Primary analysis methods used to control thermal treatments of wood and its effect on decay resistance

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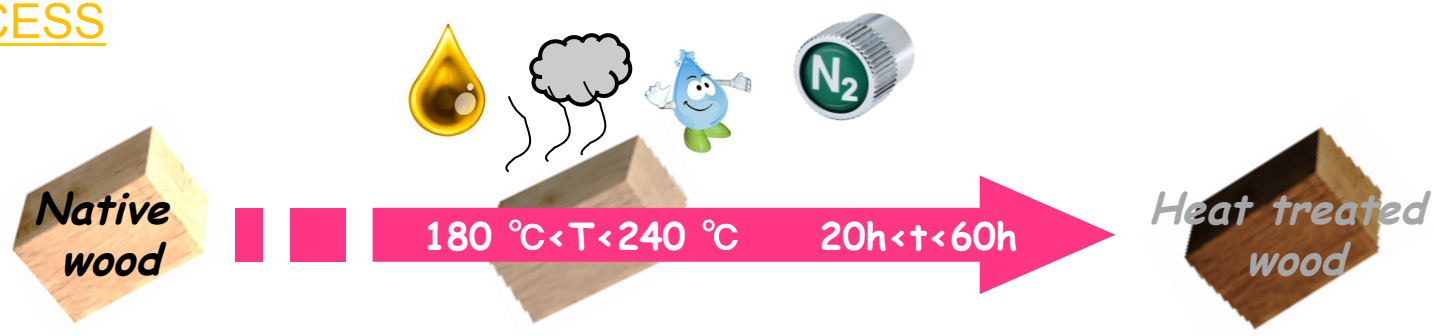
COST Action FP1407 1st Conference
"Life Cycle Assessment, EPDs and modified wood"
25 & 26 August 2015 - Koper, Slovenia

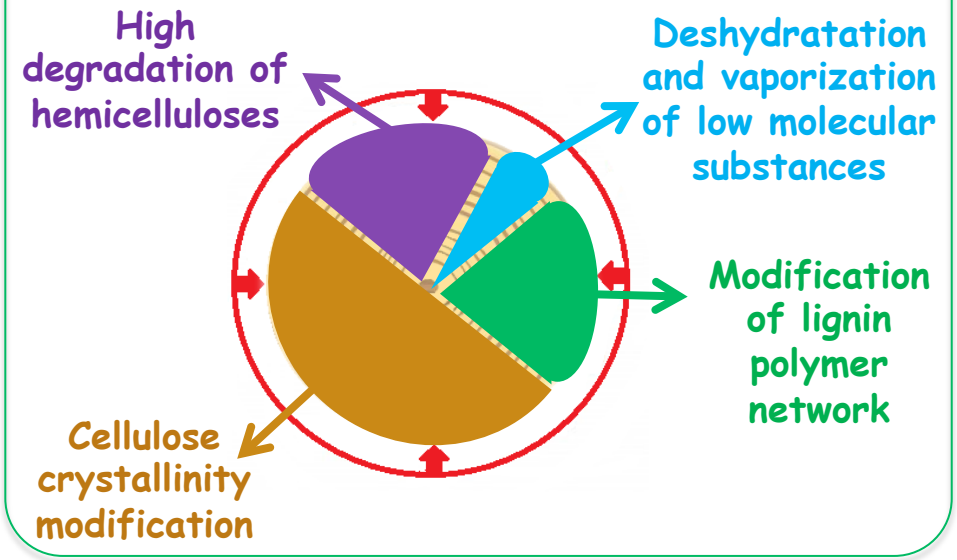
Context

Heat treatment of wood [Generalities]

PROCESS



CHEMICAL MODIFICATIONS



NEW MATERIAL PROPERTIES

Benefits

- Durability
- Dimensional stability
- Hydrophobicity
- Color

Disadvantages

- Mechanical Properties

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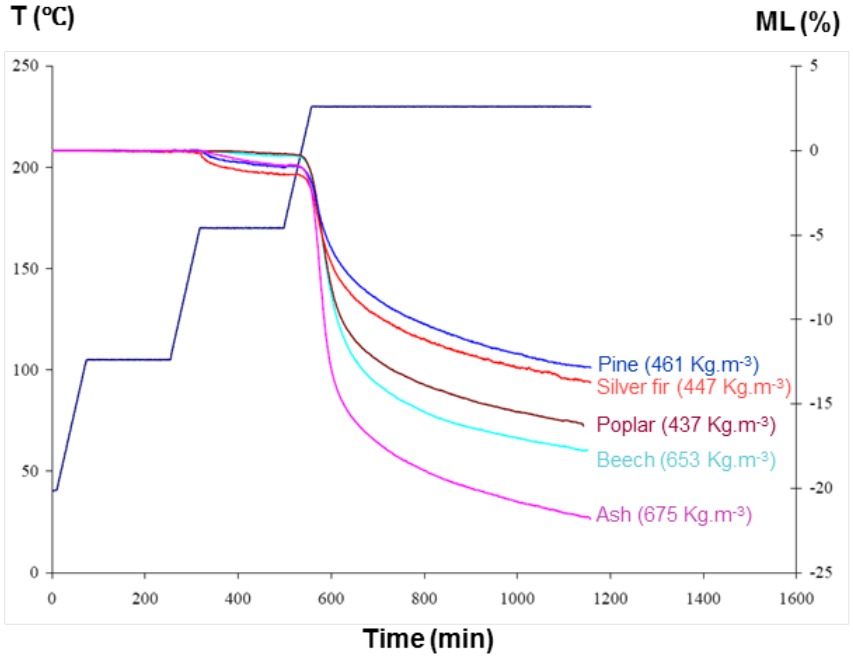
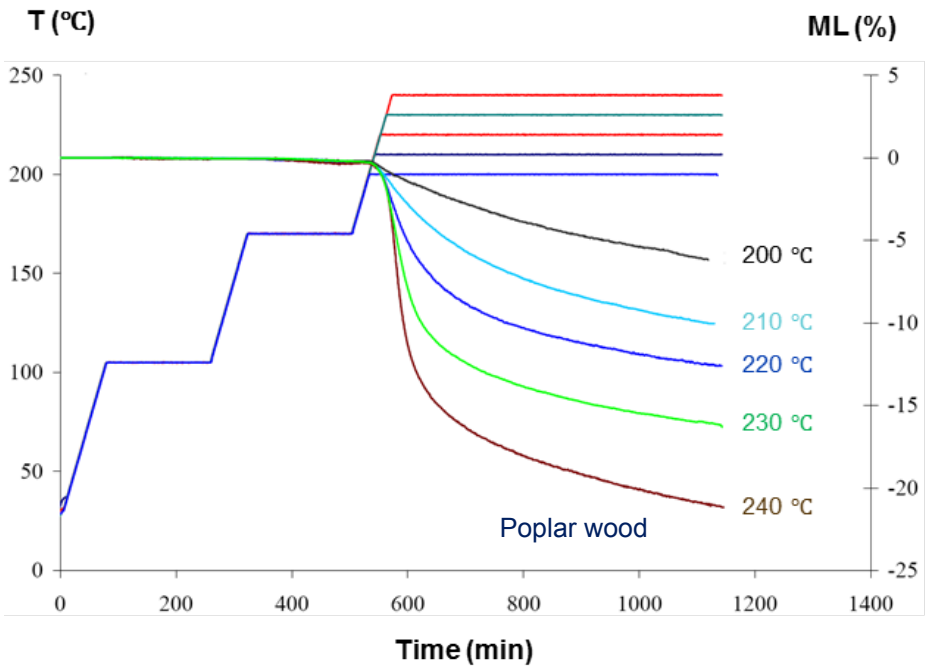
Context

Heat treatment of wood (**Wood thermal degradation kinetics**)





ML(%) evolution for different wood species heat treated at 230 °C according to treatment duration and temperature
[Chaouch *et al.* 2010]

- **Thermal degradation kinetic is influenced by the nature of wood species**
  [Chaouch *et al.* 2010]
- **ML (%) depends on Treatment intensity : temperature – duration**
  [Candelier *et al.* 2011]
- **ML (%) defines conditions of 1 treatment for 1 wood species**

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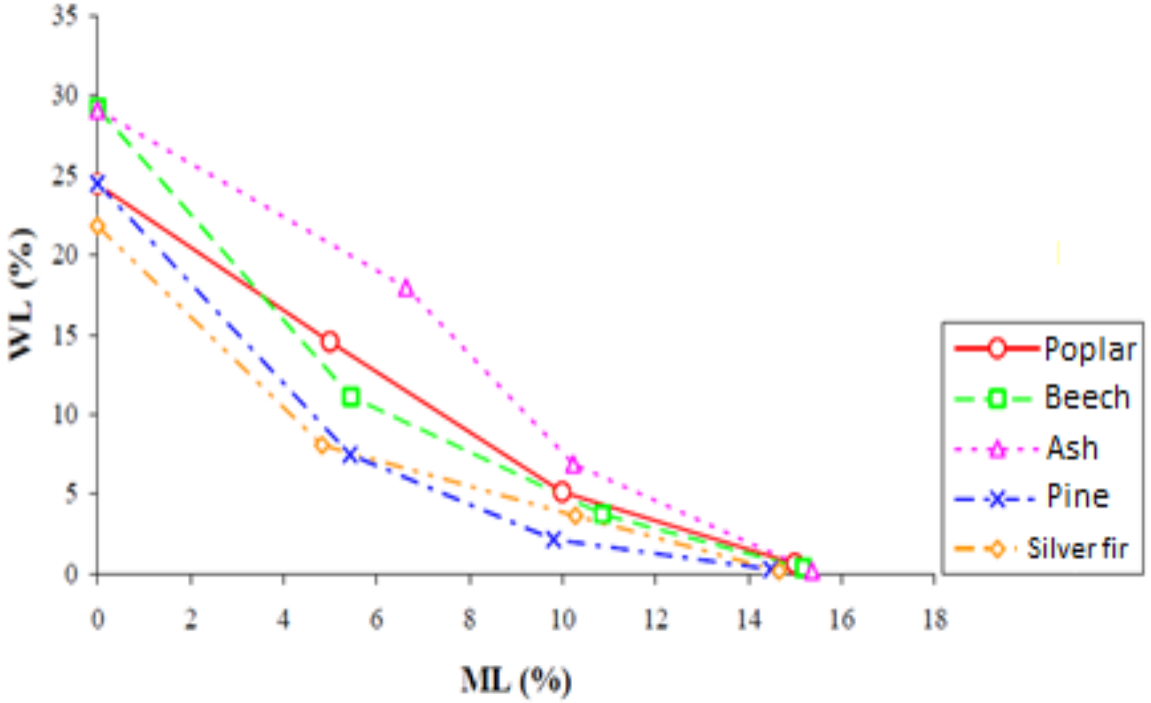
Context

Heat treatment of wood (**Decay resistance prediction**)



Correlation between weight loss by *Coniophora puteana* (WL %) and decrease in mass (ML %) for heat treatments on different European wood species at 230°C [Chaouch et al. 2010]

- **Treatment intensity characterized by ML (%) could be an indicator to predict heat treated wood durability.** [Kortileinen *et al.* 2000] [Chaouch *et al.* 2011]

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Context

Industrial objectives (Decay resistance = Modified wood quality)

Wood thermal degradation is not controlled, due to heterogeneous heat transfer in treatment oven.

Industrial target

Obtain a good heat treated wood quality

Homogeneity and repeatability

Introduction of a fast and accurate system for measuring this mass loss on an industrial scale is very difficult.

- **Find indicator control heat treatment process and to predict heat treated wood decay resistance**
- **Improve the process pilotage by developing of optimal treatment conditions, depending on the desired material properties.**

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Context

Decay resistance tests (Issues)

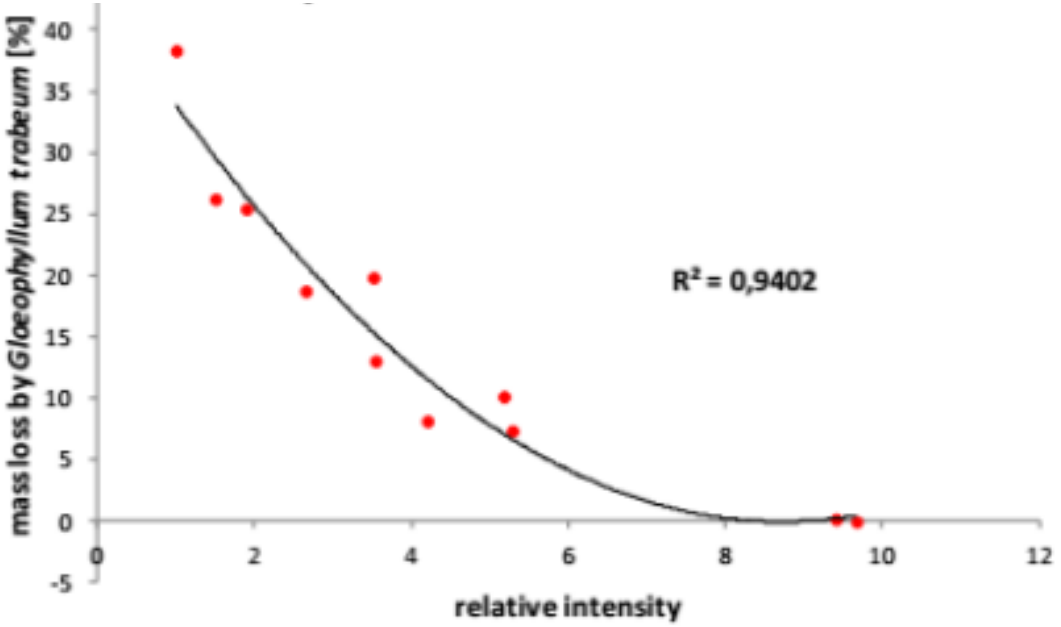
- Standards usually used to test decay resistance of chemically treated wood, needed some amendments to evaluate the resistance of modified wood towards Basidiomycetes, such as a prolonged test exposure. [Junga and Militz 2005]
- Biological resistance of the heat treated material to its low equilibrium moisture content during a decay test (i.e. the moisture content of the heat treated material is not enough for fungal growth). [Kamdem et al. 2009]
- Thus, durability tests on modified wood should be carried out over a exposure time (i.e. longer than 16 weeks of exposure) so as to overcome a mis-estimation of the durability of the new material (choice of fungi ?).
- **These laboratory wood decay resistance tests are destructive, time and money consuming and derivative methods to predict the durability of the heat-treated materials are crucially needed.**

Decay resistance prediction

Spectrometric analysis (Electron Spin Resonance - ESR)

- Measurement of microwave resonance absorbance in the presence of an applied magnetics field.
- For thermally modified wood, an increase of the ESR signal intensity can be measured due to the formation of free radicals during the process.

Estimation of decay resistance:



Correlation between weight loss by *Gloeophyllum trabeum* (WL %) and ESR- relative intensity [Altgen et al. 2012]

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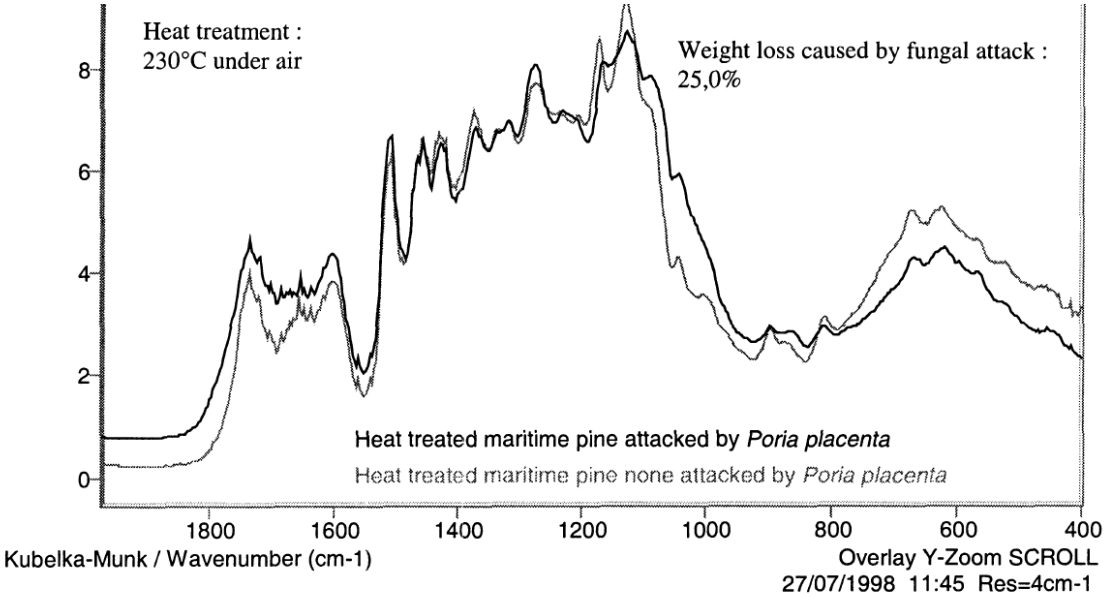
Decay resistance prediction

Spectrometric analysis (DRIFT- Spectroscopy)

- Diffuse Reflectance Infrared Fourier Transform Spectroscopy (DRIFTS) is an infrared spectroscopy technique used on powder samples with no preparation.
- Possibility to create referential spectrum related to targeted heat treated wood quality by comparison on wood chemical composition modification.

Estimation of decay resistance:



Infrared spectra of thermal treated maritime pine degraded by *Poria placenta* [Weiland et al. 2003]

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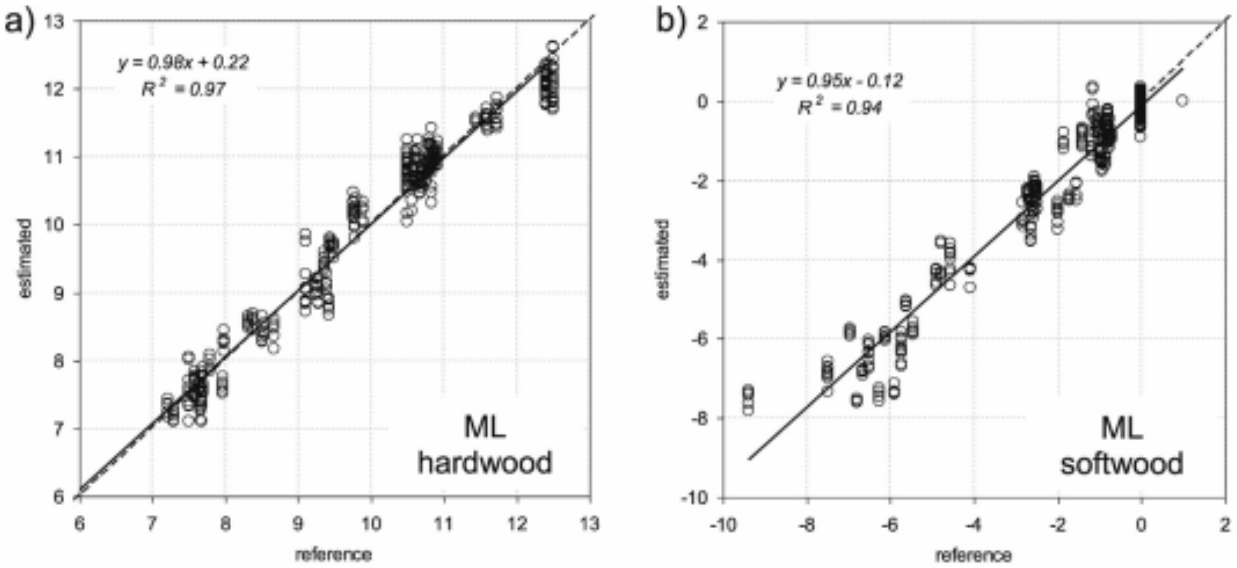
Decay resistance prediction

Spectrometric analysis (NIR- Spectroscopy)

- Good potential to be used for heat treated wood quality checking. [Bächle et al. 2012]
- Both important parameters characterizing quality of TMW (EMC and ML) were predicted with high accuracy. [Sandak et al. 2015]
- No study has yet been conducted to predict directly heat treated wood durability.

Estimation of ML (%)



PLS predicted versus measured values of Mass Losses of thermally modified softwoods and hardwoods [Sandak et al. 2005]

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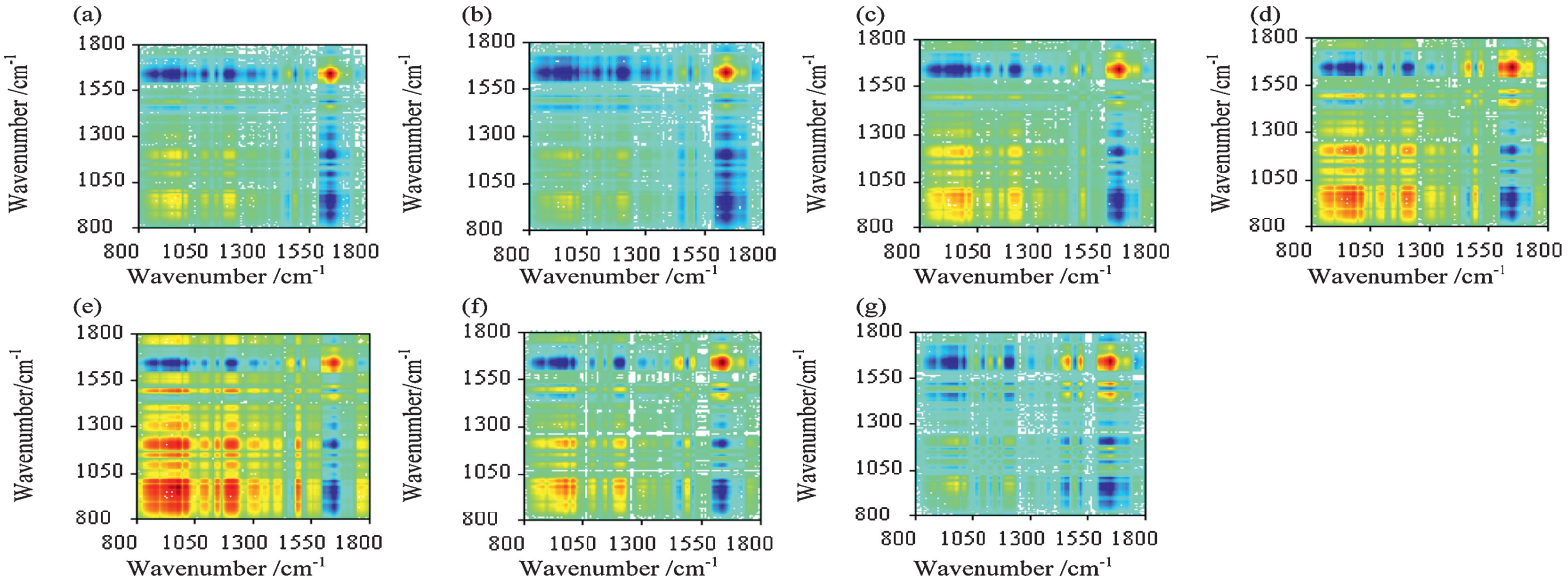
Decay resistance prediction

Spectrometric analysis (FTIR- Spectroscopy)

- Advantages: accuracy, simplicity, and ability of performing very high number of tests without needs of any destruction to the material.

- FT-IR analysis method shows also good potential utilization to estimate heat treated wood durability, relating to heat treated wood chemical changes.

Estimation of decay resistance:



Synchronous 2D-IR spectra and auto-peaks of wood samples in the 1800–800 cm1 region of: (a) reference, steam-heat treated wood under (b) 120 °C, (c) 140 °C, (d) 160 °C, (e) 180 °C, (f) 200 °C, (g) 220 °C [Li et al. 2015].

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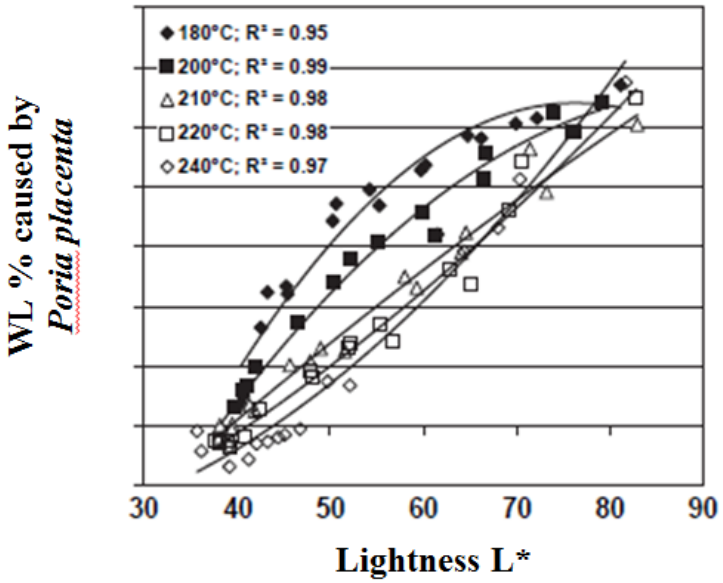
Decay resistance prediction

Colorimetric analyses [CIELAB system]

- CIELAB system is the most commonly used method to estimate material color.
- Not suitable as predictor of heat treated wood quality because color distribution through the thermally treated boards is not homogeneous (earlywood / latewood, resin…)

Estimation of decay resistance:



Correlation between weight loss by *Poria placenta* (WL %) and Lighteness L*, for different heat treatments on Norway spruce at different temperatures [Welzbacher et al. 2008]

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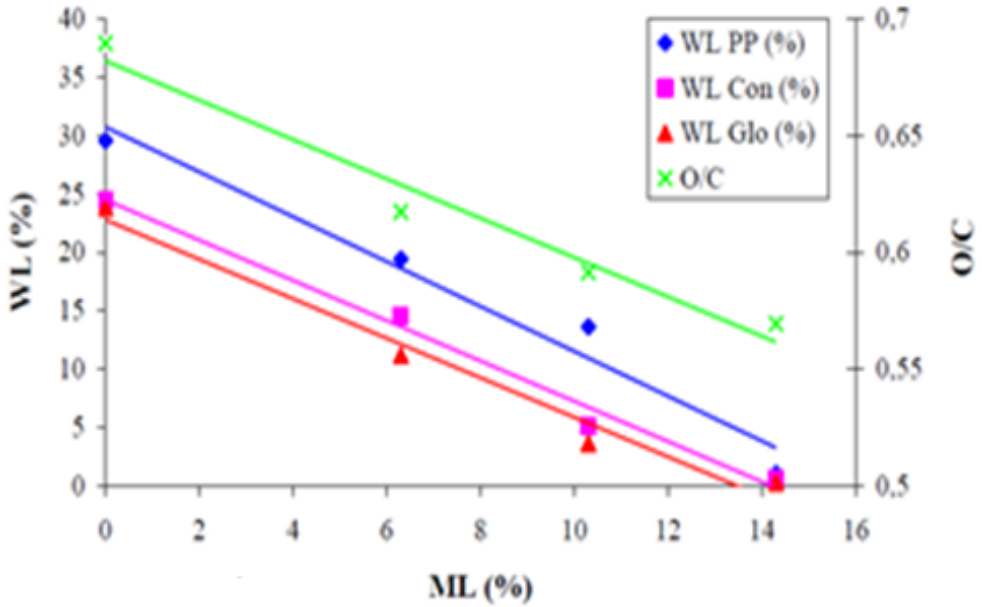
Decay resistance prediction

Elemental Composition [0/C ratio]

- Carbon content increase according to the treatment intensity level.
- Such a measurement needs specific apparatus and time.

Estimation of decay resistance:



PP: Poria placenta
Con:Coniophora puteana
Glo: Gloeophyllum trabeum

Correlation between weight loss by different rots (WL), Mass loss due to heat treatment (ML) and O/C ratio, for heat treatments performed under nitrogen on poplar at 230°C [Chaouch 2011]

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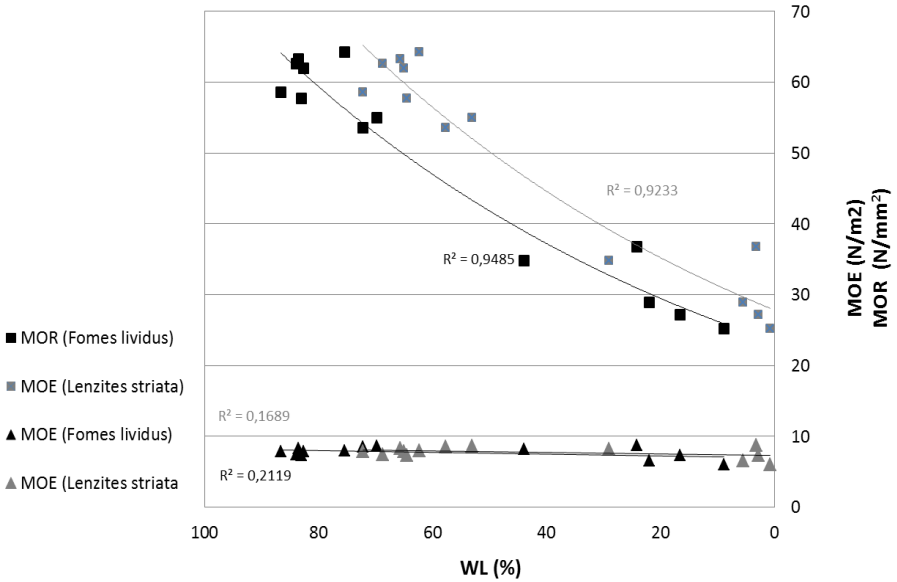
Decay resistance prediction

Industrial Data [Mechanical properties]

- To perform non-destructives mechanical test to estimate heat treated wood decay resistance.

- Acoustic analysis could be a potential method to do it in an industrial scale.

Estimation of decay resistance:



Correlation between weight loss by two different rots (WL), MOE and MOR in bending destructive test, for heat treatments performed on Malapapaya wood (180-230°C, 30-120 min) [Jimenez et al. 2009]

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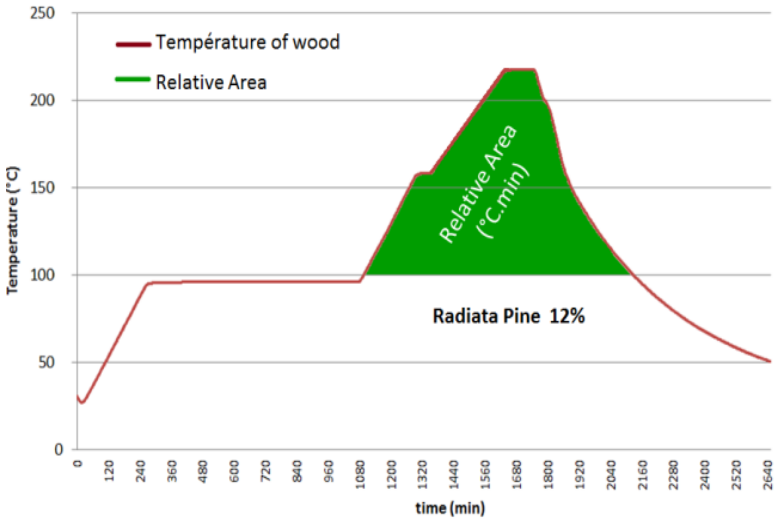
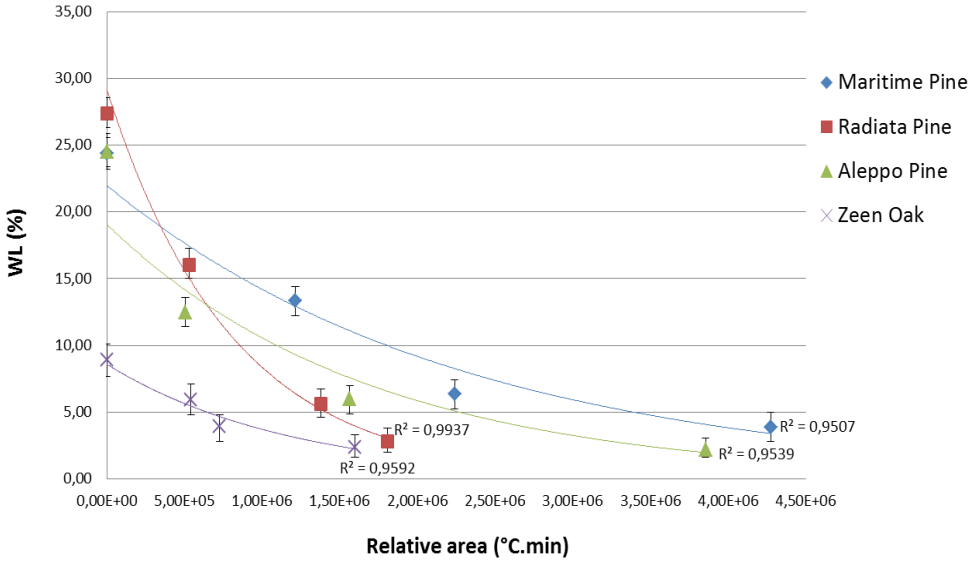
Decay resistance prediction

Industrial Data [Temperature kinetics]

- Wood thermal modification depends mainly on treatment intensity related to temperature and duration.
- Temperature kinetics [T°C = f (time)] should be a good parameter to predict wood Mass Loss and also decay resistance.

Estimation of decay resistance:





Relative area determination and (b) Prediction of Weight Losses due to *Poria placenta* exposure by determination of relative Area, for different wood species [Candelier et al. 2015]

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Conclusion

- **ML (%) is an efficient indicator to wood modification level and also, so far the most accurate indicator to heat treated wood decay resistance.**
- **ML (%) is difficult to be measured at industrial scale.**
- **Some analyses could predict this Mass Loss to estimate the wood decay resistance or could predict it directly.**
- **Color methods is too approximate**
- **Elemental or spectroscopic analyses need equipments and analysis time.**
- **Non destructive mechanical tests could be a great industrial solution, but mechanical – physical (MC%) relations remain to be check for heat treated wood.**
- **Temperature kinetics seem to be an interesting solution, but this method must be verified at industrial scale. This solution gives only a global estimation (not for each heat treated wood board).**

THANK FOR YOUR KIND ATTENTION

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