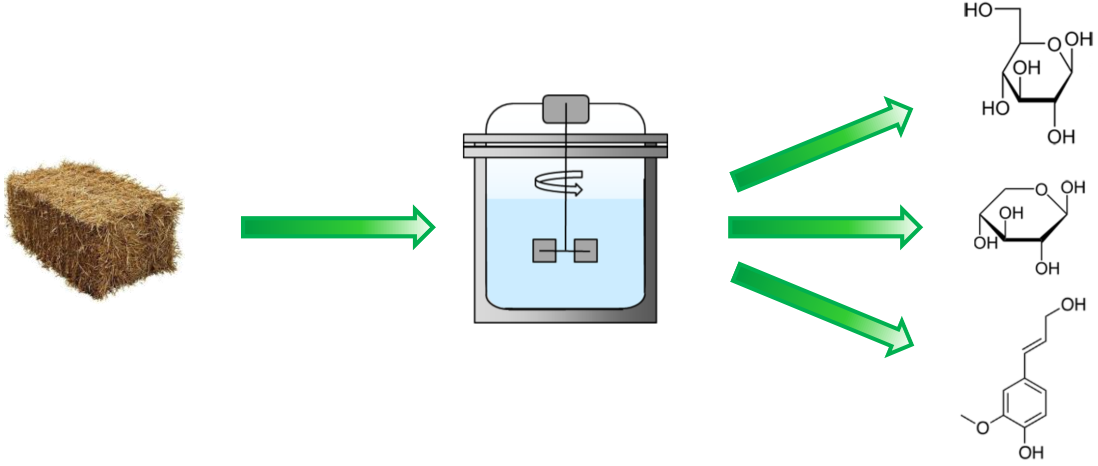
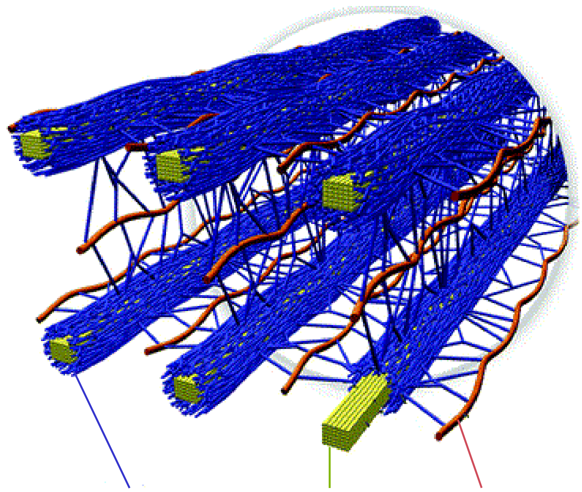
Lignin-first biorefinery

Lignin-first fractionation of lignocellulosic biomass from agricultural residues



Filippo Brienza, PhD student, UCLouvain

Lignin valorization is an open challenge



Lignocellulose

Carbohydrates → Paper, biofuels, chemicals

Lignin →

High Value
Low volume

Fine Chemicals

Polymers

Biofuels

Industrial Additives

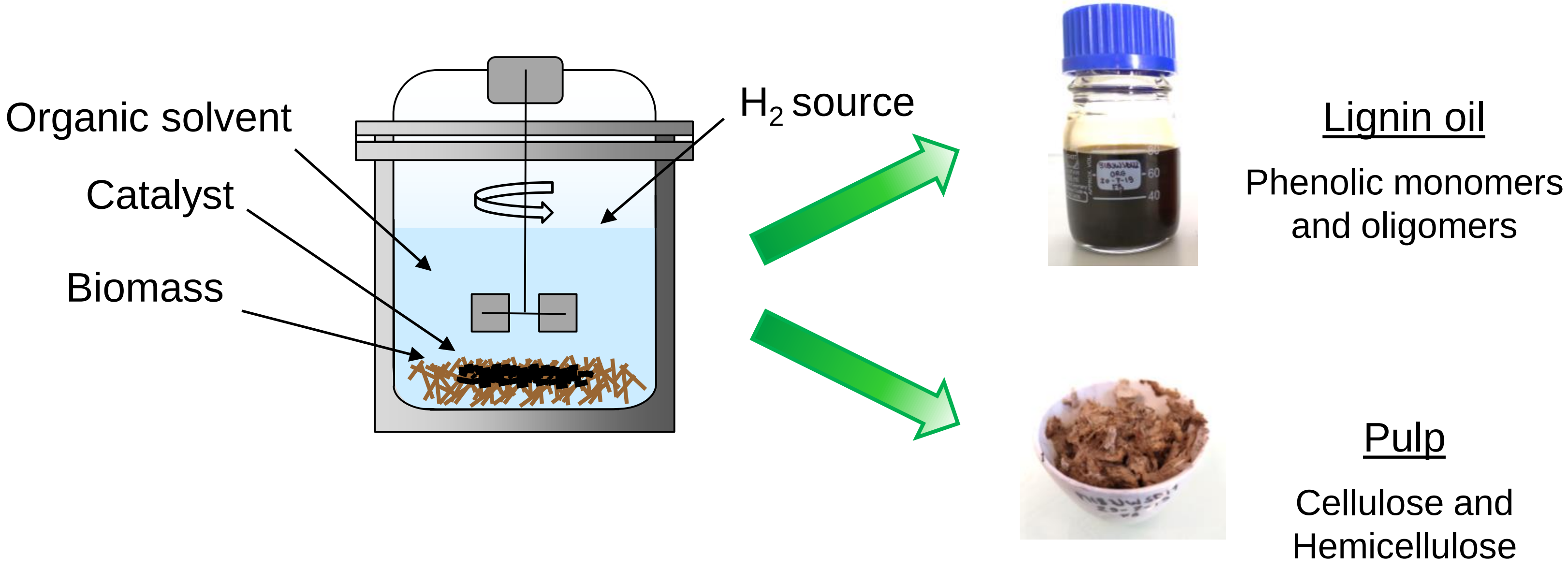
Energy

Low Value
High volume

Adapted from Brandt et al., GreenChem, 2013, 15, 552

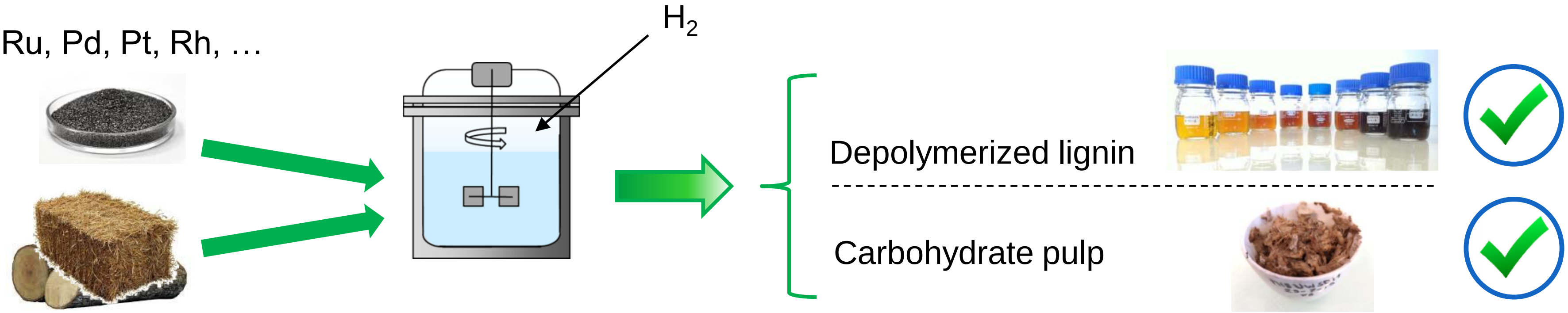
Lignin-first biorefineries: full biomass utilization

REDUCTIVE CATALYTIC FRACTIONATION (RCF)



Current state of Reductive Catalytic Fractionation

Object of the present work



<u>Target biomass</u>: Wheat straw

<u>Catalyst</u>: Ru/C

PROCESS CONDITIONS

- Pressure (H_2 / N_2)
- Solvent

PERFORMANCE INDICATORS

- Carbohydrate retention in the pulp
- Yield of delignification
- Yield of phenolic monomers

Performance indicators

Carbohydrate retention

$$R_{C5+C6} = \frac{m_{C5+C6_{pulp}}}{m_{C5+C6_{IN}}}$$

Delignification

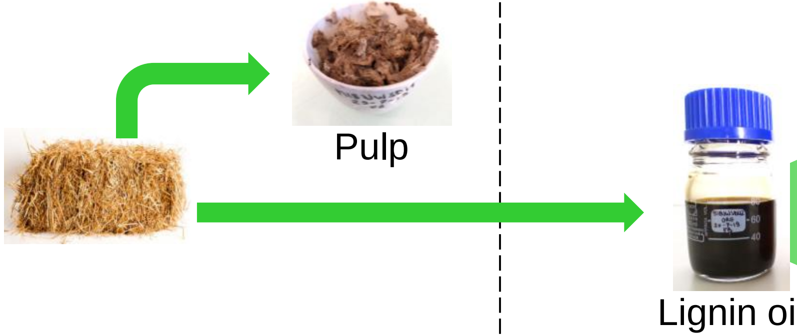
$$Y_{Delig} = \frac{m_{lignin\ oil}}{m_{lignin_{IN}}}$$

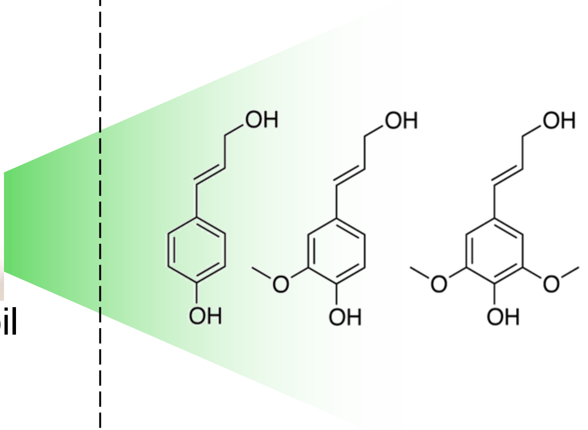
Phenolic monomers

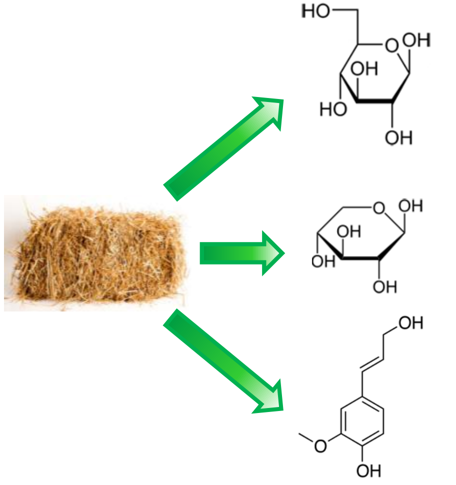
$$Y_{Mono} = \frac{m_{lignin\ monomers}}{m_{lignin_{IN}}}$$

Efficiency Indicator

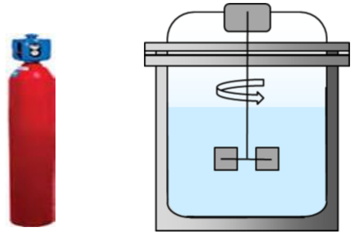
$$Eff = R_{C5+C6} Y_{Delig} Y_{Mono}$$





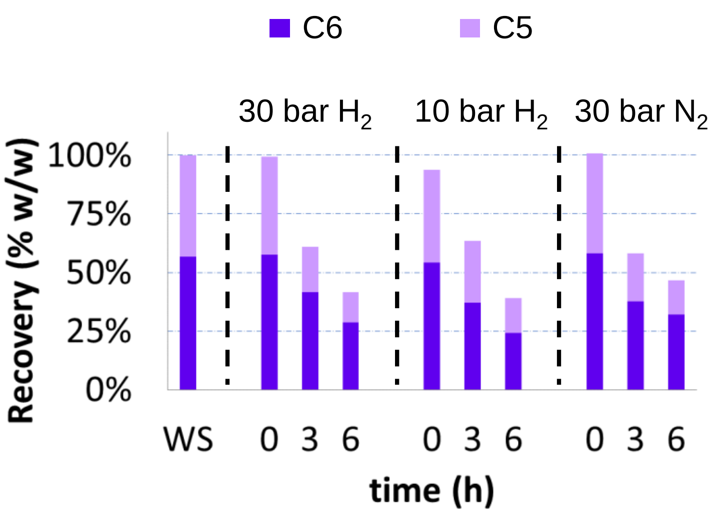


Hydrogen gas enhances monolignols production

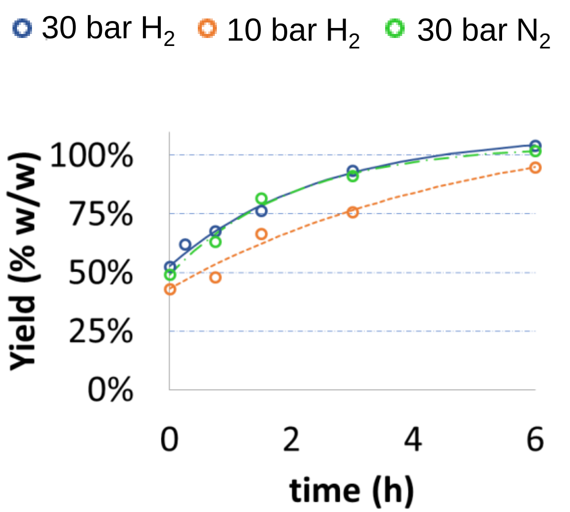


- Pressure (H_2 / N_2)
- Solvent: MeOH
- Temperature: 250 °C

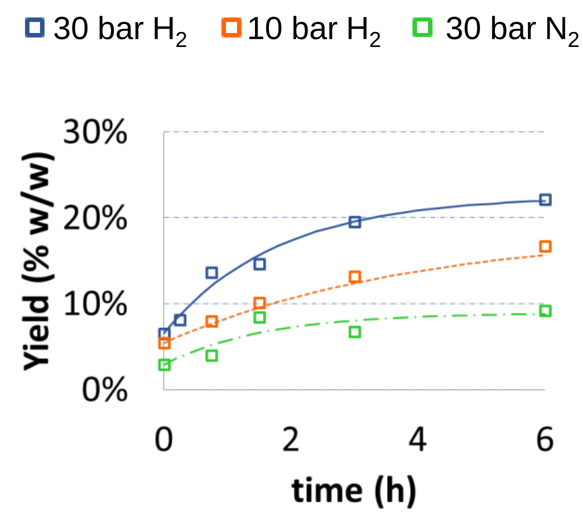
Carbohydrates



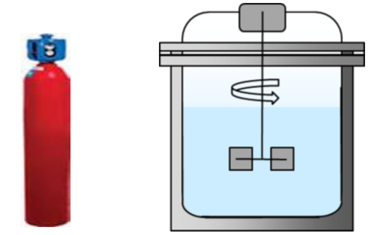
Delignification



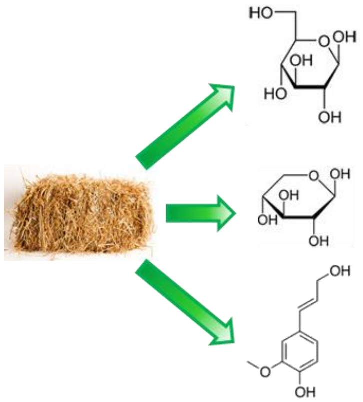
Phenolic monomers

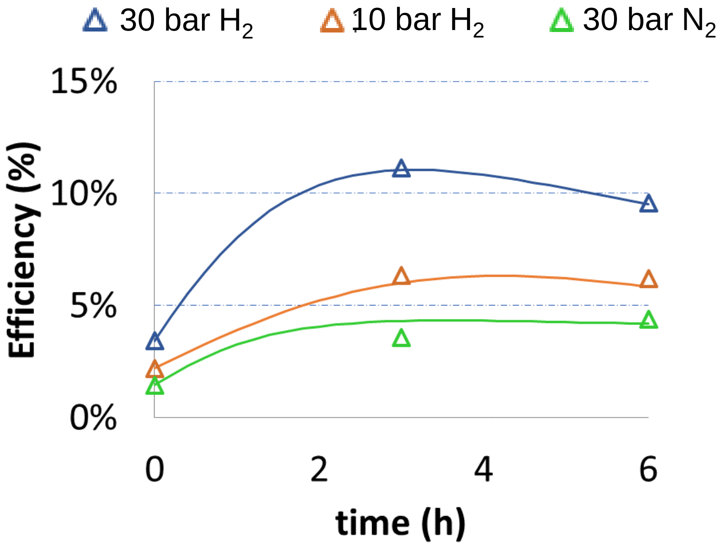


Efficiency is favored by high H_2 pressure

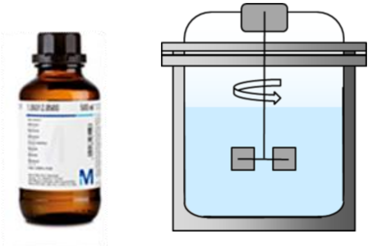


- Pressure (H_2 / N_2)
- Solvent: MeOH
- Temperature: 250 °C

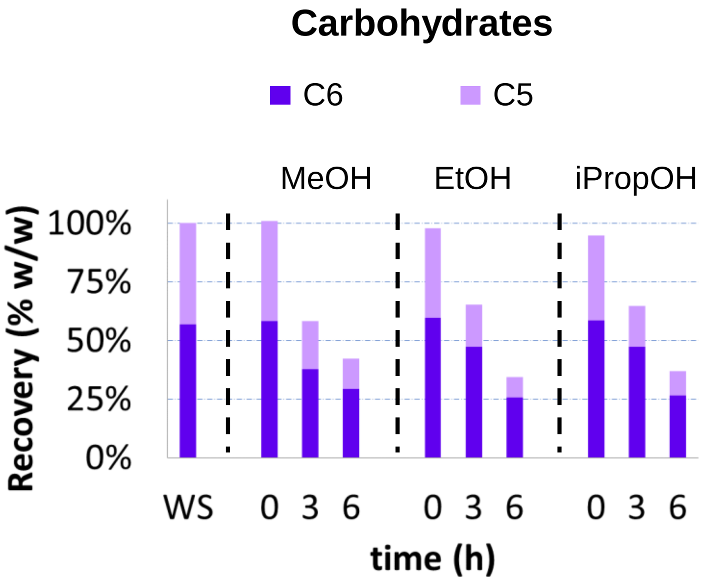


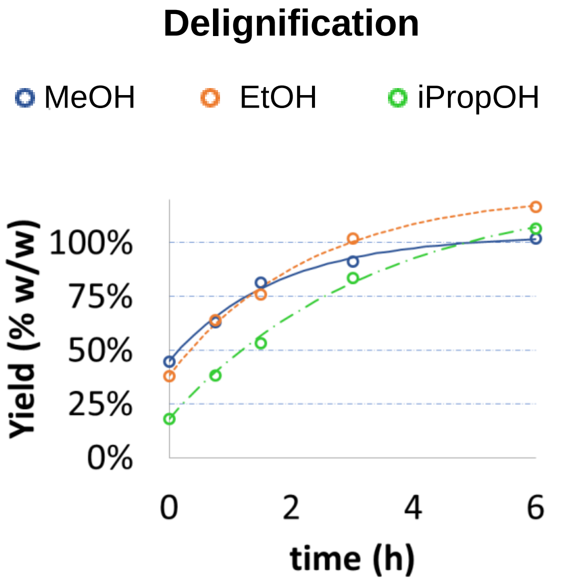


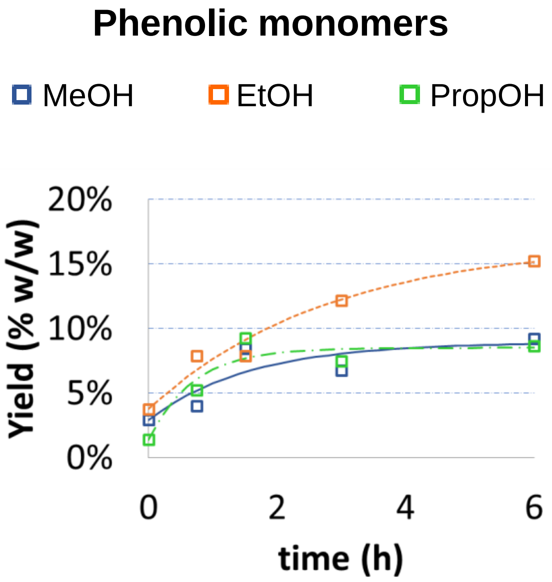
Ethanol boosts the yield of monolignols



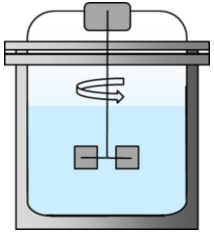
- Pressure: 30 bar of N_2 at ambient temperature
- Solvent
- Temperature: 250 °C



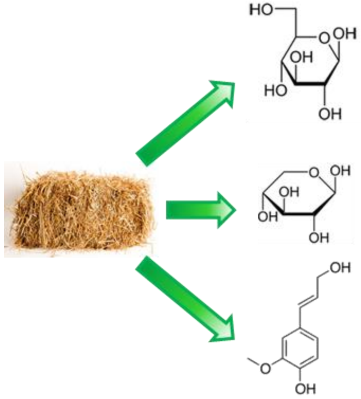


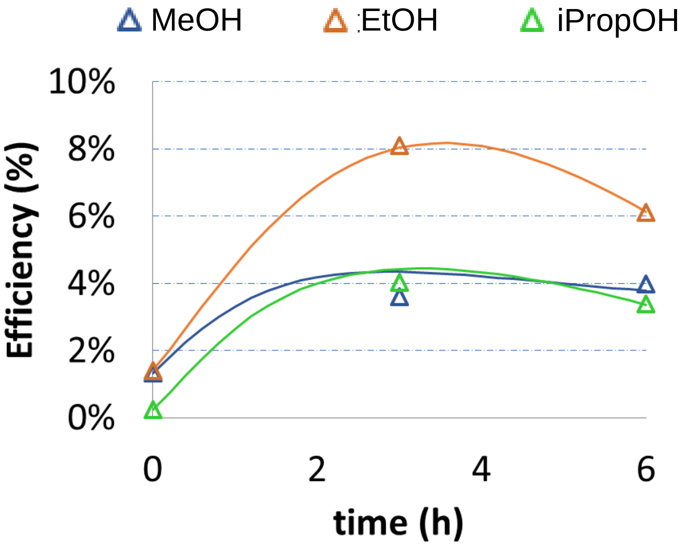


Ethanol gives the best efficiency in absence of H_2



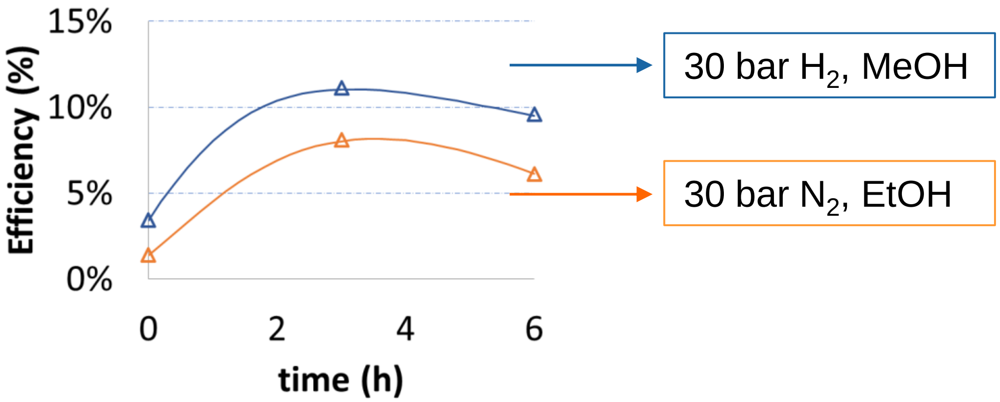
- Pressure: 30 bar of N_2 at ambient temperature
- Solvent
- Temperature: 250 °C





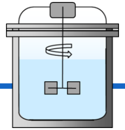
Conclusion: Towards a hydrogen-free process

- Wheat straw is suitable for reductive catalytic fractionation

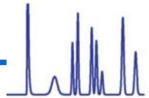


- Development of a hydrogen-free lignin-first biorefinery from wheat straw

PERSPECTIVES



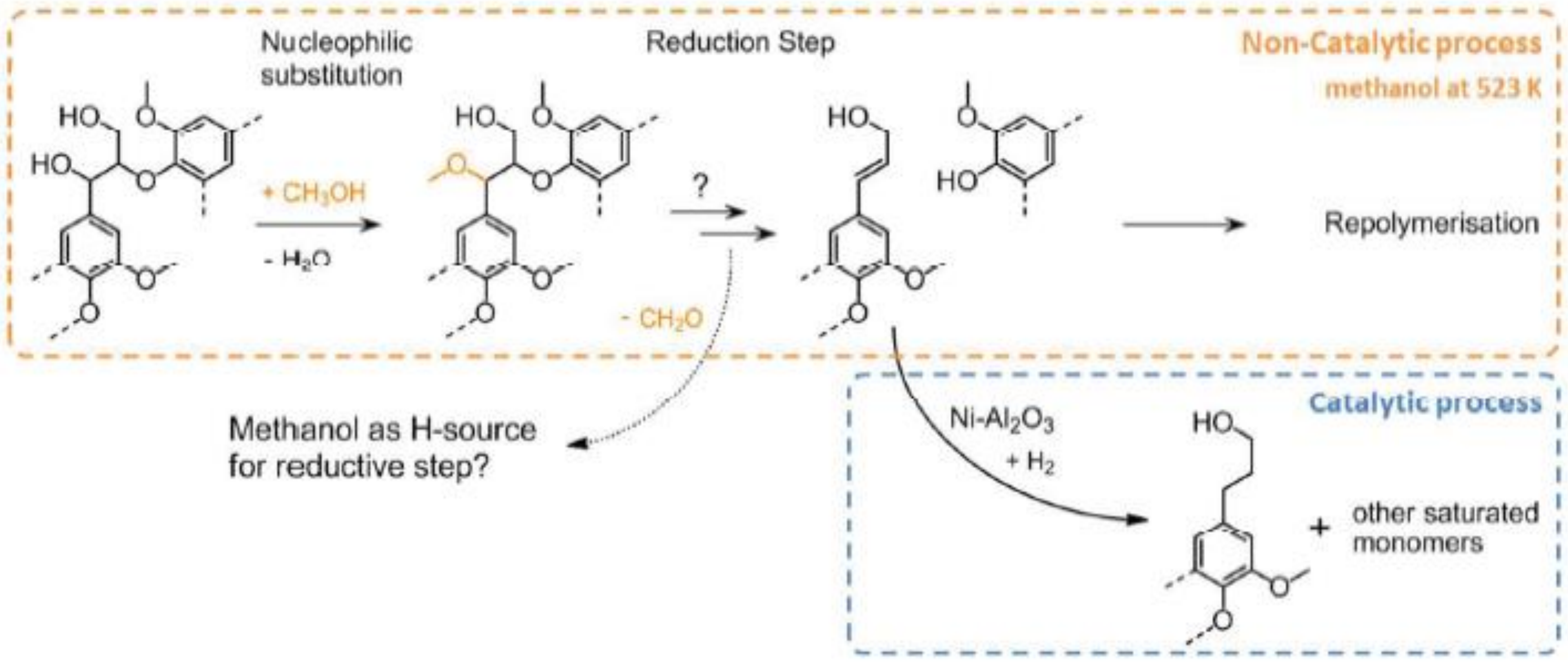
Introduction of an acid catalyst



Analysis of MW of extracted lignin

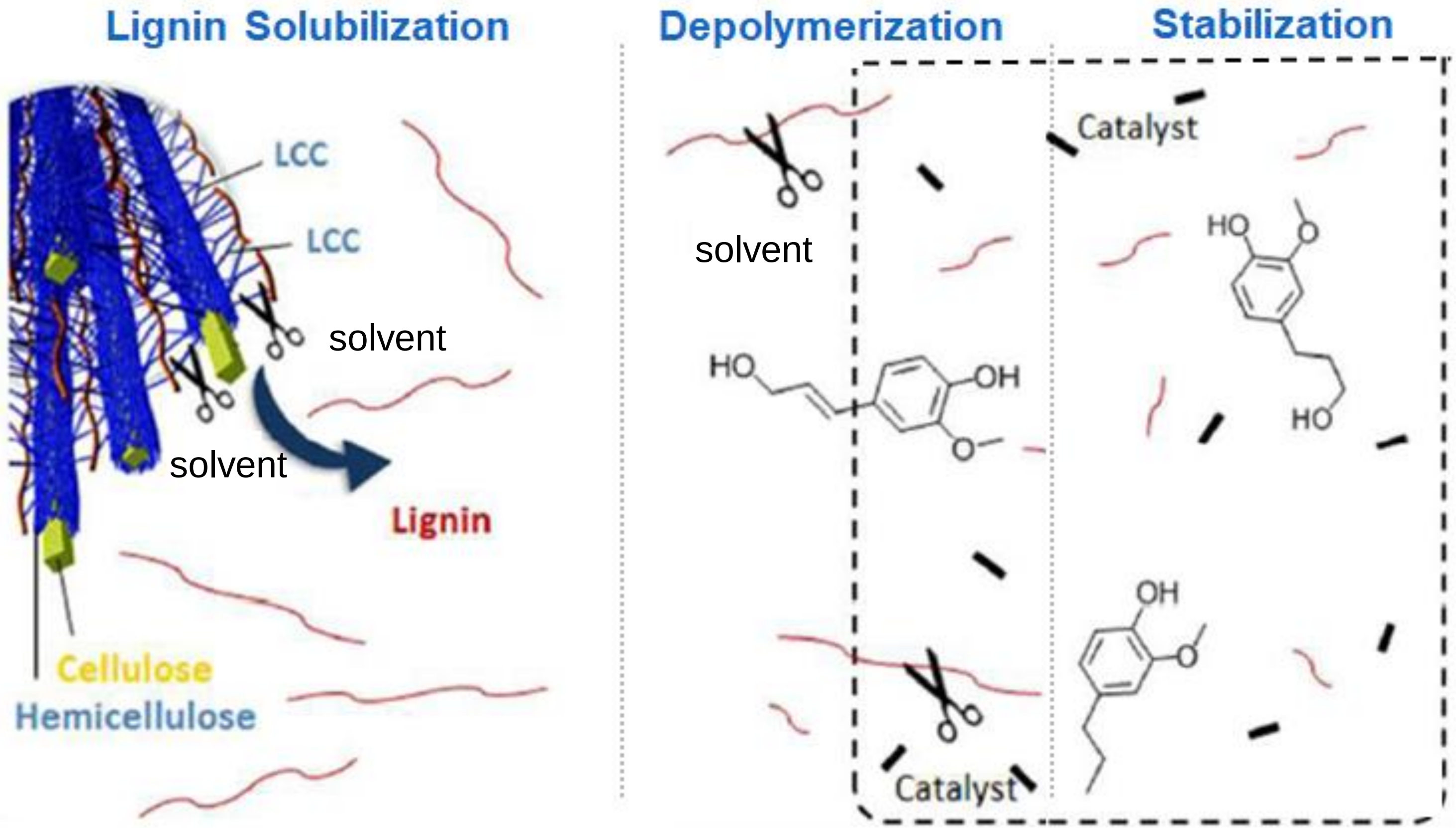
THANKS FOR YOUR ATTENTION

Mechanism of lignin monomers formation in RCF



Van Den Bosch et al., GreenChem, 2017, 19, 3317

Catalytic hydrogenation enhances monolignols yield



Adapted from Van Den Bosch et al., GreenChem, 2017, 19, 3320

Kinetic models

Carbohydrate retention

$$R_{C5+C6}{}' = K_1(1 - e^{-\frac{t}{\tau_1}})$$

Delignification

$$Y_{delig}{}' = K_2(1 - e^{-\frac{t}{\tau_2}})$$

Phenolic monomers

$$Y_{Mono}{}' = K_3(1 - e^{-\frac{t}{\tau_3}})$$

Efficiency Indicator

$$Eff' = R_{C5+C6}Y_{Delig}Y_{Mono} = K_1K_2K_3(1 - e^{-\frac{t}{\tau_1}})\,(1 - e^{-\frac{t}{\tau_2}})(1 - e^{-\frac{t}{\tau_3}})$$

Wheat straw composition

Ash	6.1	g / 100 g DM
H_2O Extractives	15.8	g / 100 g DM
EtOH Extractives	3.5	g / 100 g DM
Acid Insoluble Lignin	13.6	g / 100 g DM
Glucan	33.6	g / 100 g DM
Xylan	20.6	g / 100 g DM
Arabinan	2.5	g / 100 g DM