SWST 48th Annual Convention

Influence of wood structure on moisture desorption and changes in its properties above the fiber saturation point

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UNIVERSITÉ LAVAL

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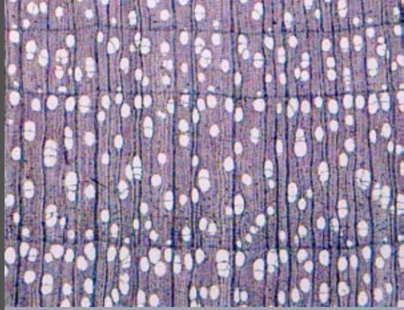
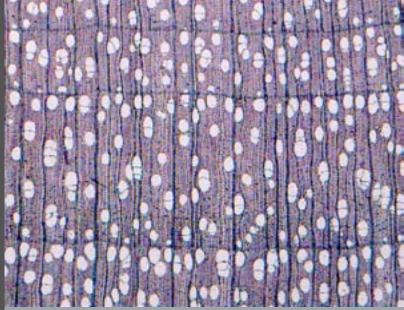


Plan

- Objectives
- Definitions
- Material and Methods
- Results
- Conclusions

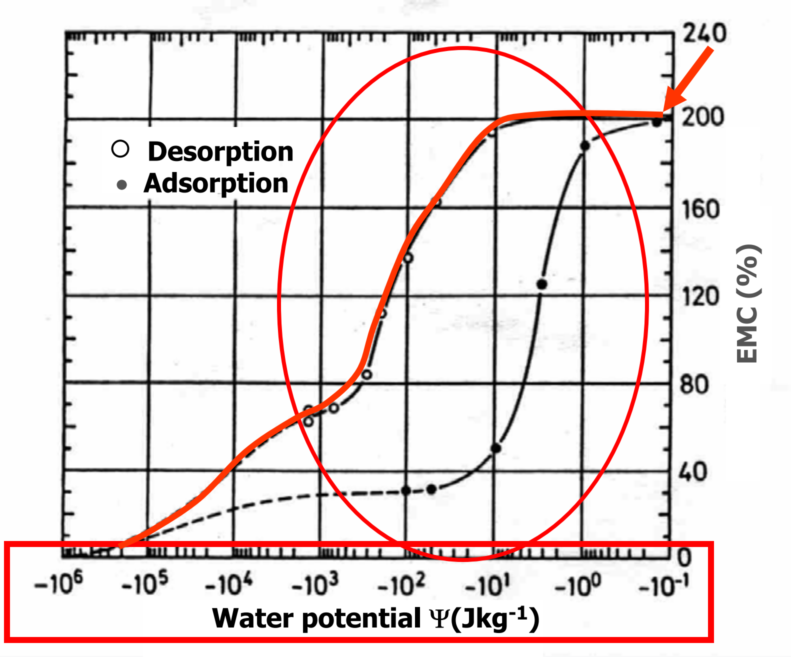


Objectives

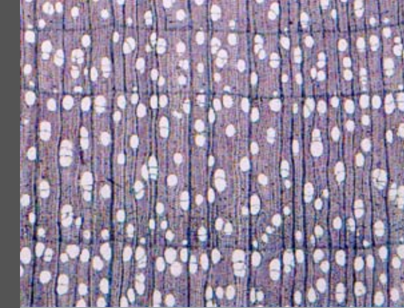
- Influence of wood structure on boundary moisture desorption.
- Changes in wood properties above the FSP (influence of wood structure on these changes).

Definitions

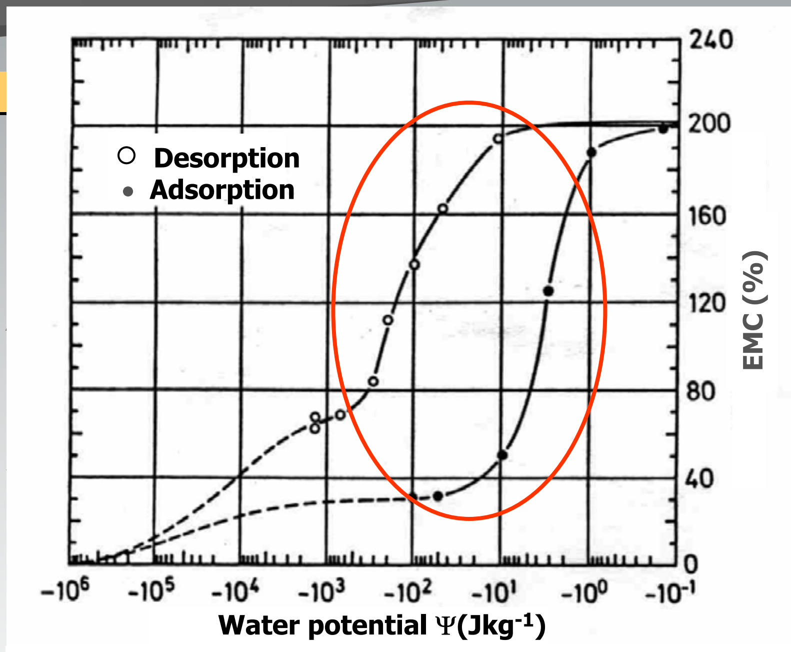
- Boundary desorption
  - Water potential (Ψ): water in a medium is characterized in terms of its energy state
  - MC x Ψ : region between 96% and 100% RH is spread out (wood structure highly affects the drainage curve in this region)



EMC-water potential relationship of western hemlock sapwood at 21°C (Fortin 1979).



Definitions



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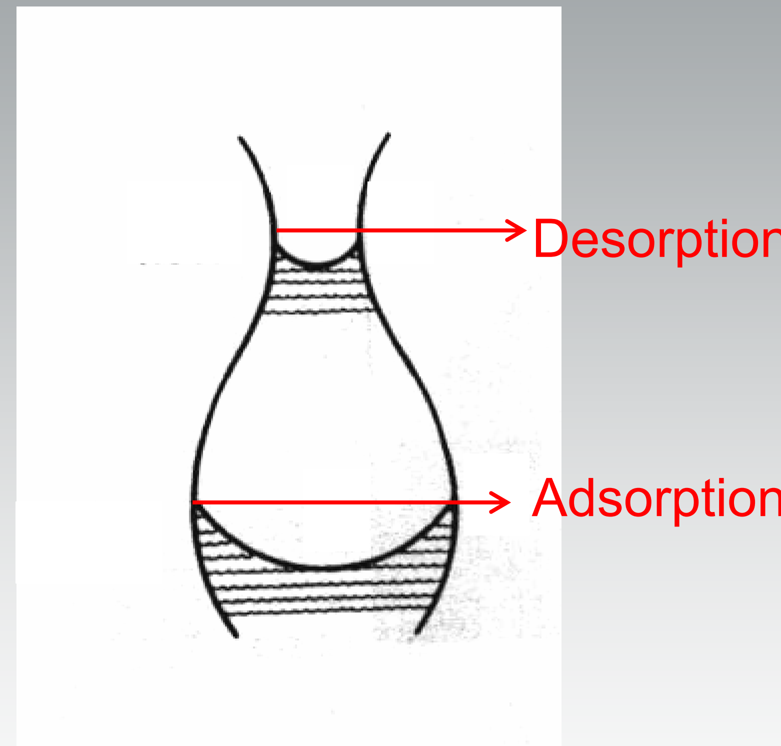
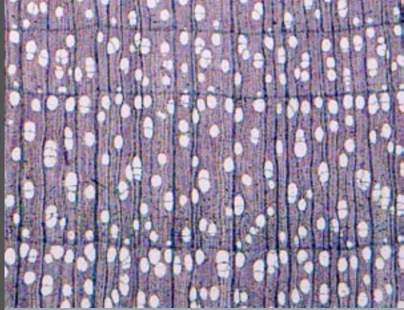


– Capillary system of wood → cavities interconnected by narrow channels

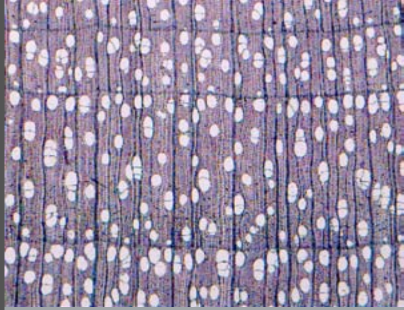


Definitions

- Fiber saturation point (FSP)

"Moisture content (MC) at which the cell walls are saturated with bound water with no free water in the cell cavities (Tiemann 1906)."

"FSP is the MC below which the physical and mechanical properties of wood begin to change as a function of MC (USDA 1974)."

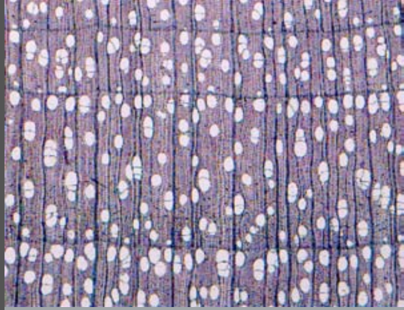


Definitions

- Fiber saturation point (FSP)

"Shrinkage in beech begins to take place above the FSP (Stevens 1963)."

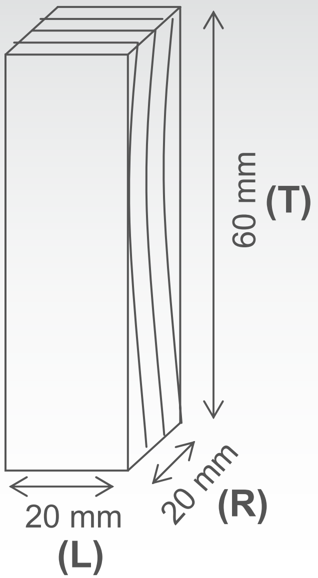
"Bound and free water appear to coexist over a significant range of water potentials - above and below the FSP (Siau 1995)."



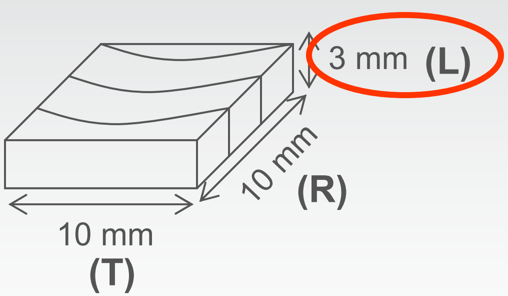
Material

- Yellow birch (*Betula alleghaniensis*)
  - Sugar maple (*Acer saccharum*)
- American beech (*Fagus grandifolia*)

Sorption and physical-mechanical tests



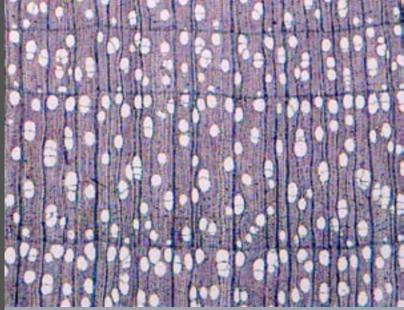
Mercury porosimetry



Anatomical analysis

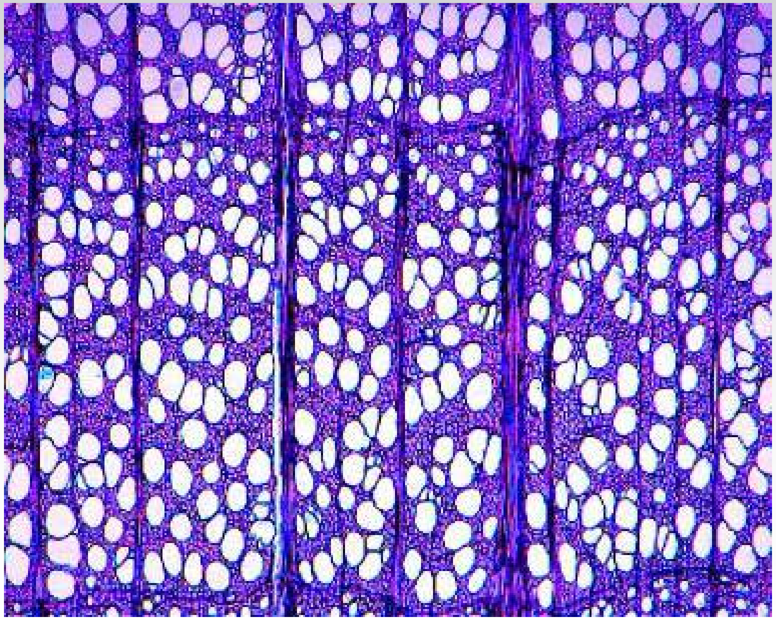
TR: 10mm x 10mm x 20µm

TL: 10mm x 10mm x 30µm

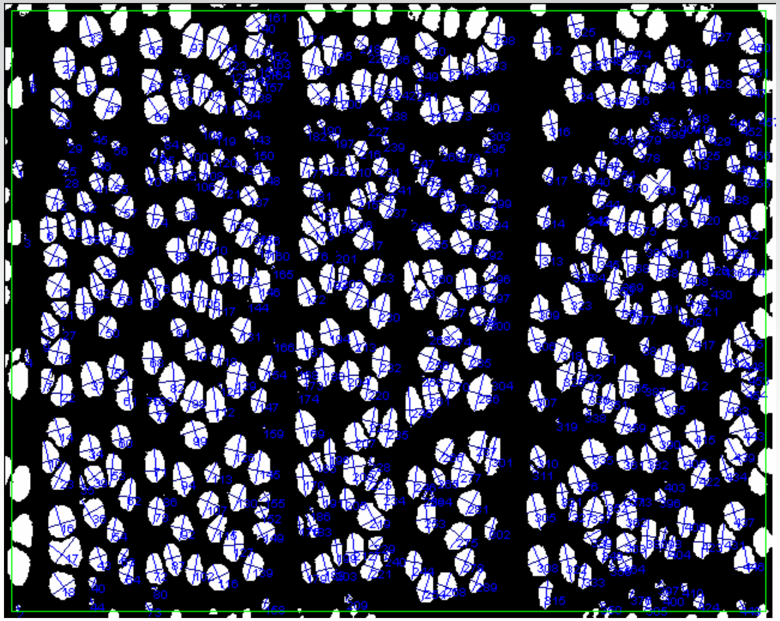


Material

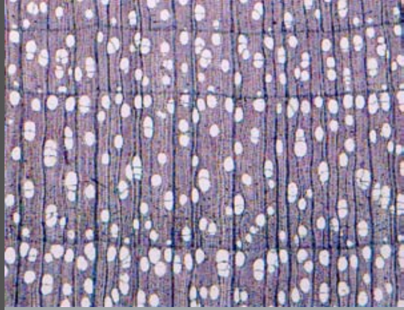
- Anatomical analysis
  - Microsections were double stained
  - Image treatment (Micromorph)
  - Quantitative anatomical analysis (WinCell)



Beech – TR original image



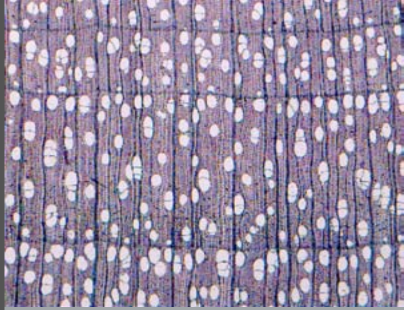
Beech – treated image



Methods

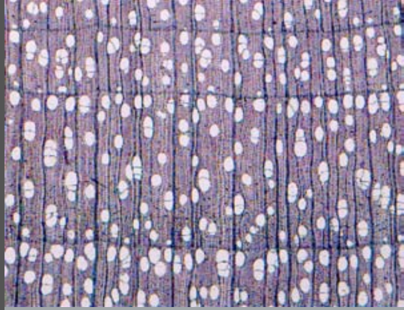
- Moisture sorption tests
  - Full saturation under distilled water
  - One condition in adsorption above distilled water
  - Five desorption conditions using pressure membrane method (RH>96%)
  - Five desorption conditions using saturated salt solutions (33% ≤ RH ≤ 90%)

Methods

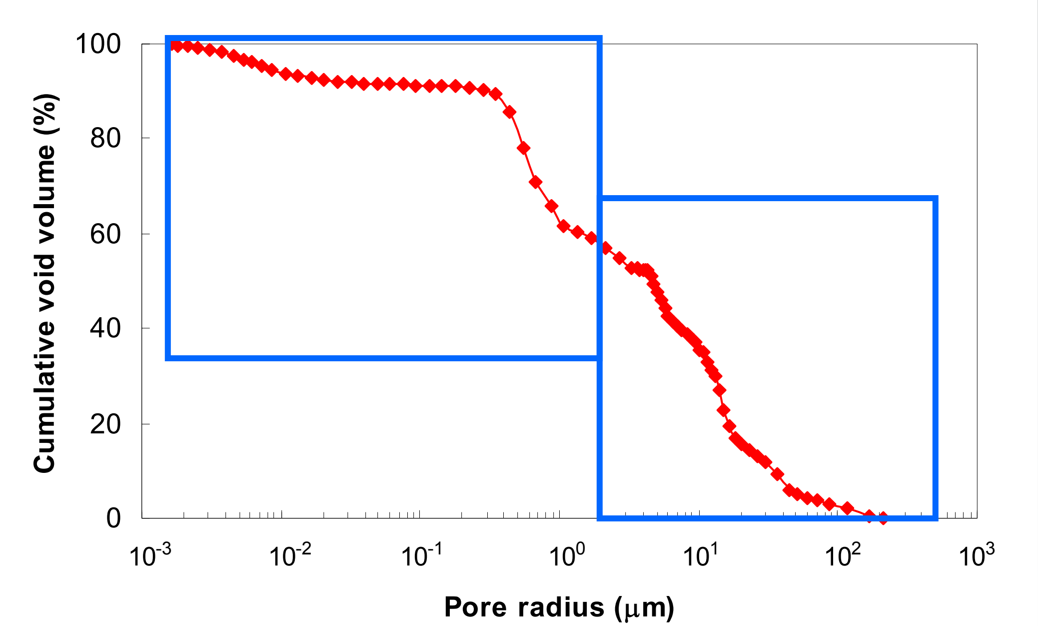


- Moisture sorption tests
- Shrinkage and mechanical tests at EMC
- Quantitative anatomical analysis
- Mercury porosimetry analysis

Methods



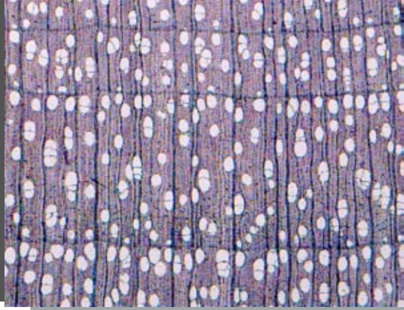
- Mercury porosimetry analysis
  - Micromeritics AutoPore IV Series
    - Low pressure – 0 to 50 psi (pore radius from 180 μm to 1.8 μm)
    - High pressure – AP to 60,000 psi (pore radius until 0.0015 μm)

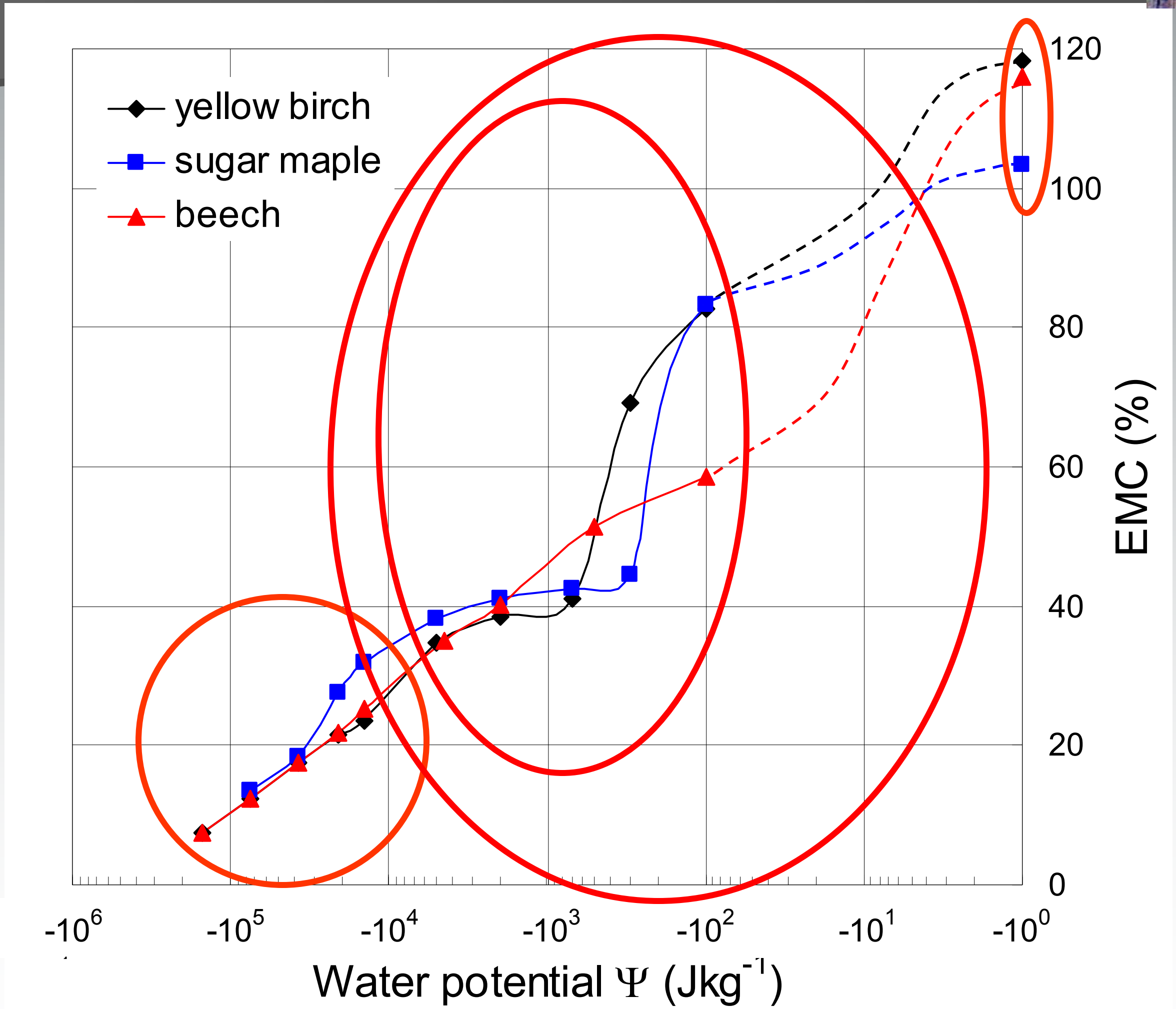


Cumulative void volume of yellow birch obtained by mercury porosimetry analysis.

Results

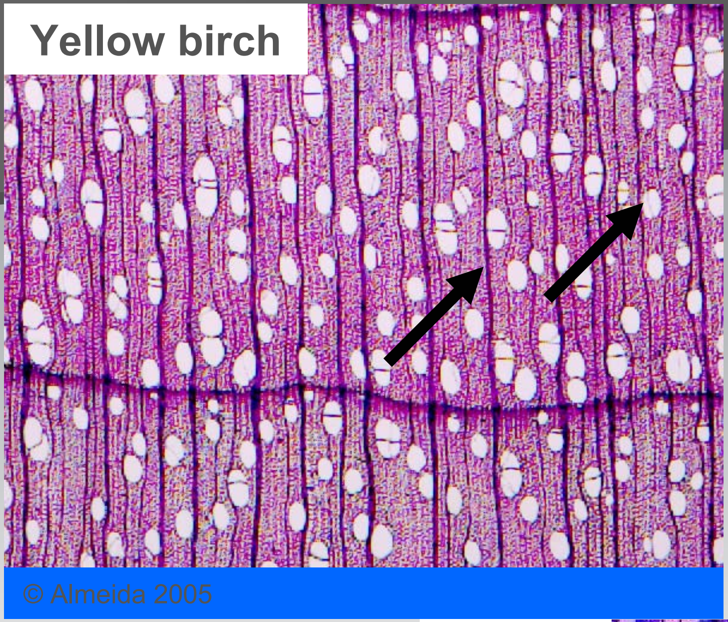
Desorption curves

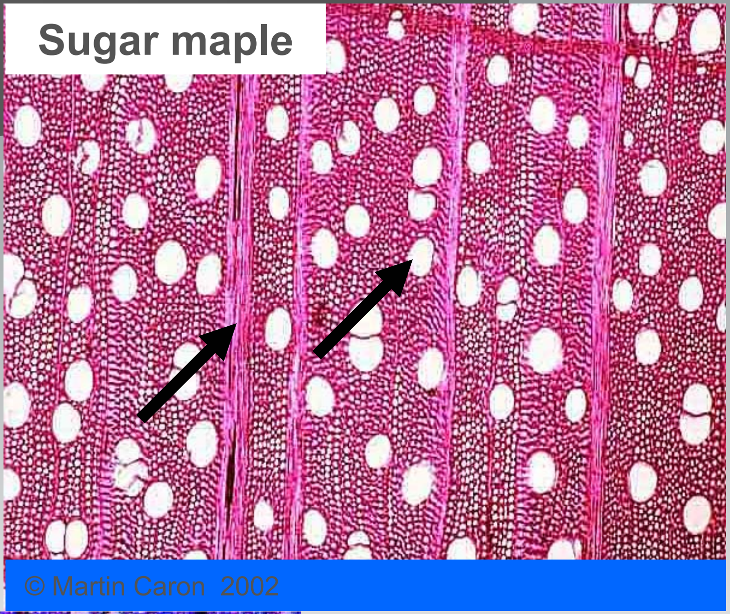


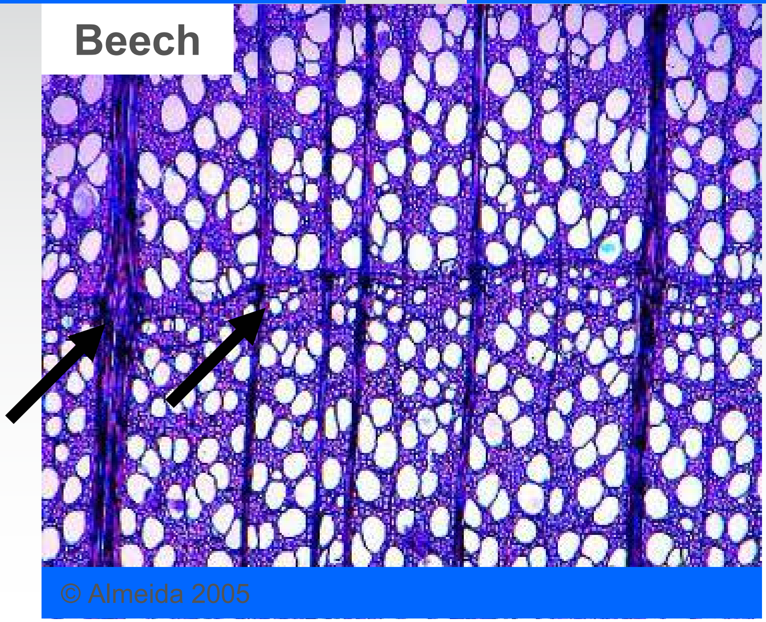


Equilibrium moisture content-water potential relationship at 25°C (yellow birch and beech) and at 20-21°C (sugar maple, Hernández and Bizoň 1994).

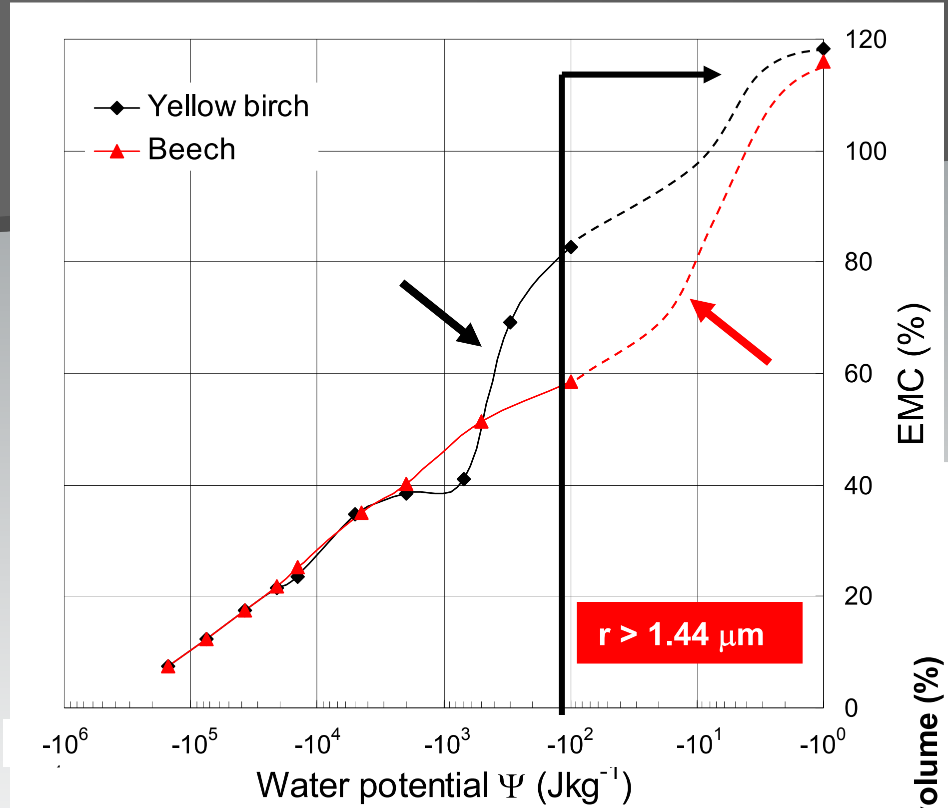
Results - Wood anatomy



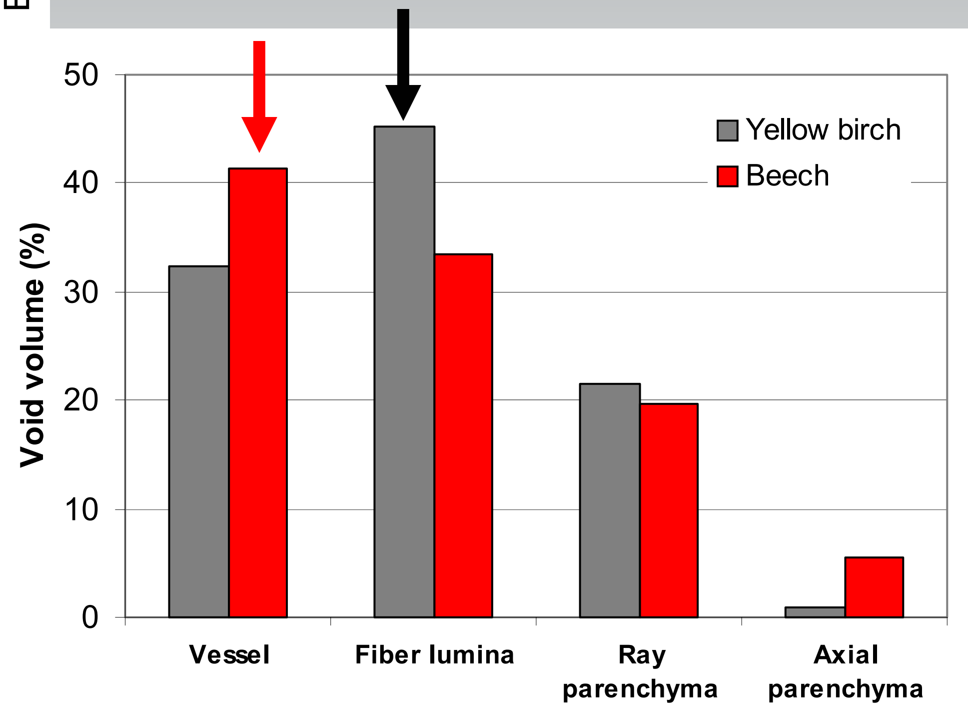




Results - Wood anatomy



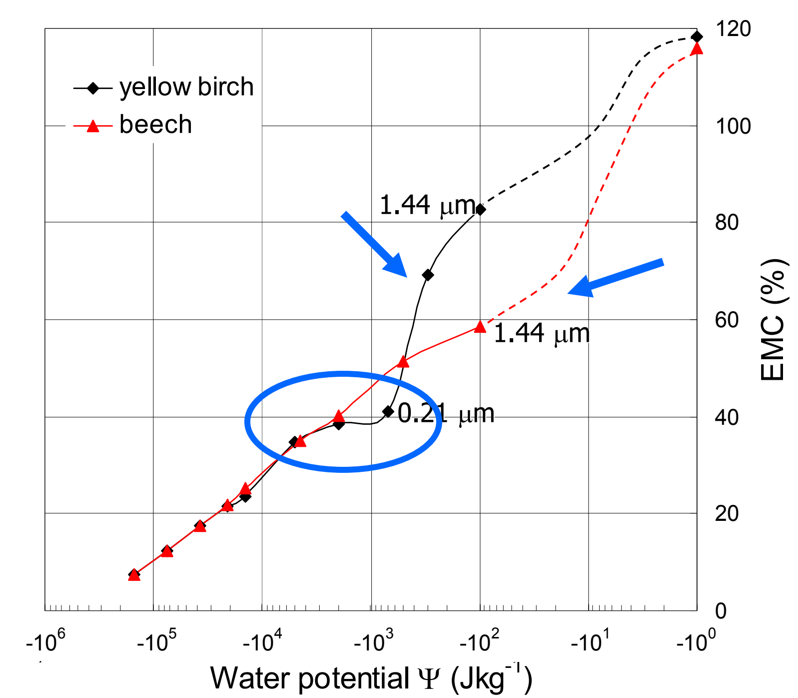
Equilibrium moisture content-water potential relationship at 25°C.



Void volume proportion of the wood elements.

Results - Mercury porosimetry

<Vessel radius (beech)> = 20 μm (anatomy)
= 18 μm (porosimetry)



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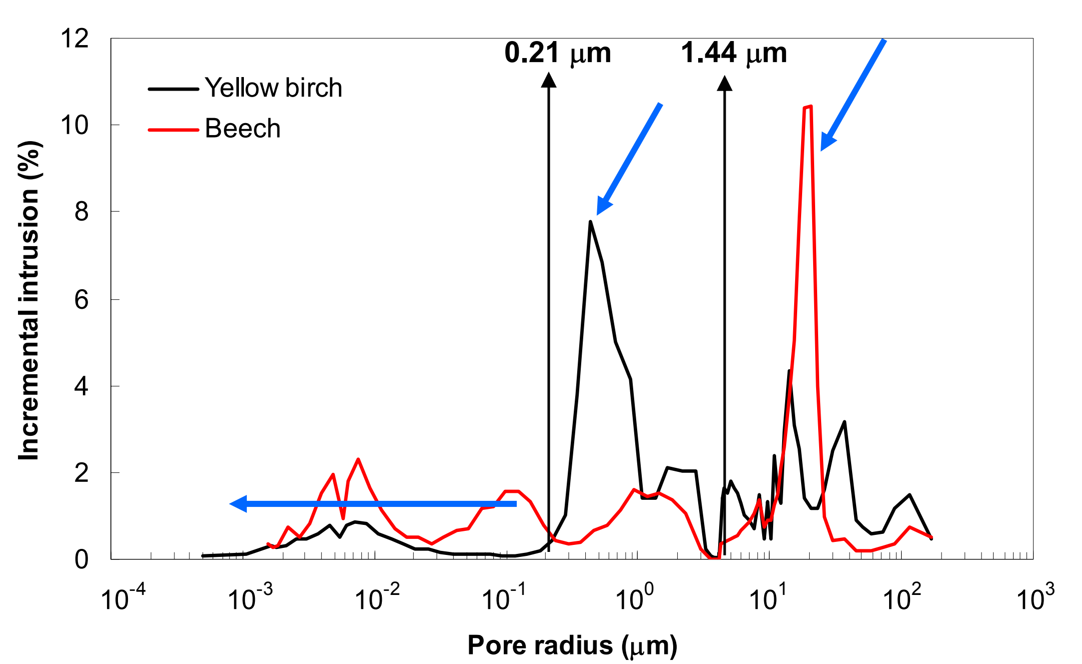
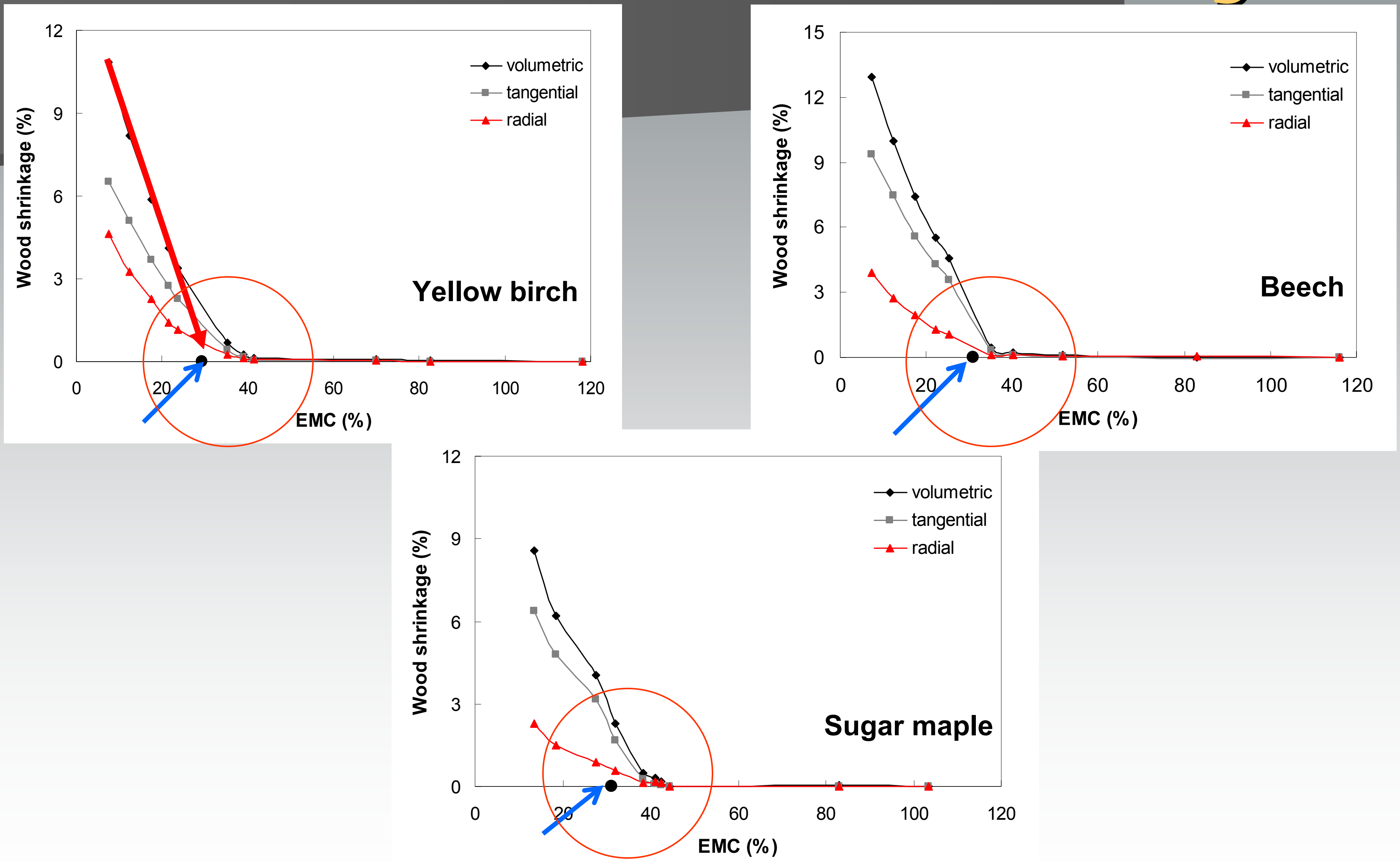


Incremental intrusion obtained by mercury porosimetry.

Results - EMC x wood shrinkage



Wood shrinkage as a function of the EMC at 25°C (yellow birch and beech) and at 20-21°C (sugar maple, Hernández and Bizoň 1994).

Results - EMC x wood shrinkage

- EMC: shrinkage statistically significant

$$\text{Diff} = (\text{T and R})_{\text{Full Saturation}} - (\text{T and R})_{\text{EMC}}$$

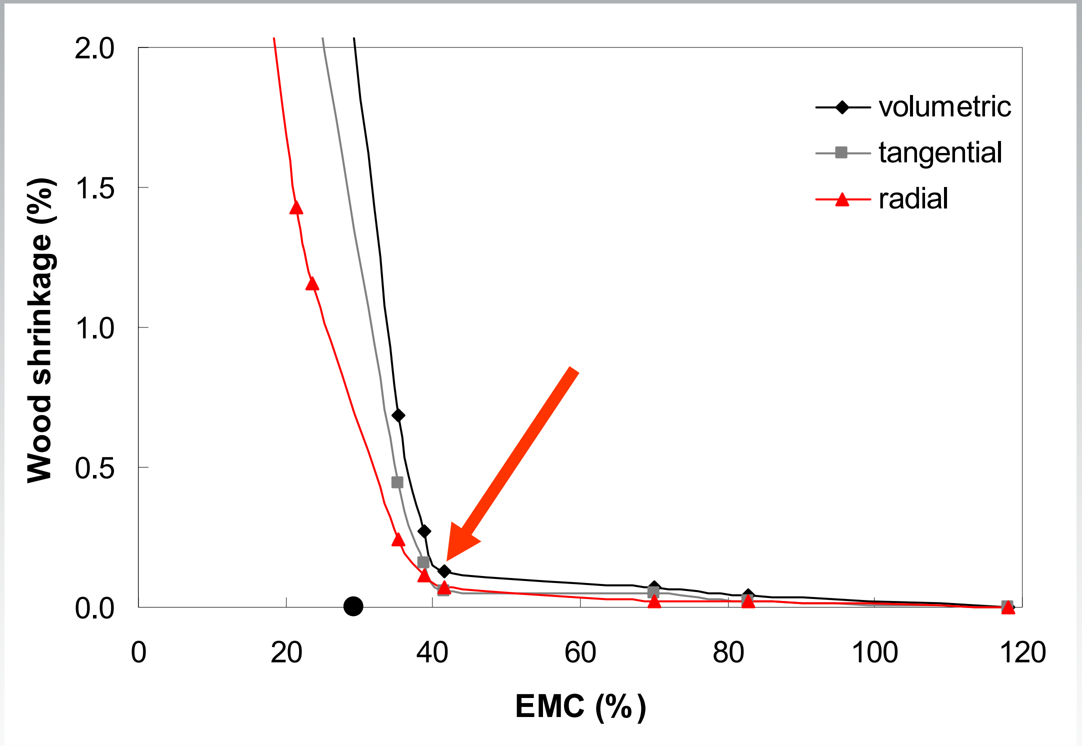
Paired t-test Diff >0

Table 1. EMC below which shrinkage was statistically higher than zero[1].

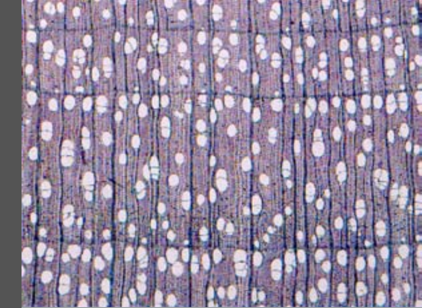
Wood species	EMC (%)	FSP (%)
Yellow birch	41	29.2
Beech	40	30.9
Sugar maple	43	31.1

[1] $\alpha = 0.01$ ** (1% probability).

Results - EMC x wood shrinkage



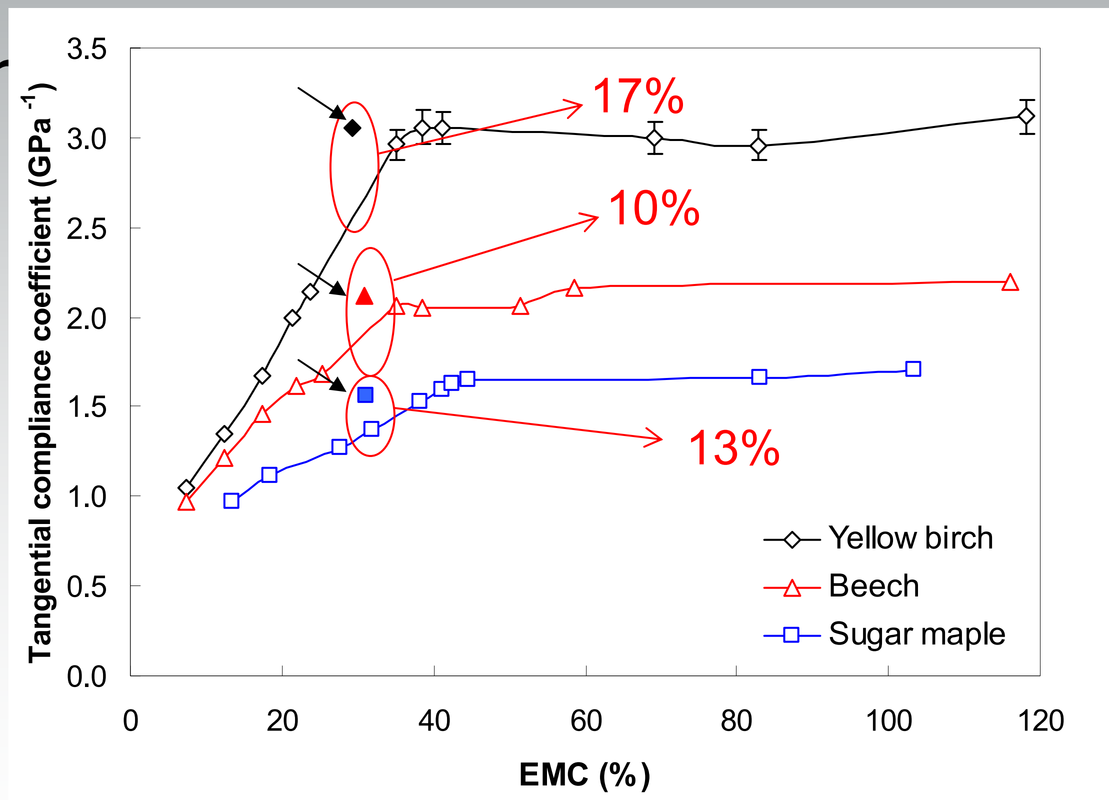
Wood shrinkage as a function of the EMC at 25°C (yellow birch).



Results

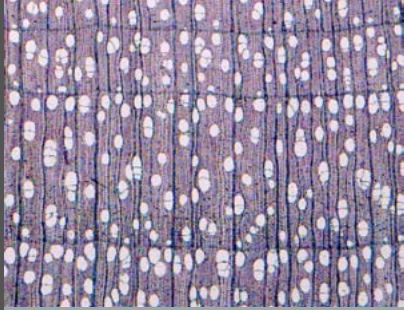
EMC x mechanical properties

Tar $1/E_T$



Compliance coefficients s_{33} in tangential compression as a function of the EMC at 25°C (yellow birch and beech) and at 20-21°C (sugar maple, Hernández and Bizoň 1994).

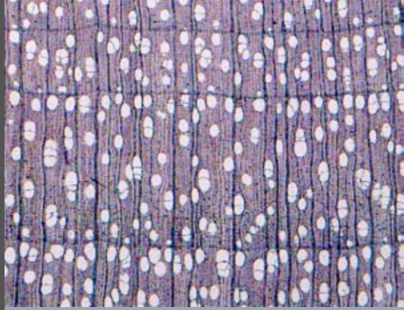
Conclusions



- Shape of the boundary desorption curve in the region governed by the capillary forces is particular to each wood species.

- At equilibrium, the radial, tangential and volumetric shrinkage begin above FSP.

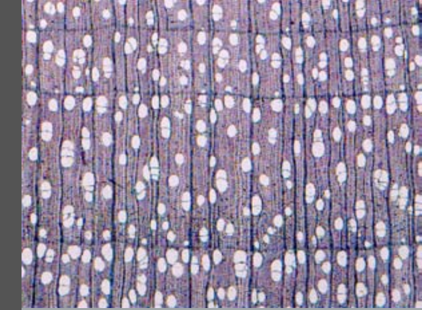
Conclusions



- At equilibrium, the MC affects the tangential compliance coefficient beyond the FSP.

- In the desorption phase, loss of bound water begins in presence of liquid water. The EMC at which this loss begins depends on wood species.

Bibliography



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- Siau, J.F. 1995. *Wood: Influence of moisture on physical properties*. Virginia Polytechnic Institute and State University, VA.
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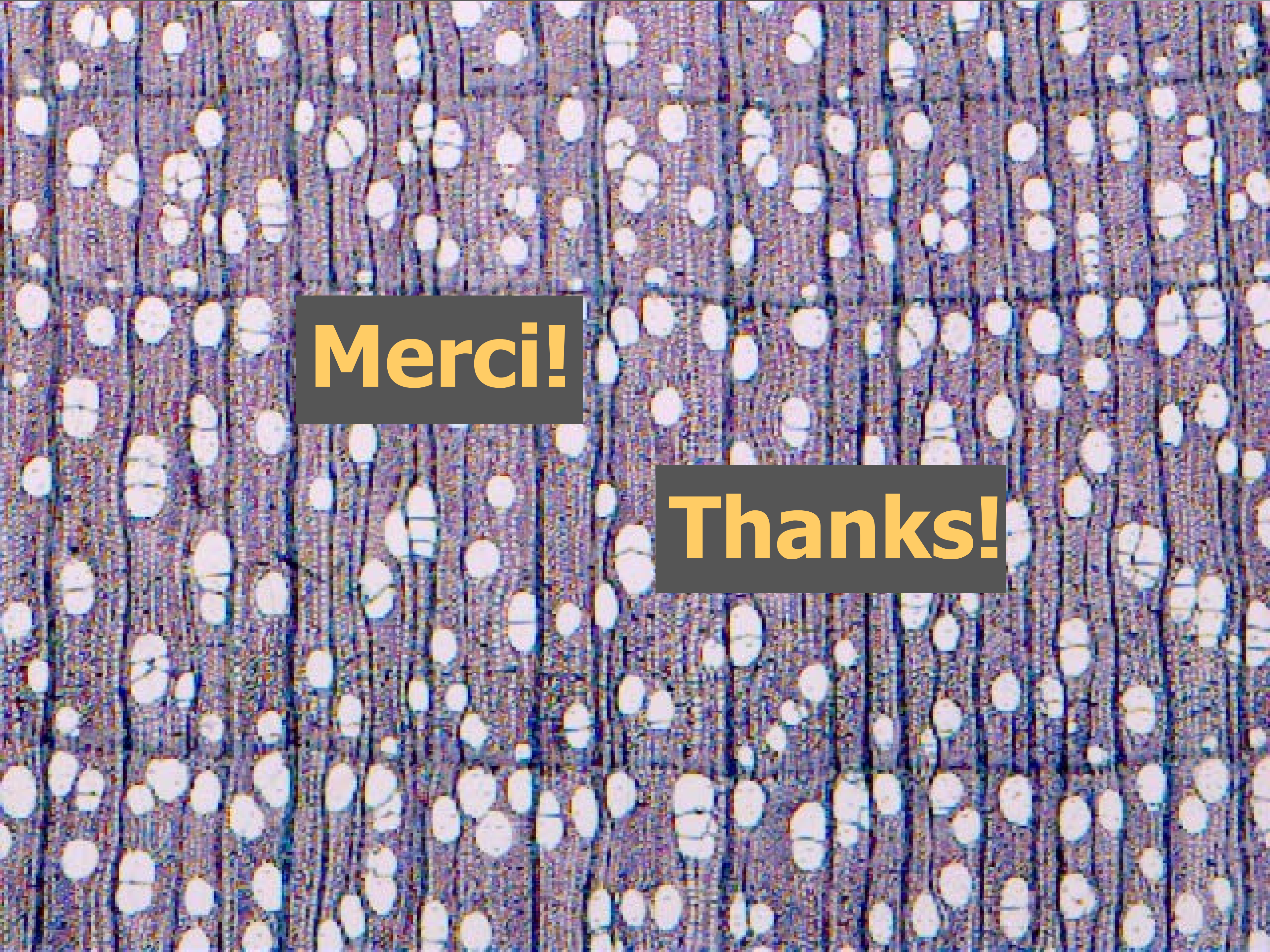

Merci!
Thanks!

Methods – sorption tests

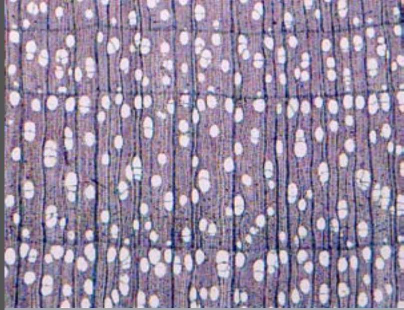


Table 2. Sorption tests characteristics.

State of sorption	Saturated salt solution	RH (%)	Water potential (Jkg^{-1})
Equilibration over saturated salt solutions at 25°C			
Adsorption	H_2O	≈ 100	
Desorption	ZnSO4	90	-14 495
Desorption	KCl	86	-20 750
Desorption	NaCl	76	-37 756
Desorption	NaBr	58	-74 941
Desorption	MgCl2	33	-152 526

Methods

- Mercury porosimetry

$$P = \frac{-2\gamma\cos\theta}{r}$$

γ est la tension superficielle (0,485 N/m)
r est le rayon du capillaire
θ est l'angle de contact avec le substrat
(de 90° à 180°, mercure = 130°)

Methods – sorption tests

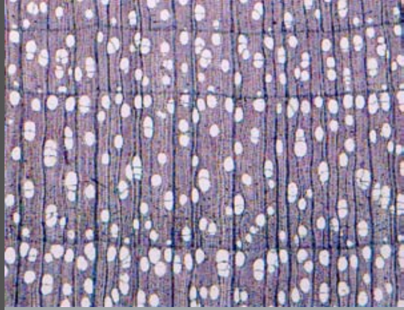


Table 3. Sorption tests characteristics.

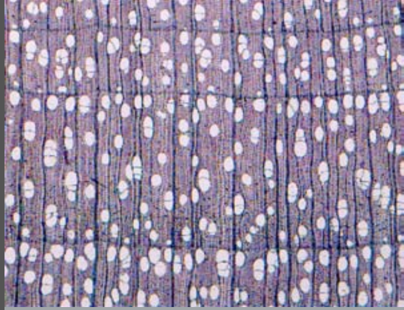
State of sorption	Chemical or saturated salt solution	Nominal relative humidity (%)	Water potential (Jkg^{-1})	Radius of curvature of the air-water meniscus (µm)
Full saturation under distilled water				
Saturation	H_20	100	0	∞
Equilibrium under a pressure membrane at 25°C				
Desorption	-	99.927	-100	1.440
Desorption	-	99.782	-300	0.480
Desorption	-	99.492	-700	0.206
Desorption	-	98.557	-2 000	0.072
Desorption	-	96.431	-5 000	0.029

$$r = \frac{-2\gamma\cos\theta}{\psi}$$

-10^2 J/kg → rayon ≥ 1.44 µm

Vaisseaux (diam. ≥ 50 µm)

Works in progress



- Effect of the temperature in the beginning of physical mechanical changes;

- NMR of beech, sugar maple and tropical hardwood at different EMC

(proportion of bound and free water x EMC)