (Cellulast 1.5 L, Novozymes, Denmark)**
  - Endo- and exo-1,4-β-glucanase, 1,4-β-glucosidase (low activity)

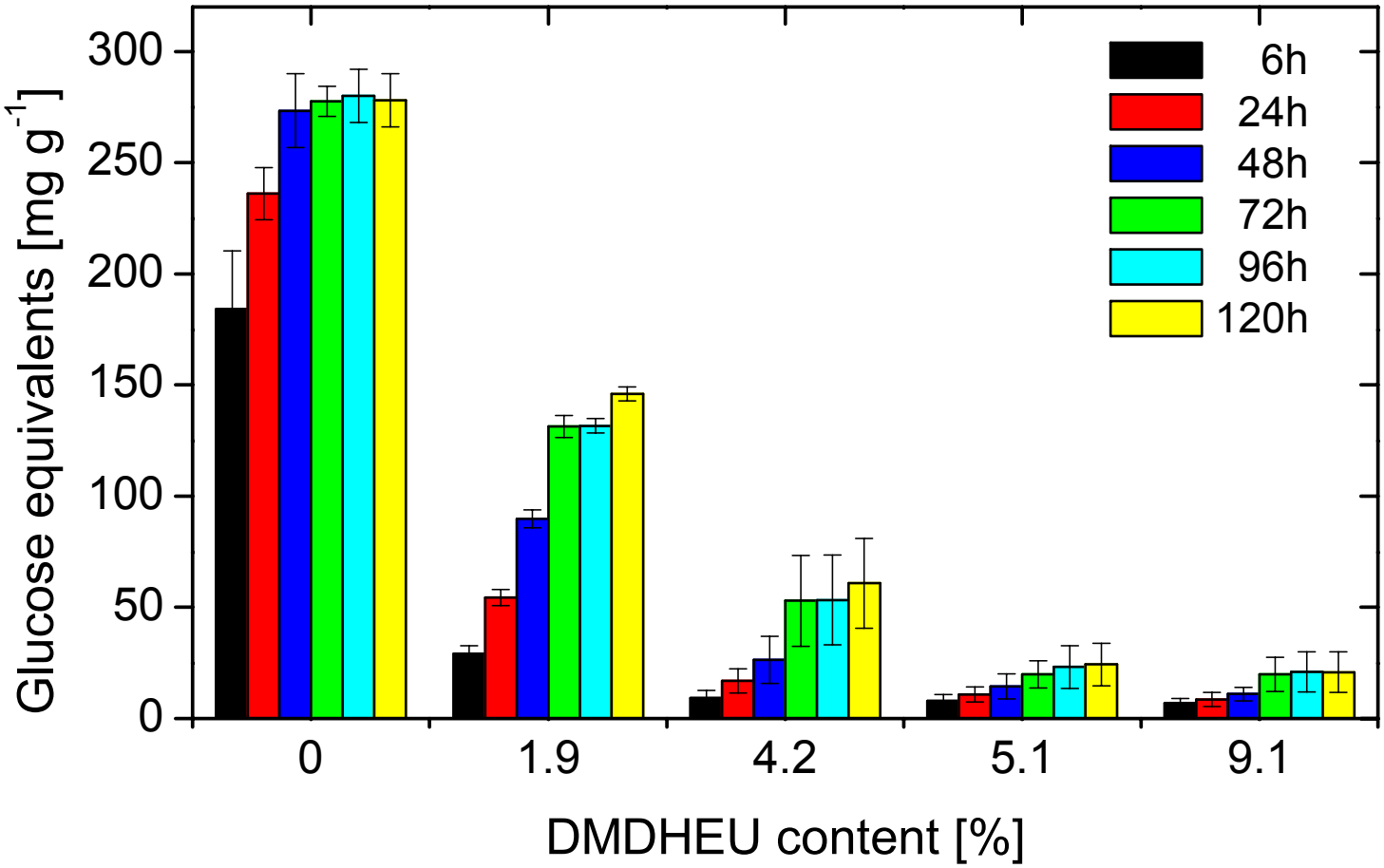
- **Fenton's reagent**

  $H_2O_2 + Fe^{2+} \rightarrow HO\cdot + HO^- + Fe^{3+}$

  - Hydroxyl radicals (**HO·**) exhibit the highest redox-potential in biological systems!

    $HO\cdot + H^+ + e^- \rightarrow H_2O \qquad E^0 = +2180\ mV$

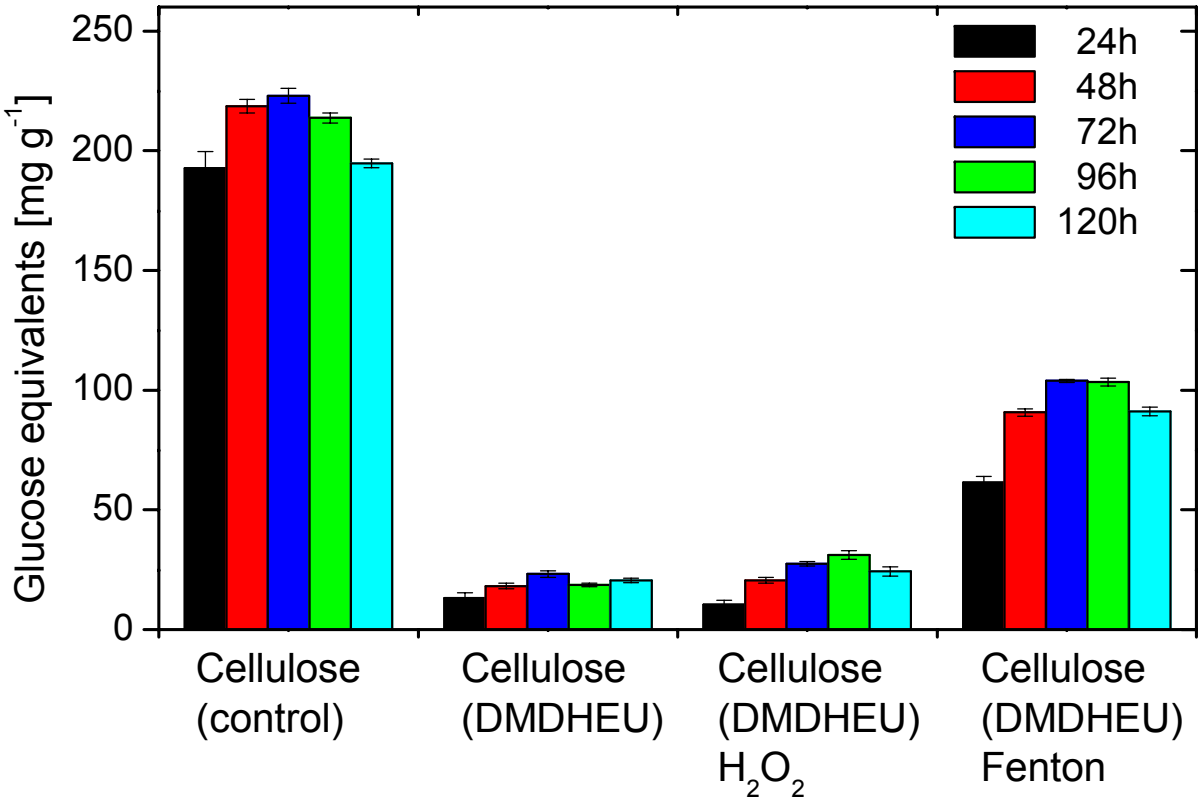
Enzymatic Sugar Release (Cellulose)



Cellulase (final concentration 1.1 U ml^{-1}, pH 5.0)

Enzymatic Sugar Release (Cellulose)

Effect of pre-treatment

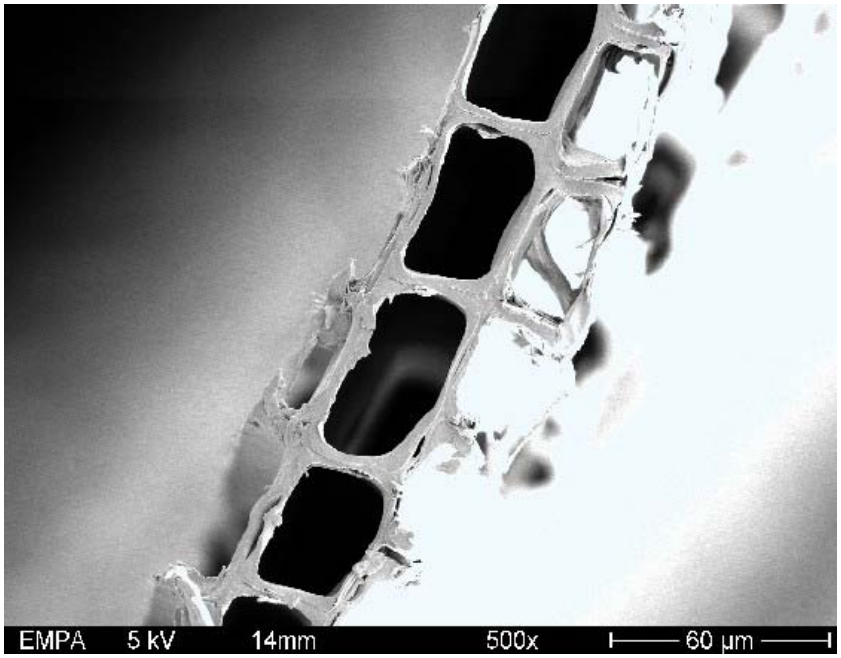


9.1% DMDHEU content / cellulase (1.1 U ml^{-1})

Tensile Strength of Micro-Veneers

Tensile strength of Scots pine veneer strips was tested after incubation with Fenton‘s reagent

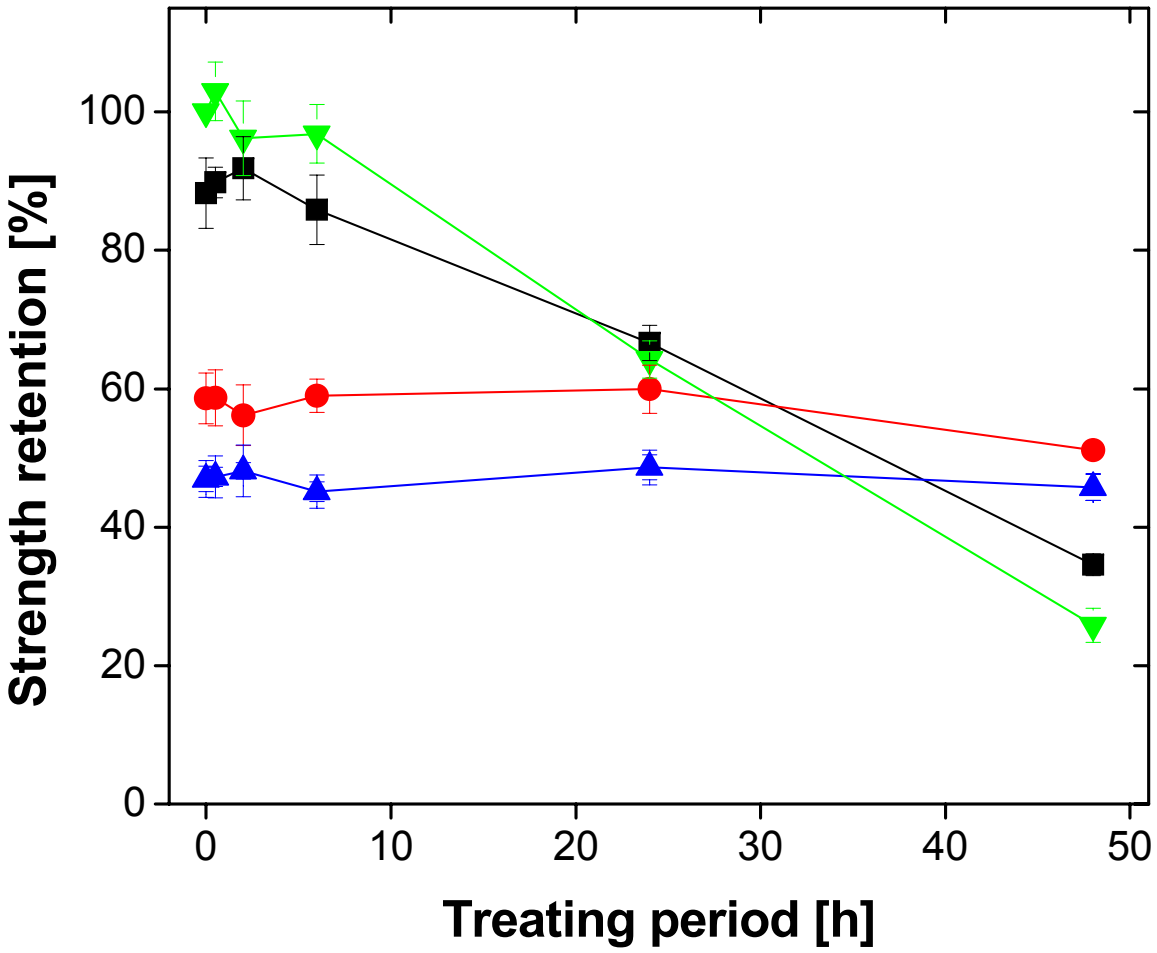
Field-emission-SEM



19 mm x 105 mm x 80 µm

Photo: P.D. Evans

Fenton‘s Reagent and Tensile Strength



$H_2O_2 + Fe^{2+} \rightarrow$

$HO\cdot + HO^- + Fe^{3+}$

Summary / Conclusions

- 10-14 % WPG was necessary to protect the wood
- Fungal colonisation decreased with WPG
  - Fungal activity was detected even at highest WPG
- Decay (weight loss) was not increased by milling
- Hydrolysis through cellulase decreased with degree of modification
- DMDHEU treated protected veneers against oxidative degradation through hydroxyl radicals

Thank you for your attention!