Åbo Akademi
University

Depolymerization of lignin – an opportunity for further valorization?

Depoly2ols

Prof. Patrik Eklund
Lignin seminar 2024

Åbo Akademi University

Organic Chemistry

- Excellence in research and education
- Expertize in organic chemistry at molecular level (structure, reactivity & chemical and biological properties)
- New functional molecules and materials by sustainable chemistry

Prof. Patrik Eklund
(Prof. Reko Leino)

Lecurers: Tiina Saloranta-Simell, Robert Lassfolk, Jan-Erik Lönnqvist

ORGANIC CHEMISTRY IS BEAUTIFUL

Research areas & activities

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Biomass & Biopolymers

Lignin, cellulose, hemicelluloses

Natural products & carbohydrates

Polyphenols, mono and oligosaccharides

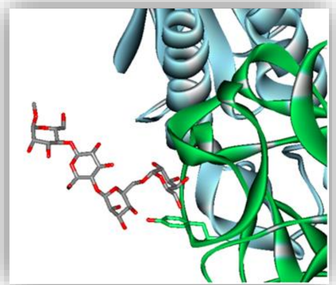
Environmental Chemistry

Pharmaceuticals in the environment, waste water treatment

Valorization - application driven research

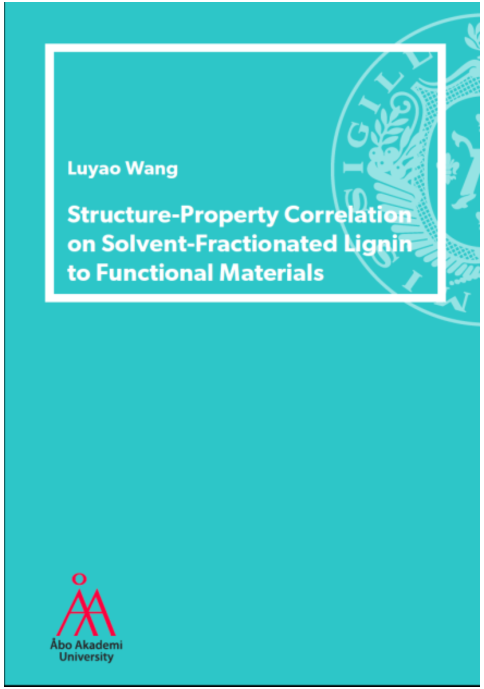
- Fundamental chemistry (structure and reactivity)
- Organic synthesis & toolboxes for chemical modification
- Bioactive molecules

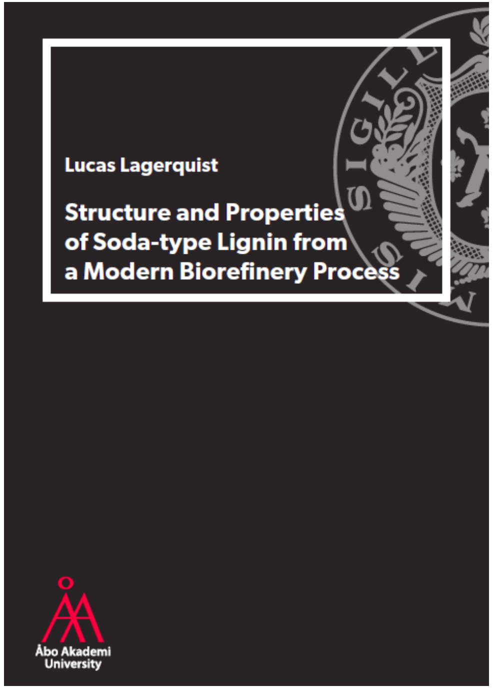
Advanced analytical tools: **NMR and MS**



Lignin – How do we want to use ligning?

- **As a macromonomer?**
- As an antioxidant?
- As antimicrobial agent?

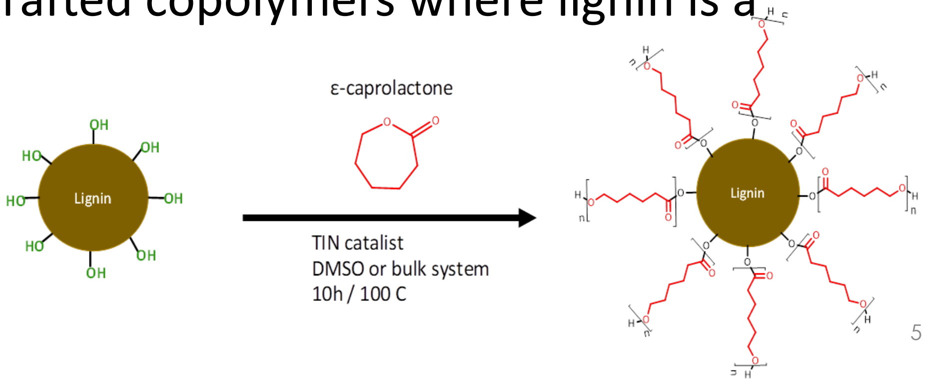




As a macromonomer i resin and polymer chemistry

- Lignin can be used as a macromonomer in co-polymers, where lignin is covalently bound.
- In most cases the phenolic as well as the aliphatic OH-groups are used as a polyol structure to replace other (synthetic) polyols.
- **Thermosets and resins**: Phenol-formaldehyde resins, epoxy resins, polyurethanes, acrylates.
- **Thermoplastic co-polymers**: Lignin grafted copolymers where lignin is a macromonomer/macroinitiator

  often as polyesters or acrylate.



Lignin a polyol macroinitiator

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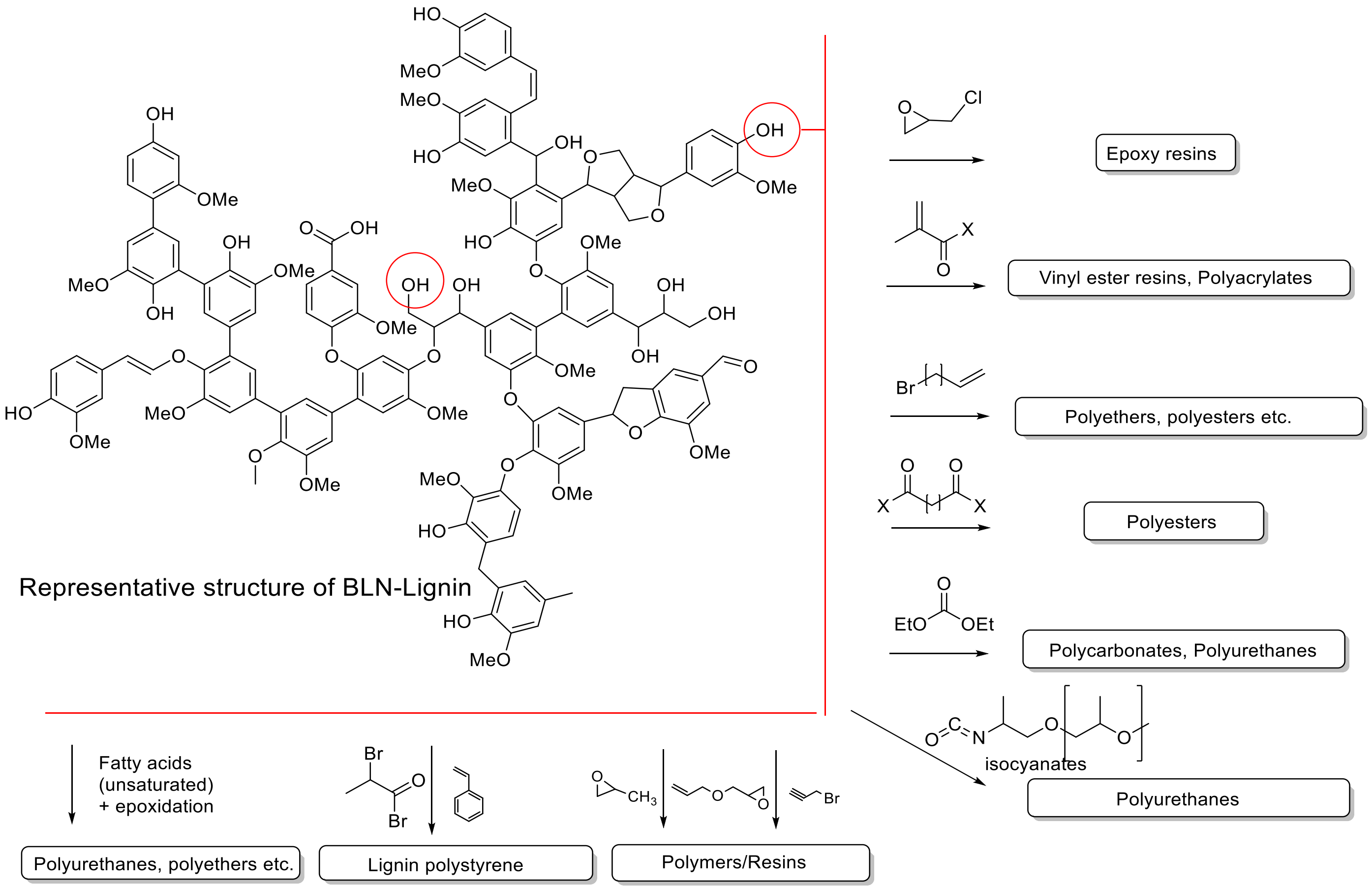


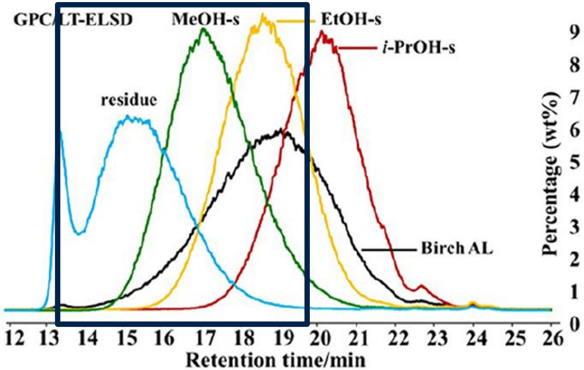
Lignin co-polymers – Lessons learned from LigninReSurf!

Problems with (in some cases)

- Solubility & miscibility in different formulations
- Compatibility, phase separation
- Curing (in UV curable formulations)

Depolymerization?

Best performance

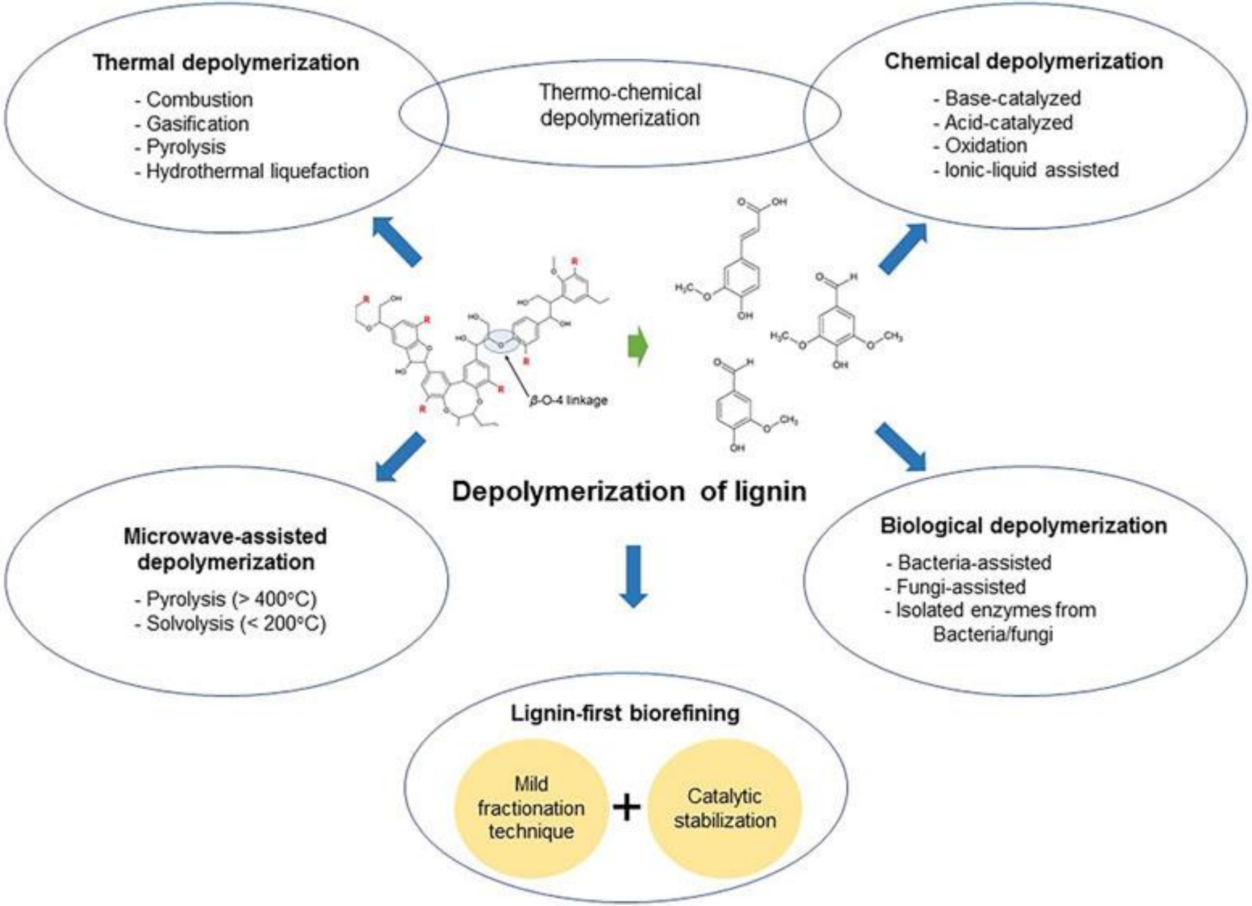


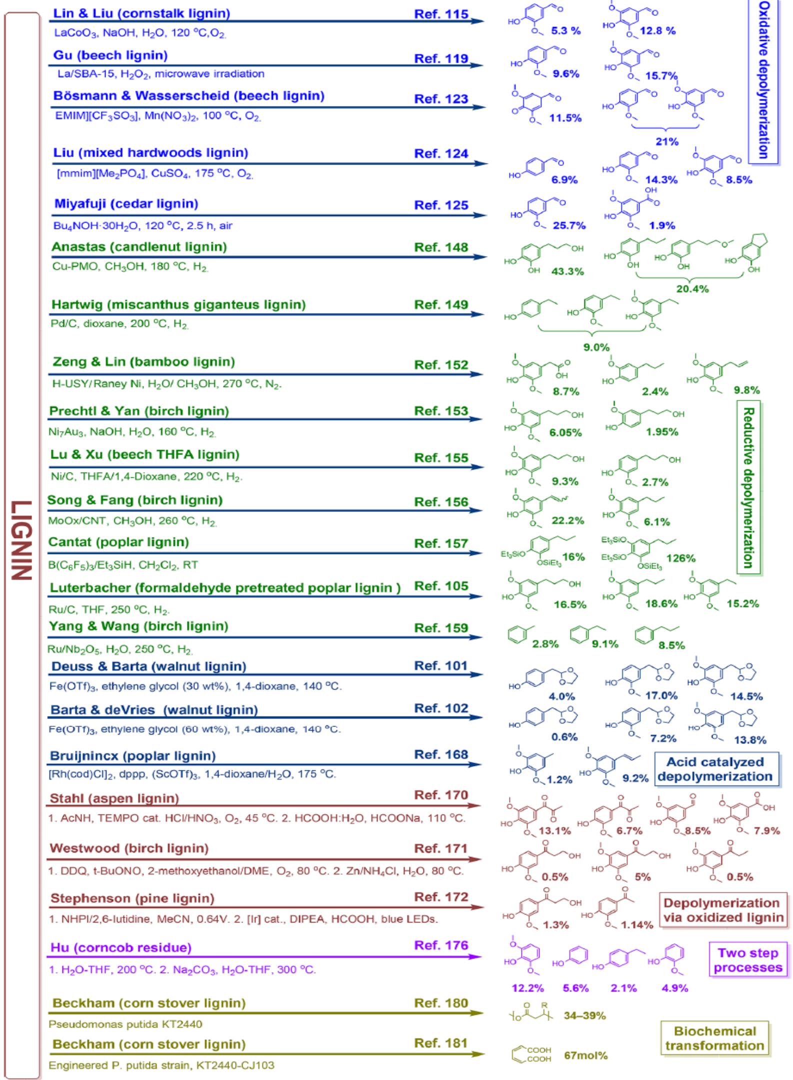
Structure – performance – relationship

=> Low molar mass fractions tend to perform bett

- better solubility
- higher OH-group content
- better reactivity

Depolymerization





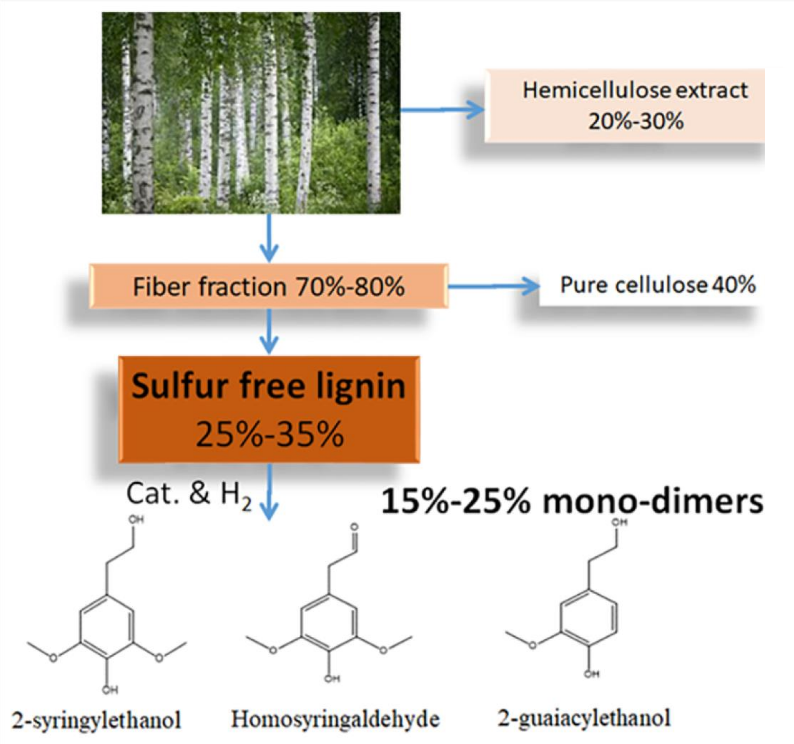
CHEMICAL REVIEWS
Review
Cite This: Chem. Rev. 2018, 118, 614–678
pubs.acs.org/CR

Bright Side of Lignin Depolymerization: Toward New Platform Chemicals

Zhuohua Sun,[†] Bálint Fridrich,[†,‡] Alessandra de Santi,[†,‡] Saravanakumar Elangovan,[†] and Katalin Barta[*,†]

- Monomeric platform chemicals are often the target
- Yields are typically 1-20%
- Depolymerization to lower the Mw – production of oligomers is less explored

Depolymerization of BLN-Lignin



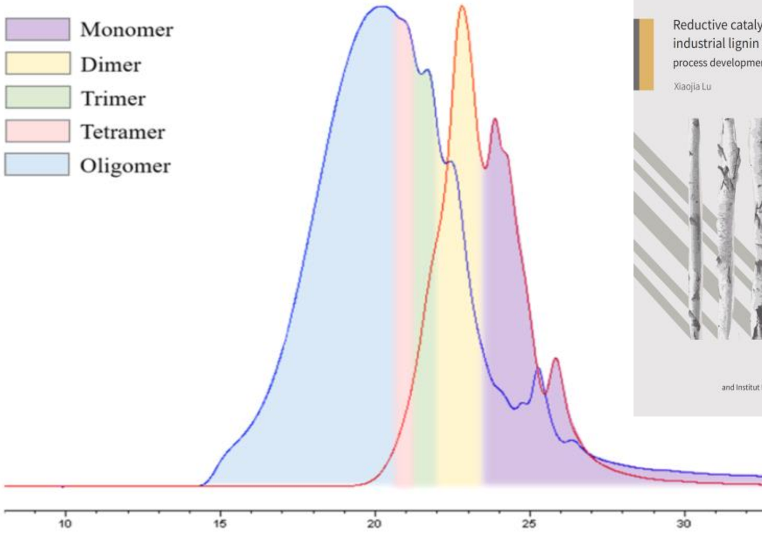
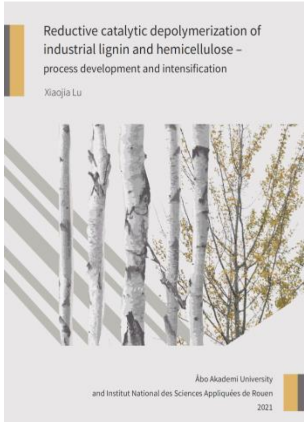


Figure 2. Schematic diagram of semi-quantitative analysis of liquid product distribution by HPSEC, method A. The blue line represents the substrate and the red line, the RCD product.



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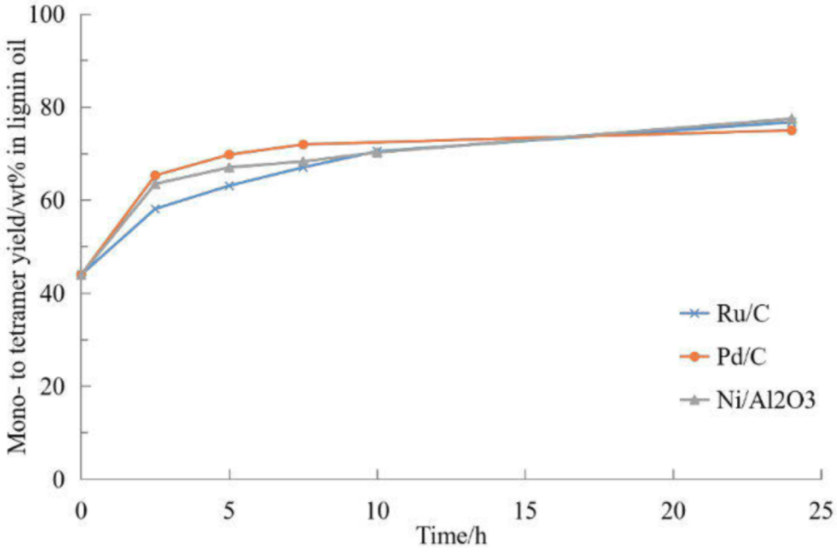
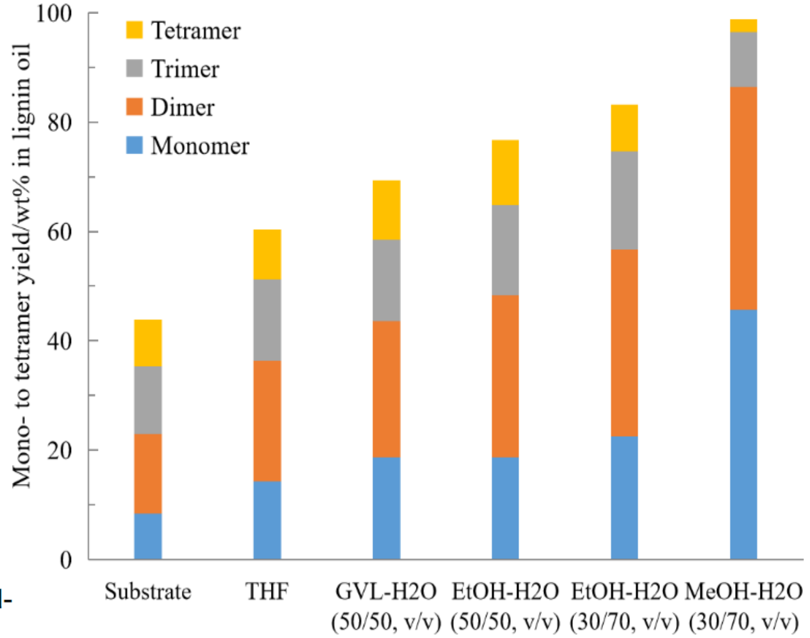
Depolymerization of lignin

Influence of catalyst and solvent on kinetics and product distribution





Reductive Catalytic Depolymerization of Semi-industrial Wood-Based Lignin

Xiaojia Lu, Lucas Lagerquist, Kari Eränen, Jarl Hemming, Patrik Eklund, Lionel Estel, Sébastien Leveneur, and Henrik Grénman*

Cite This: https://doi.org/10.1021/acs.iecr.1c03154 Read Online

Ru/C, T=240°C, $P_0(H_2)$=20 bar

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Tailored polyphenols and polyols from fractionation and depolymerization of biorefinery lignins (Depoly2ols)

Project period: 1.1.2024 - 31.12.2026

Patrik Eklund, Chunlin Xu, Henrik Grénman

BUSINESS FINLAND

Project overview and objectives

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- This project aims to develop a tailored and optimized process for reductive depolymerization of lignin (continuous reactors) combined with separation of lignin based oligomers.
- The potential production of polyphenolic oligomers from different biorefinery lignins for applications ***in polymer and resin chemistry*** and as antioxidant and antimicrobial agents will be investigated
- Modelling of large-scale production

Stockholms universitet

vito
Flemish Institute for Technological Research

BOKU
University of Natural Resources and Life Sciences, Vienna

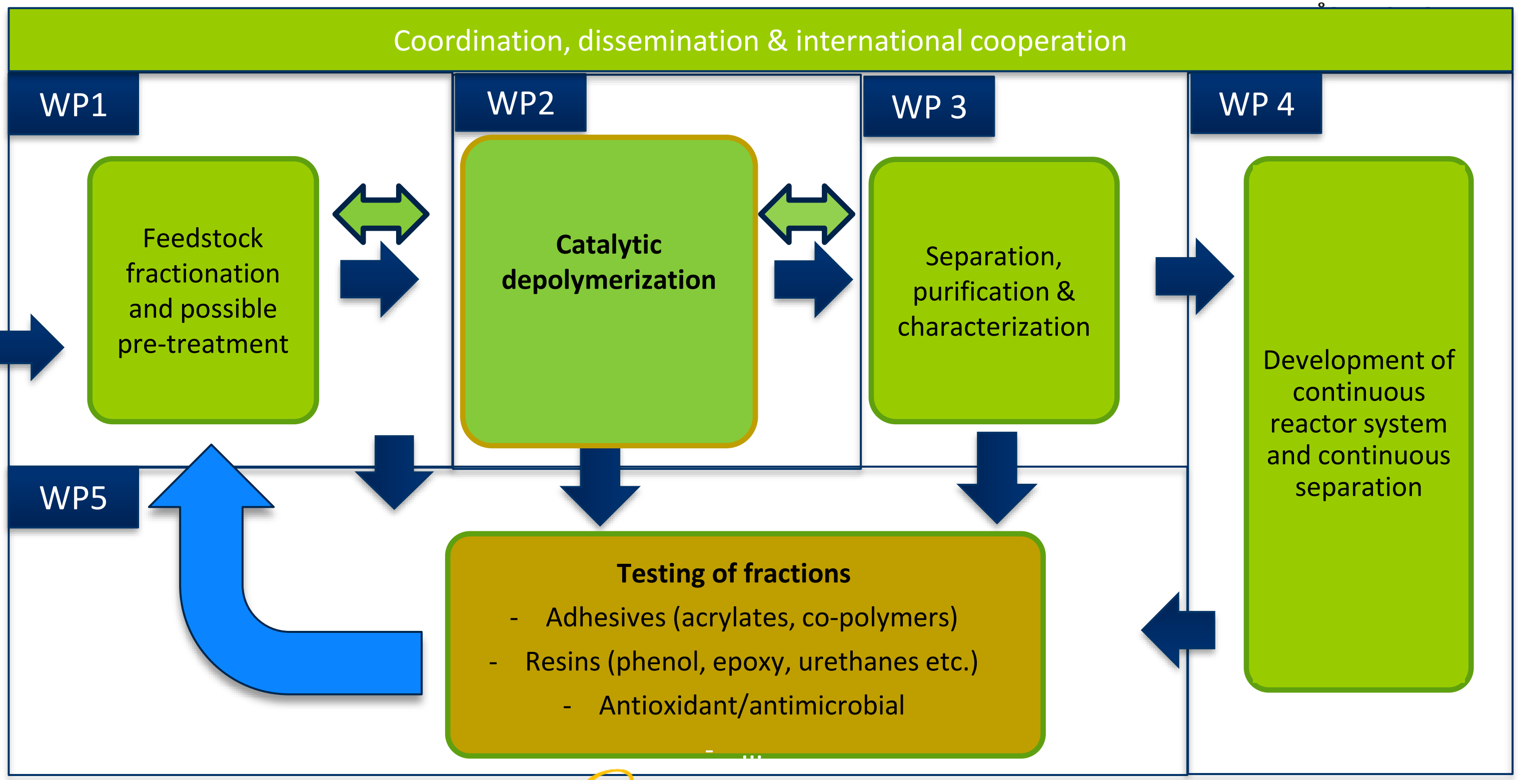
Beyond Circularity
Valmet

Biorefinery

Lignin from different sources (hardwood, softwood, straw, husk)

Kraft
Hydrolysis
Soda
Organosolv

Lignin providers:
CH Bioforce, Boreal biproducts, UPM, Metgen

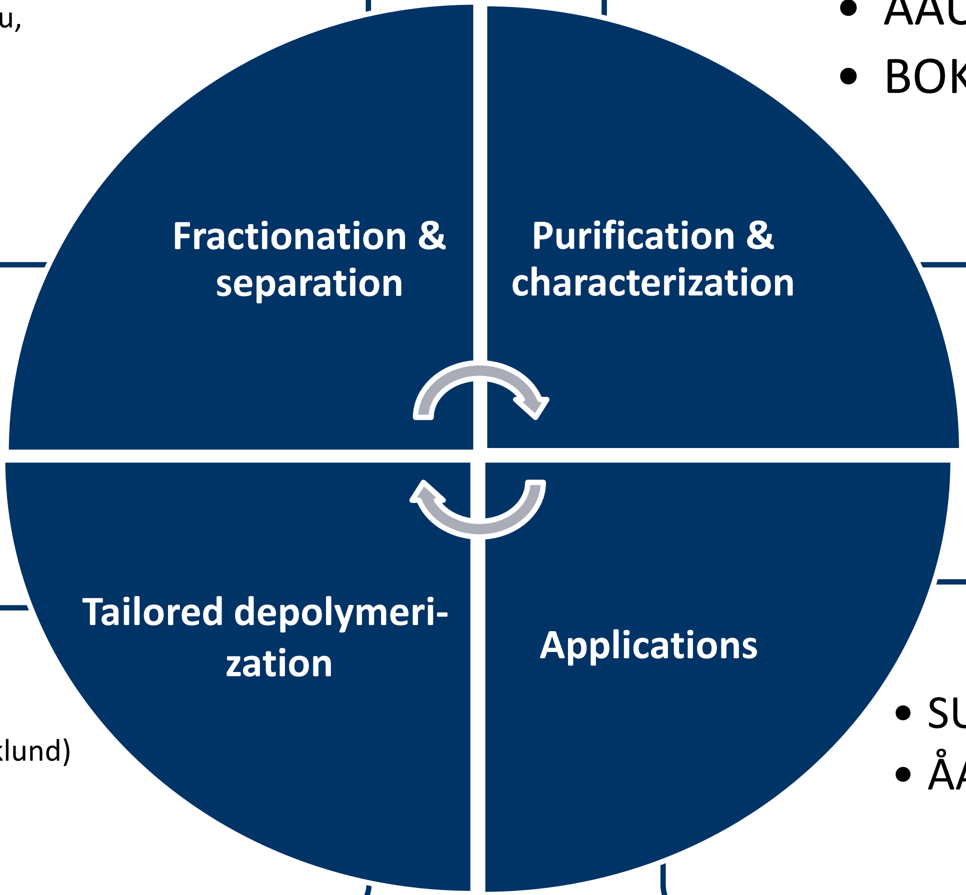


SHAPE ECOSYSTEM
MIRKA

Research teams

- ÅAU (Eklund, Xu, Grénman)
- VITO (Feghali, Vanbroekhoven)

- ÅAU (Eklund, Lassfolk)
- BOKU (Rosenau)



TASKS

- ÅA (Grénman, Eklund)
- VITO (Feghali, Vanbroekhoven)

- SU (Sipponen)
- ÅA (Eklund, Grénman, Xu)

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Characterization

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Contents lists available at ScienceDirect

Industrial Crops & Products

journal homepage: www.elsevier.com/locate/indcrop

ELSEVIER

Structural characterization of birch lignin isolated from a pressurized hot water extraction and mild alkali pulped biorefinery process

CrossMark

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Cite This: ACS Sustainable Chem. Eng. XXXX, XXX, XXX−XXX

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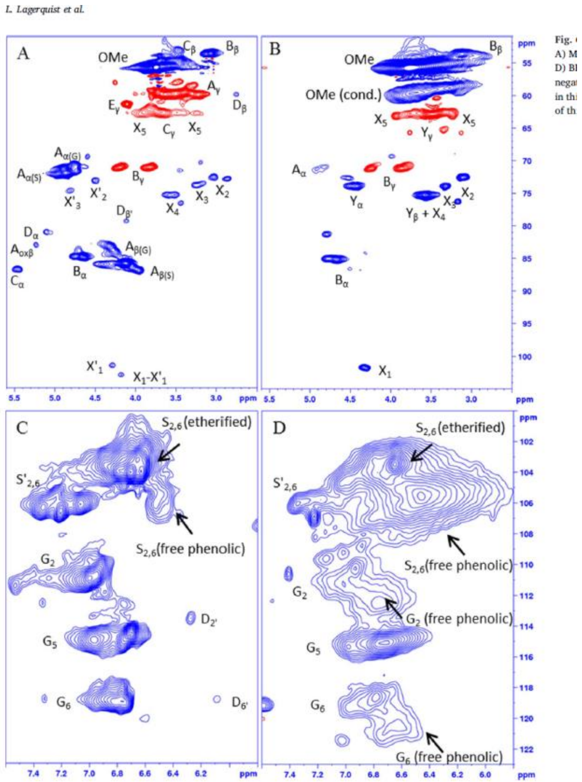
Utilization of ^{31}P PULCON for Quantitative Hydroxyl Group Determination in Lignin by NMR Spectroscopy

Lucas Lagerquist,[†,§] Jani Rahkila,[‡,§] and Patrik Eklund[*,†]

[†]Johan Gadolin Process Chemistry Centre, Laboratory of Organic Chemistry, Åbo Akademi University, Biskopsgatan 8, 20500 Turku/Åbo, Finland
[‡]Instrument Centre, Åbo Akademi University, Biskopsgatan 8, 20500 Turku/Åbo, Finland



CCMA
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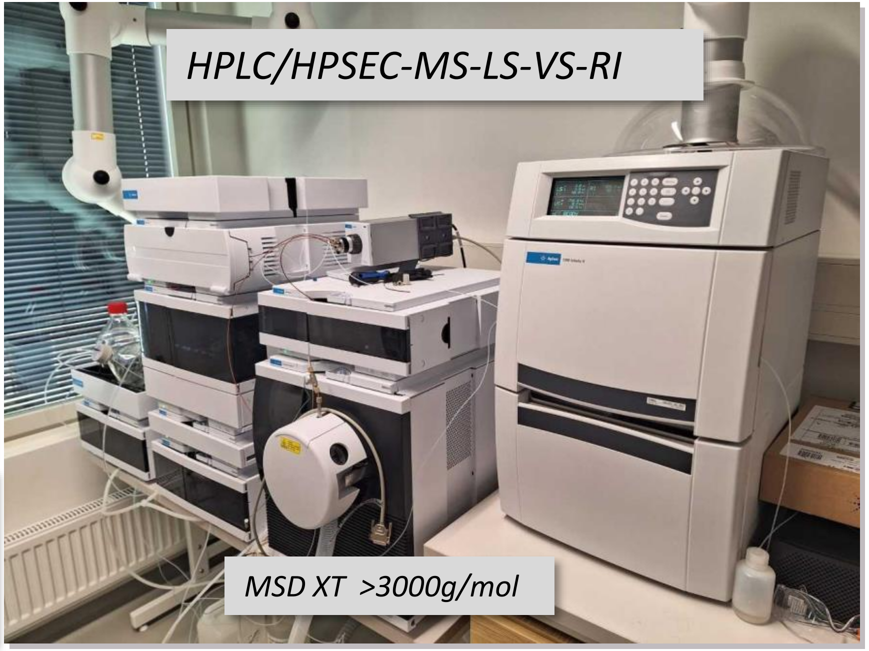
NMR:
600 MHz with Prodigy TCI (inverted CryoProbe)
3x500 MHz, 2 with Smartprobe, 1 with Prodigy BBO (CryoProbe)
400 MHz with CP-MAS (solid state) , HR-MAS (semisolid state)

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