Wood Core Shell Structures for use in Wood Plastic Composites

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WPC Utilization

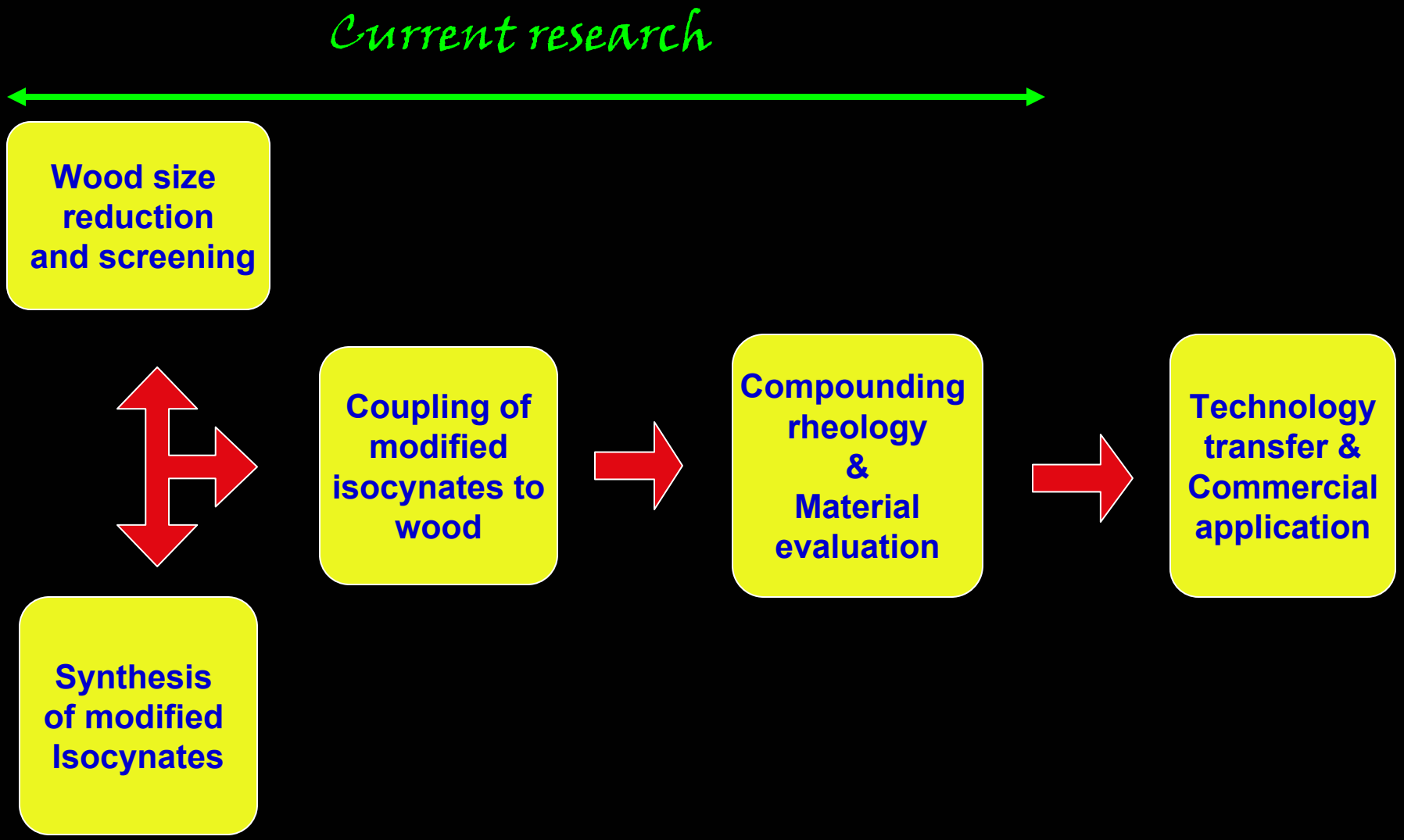
- Over 70 firms in the US & Canada produced WPC in 2002 worth $1.03 billion
- Market had grown rapidly & dominated by the decking market
- Speculated growth - $1.95 billion by 2006 (Plastic news)
- New opportunities for WPC for semi-structural applications

Objectives of study

Create a high-performance WPC materials:

1. **Modify the wood surface to create core-shell like structures to reinforce WPC**
   - **Modify surface with an alkyl substituted isocyanate**
     - **Improve coupling & therefore performance**

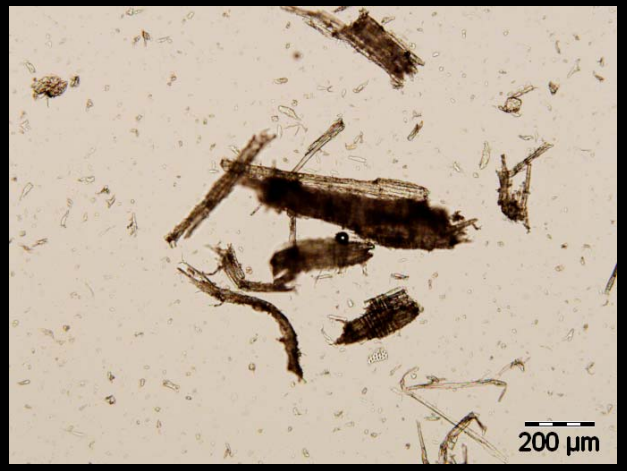
Project overview



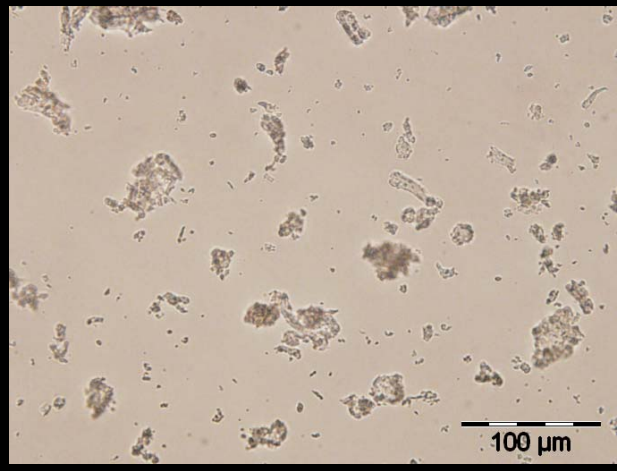
Fiber generation

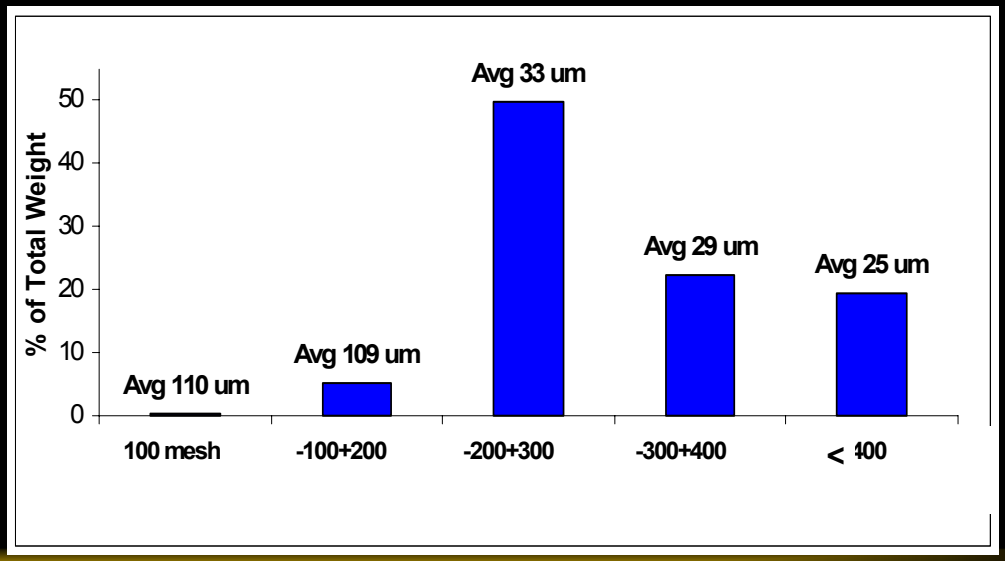
- Commercial maple flour (100#)
- Ball milled
- Screened
  - 200-300#
- Particle analysis

Original

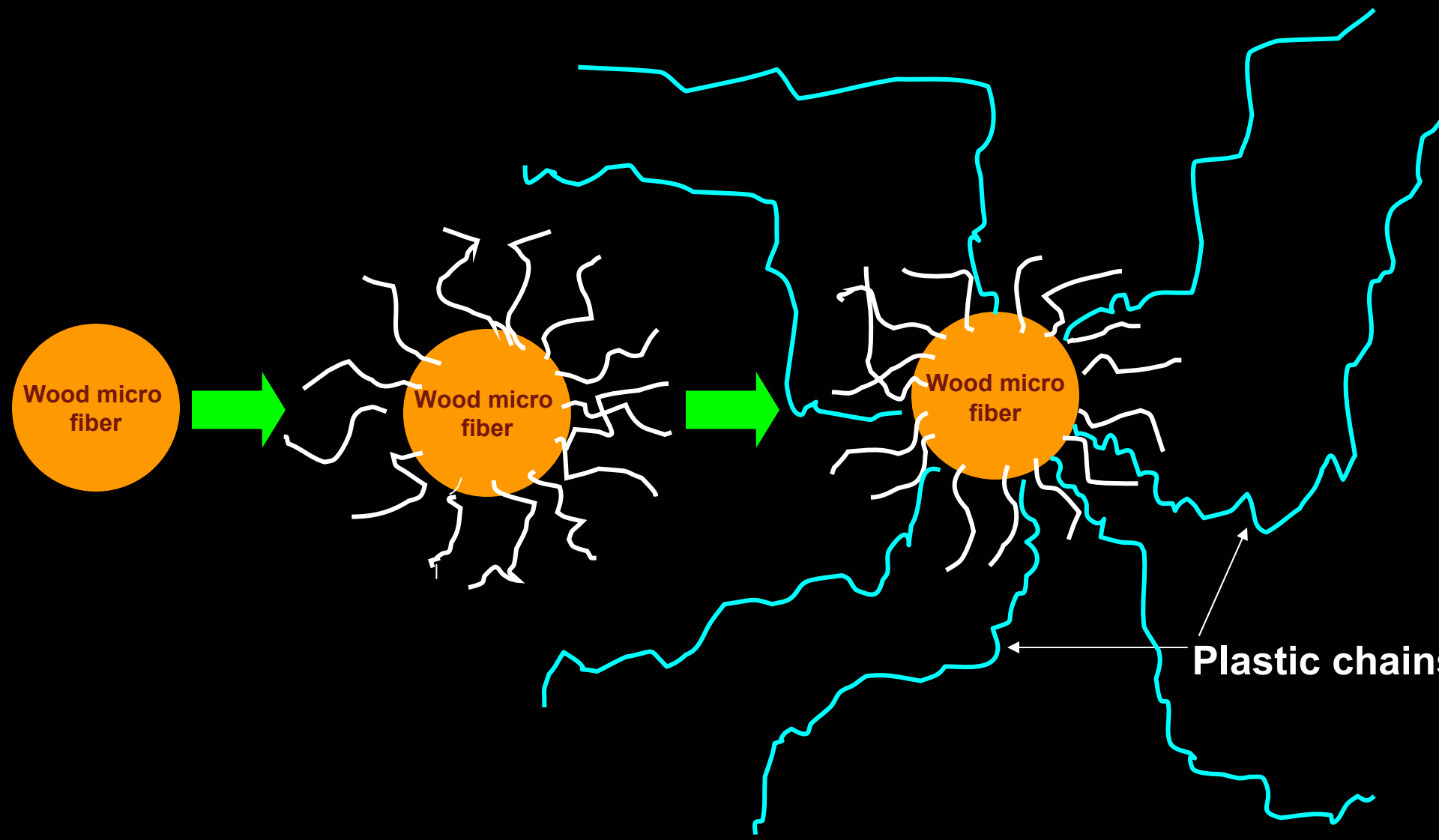


Screened fraction





Wood modification strategy



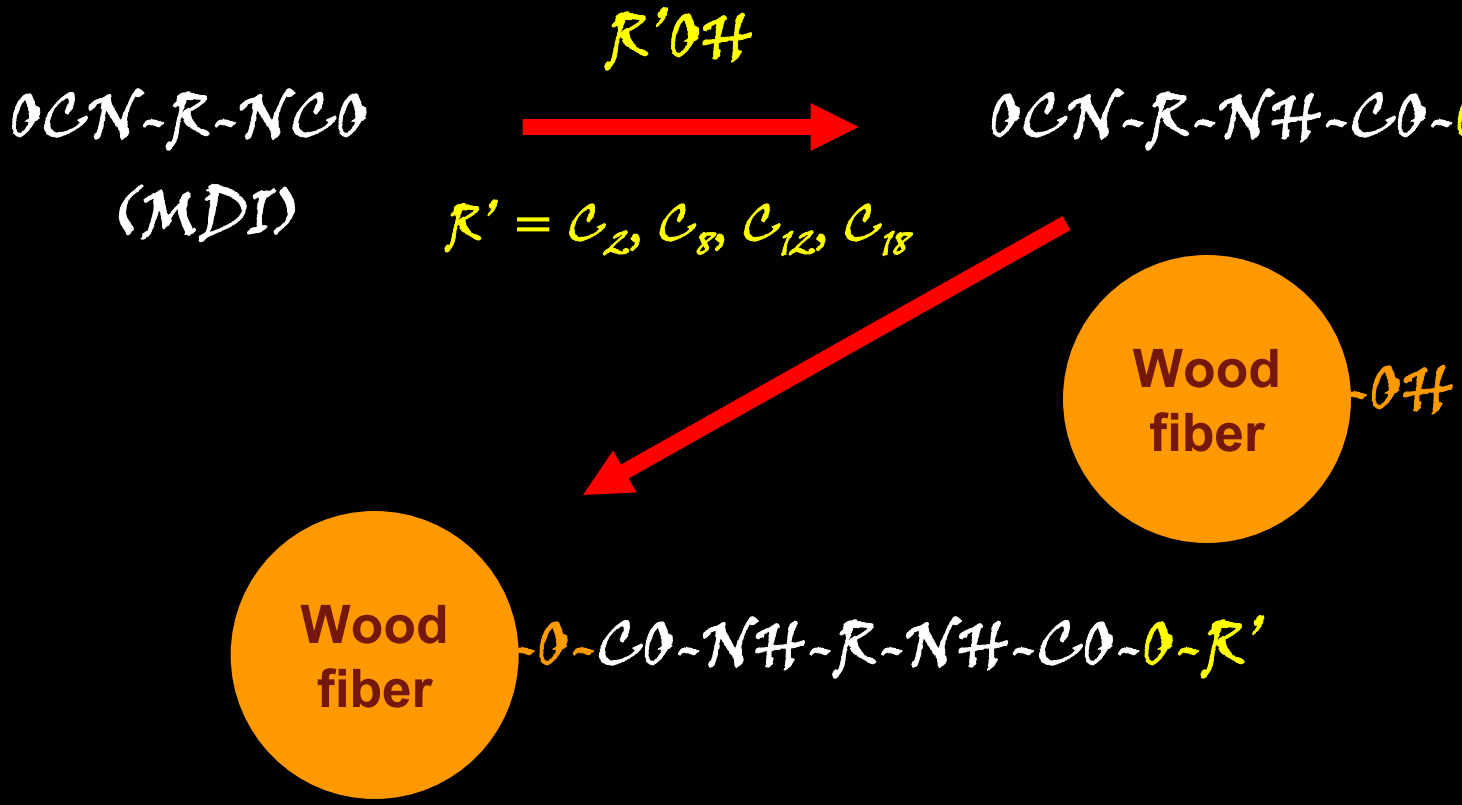
Chemical approaches

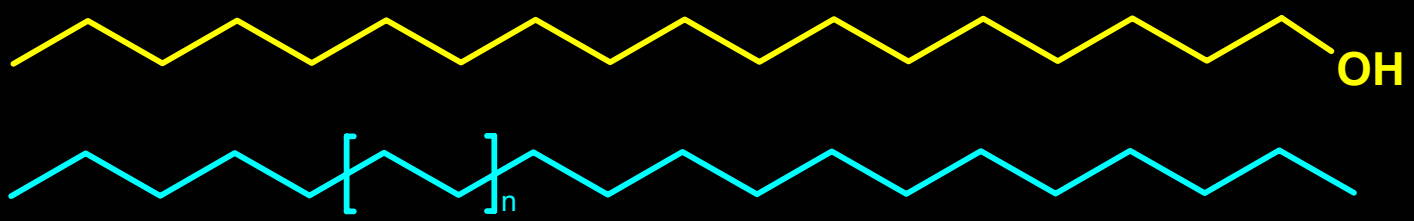
1. Synthesize aliphatic isocyanates which can couple to wood

2. Activate wood with a diisocyanate which can then couple to an aliphatic alcohol

3. Activate wood with a diisocyanate which can then couple to an aliphatic amine

Approach 1





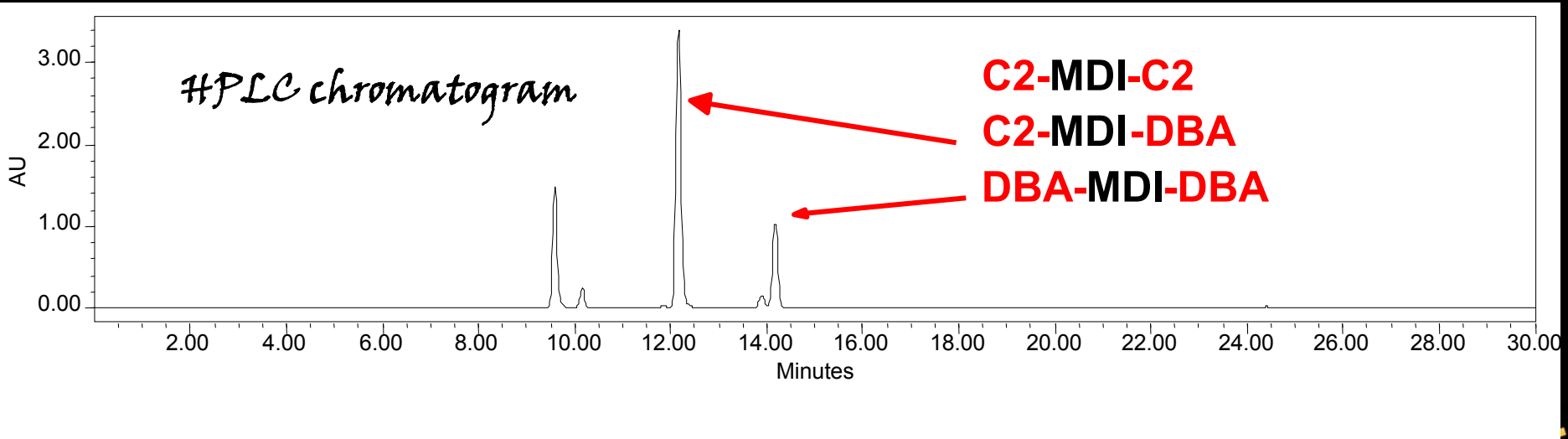
= $C_{18}H_{37}OH$

= polyethylene

1: Aliphatic isocyanate synthesis

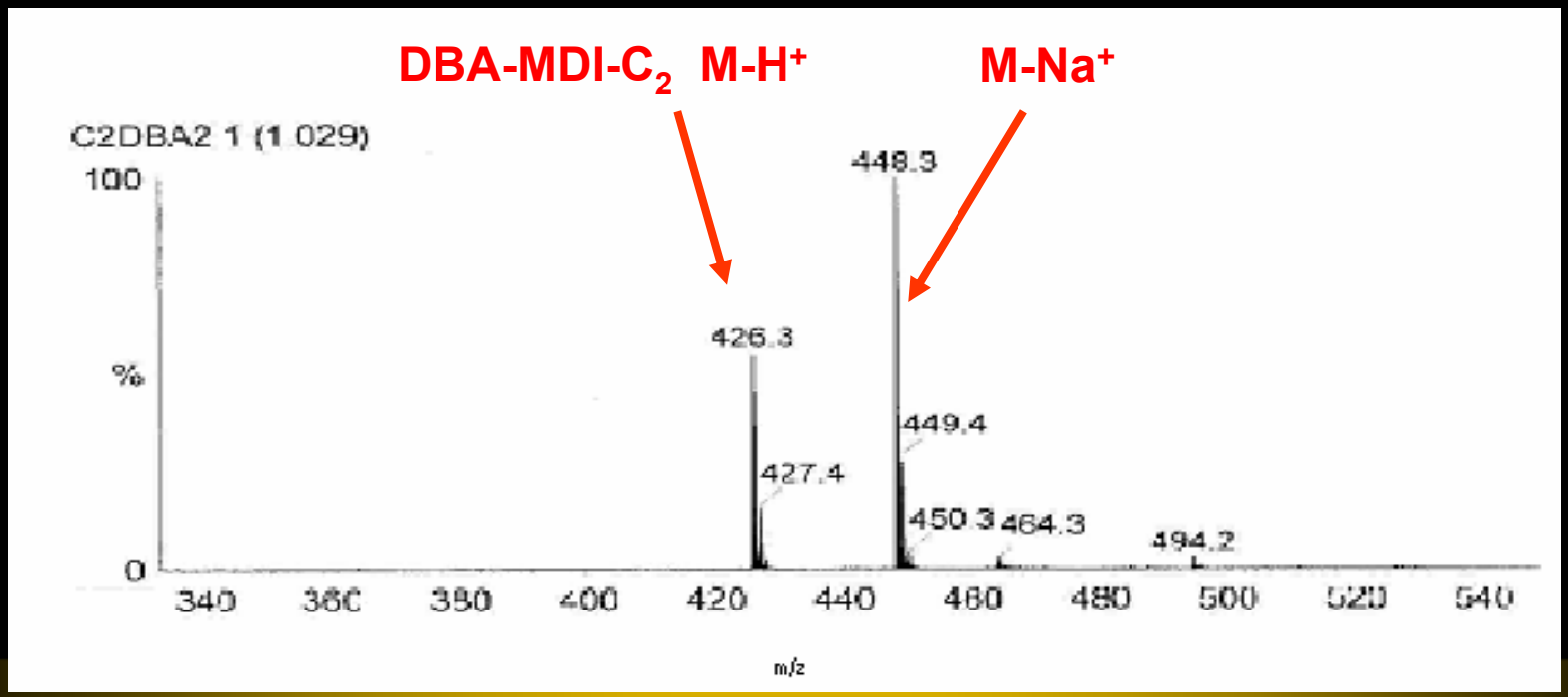
OCN-R-NCO (MDI) —R'OH→ OCN-R-NH-CO-O-R'

- Do we have the correct chemistry?
- Need to derivatize the isocyanate group with dibutyl-amine (DBA)
- Separate compounds (3) by HPLC



1: Aliphatic isocyanate synthesis

- Isolate/collect HPLC peaks
- Characterize each peak by electrospray-MS
  - +ve psuedomolecular ions
  - ($M\text{-}H^+$ / $M\text{-}Na^+$)

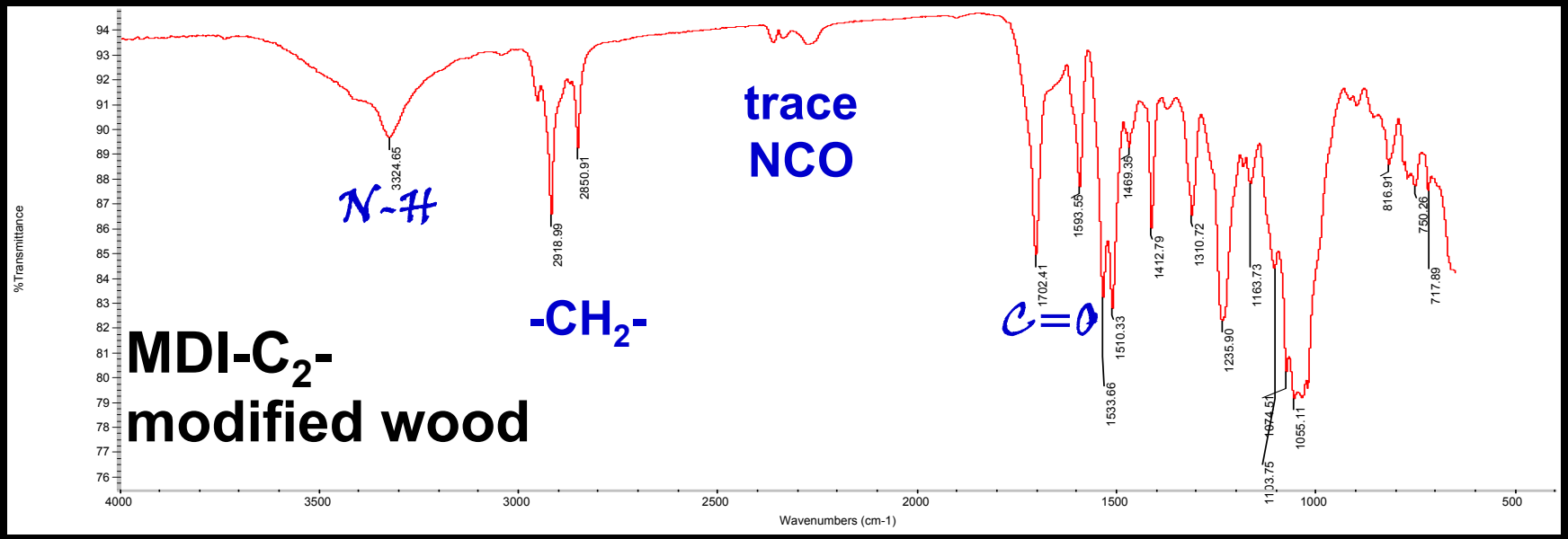


1. Wood modification

- 300# maple (extr. free) dispersed in toluene
- Add OCN-R-NH-CO-O-R' & react for 24-72 h
- Monitored reaction by TLC as DBA derivatives
- Washed & dried

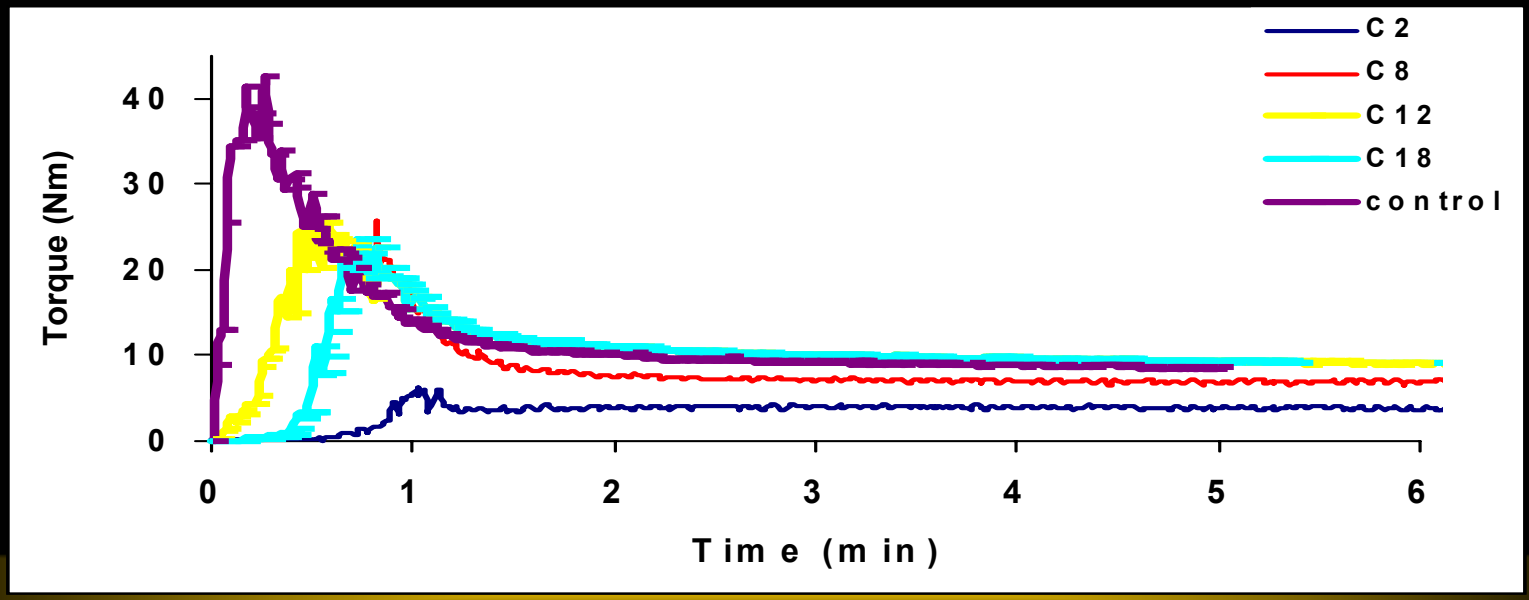
Fatty alcohol	C_2H_5OH	$C_8H_{17}OH$	$C_{12}H_{25}OH$	$C_{18}H_{37}OH$
Weight gain (%)	37	51	29	63

1. FTIR spectroscopy



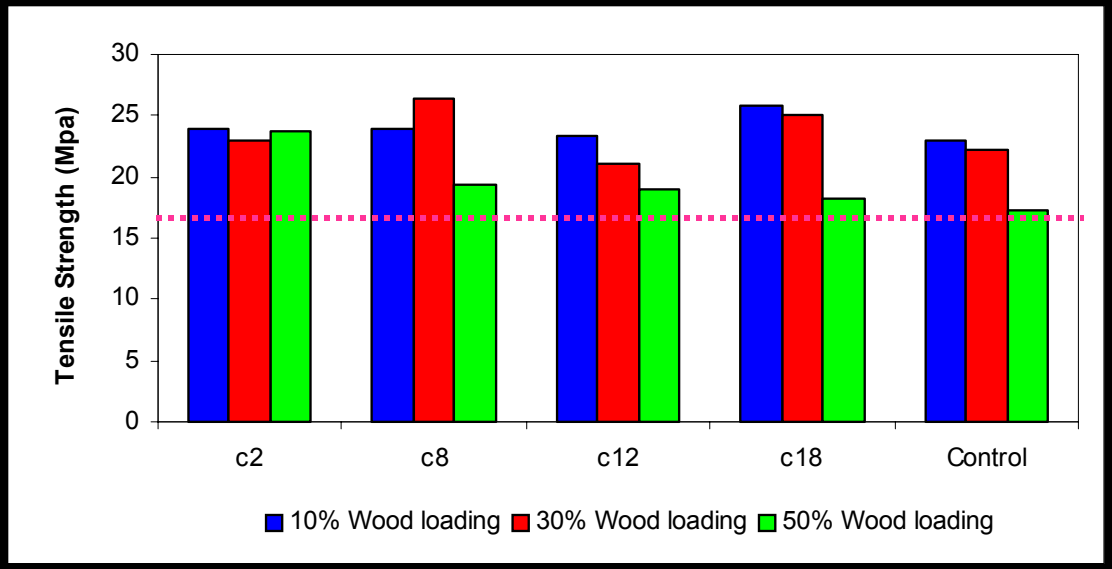
1. Compounding

- Haake torque rheometer
- 163°C, 35rpm, 5 min
- 0-50% wood (60g)
- HDPE (Equistar LB01000)



1. Molding & tensile properties

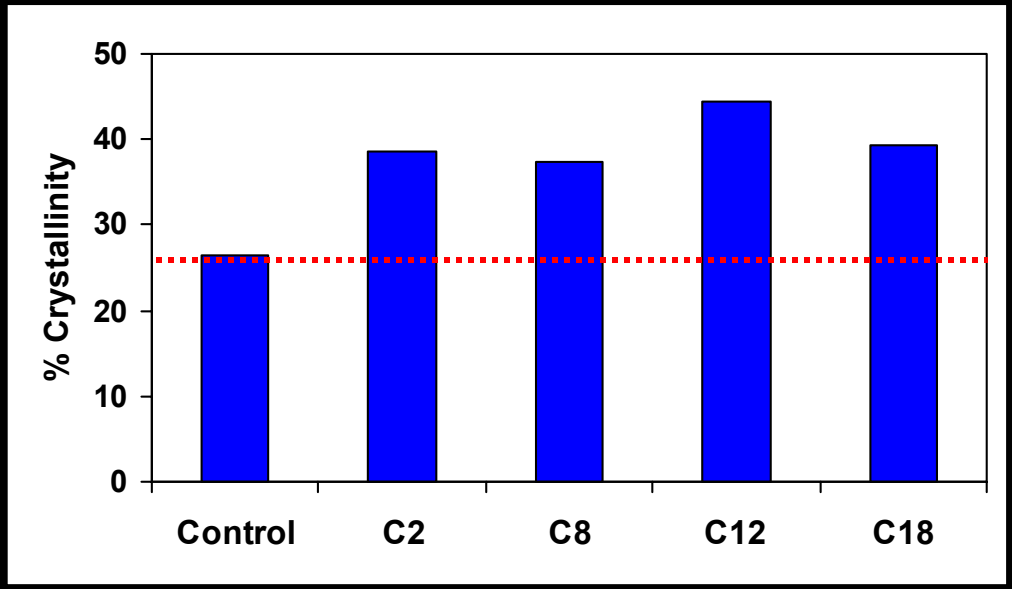
- Tensile specimens were injection molded from compounded blends (Dynisco LMM)
- Tensile testing
  - Instron 5500R
  - ASTM 1708-02a
  - 1 mm/min
- Improvement in tensile strength for some modified fibers
  - C_8 & C_{18} at 30% wood
  - C_2 at 50% wood



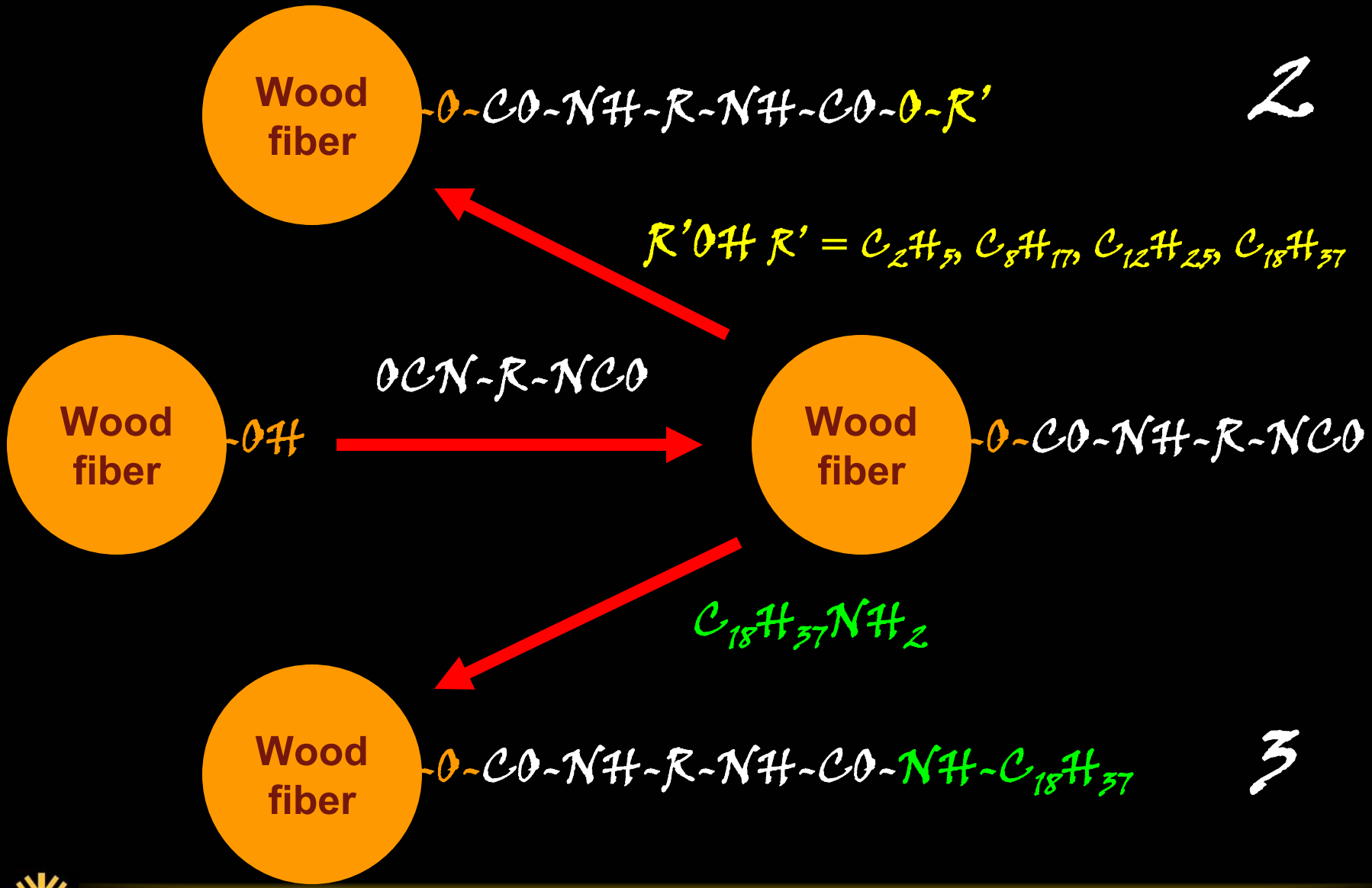
1. Thermal analysis

- Mettler Toledo DSC
- 10°C/min +/- ramps
- Wood modification increased % crystallization
- However, No trends were observed between crystallinity & tensile properties

WPC, 30% wood content



Approaches 2 & 3

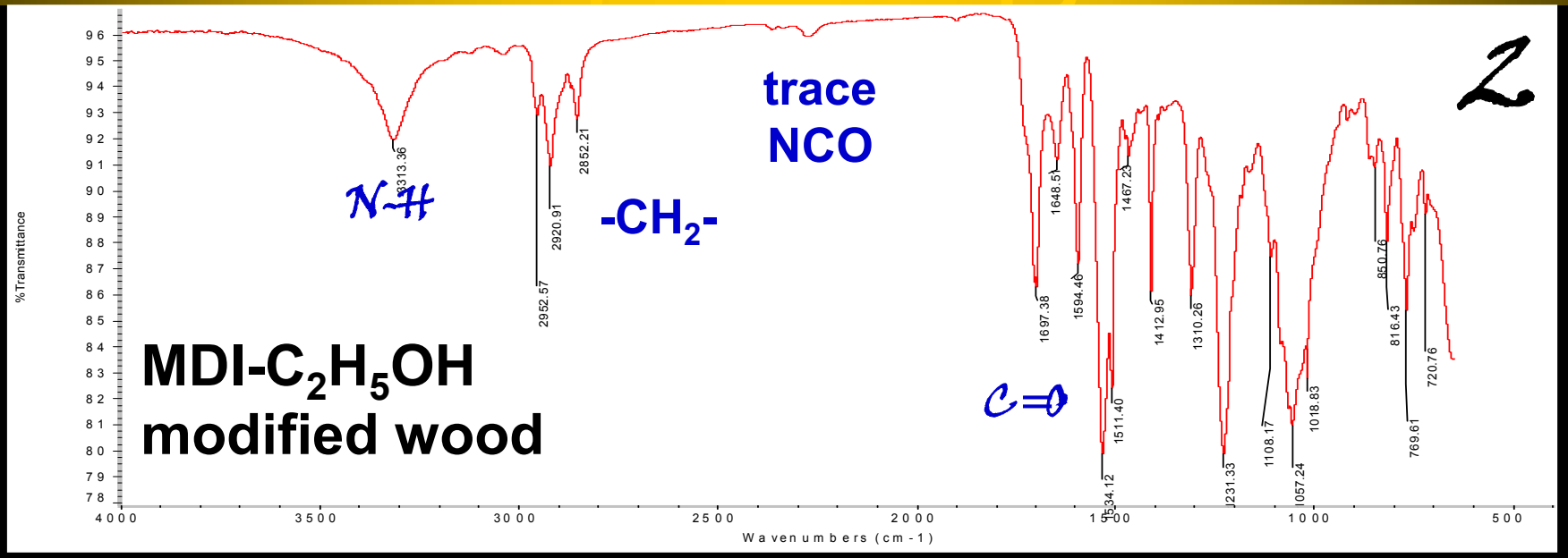


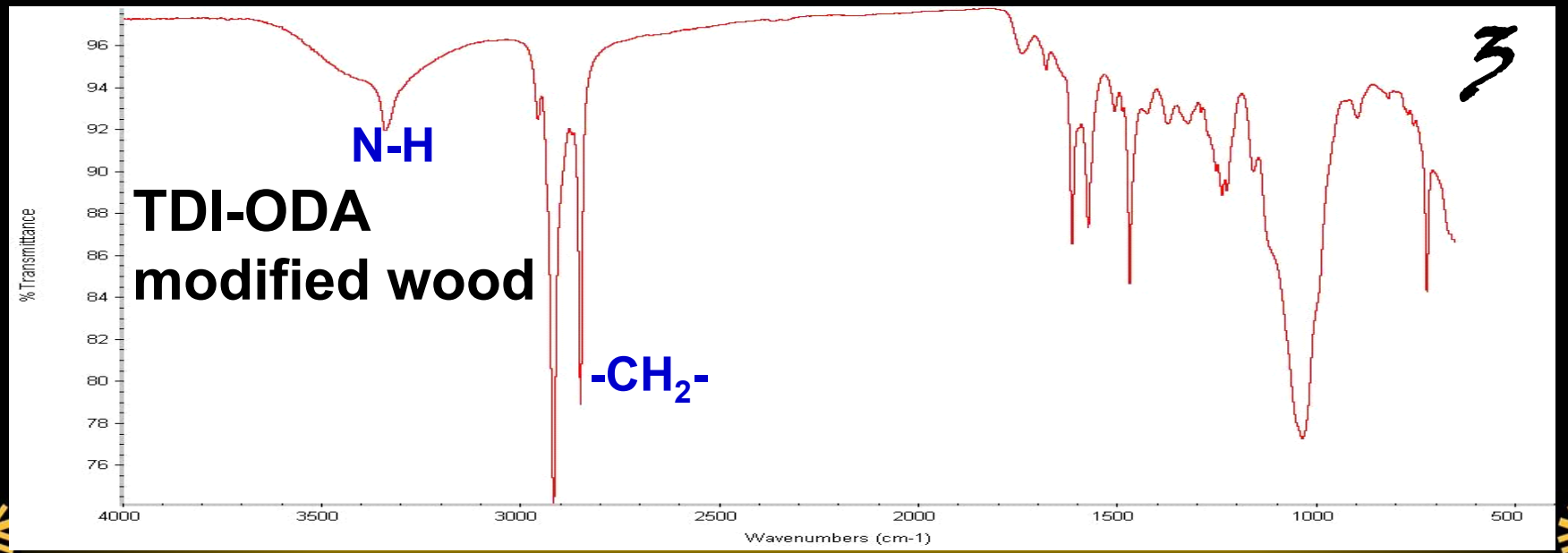
2 & 3. Wood modification

- 300# maple (extr. free) dispersed in toluene
- Add MDI (or TDI) & react for 24-72 h
- Decant solvent
- Add alcohol (or amine) & react for 24-72 h
- Washed & dried

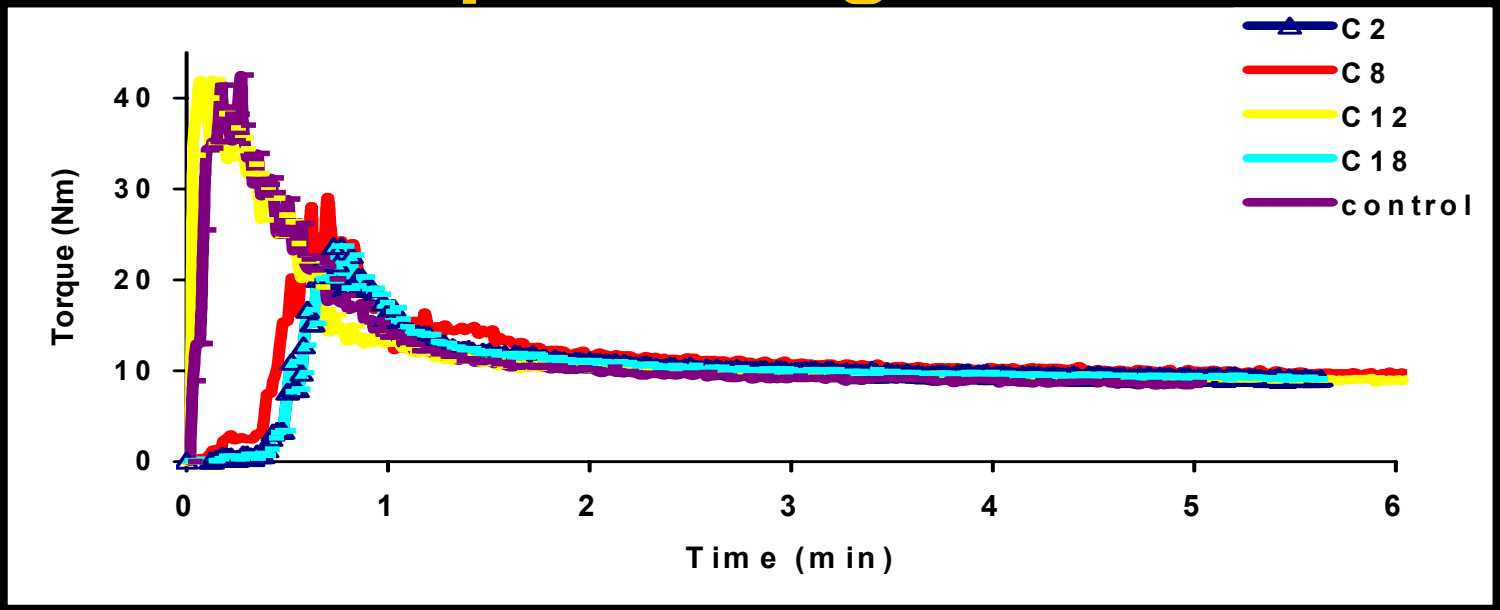
Alkyl grp	C_2H_5O -MDI	$C_8H_{17}O$ -MDI	$C_{12}H_{25}O$ -MDI	$C_{18}H_{37}O$ -MDI	$C_{18}H_{37}NH$ -MDI	$C_{18}H_{37}NH$ -TDI
Weight gain (%)	40	53	33	43	60	62

2 & 3. FTIR spectroscopy





2 & 3. Compounding



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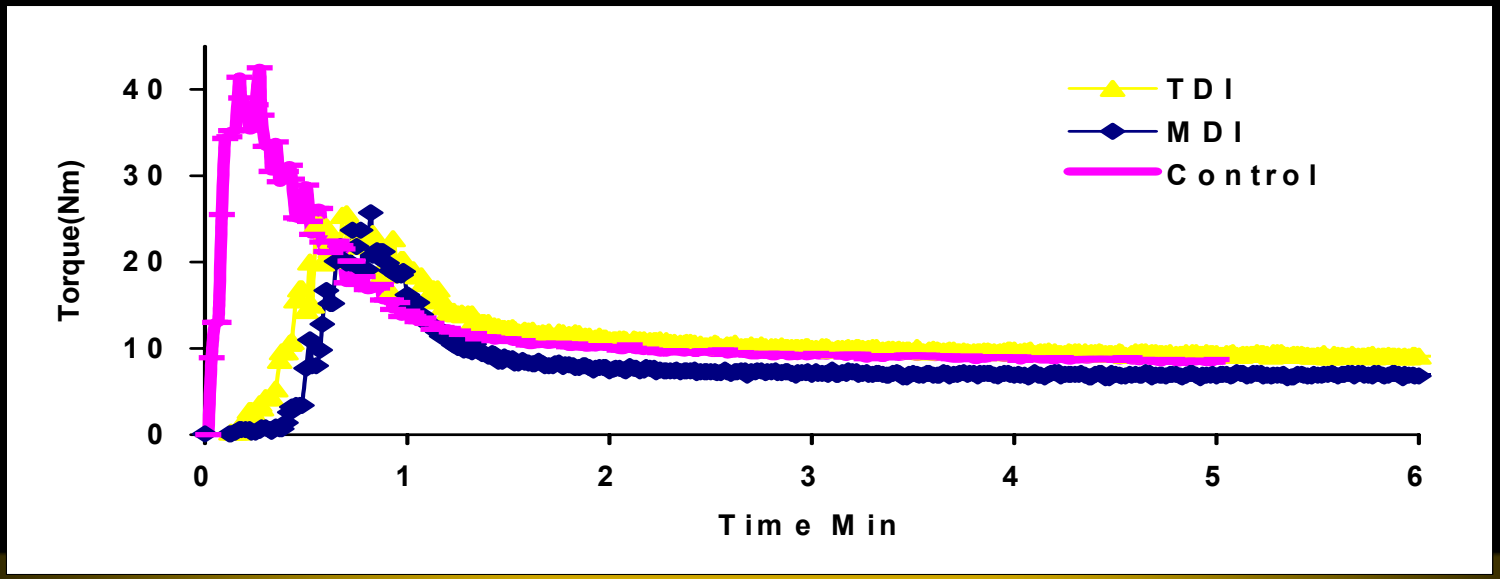

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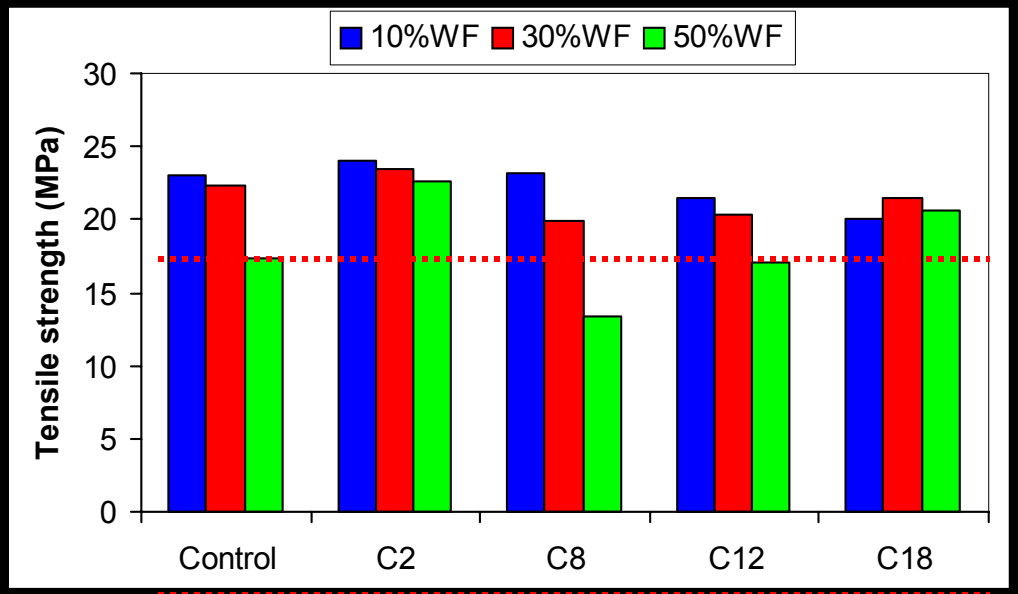
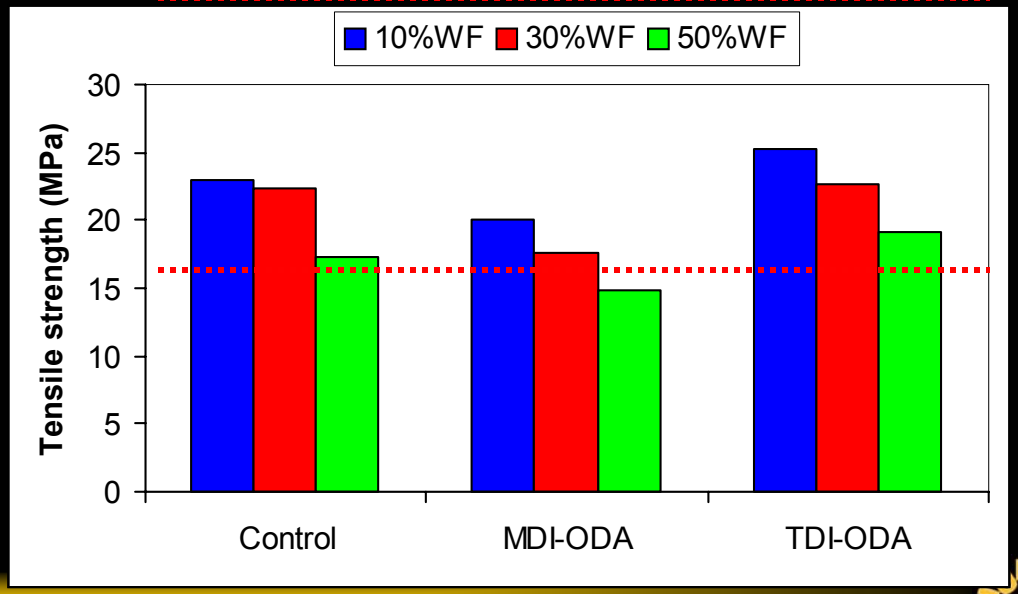
2 & 3. Tensile results

- WPC from C_2 & C_{18} fiber gave strength improvements at 50% wood content

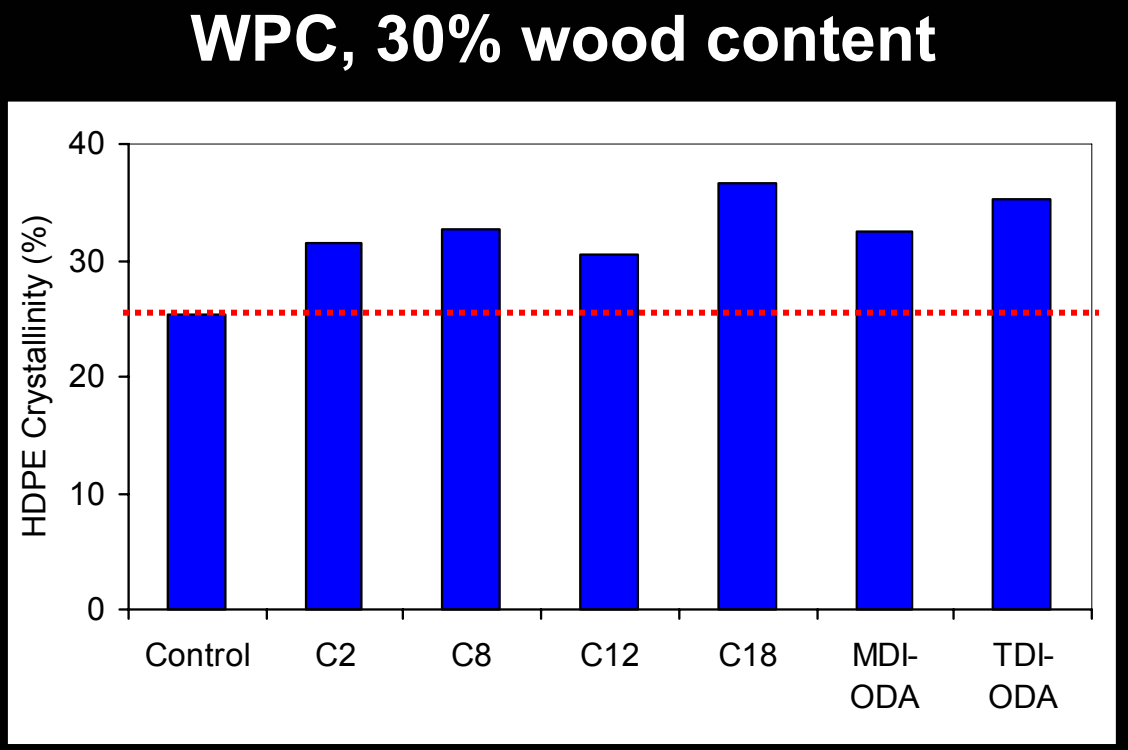
- WPC from TDI-C_{18} fiber gave strength improvements





2 & 3. Thermal analysis

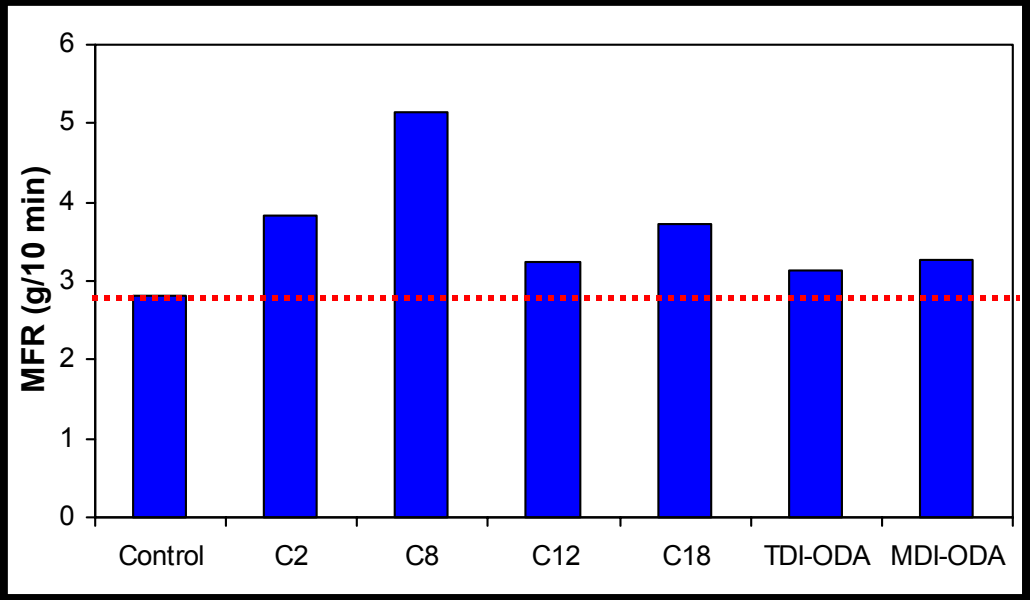
- Observed and increase in HDPE crystallinity due to wood modification
- However, No trends were observed between crystallinity & tensile properties



2 & 3. Melt Flow

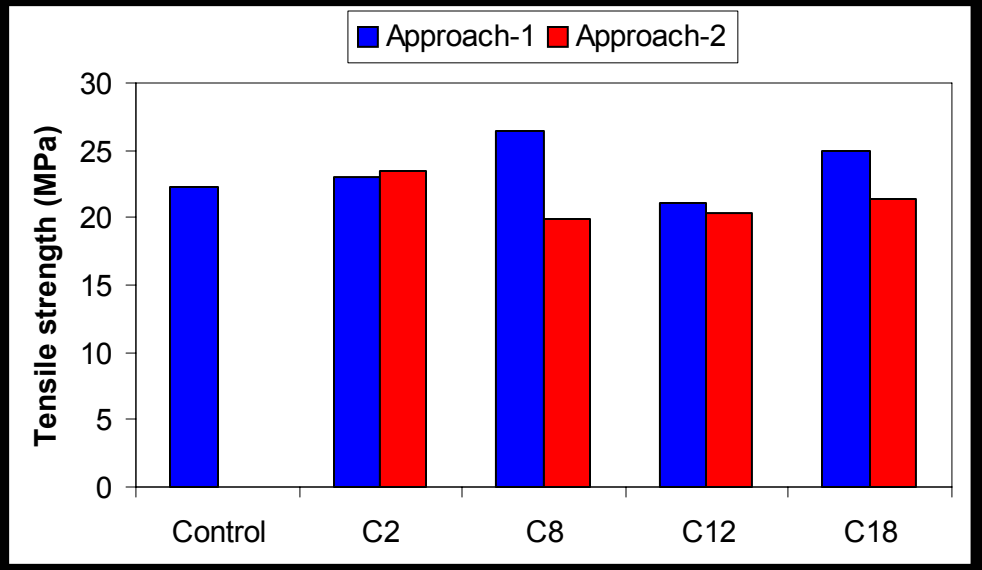
- MFI measured
  - 10kg, 190°C, 300s
- MFR decreased on wood modification
  - Especially the C_8 modified fiber
- Similar trend observed in torque rheometry

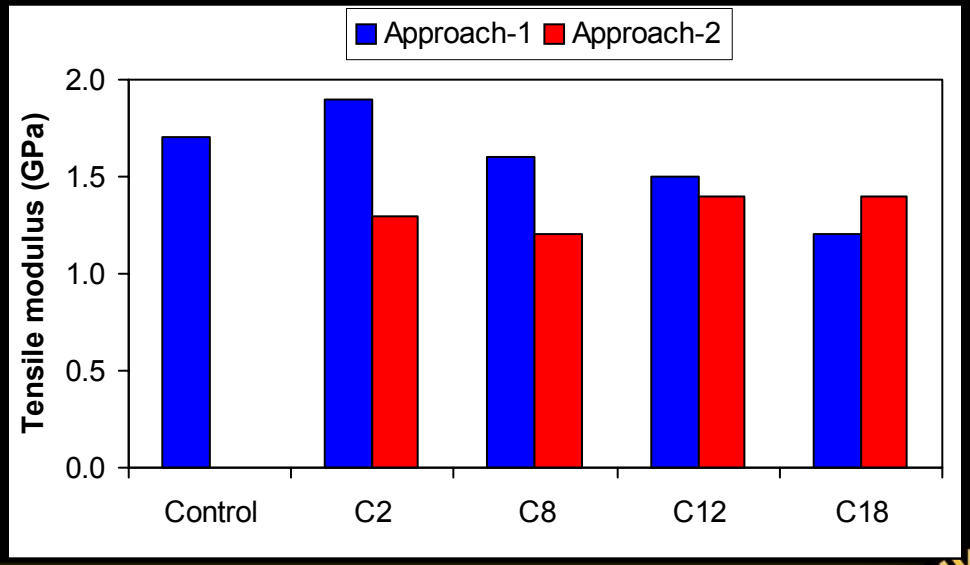
WPC, 30% wood content



Comparison between approaches

- Approach 1 takes longer to prepare modified fiber
- Tensile properties were generally higher from fiber prepared from approach 1





Conclusions

- Wood surface modification has a positive effect on:
  - Improved compoundability
  - Reduced melt viscosity
  - Slight improvement in tensile strength
  - Approach 1 gave better props.
  - Approach 2 & 3 more adaptable for an industrial process

Outcomes:

- Lower melt viscosities suitable for injection molding applications
- Higher wood loadings achievable at the same melt viscosity

Ongoing work:

- Extrusion trials
- DMTA analysis
- Rheological studies
- WPC morphology (microscopy)
- Wood fiber surface energetics & chemistry
- Water adsorption trials

Questions?

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