Advantages of hot-water extraction pre-treatment in the manufacture of wood composites

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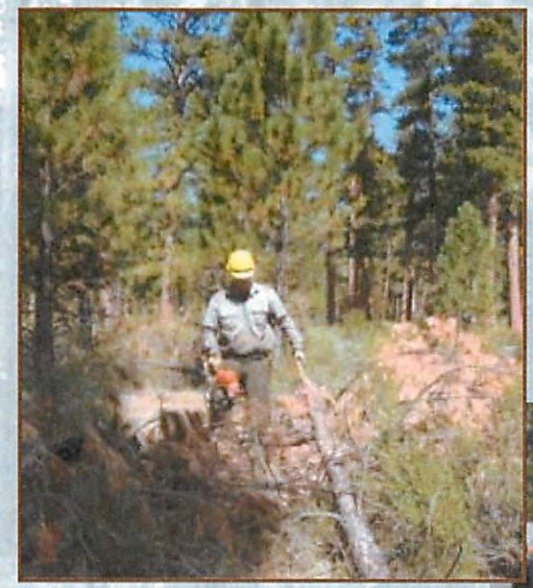
World Class. Face to Face.

Forest Thinnings



Why?

- increase raw materials basket
- improve properties of existing technologies
  - reduce hydroscopicity
  - increase dimensional stability
- derive more value-added products through integration of technologies

Wood characteristics = Product properties

- CELLULOSE … The most valuable constituent of biomass
- *Hemicellulose …* negatively affects product properties

Hypothesis

Removal of hemicelluloses and presence of lignin on the surfaces of wood fibers allow:

- easier processing of composites
- provide improved properties to products as consequence of the plasticity and melting of lignin during processing
- crosslinking reactions during composites manufacture
- better affinity with adhesives and thermoplastics
- reduced wood-water affinity

- Alternatives to improve water resistance of wood composites is necessary
- One option is through modification of wood properties by removing hemicelluloses
  - Thermal processes such as hot water extraction (chemical free, autocatalytic process)

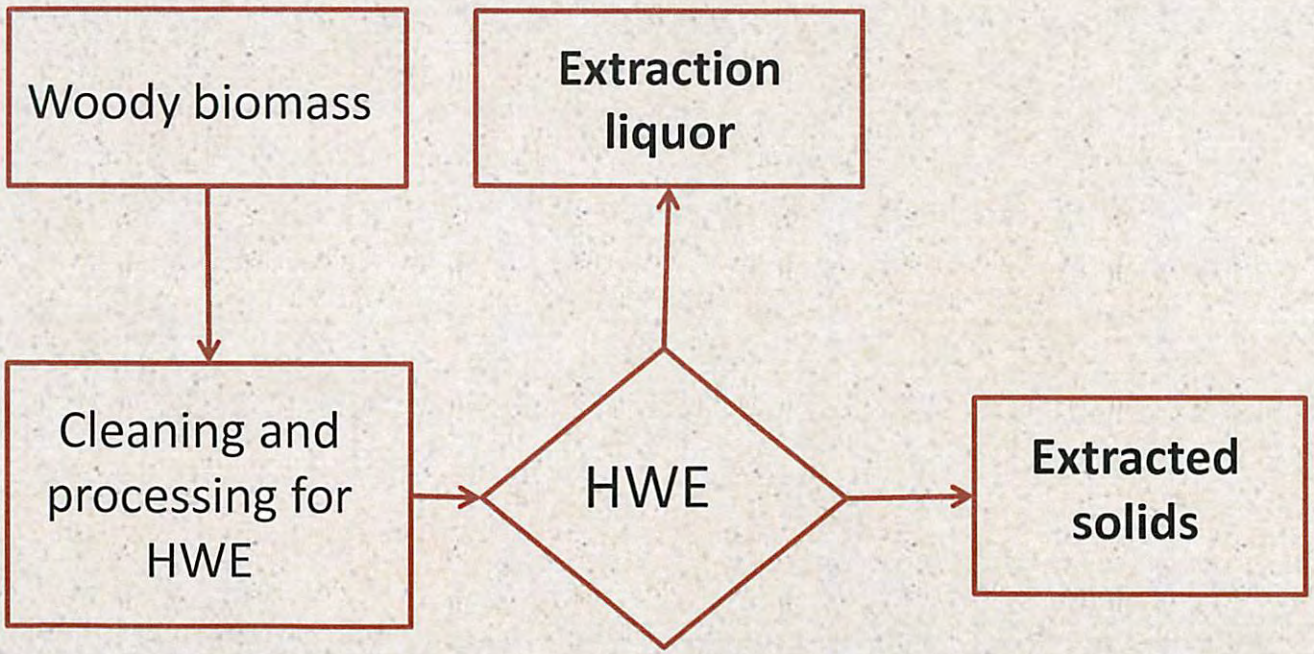
Integration of HWE with wood composites production

Woody biomass

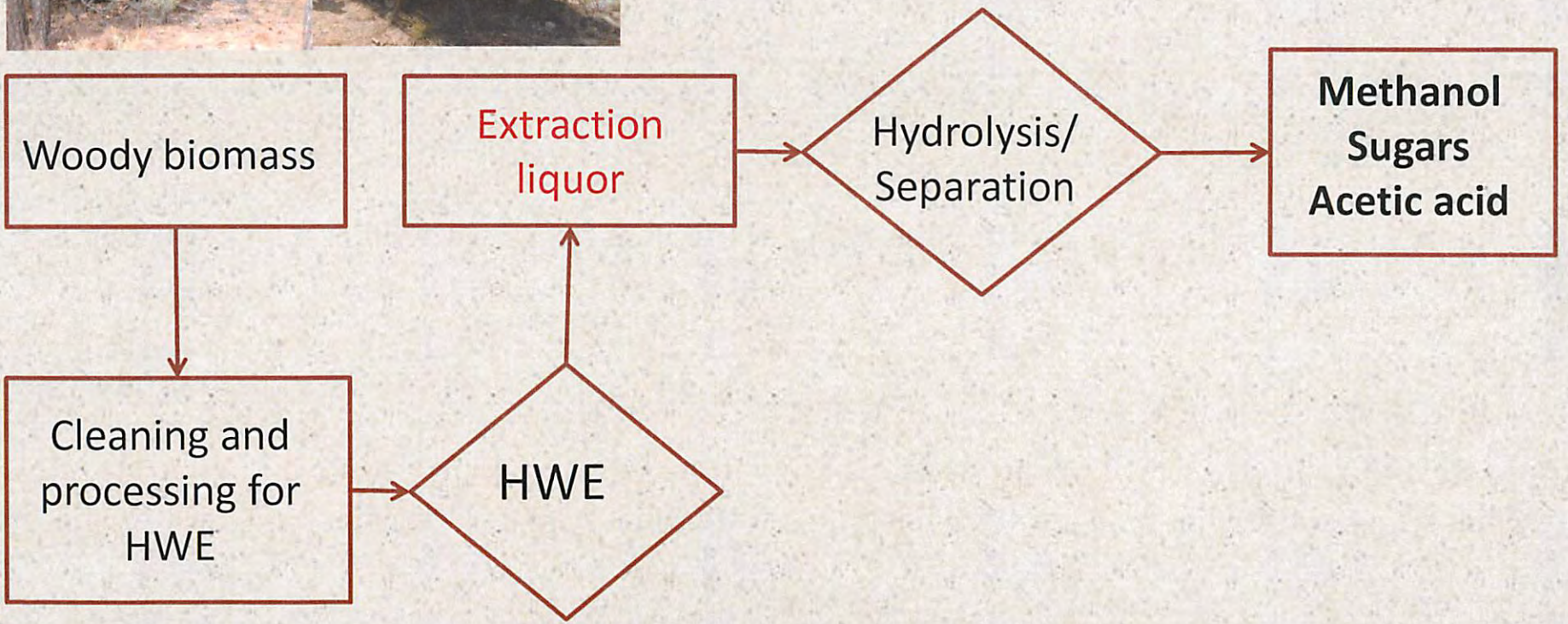
↓

Cleaning and processing for HWE → **HWE**

Integration of HWE with wood composites production



Integration of HWE with wood composites production



(from Amidon et al. 2008)

Integration of HWE with wood composites production

Woody biomass

Cleaning and processing for HWE

HWE

Extracted solids

Wood composites (e.g. WPC, particleboard)

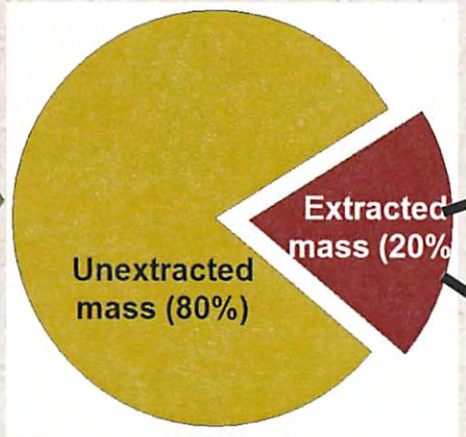
(from Amidon et al. 2008)

How?

Small logs
Ponderosa pine
Undebarked

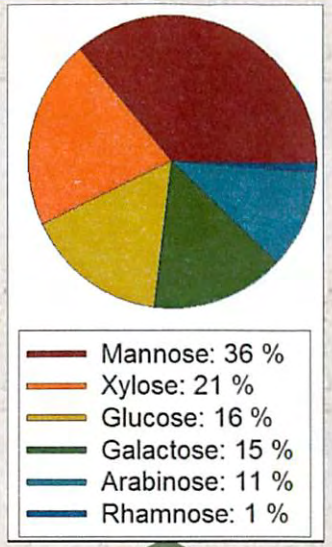
HWE

T = 160°C,
t = 90 min



SUGARS (~67%)

ACETIC ACID + INORGANICS + OTHERS



WPC

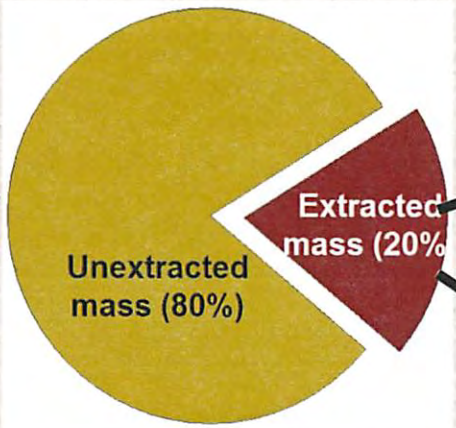
Our process

Small logs
Ponderosa pine
Undebarked

HWE

T = 160°C,
t = 90 min

Relatively simple
No chemicals,
No residuals



SUGARS
(~67%)

ACETIC ACID +
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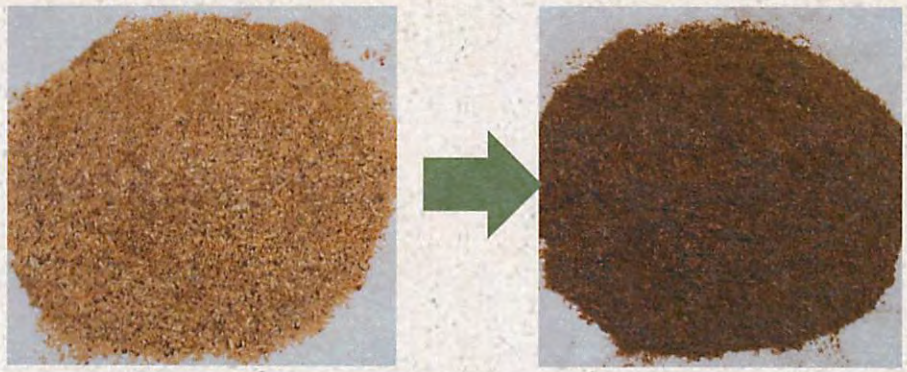
WPC

Effects of HWE



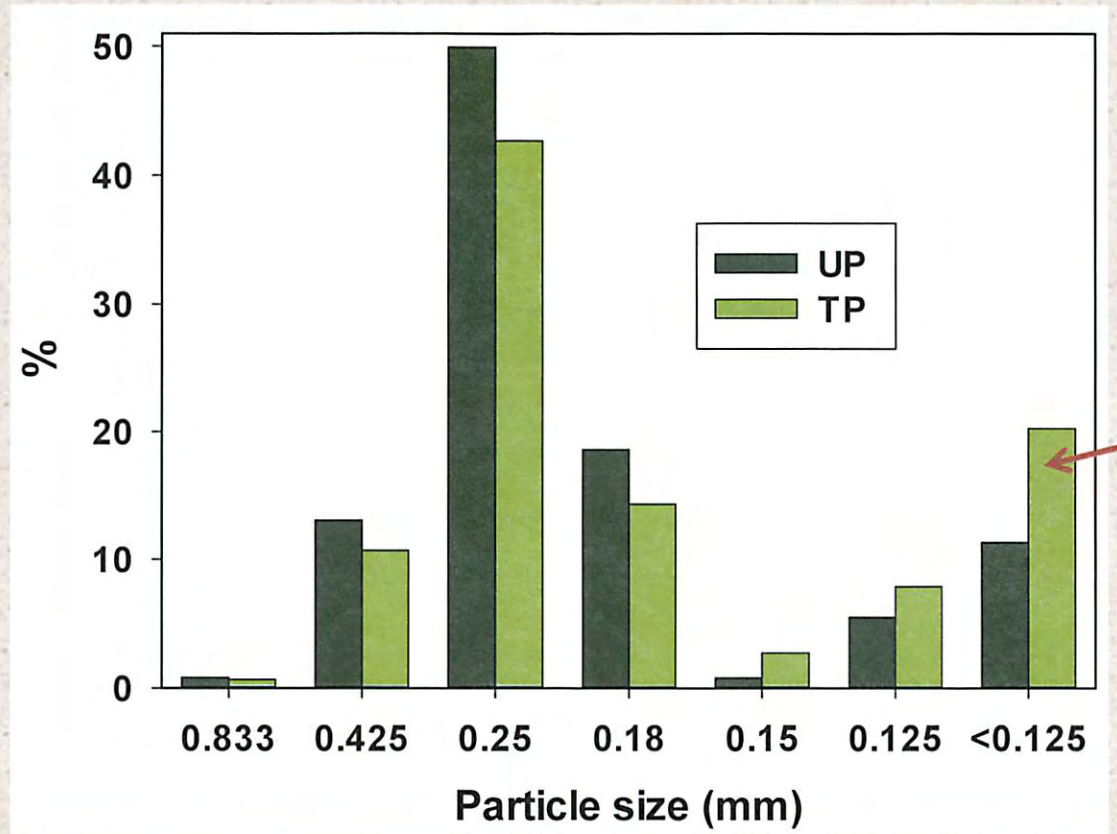
Unextracted pine
(UP)

Extracted (treated) pine
(TP)

Change in color

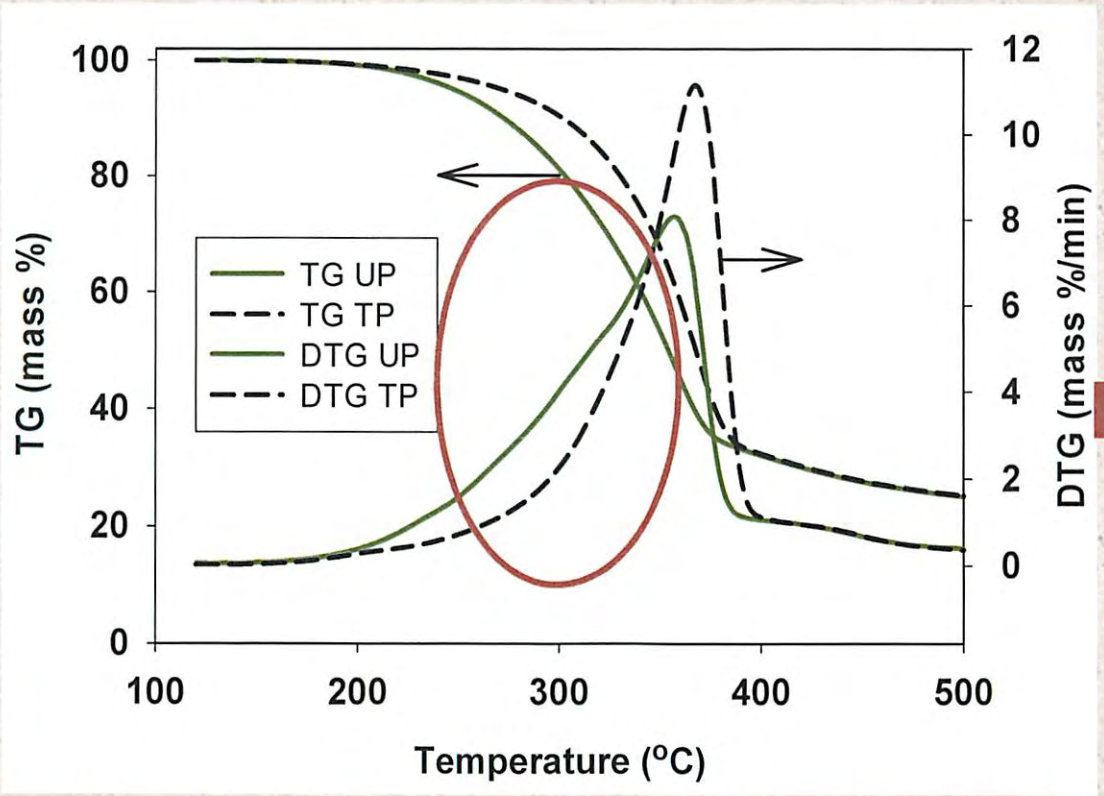
- oxidation of phenolic compounds
- presence of reduced sugars and amino acids
- emanation of formaldehydes (Sandoval-Torres et al. 2010)
- color of modified wood affects color of composites

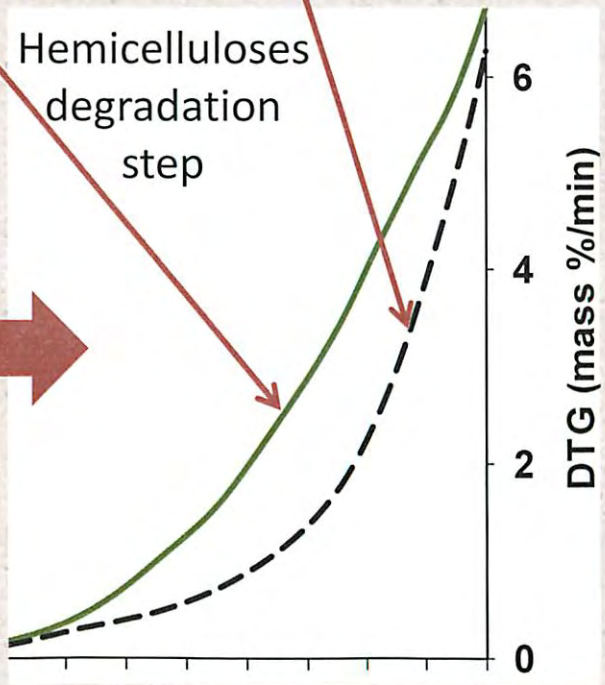
Effects of HWE



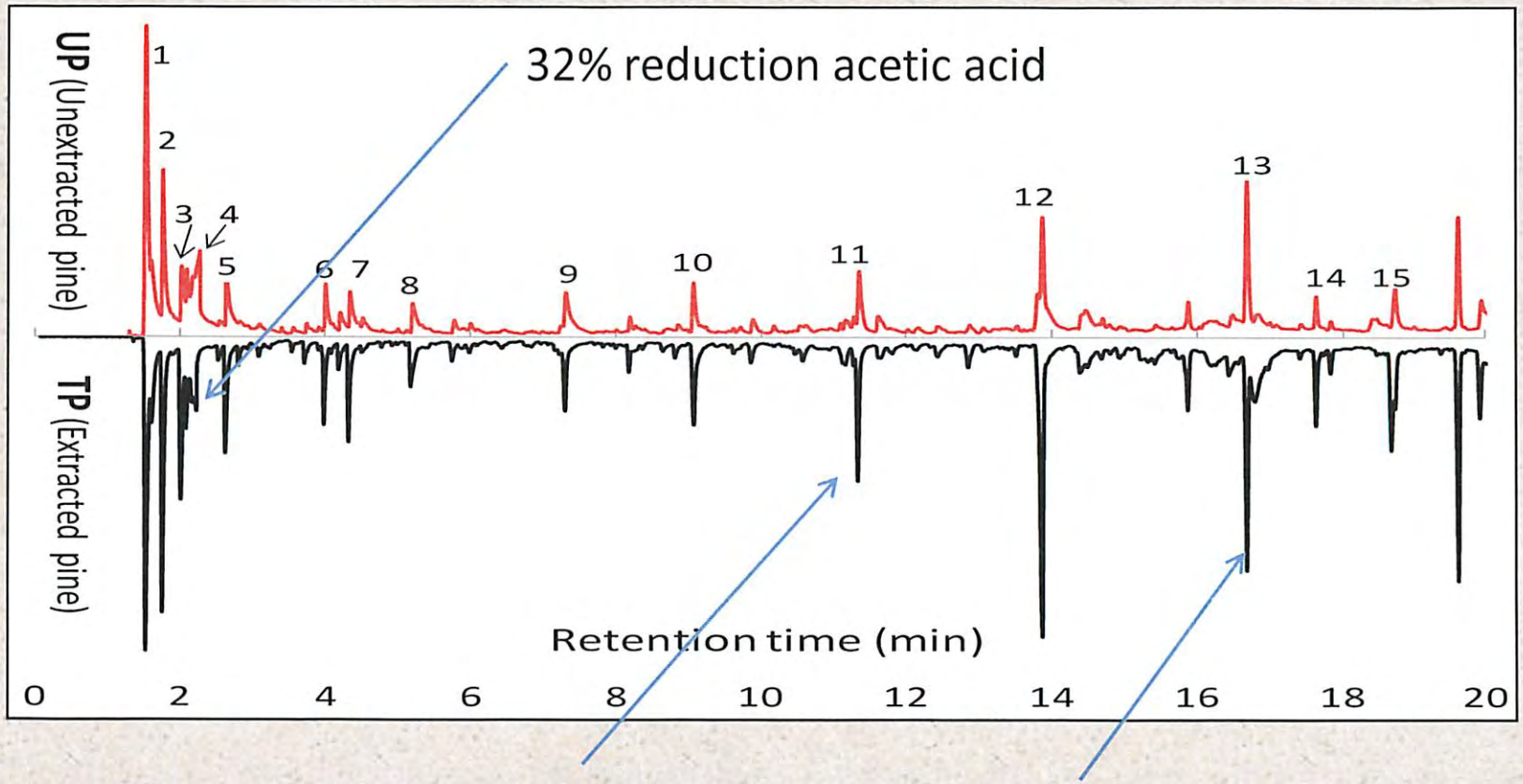
Grindability:
more fines in TP

Effects of HWE





Semiquantitative analysis: Py GC/MS

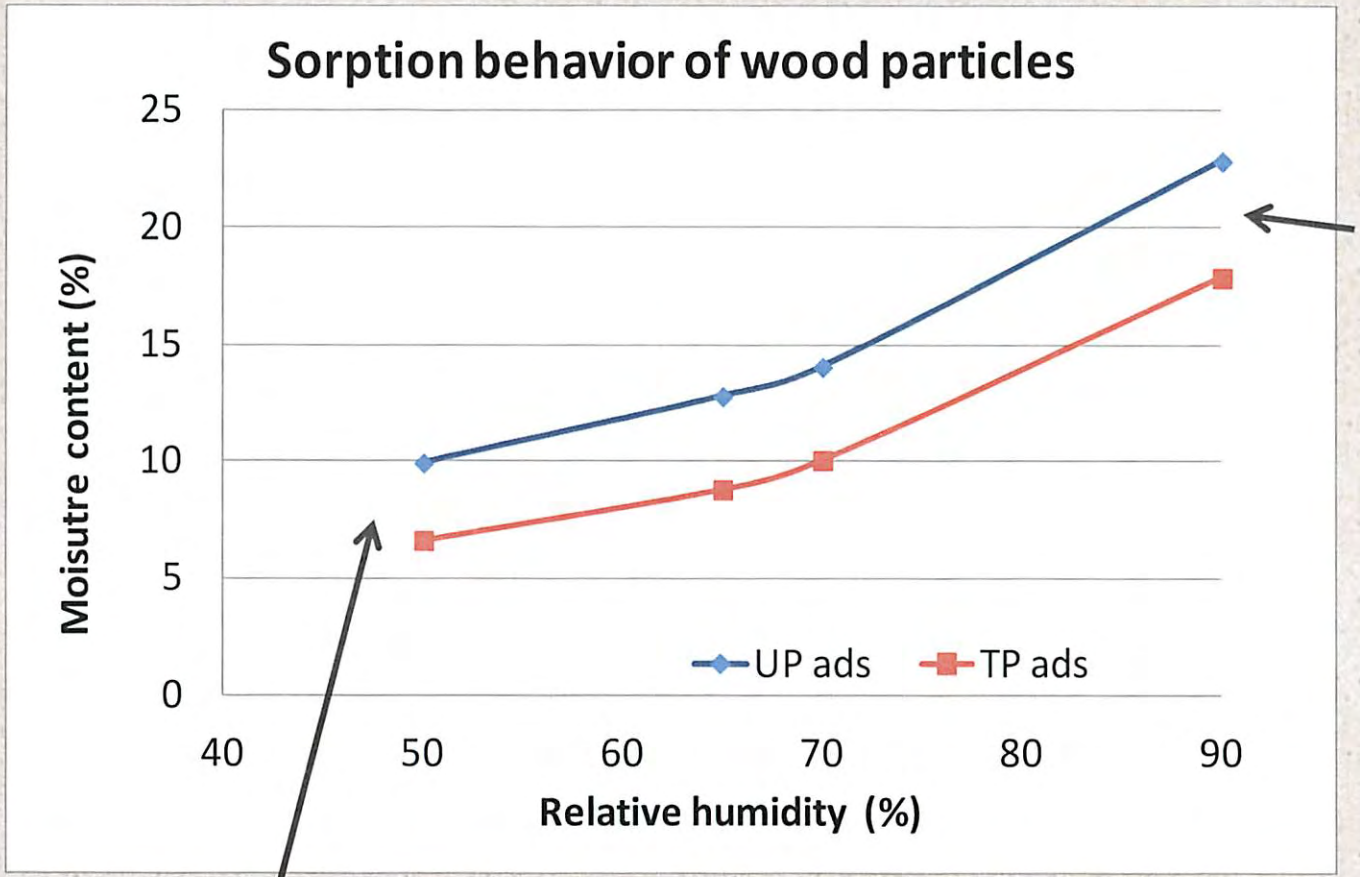


In TP, the intensities of the lignin-type peaks 11 (phenol) and 13 (2-methoxy-4-vinylphenol) were increased by 1.7 and 1.4 times, respectively.

Quantitative chemical composition

Constituent	UP (ppm)	TP (ppm)	% change
Arabinose	1.637±0.037	0.143±0.013	−91.3
Galactose	1.757±0.042	0.518±0.027	−70.5
Glucose	18.604±0.479	23.082±1.491	+14.3
Mannose/Xylose	7.628±0.236	5.166±0.307	−32.3

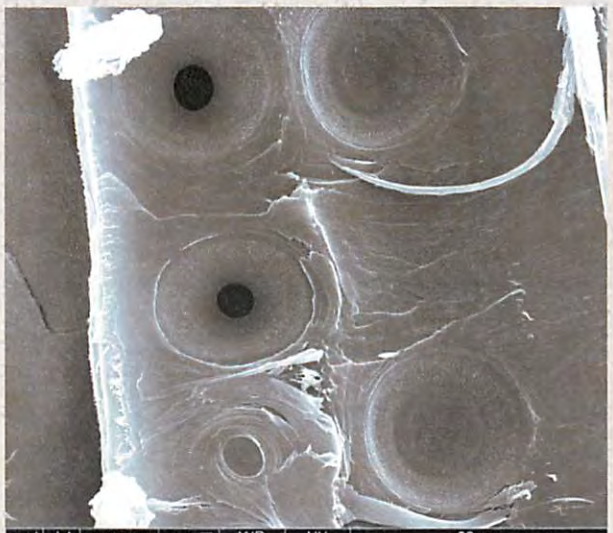
Effect of HWE on affinity with moisture



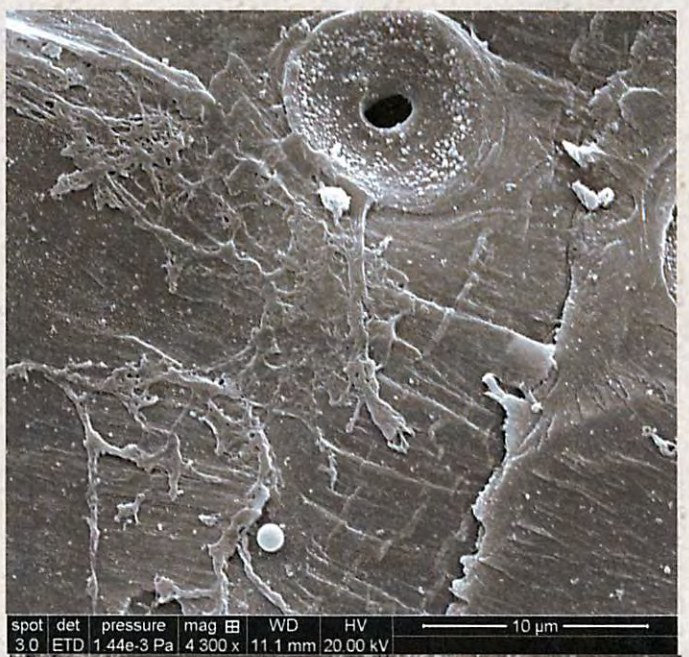
22% reduction MC

34% reduction of Moisture Content (MC)

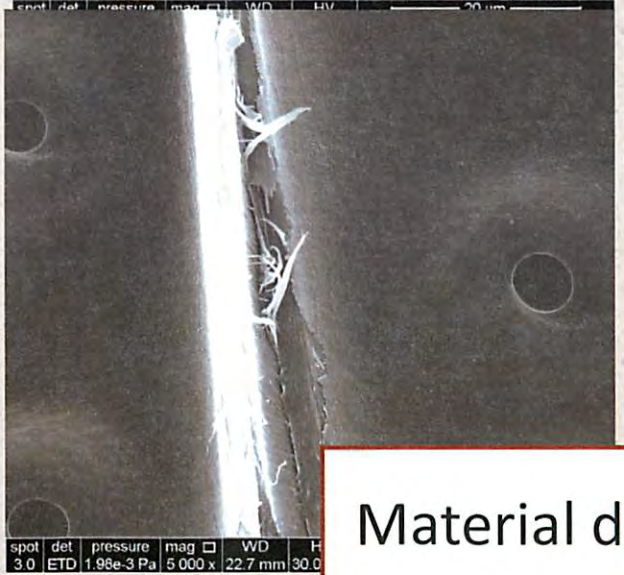
Effect of HWE on morphology



UP



TP



Material deposited on the surface is attributed to be lignin

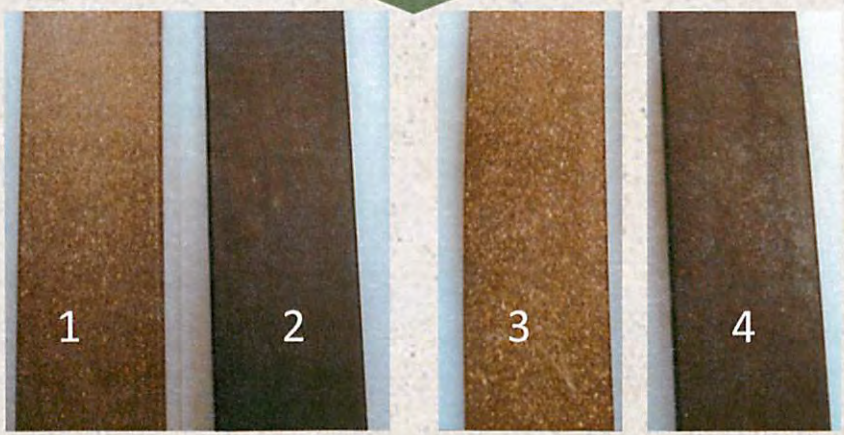
Production of WPCs

58% wood

Die temperatures:
175 and 190°C

COMPOUNDING/ EXTRUSION
(35-mm intermeshing twin-screw extruder)

HDPE or PP (32%) **+ additives and lubricant** (10%)

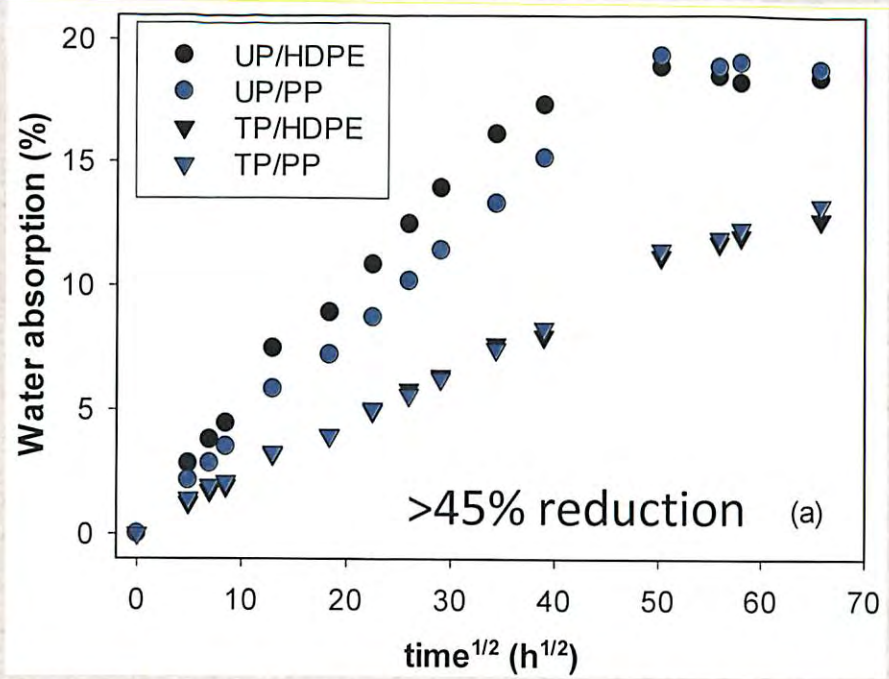


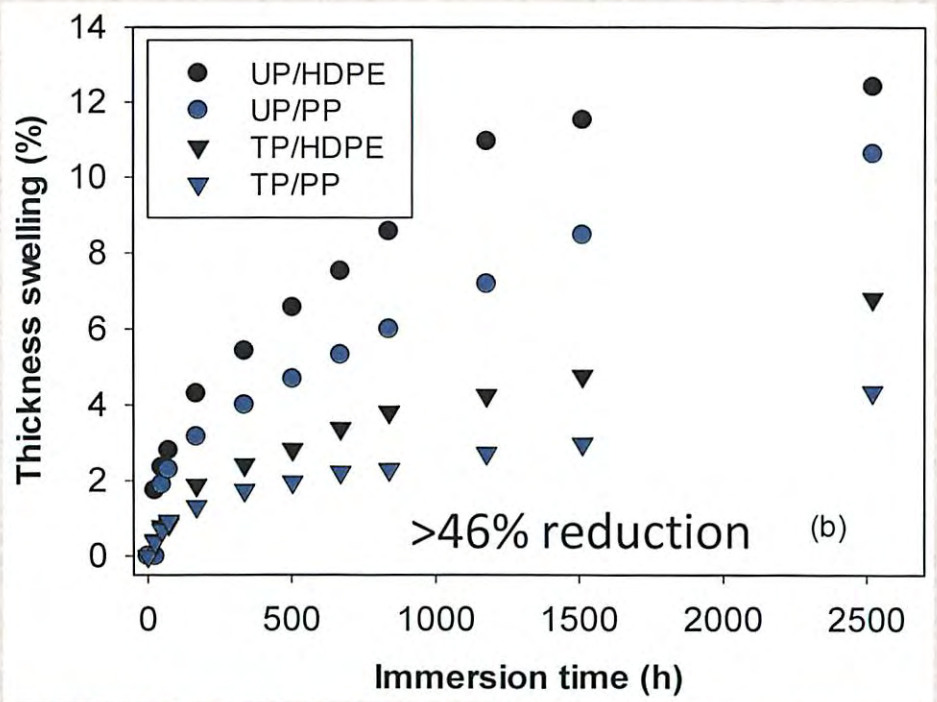
Formulation	Density (g/cm³)
1- UP+HDPE	1.18±0.03
2- TP+HDPE	1.18±0.03
3- UP+PP	1.10±0.01
4- TP+PP	1.10±0.01

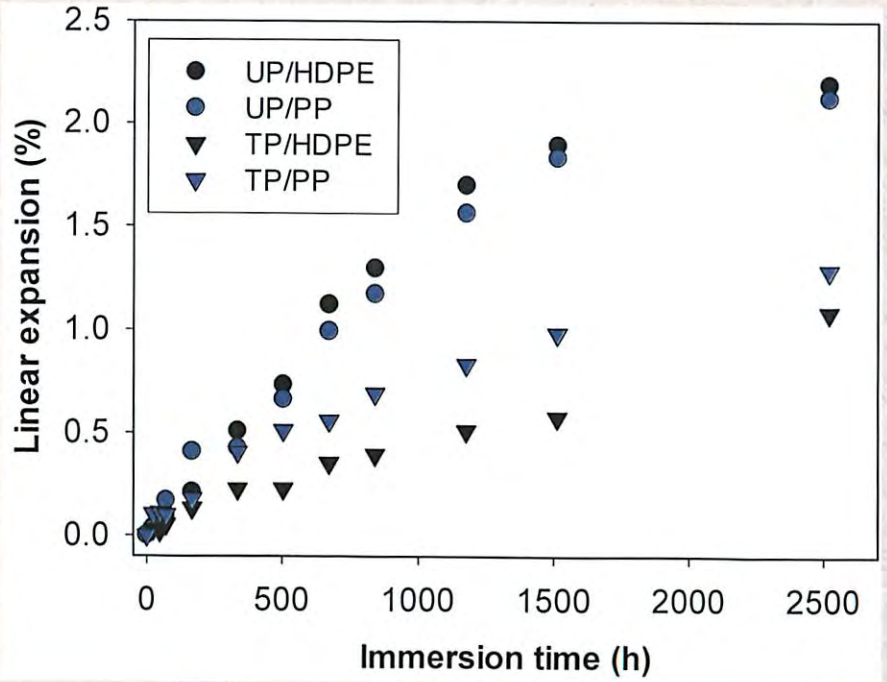
Evaluation of WPCs

- Long term water absorption **(180 days)** (ASTM D570)
- Mechanical properties (ASTM D790)

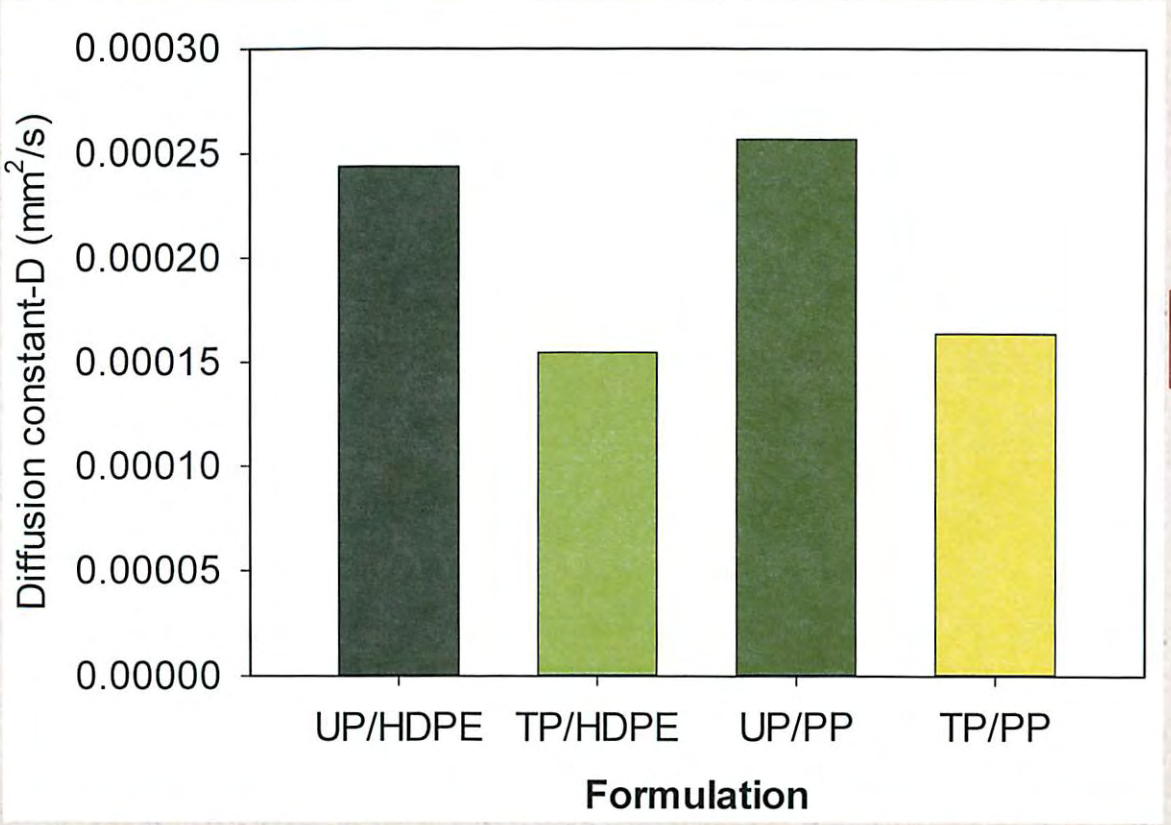
Water immersion tests







Diffusion of water in WPCs

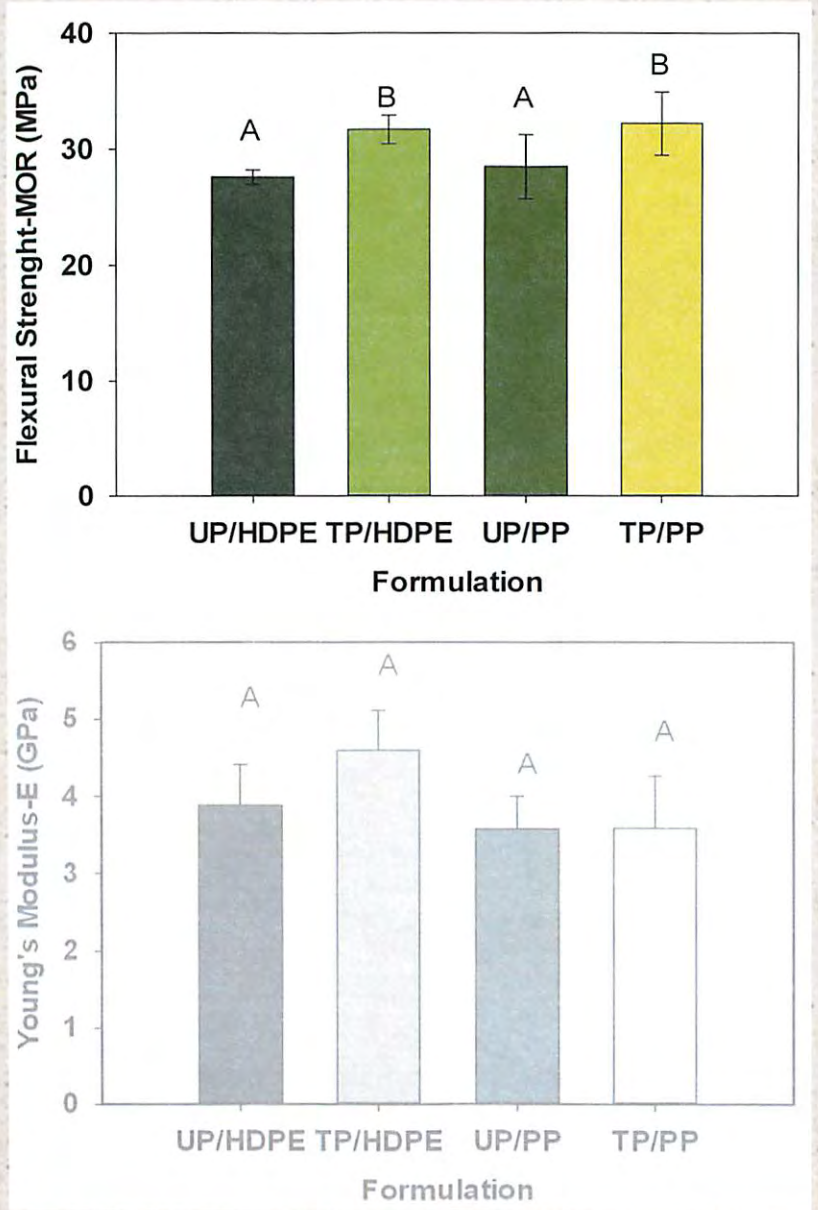


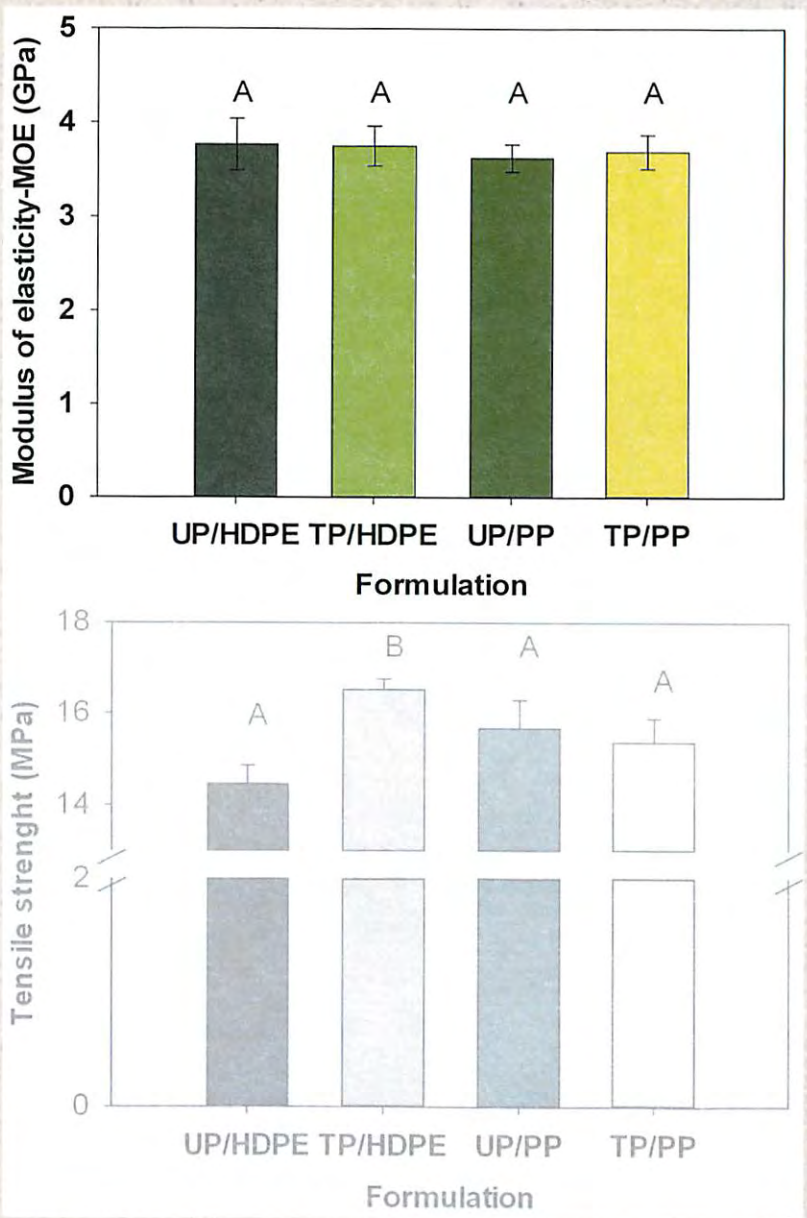
~36% reduction in D

(Fick's Law of Diffusion)

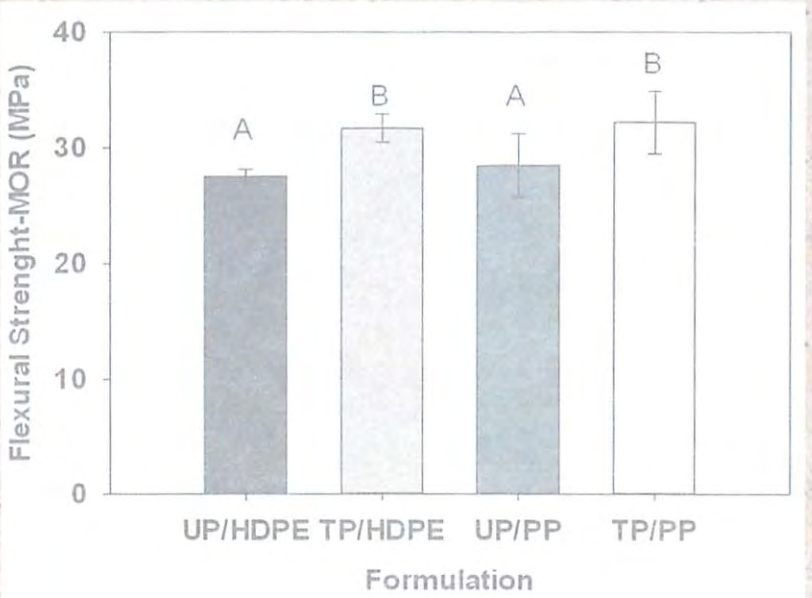
Procedure of Rangaraj and Smith (2000)

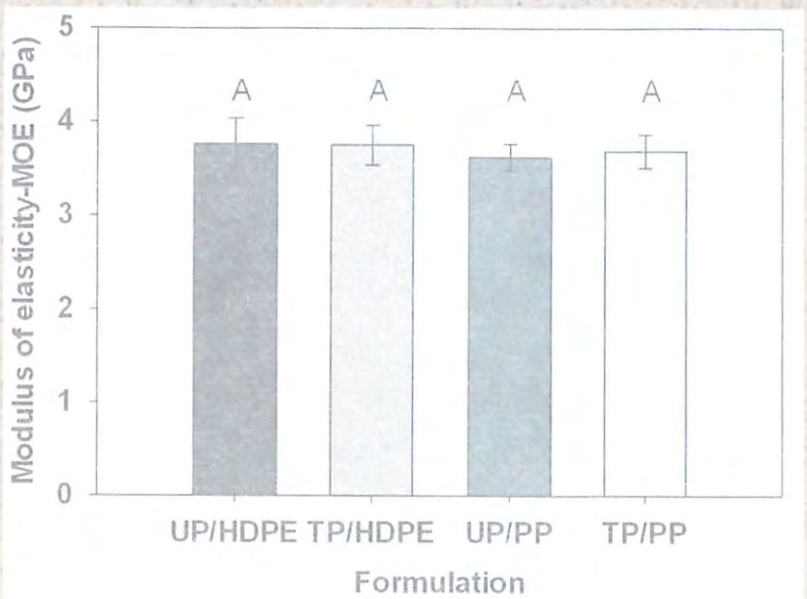
Mechanical tests results

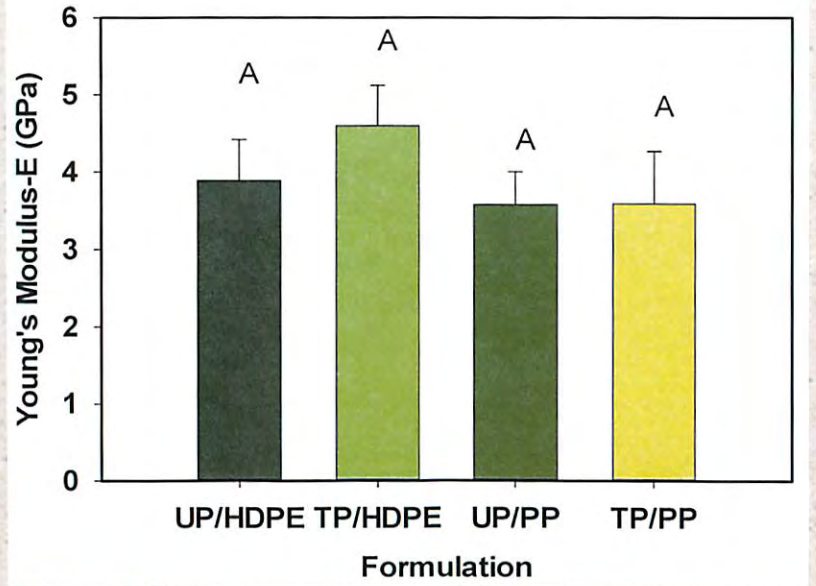


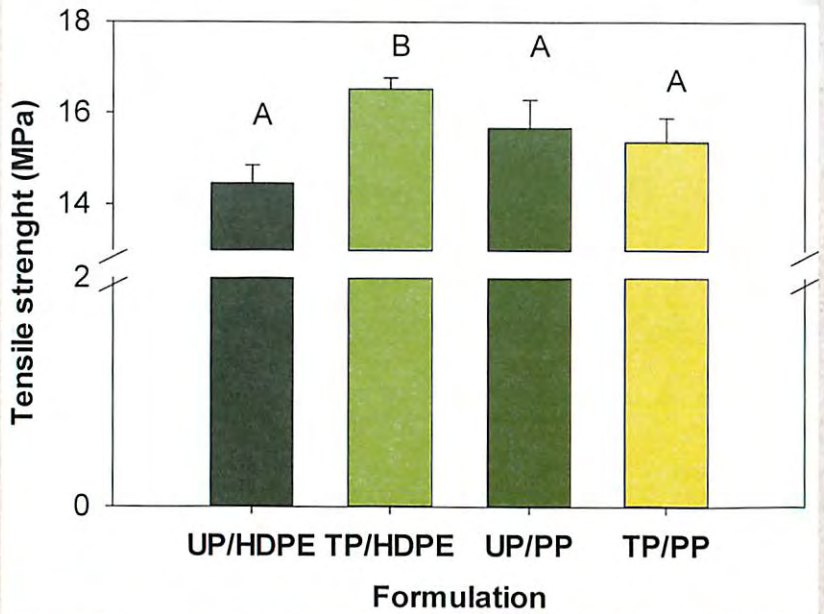


Mechanical tests results



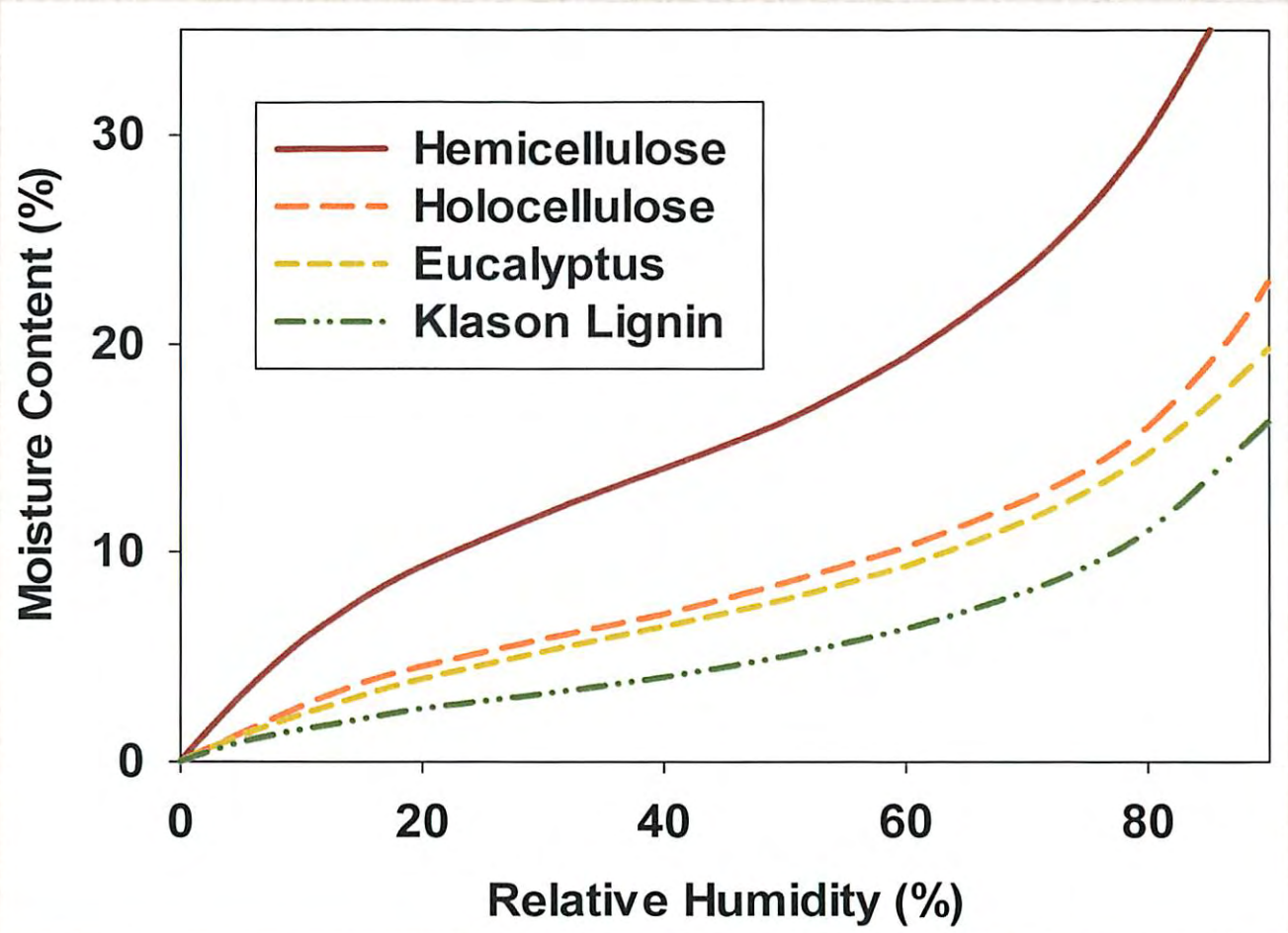






- Changes in chemical composition
  - *Decrease of hemicelluloses*
  - *Relative increase of cellulose content*
  - *Higher proportion lignin content*
- Structural and morphological changes

Hemicellulose is the most hydrophilic constituent of wood

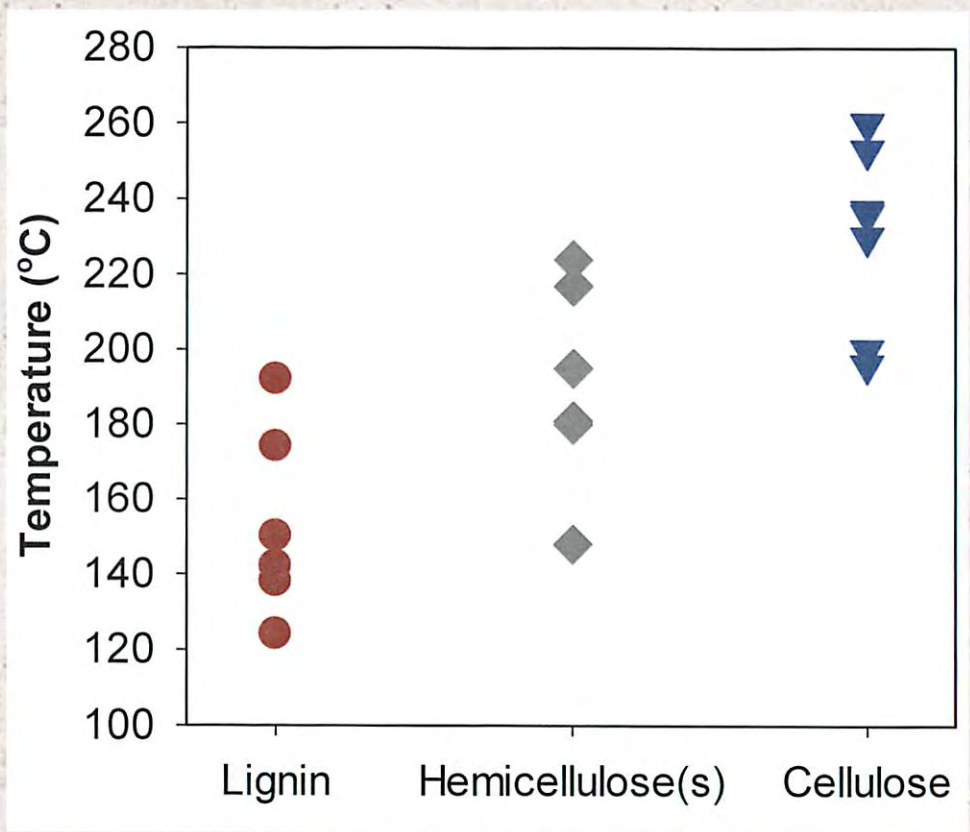


Adapted from Skaar, C. 1972. *Water in Wood*

Low thermal stability of lignin

- Temperatures >130°C are known to cause **lignin softening in middle lamellae**
- At 165-185°C, T_g of lignin is passed and the **softened lignin coats the surface of the separated fibers**

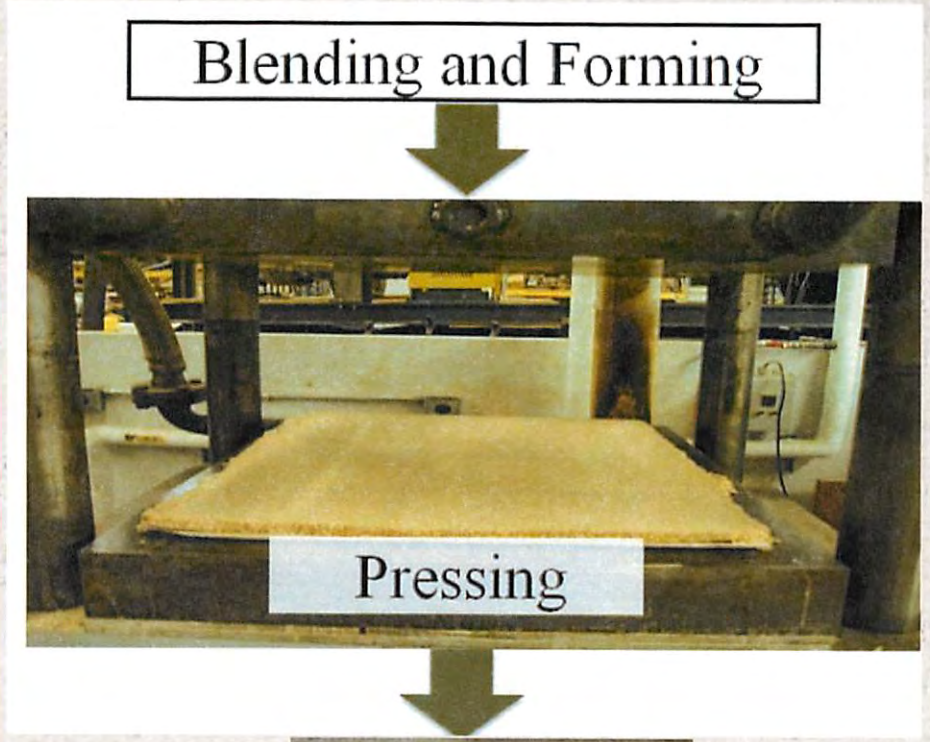
  (Fengel & Wegener, 1989)
- SUNY's hot-water extraction: 160°C for 90 min



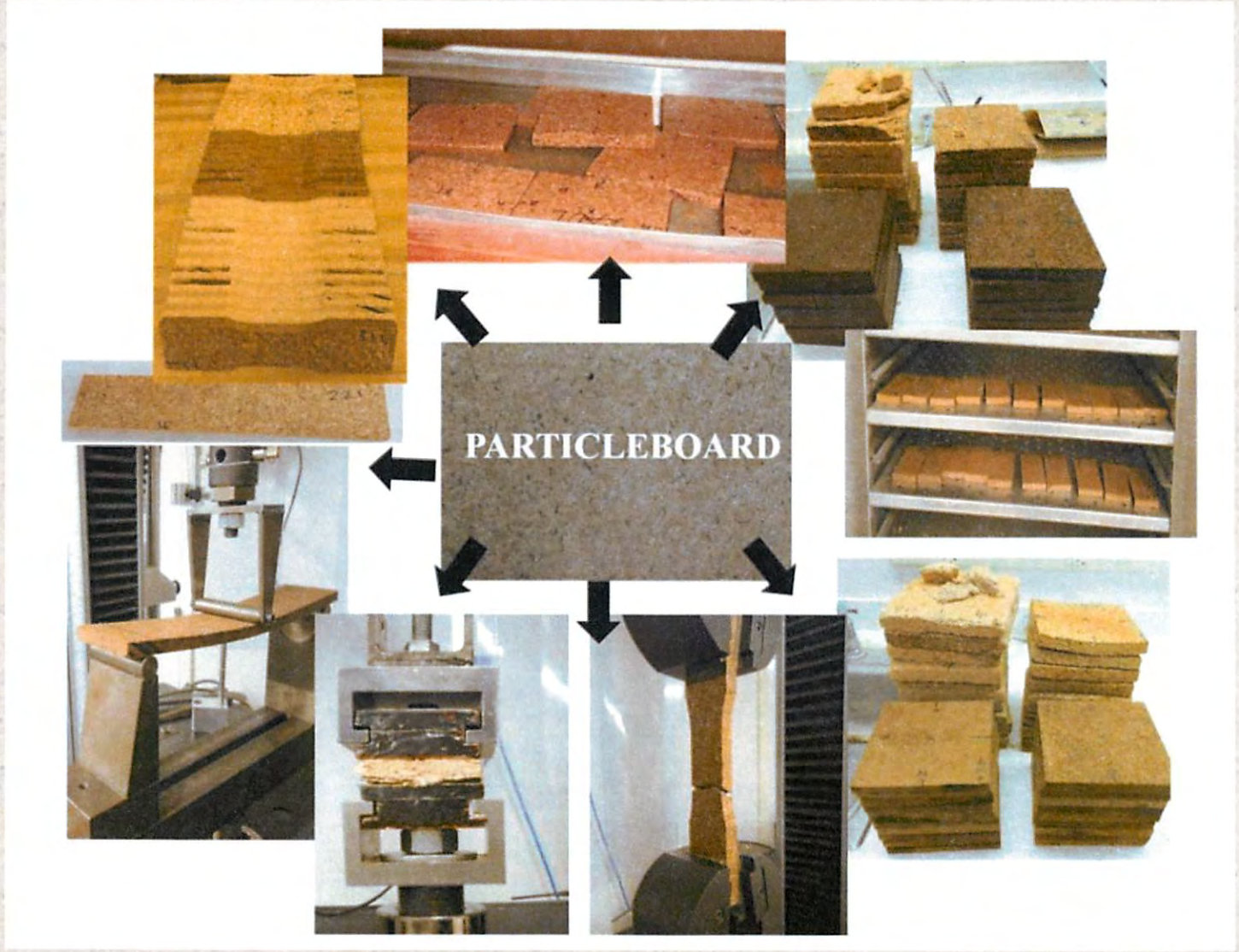
Adapted from: Salmen, N.L. 1982.

Effect of HWE on particleboard

- 7% MUF
(modified urea-formaldehyde)
- Density = ~670 kg/m^3)
- Panels dimensions:
610 x 610 x 12.5mm

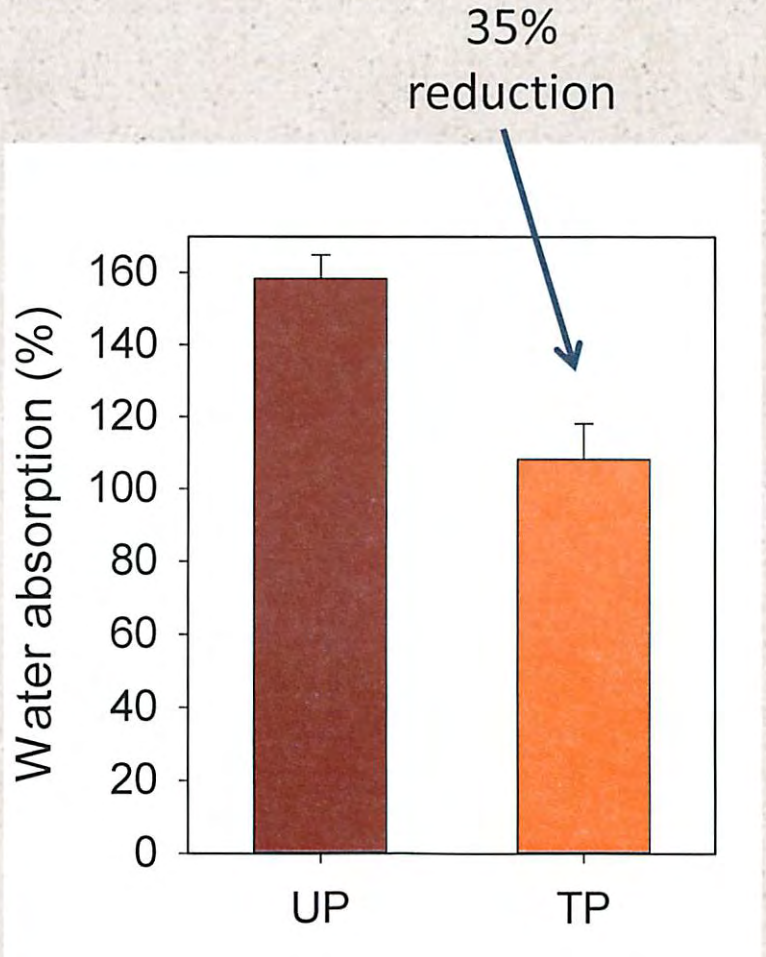


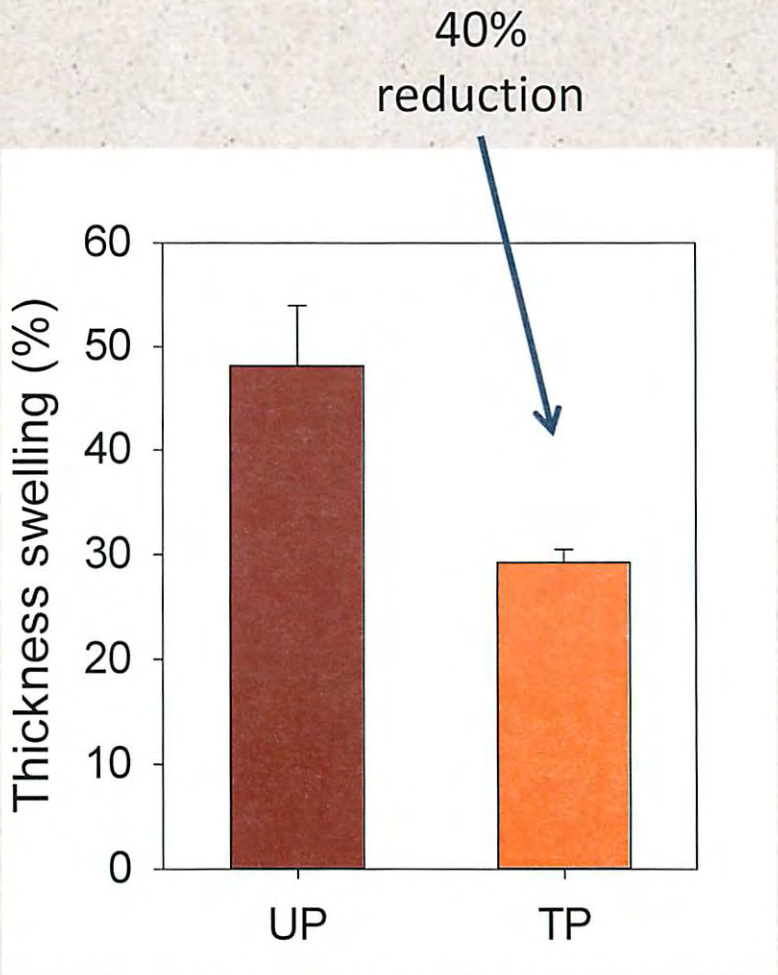
Evaluation of particleboard



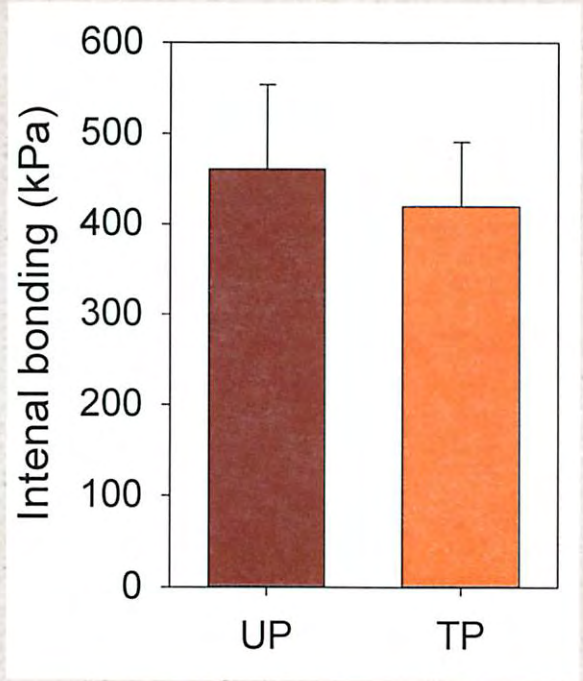
Testing according to ASTM D1037 06a and ANSI A208-1-1999

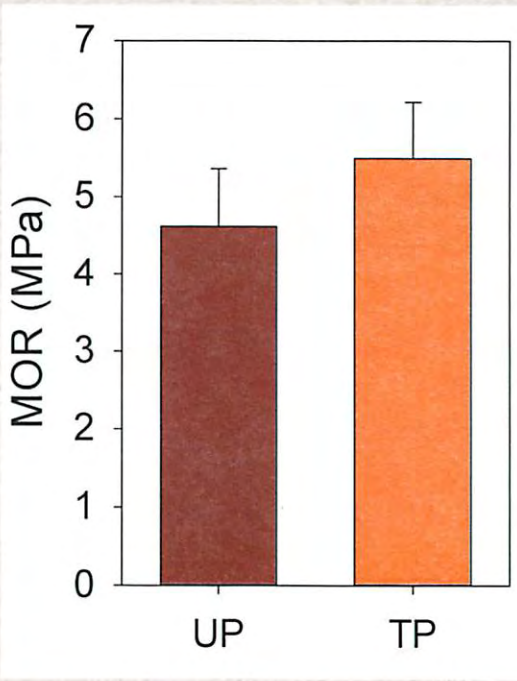
Water absorption and thickness swelling (24-h immersion)

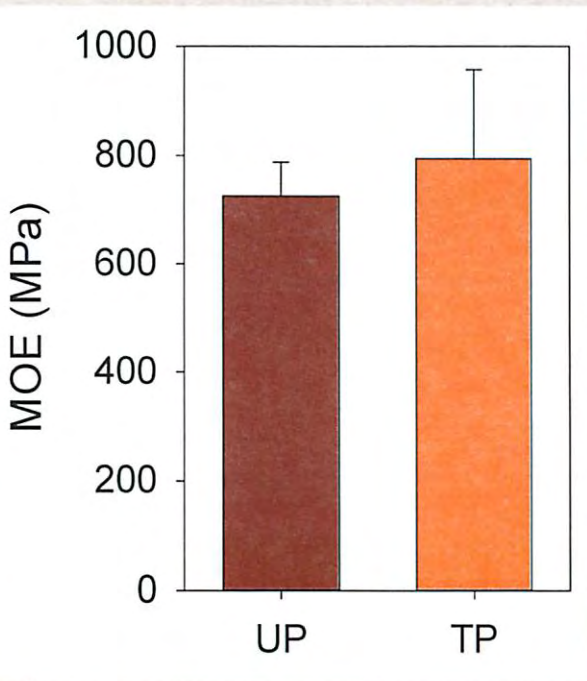




Mechanical properties

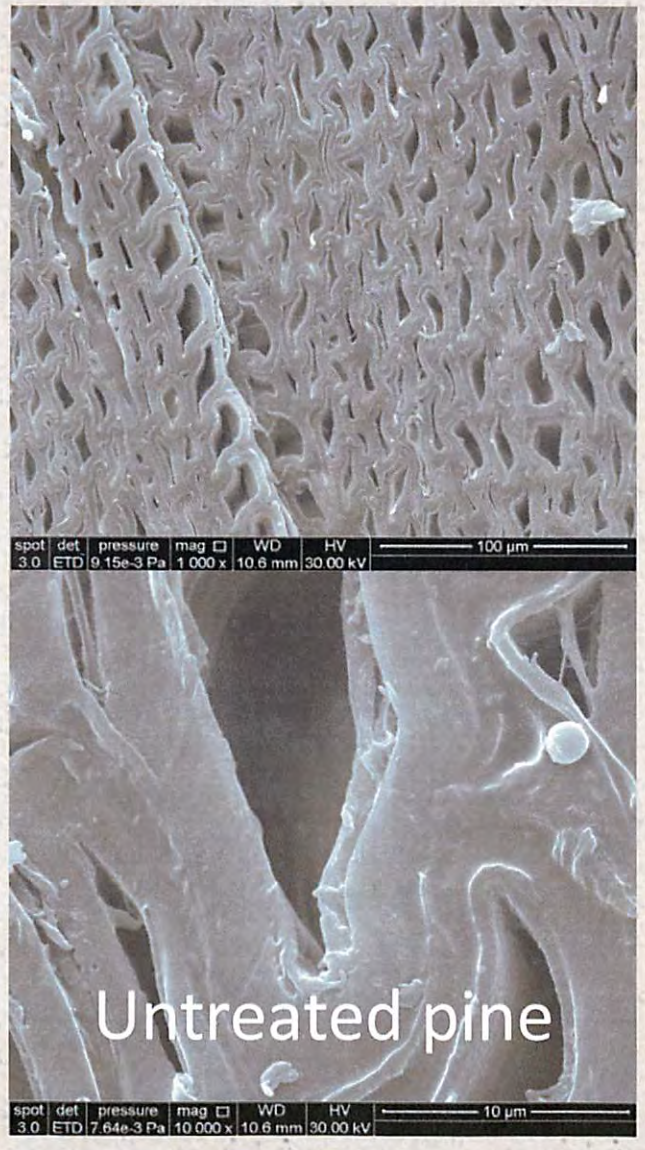






Statistically no changes in mechanical properties

Better deformation of wood



HWE impacted:

- Deformation
- Compressibility
- Contact area
- Presence of voids

Chips compressed at 150°C, 50 MPa, 3 min

What did we learn?

- HWE enhanced moisture resistance of WPCs (PP and HDPE) produced with *undebarked* pine.
- HWE process provides a potential solution to increase WPC dimensional stability and reduce micro-cracking.
- Positive impact of chemical modification changes through HWE on properties that affect the durability of WPCs.
- Mechanical properties were either same or showed improvement.
- Integration of HWE in composite plants could diversify products portfolio (sugar-rich hemicellulose extraction for biofuels and other value-added co-products).

The bottom line.....

Biorefinery technology produces value out of wood & extract streams

BUT

need BOTH to make it work

For more detailed information:

Pelaez-Samaniego, M.R., Yadama, V., Lowell, E., Amidon, T.E., and Chaffee, T.L. 2012

Hot water extracted wood fiber for production of wood plastic composites (WPCs).

Holzforschung 67(2): 193-200