Closed Cycles and the Circular Society 2023:
The Power of Ecological Engineering

1-5 October 2023, Chania, Greece

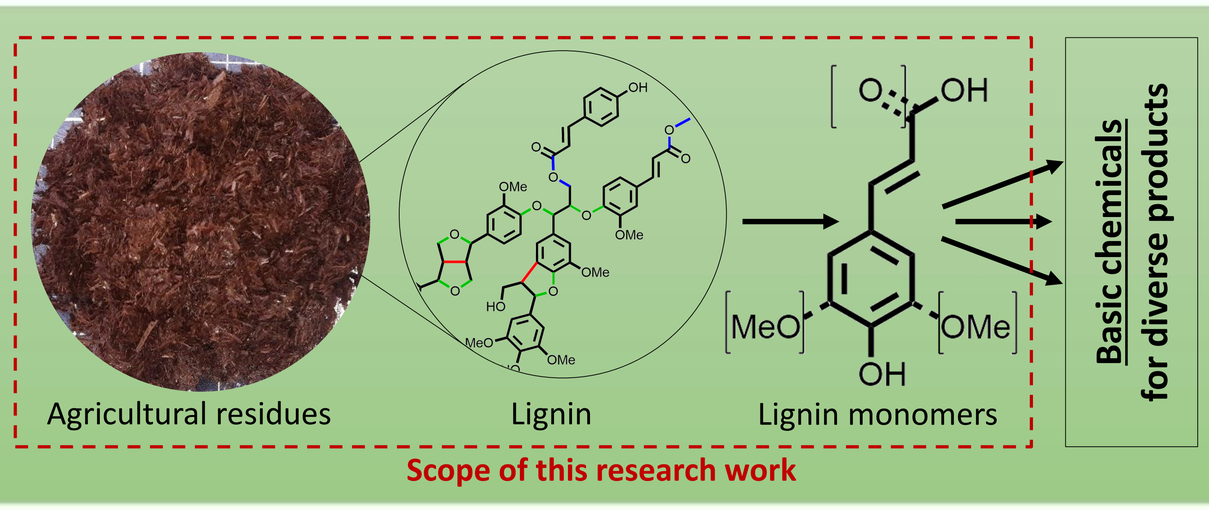
www.iees.tuc.gr

Production of biogenic aromatics from lignocellulosic agricultural residues

Timo Steinbrecher[1], Magdy Sherbi[2], Marvin Scherzinger[1], Jakob Albert[2], Martin Kaltschmitt[1]

[1] Institute of Environmental Technology and Energy Economics, Hamburg University of Technology, Germany

[2] Institute of Technical and Macromolecular Chemistry, University of Hamburg, Germany



1) Motivation and goal

1. Challenge: **aromatic chemicals** are almost exclusively produced from fossil petroleum nowadays.
   Potential: the **plant polymer lignin** is composed of aromatic monomers, abundant worldwide in non-food biomasses like **agricultural residues**.
2. Challenge: **conventional biorefineries** (f.e. for paper production) lead to **structural degradation of lignin**, which impedes its selective depolymerization to monomers.
   Potential: lignin degradation can be avoided by applying only **mild processes** (hypothetically anaerobic digestion) for lignin accumulation and depolymerization could be performed using **active stabilization strategies** ("lignin-first processes" like reductive catalytic fractionation).

Goal: **Depolymerization of lignin in agricultural residues like straw and straw digestates by reductive catalytic fractionation.**

2) Process

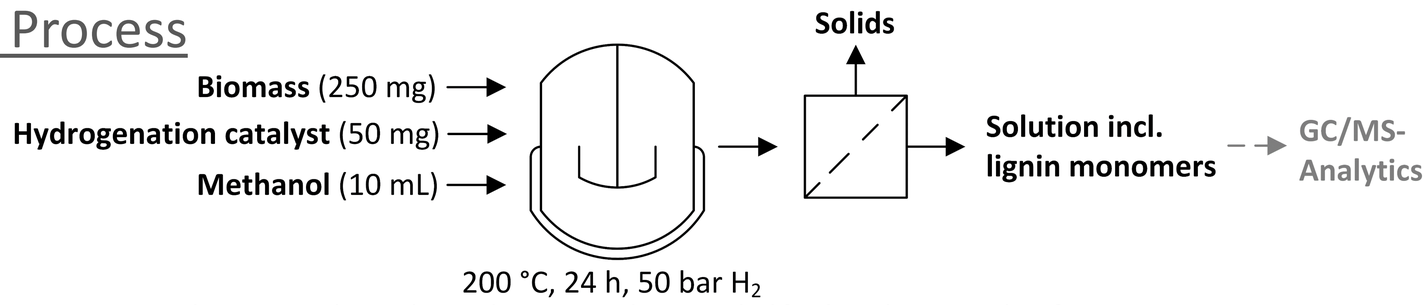


Figure 1: General experimental procedure and process conditions applied for the reductive catalytic fractionation screening experiments.

Table 1: Composition of the substrates used.

	Beech wood	Rye straw	Industrial straw digestate
	in wt% (based on dry mass)		
Glucan	40.5 ± 0.3	35.3 ± 0.3	36.2 ± 0.3
Arabinoxylan	20.6 ± 0.1	25.1 ± 0.3	24.7 ± 0.3
Lignin	24.6 ± 0.5	15.2 ± 0.2	25.6 ± 0.4
Ash content	0.9 ± 0.1	7.0 ± 0.03	3.7 ± 0.1
Lignin to holocellulose ratio	0.37	0.24	0.42

3) Results

- Biogenic aromatics can be recovered from the agricultural residues straw and straw digestates by reductive catalytic fractionation.
- Lignin accumulation during anaerobic digestion (see Table 1) → higher yields on biomass-basis from straw digestates than from unfermented straw (see Figure 2).
- Apparently no significant structural changes in lignin during anaerobic digestion, except for a slight degradation of hydroxycinnamates (decrease in monomers 5 and 6; see Figure 2).
- Yields increase with hydrogen pressure up to 50 bar and with reaction time up to 7 h (see Figure 3).
- Monomer selectivity from straw digestates is influenced by H_2 pressure and catalyst choice in a similar way as observed for woods [1,2]: High H_2 pressures and catalysts like *Pd/C* and *NiO/SiO$_2$-Al$_2$O$_3$* → high shares of γ-OH-monomers 1 and 3 (see Figure 3).
- Monomer yields from hardwoods like beech woods are significantly higher both on biomass and lignin basis (see Figure 2).
- Monomers 5 and 6 only from straw and straw digestates, not from beech wood (higher selectivities from wood, see Figure 2).

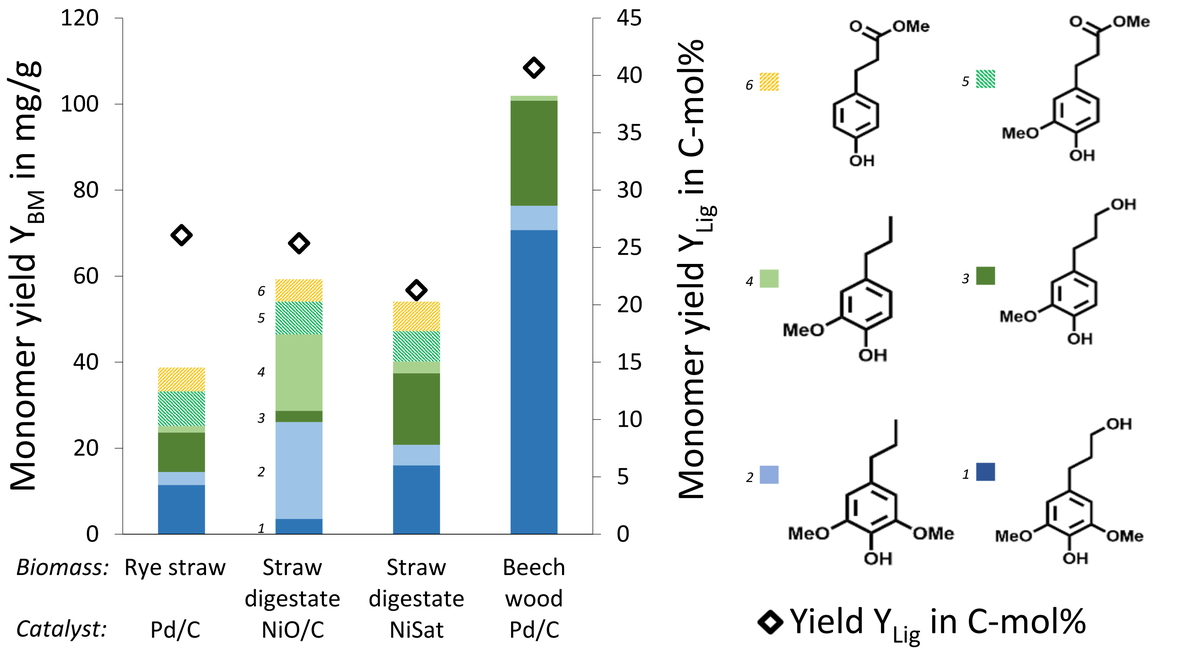


Figure 2: Monomer yields Y_{BM} based on biomass weight (left axis) and lignin-based monomer yields Y_{Lig} (right axis). NiSat=NiO/SiO$_2$-Al$_2$O$_3$.

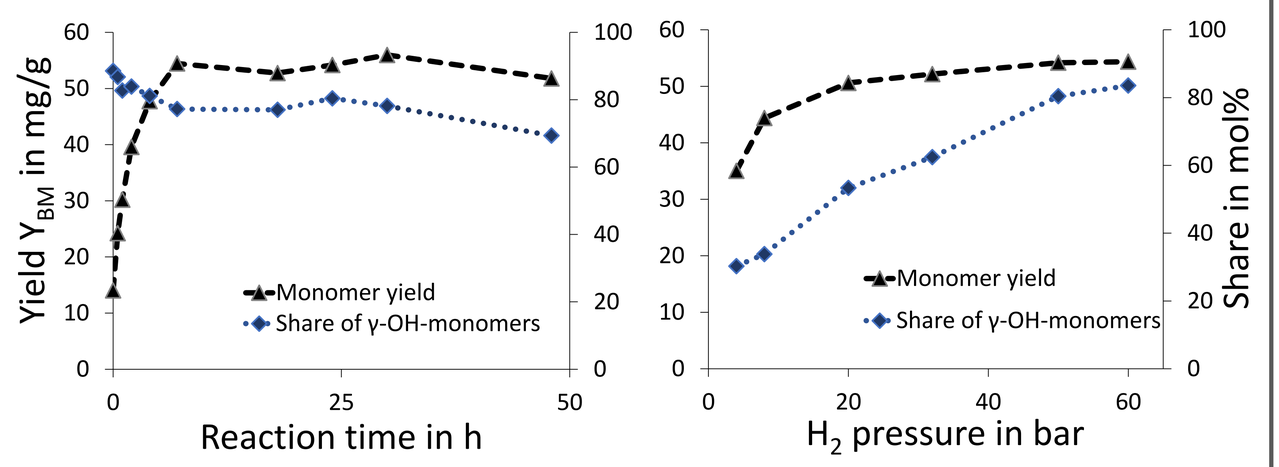


Figure 3: Influence of reaction time (left) and H_2 pressure (right) on monomer yield Y_{BM} (left axis) and share of γ-OH-monomers (monomers 1 and 3, right axis) during reductive catalytic fractionation of straw digestate. With NiSat=NiO/SiO$_2$-Al$_2$O$_3$-catalyst.

4) Conclusion

- Biogenic aromatics producible from lignin-containing agricultural residues by reductive catalytic fractionation.
- Lignin accumulation without significant structural degradation during anaerobic digestion → increased yields on biomass basis from digested biomasses compared to their unfermented counterparts.
- But: most abundant agricultural residues are herbaceous → lower monomer yields on biomass and lignin basis than from hardwoods.
- Comprehensive techno-economic assessment considering all side-streams needed for meaningful comparison.

Contact:
timo.hannes.steinbrecher@tuhh.de
+49 40 42878-4882
www.tuhh.de/iue

References:
[1] Renders, T.; Cooreman, E.; van den Bosch, S.; Schutyser, W.; Koelewijn, S.-F.; Vangeel, T. et al. (2018): Catalytic lignocellulose biorefining in n -butanol/water. A one-pot approach toward phenolics, polyols, and cellulose. In: Green Chem. 20 (20), S. 4607–4619. DOI: 10.1039/c8gc01031e.
[2] Van den Bosch, S.; Schutyser, W.; Koelewijn, S-F; Renders, T.; Courtin, C. M.; Sels, B. F. (2015): Tuning the lignin oil OH-content with Ru and Pd catalysts during lignin hydrogenolysis on birch wood. In Chemical communications (Cambridge, England) 51 (67), pp. 13158–13161. DOI: 10.1039/c5cc04025f.

SPONSORED BY THE Federal Ministry of Education and Research