5th Latin American Congress on Biorefineries
From laboratory to industrial practice
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Sustainable Biomaterials for wood panels adhesives

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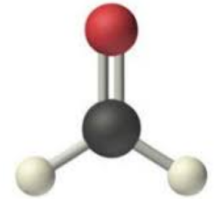
Wood based adhesives: Today



Formaldehyde, CH_2O

- *Petroleum based polymers*
- *The panel industry, is the larger user of products based on formaldehyde*
- *More than 50% of the formaldehyde produced in the world is used for the resin production and about 90 % of these resins are used in the production of wood based panels*

Approaches for Formaldehyde emission reduction in Synthetic Adhesives

- Control of synthesis and formulations
- Lowering Formaldehyde/urea Molar Ratio
- Scavengers (urea solution, dry urea, bisulphites)
- Formaldehyde catchers (low molar ratio resins)
- Introduction of crosslinkers (melamine)
- Post treatments (Ammonia solutions, etc.)

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Key drivers for the use of Bioadhesives

- *Recent government legislative changes to minimize the health effects relating to product emissions of volatile organic chemicals (VOCs), most notably formaldehyde*

- Increased pressure to be sustainable (NGO´s, Green Buildings Organization)

- *The use of renewable materials as a cost effective replacement for petrochemical components of adhesives.*

- *Price volatility of petroleum based adhesives*

- There are some organizations that believe that any formaldehyde *is unacceptable*

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Natural Adhesives: Challenges and opportunities

- Bio-based polymers are materials which are produced from renewable resources (Lignin, Protein, Tannin, etc.)

- Biobased Wood adhesives with the same bonding performance and same cost or lower than syntetic adhesives (UF or PF adhesives)

- Sustainable adhesives should not only be available at low costs, but also need to be easily distributable, fast reacting, and have a long pot life.

Disadvantages of the Biobased Adhesives

- Availability
- Properties
- Uncertainties about health and safety
- Maturity

Natural Wood Adhesives

Saccharide based

Starch

Cellulose

Hemicellulose

Protein based

Animal Glue

Casein

Soy Protein

Aromatic Based

Lignin

Tannin

Oil based

Castor oil

Canola oil

Others

Natural Rubber

Liquefied Wood

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Comparison of Biomaterials for wood panels adhesives

Biopolymer	Potential for adhesives	Crosslinker examples
Lignin	Available, low cost, low reactivity, requires modification, low moisture resistance	Aldehydes (*e.g.* glyoxal), MDI, tannin
Tannin	Good adhesion, fast curing, high viscosity, good water resistance, poor geographical availability	Hexamine, glyoxal, TRIS
Protein	Available, low pressing temperature, high viscosity, low water resistance (mostly), denaturation required	Polyamines, PAE, PEI, MDI, (ketones)
Starch	Medium cost, low reactivity, low water resistance, modification/grafting required	Epoxies, MDI, tannin, chitosan

Hemmila V. et al; RSC Adv., 2017, 7, 38604–38630

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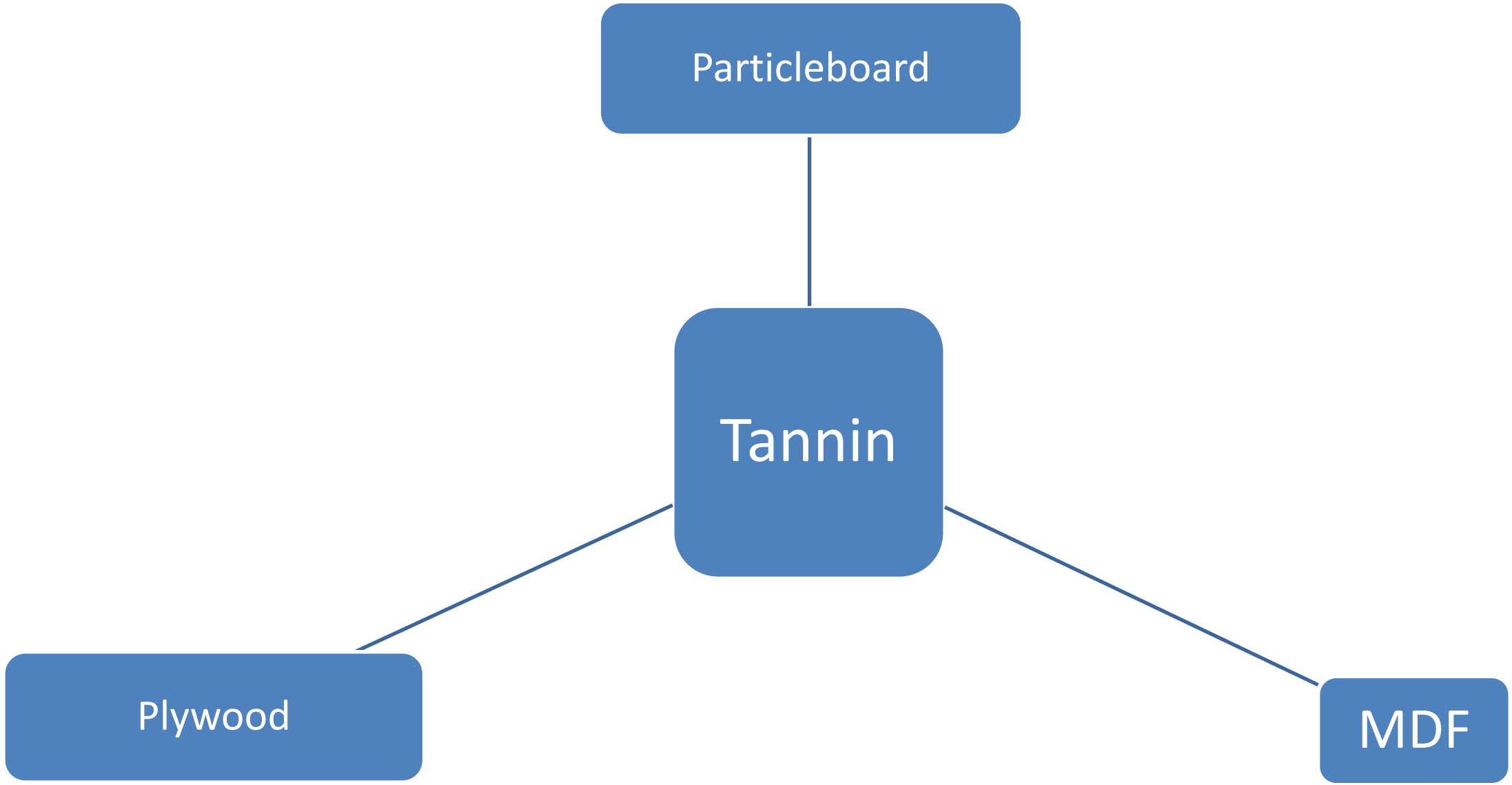
Tannin in Wood panels



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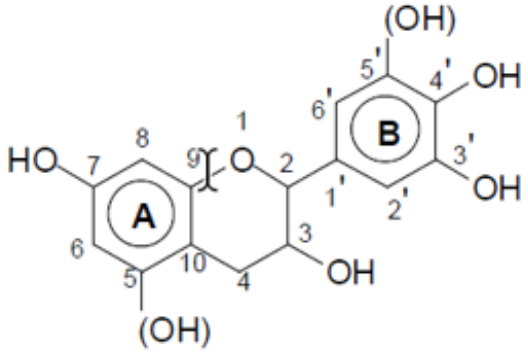
Tannin based adhesives



- Plant-derived extractives , typically obtained from bark
- Natural polymeric polyphenol very reactive
- Reaction is 10-50x faster than phenol (with formaldehyde)
- Potential to replace phenol

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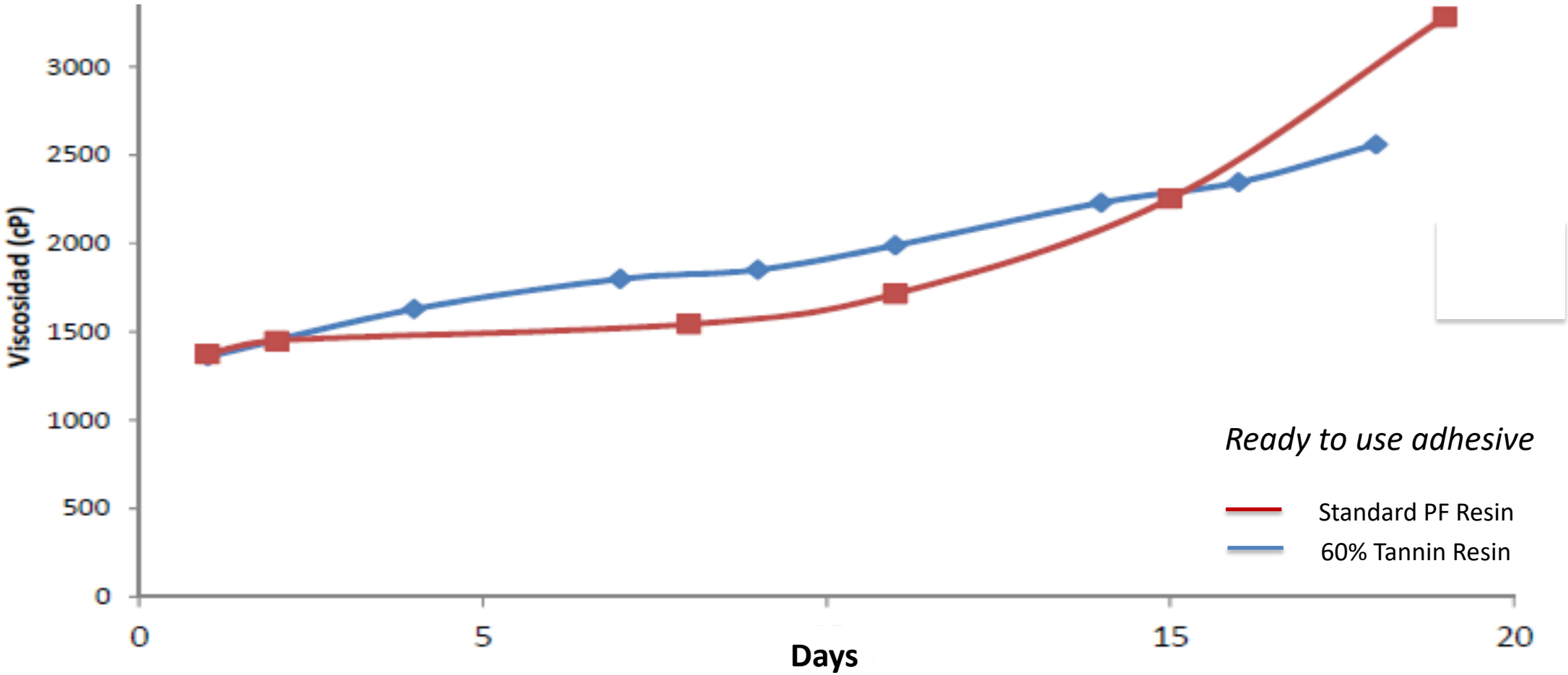
Tannin in Plywood

Resin Stability



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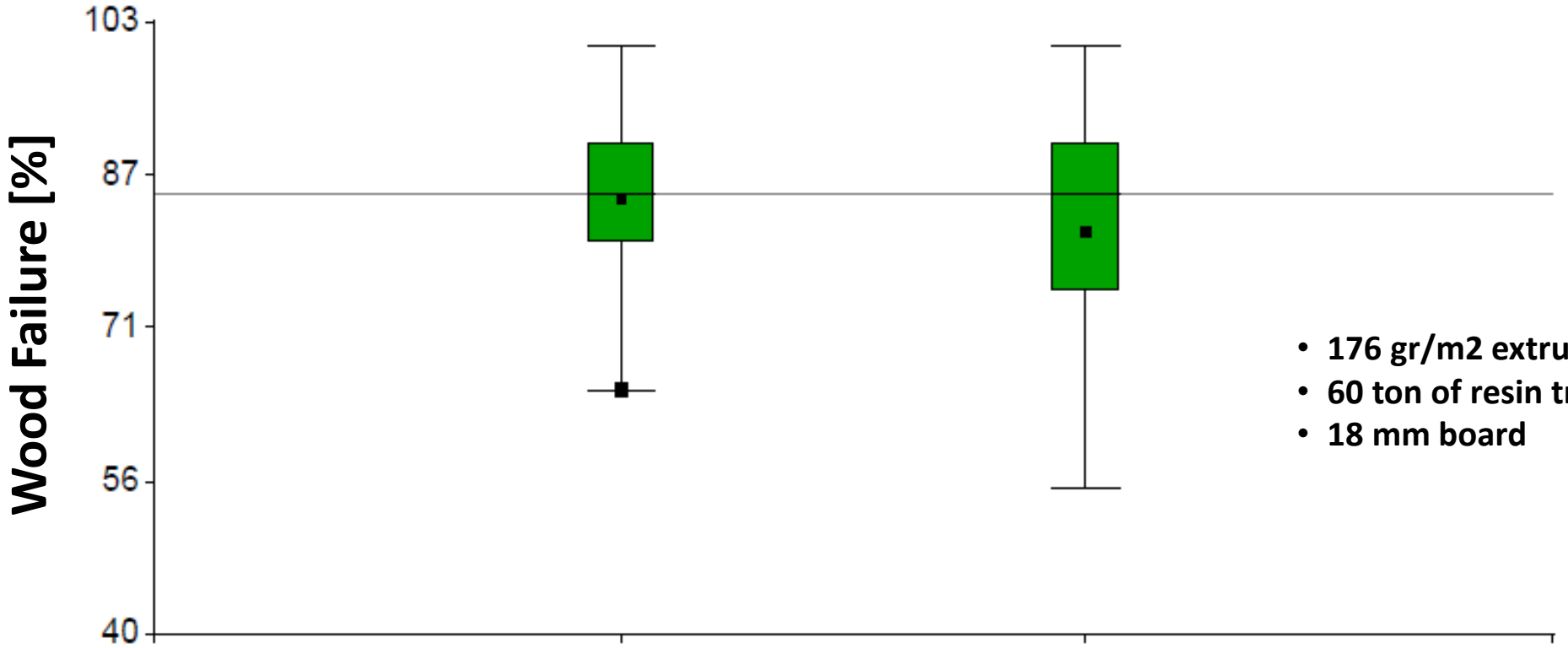
Tannin in Plywood

Industrial Trial Results.
60% Phenol replacement for Tannin



- 176 gr/m2 extruder blender
- 60 ton of resin trial
- 18 mm board

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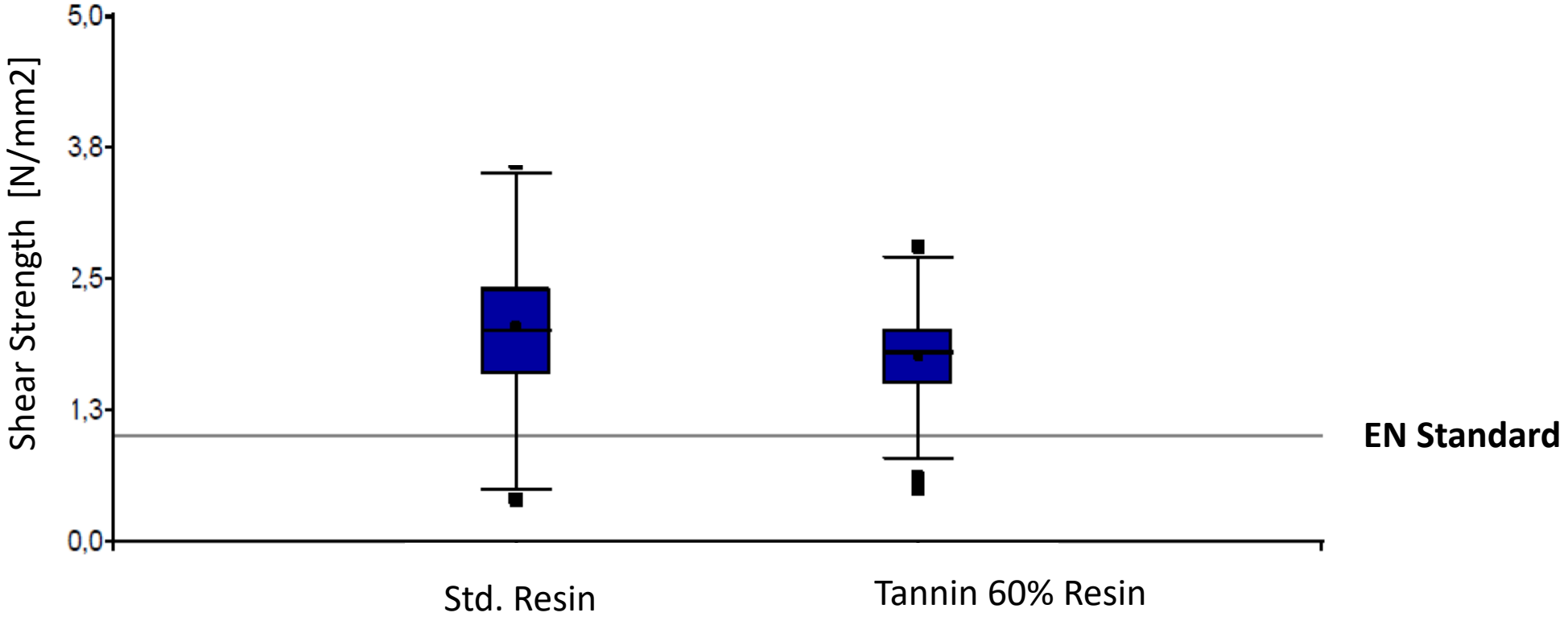
Tannin in Plywood

Shear Strength [N/mm2] 18 mm Plywood
Industrial Results



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Industrial trial using tannin based adhesive in Plywood

Blending

After prepress

After Press

Knife test

60% of Phenol replacement for radiata pine tannin

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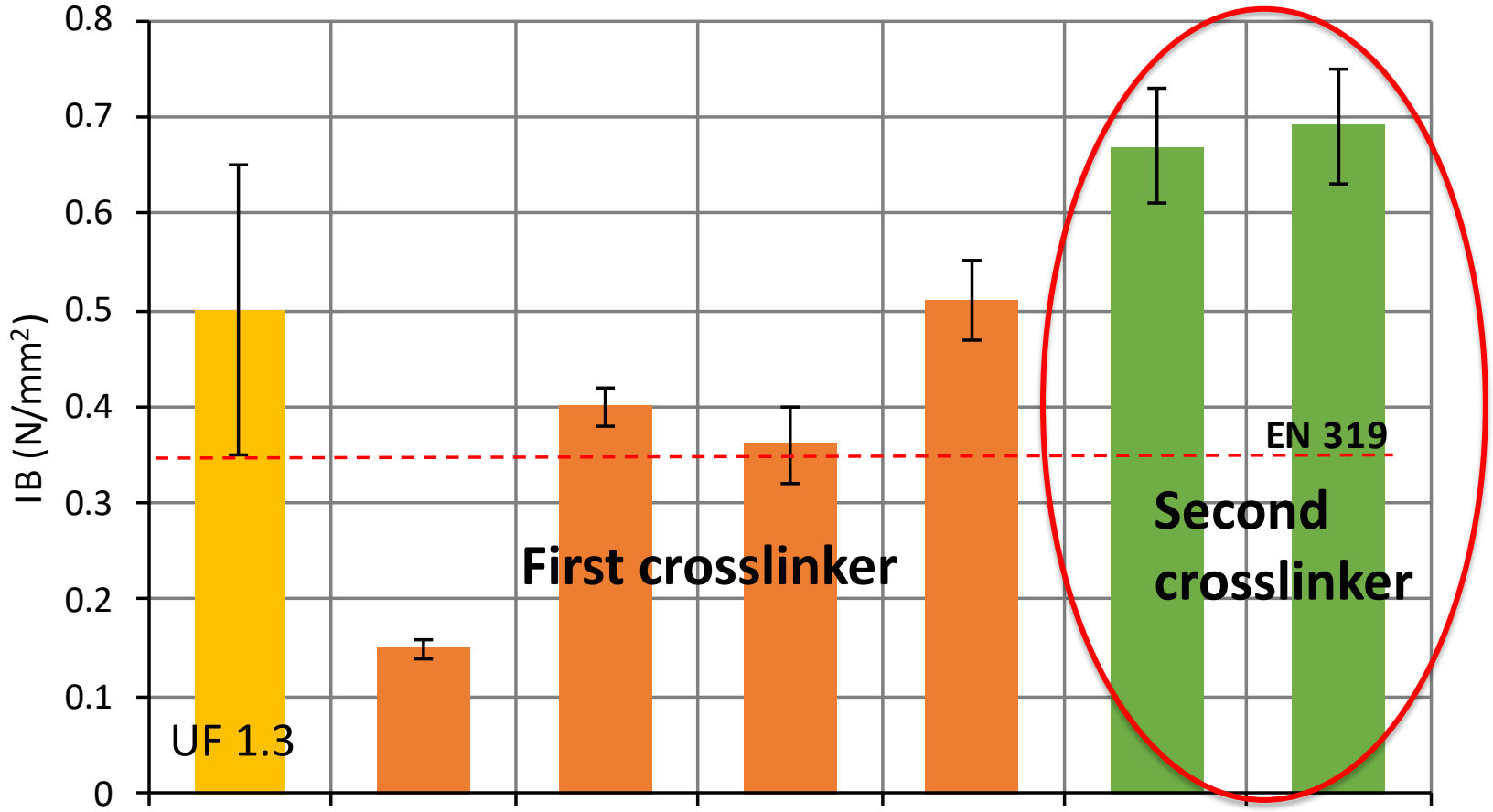
Radiata Pine Tannins in particleboard without formaldehyde



12 mm board
580 Kg/m3
8% resin Loading(CL)
11% resing loading (SL)

Pressing Time : 2 minutes at 180°C

High Potential for Tannin and second Crosslinker

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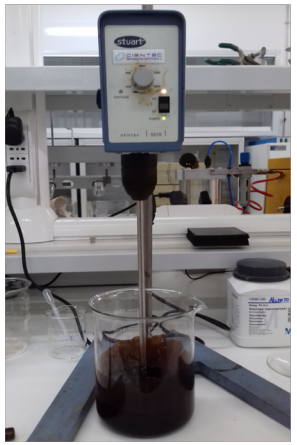
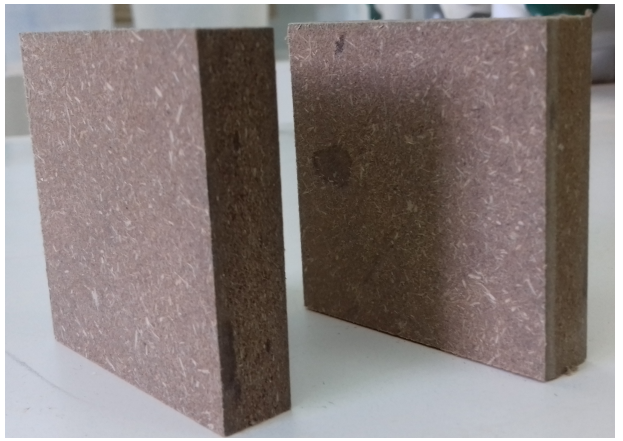
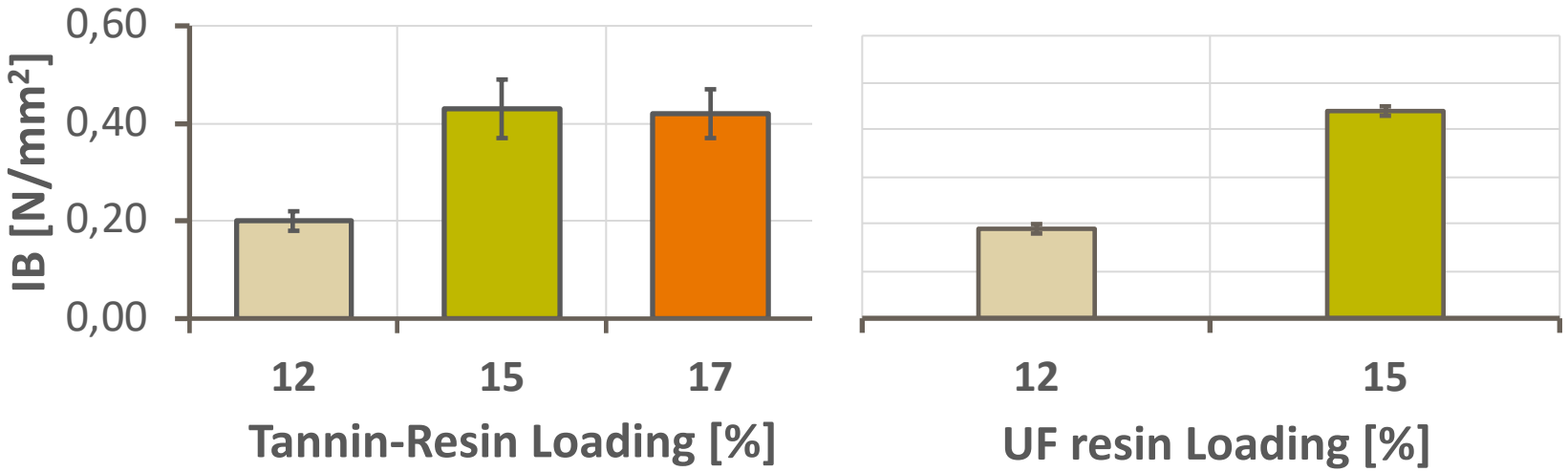
Radiata Pine Tannins in MDF without formaldehyde





12 mm MDF Board
600 kg/m3
2 minutes pressing time at 200 °C



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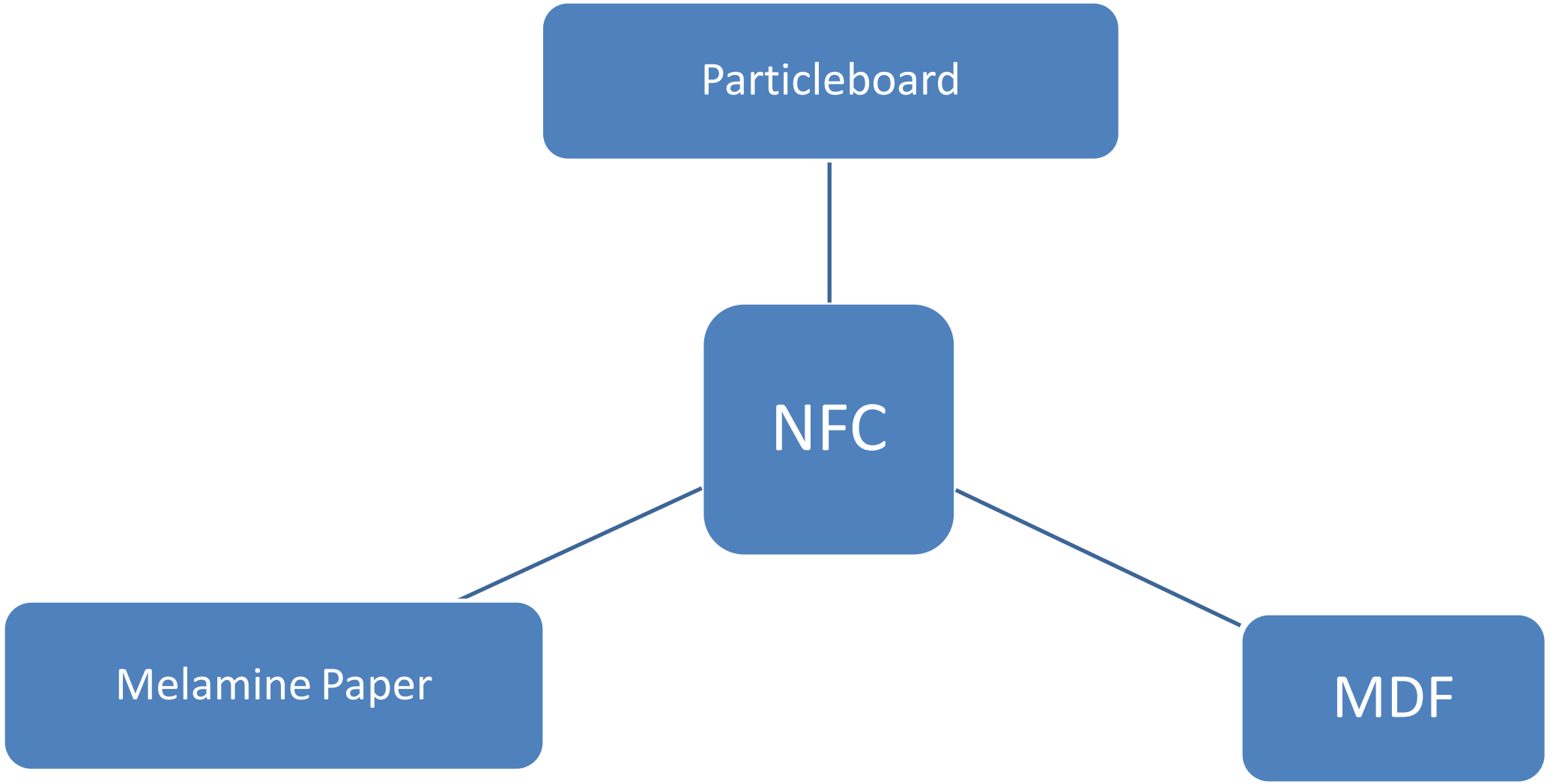
Tannin in Wood panels adhesives

- It is possible to replace until 60% of Phenol for radiata pine tannin in phenolic resins for Softwood plywood keeping the same performance at industrial scale

- It is possible to achieve similar performance (press factor, resin loading and board properties) between Tannin based adhesive free of formaldehyde and Commercial UF resins , for MDF and PB boards, at Laboratory Scale

NFC in Wood Panels



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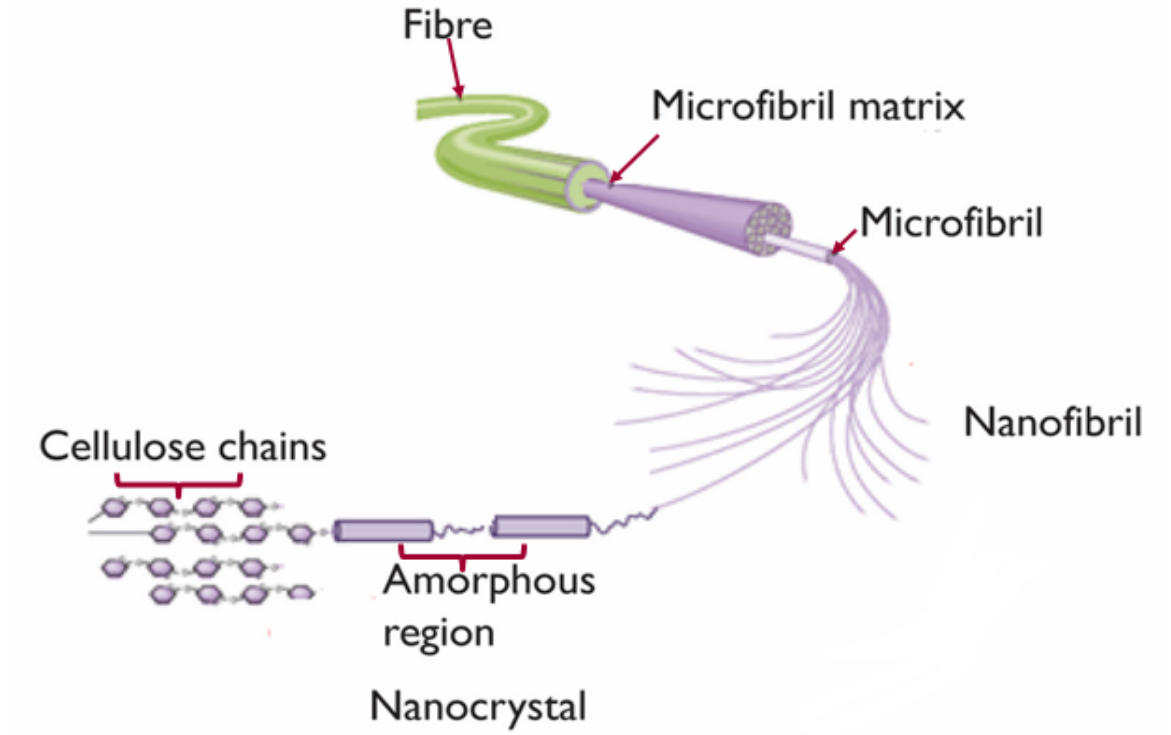
Nanocellulose: A Wood based Nanomaterial



Source: (Nelson, K. 2014)

1 mm = 10^6 Nanometers

Unique properties

- Mechanical
- Optical
- Surface area

Physical dimensions

- Diameters: ~10-100nm
- Lengths: ~100 nm–100 µm
- Different surface functionalities

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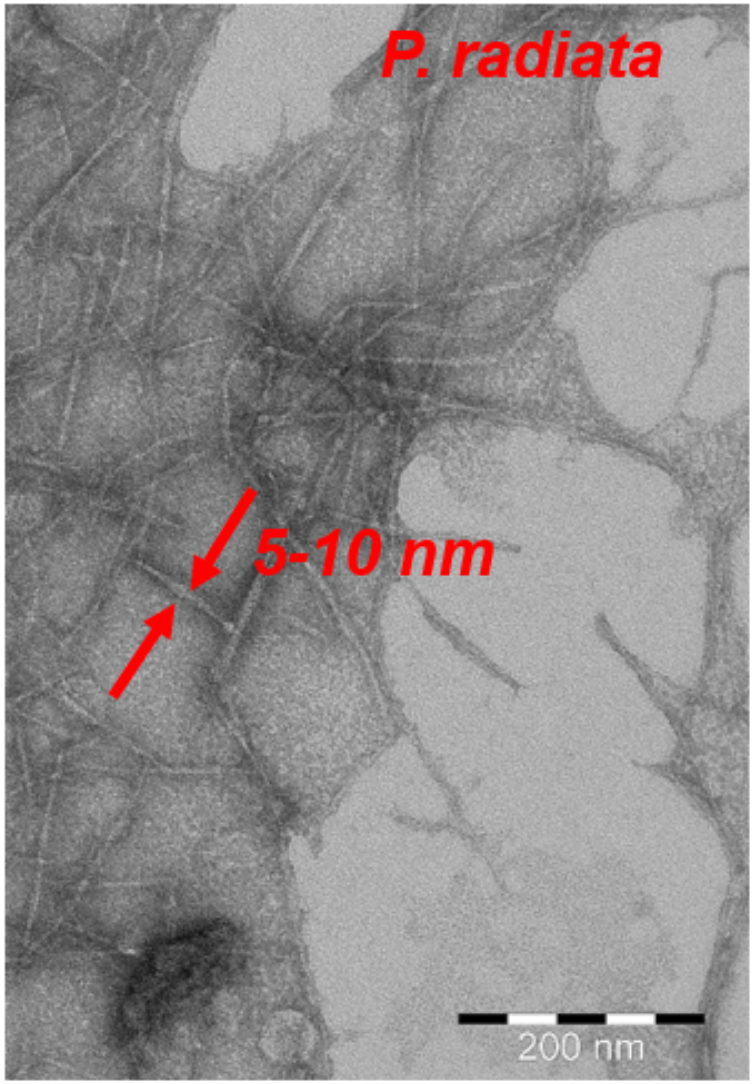
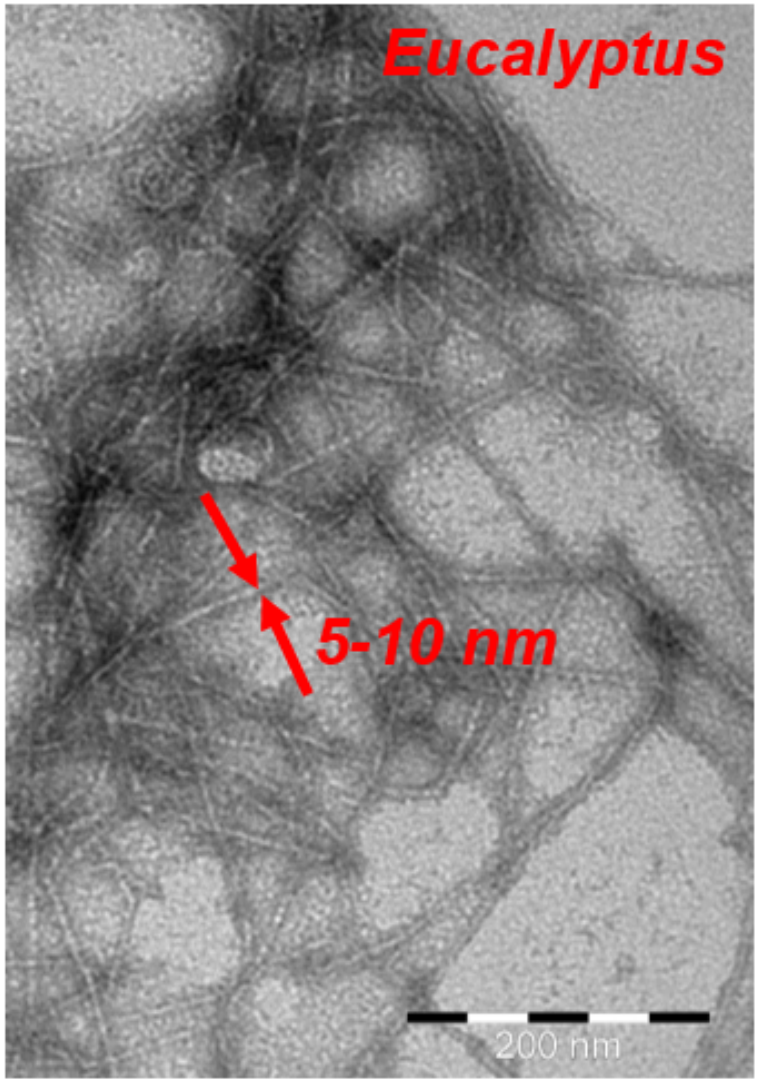
Nanocellulose in Wood Panels

- ✓ Nanocellulose-based materials have high strength and low weight.
- ✓ Nanocellulose has attributes that offer great reinforcing strength and/or optical clarity improving properties at lower costs.
- ✓ However, cellulose fibers are hydrophilic in nature

Morphology of NFC





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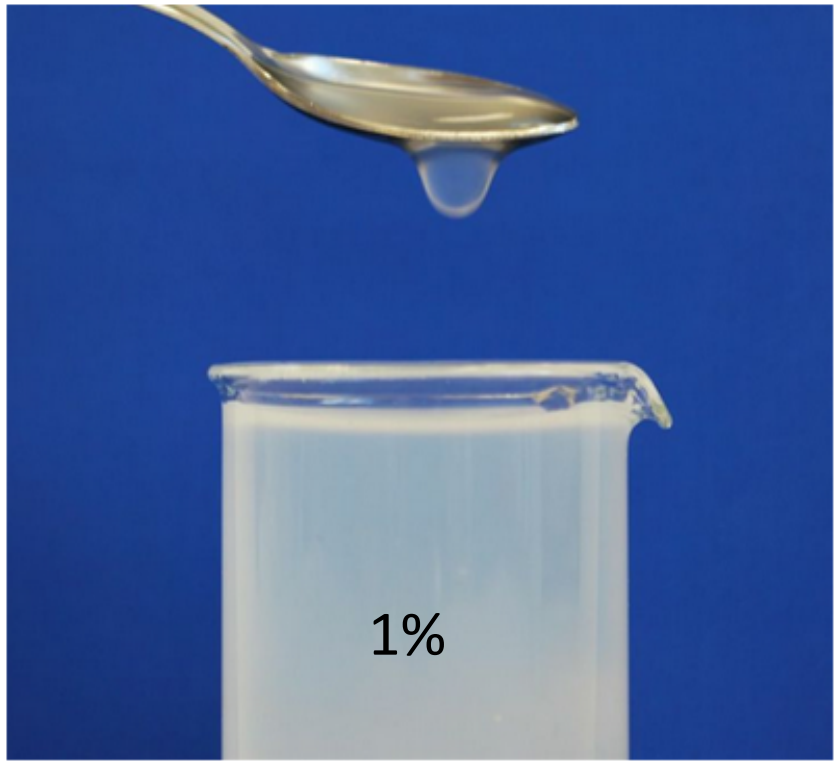
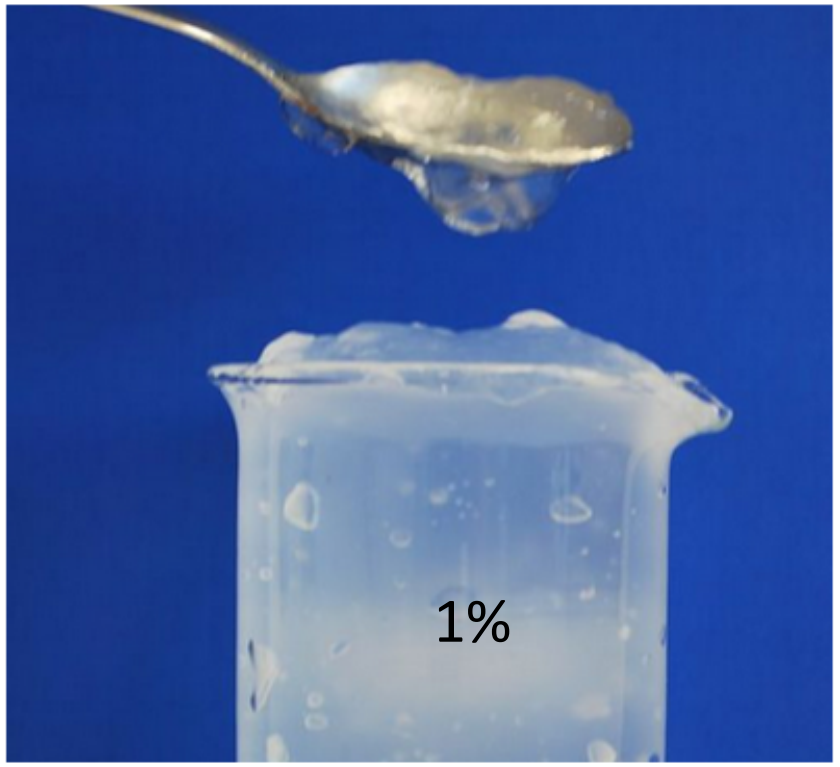
NFC of Pine and Eucalyptus



P. radiata NFC suspension



Eucalyptus NFC suspension

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NFC in Particleboard

- NFC from Radiata Pine
- Surface Resin: UF resin Molar Ratio 0.7 and 2% Melamine
- Solid content NFC : 2%
- 1% and 1.8% NFC in Surface Layer
- 3 Board Density Tested (500-540-580 kg/m3]

- **MOR increases with NFC Adittion**
- **Tickness Swelling decrease with NFC addition**

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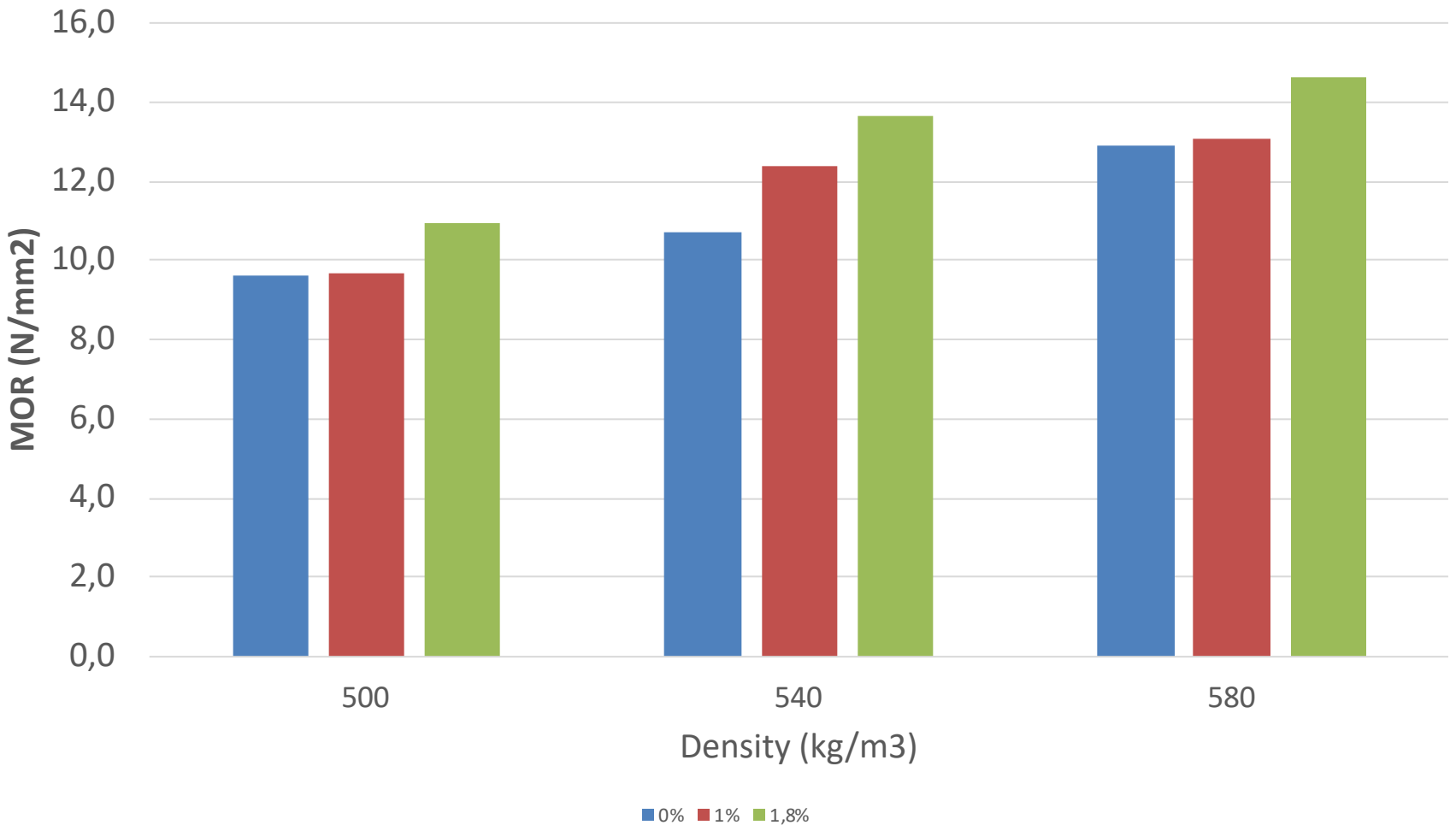
Effect of NFC in MOR from PB at different board densities



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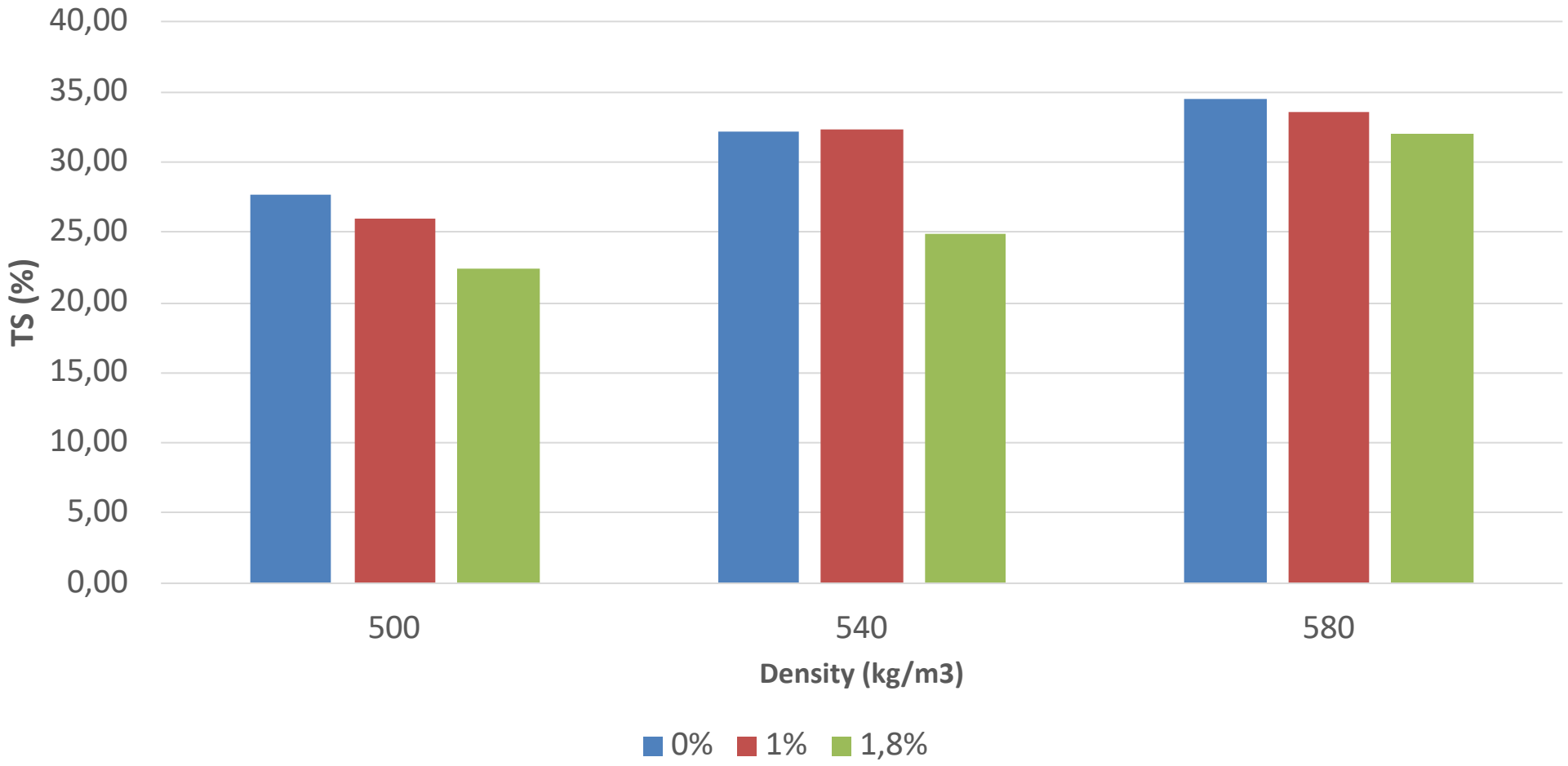
Effect of NFC in 24 h Thickness Swelling



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NFC in MDF boards

Main Objective

Identify the effect of variables such as gluing ratio and amount of NFC over the physical-mechanical properties of MDF

- NFC from Radiata Pine at 3% solid content
- Resin reinforcement with 1% and 2% of NFC
- UF resin molar ratio = 0.93
- 2 resin loading tested (18% and 16%)
- 12 mm Light board 600 kg/m3

- No clear effect in IB
- No clear effect in MOR
- No clear effect in Thickness Swelling

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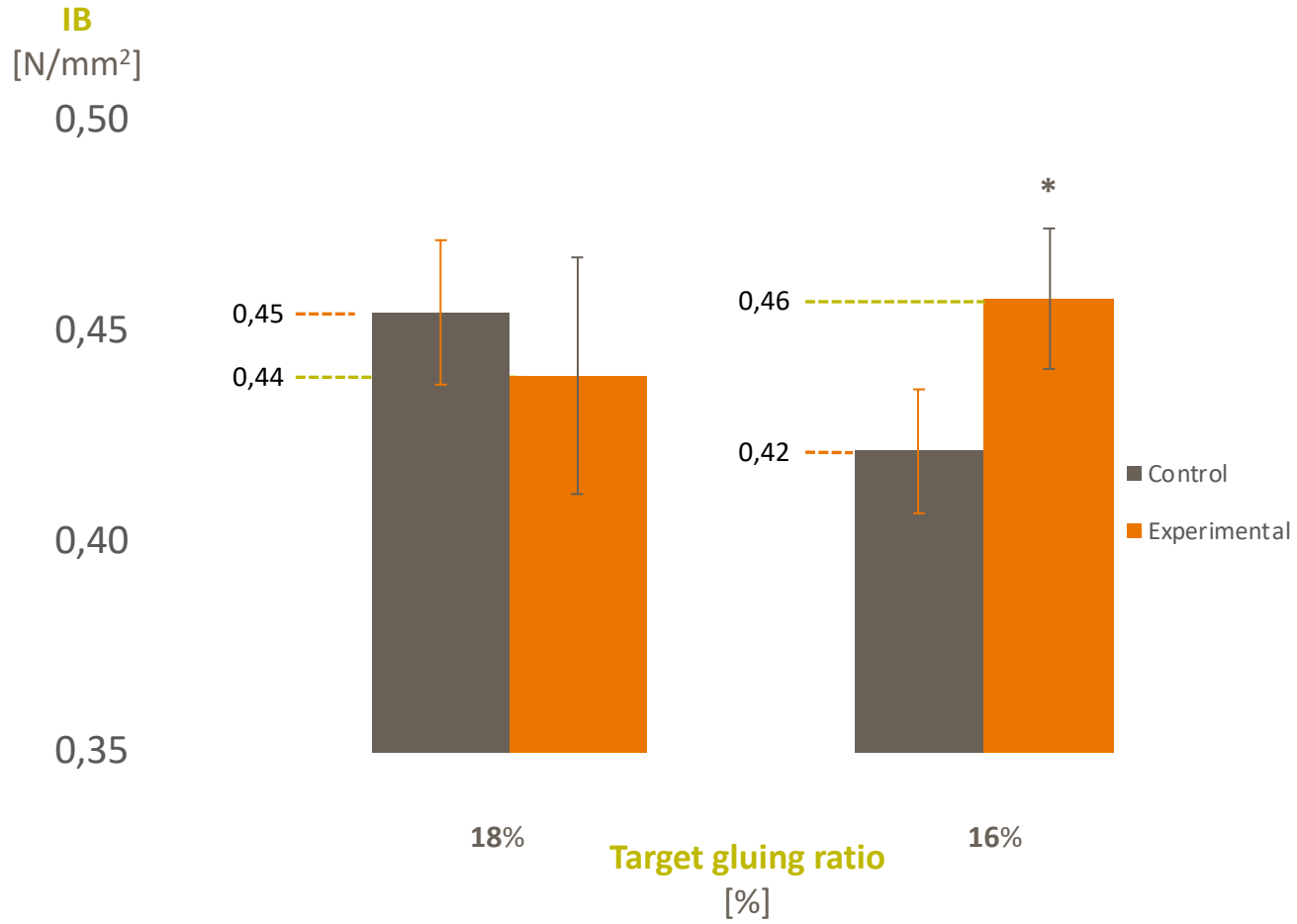
Use of NFC to improve UF resin bonding properties in MDF



- When lowering resin consumption by 10%, **IB values could be matched** by using nanocellulose as an additive

- How much? NFC/UF resin ratio: **1%**
  Mixture thoroughly mixed with mechanical stirrer

- Adding larger amounts leads to post-glued fibers. water removal challenges

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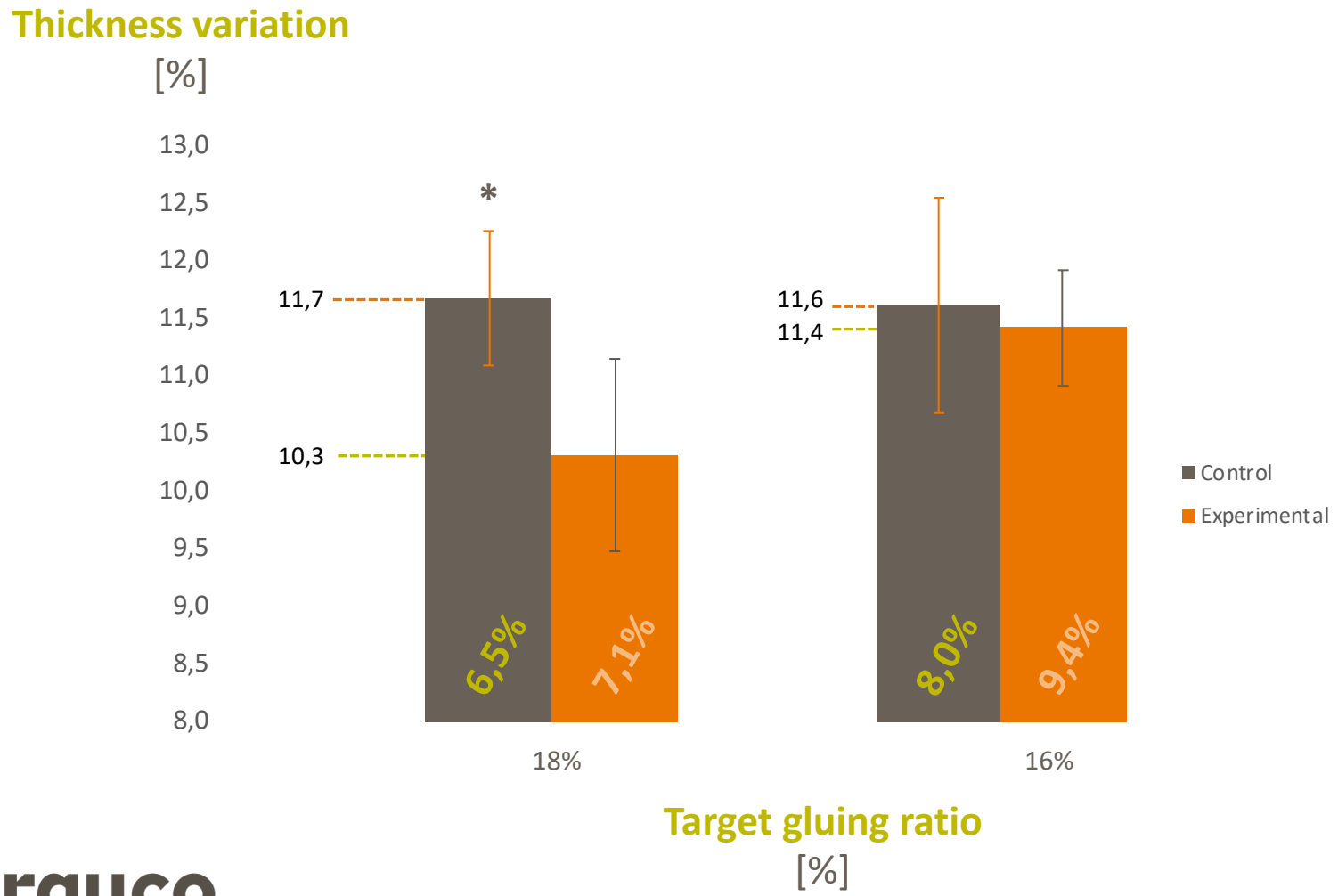
Use of NFC to improve UF resin bonding properties in MDF



- Gluing ratio of 18% showed difference when using NFC: **1,4% less swelling (12% improvement)**
- Values does not change when further reducing gluing ratio

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NFC in Melamine faced PB

Main Objective

Produce melamine-faced PB observing the behavior of NFC as an additive for MF impregnation resin

- **NFC from Radiata Pine** with and without Enzymatic Pretreatment
- Solid content: 2%
- 0,3 -1 gr/m2 NFC inmediatly after the first bath

- **Same results NFC with or without enzymatic Pretreatment**
- **80 gr/m2 paper increase about 90 cycles Taber test with NFC**
- **75 gr/m2 White paper and NFC has similar properties than 80 gr/m2 White Paper .**
- **Potential use of NFC instead of using TiO_2**

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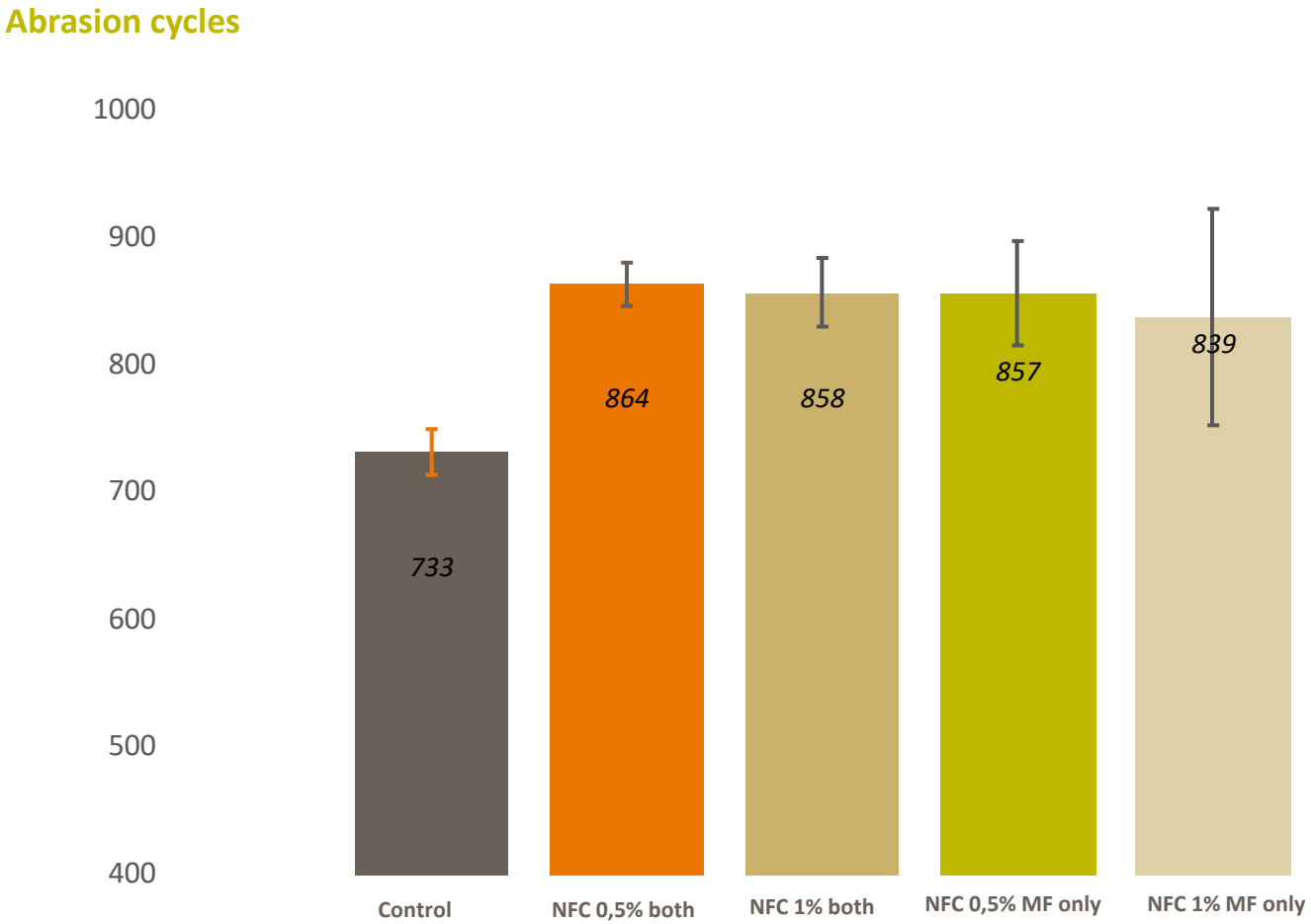
Use of NFC to improve melamine-faced PB properties



- NFC was added to the MF resin and in both baths (UF and MF) for 90 gsm white paper
- Both experimental groups increased their abrasion resistance (more than 100 cycles on average)
- Small additions of even 0,5% NFC make the difference

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Use of NFC to improve melamine-faced PB properties

Abrasion test – 500 Cycles

Left: Control group
Right: Experimental group

Abrasion test – 800 Cycles

Left: Control group
Right: Experimental group

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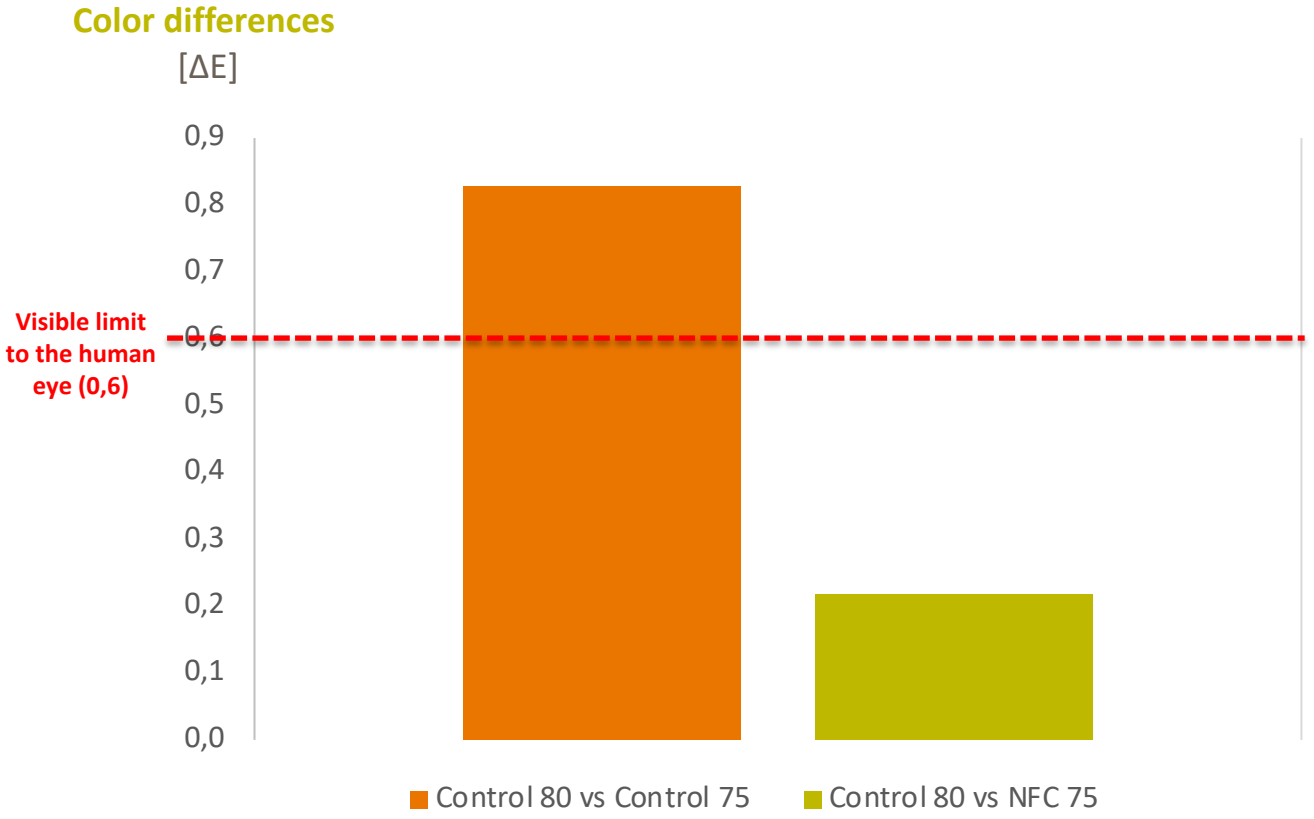
Use of NFC to improve melamine-faced PB properties

What about the color differences? (*white paper*)



When reducing paper grammage (from 80 to 75 gsm) NFC addition **helps reducing the color differences:**

- Comparing 75 to 80 gsm white paper: the difference is visible (ΔE: 0,83)
- Comparing 75 **+ NFC** to 80 gsm white paper: imperceptible difference (**ΔE: 0,22**)

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Nanocellulose in Paper Impregnation

- **Nanocellulose increase Abrasion Test value of TFM**
- **Nanocellulose can be used to increase Opacity of white paper instead of using Titanium Dioxide**
- **Nanocellulose produces more flexible impregnated paper reducing paper damages by paper handling**
- **It should be possible to reduce 5-10 gr/m^2 in paper weight keeping the same properties of the TFM using nanocellulose to reinforce the impregnated paper**

Conclusions

- **Synthetic resins are coming under increasing restrictions due environmental exposure regulations**
- **NFC and Tannin could be used as natural, suistainable options to reinforce or sustitute traditional synthetic adhesives**
- **Improvement in the performance of bio-adhesives is a key focus for existing research**

The near future

The near future will be an environmentally friendly bioadhesive based on natural and renewable resources and produced under sustainable conditions

¡¡ Renewables for a better life !!

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¡¡THANK YOU !!

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¡¡ *Happy Birthday to my friend Alex Berg* !!

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