Production of colloidal lignin particles from biorefinery lignins and application for stabilization of Pickering emulsions

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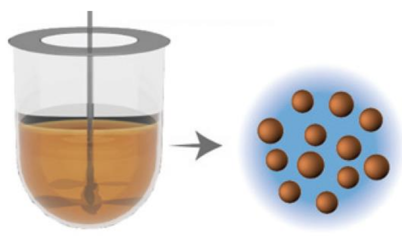
Introduction

Lignin

- **Second most abundant biopolymer in nature** ⟹ An important raw material for future biobased chemicals and materials.
- **Complex structure** ⟹ Full utilization of the widely available technical lignins streams from biomass processing remains a challenge.

Colloidal lignin particles (CLPs)

✓ Spherical lignin particles in colloidally stable aqueous dispersions can be produced by solvent shifting: lignin is dissolved in an (aqueous) organic solvent and precipitated in an antisolvent (typically water) [1].



✓ The capacity of CLPs of acting as stabilizers for Pickering emulsions has been demonstrated for various lignins [2-4].

The production of CLPs is a possible route for technical lignin valorization towards novel biomaterials with tailored properties.

Approach

Technical lignins

✓ **Structural characterization** to assess potential routes for CLPs production and modification for further applications.

✓ **Production of nanoparticles** with tailored properties for targeted applications.

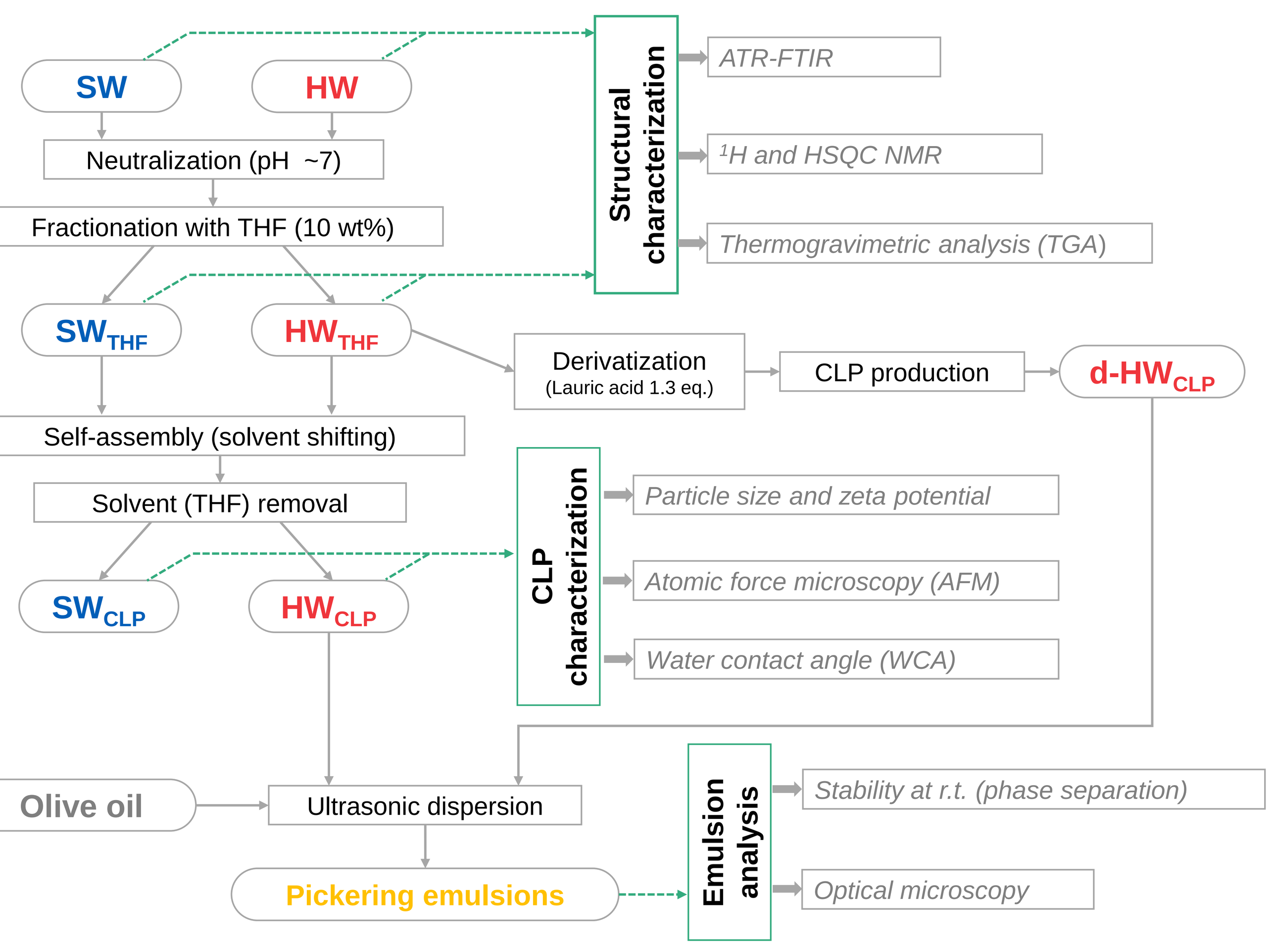
✓ **Chemical derivatization** to enhance behavior in applications.

✓ **Application** of the unmodified and modified CLPs for stabilizing Pickering emulsions.

Method

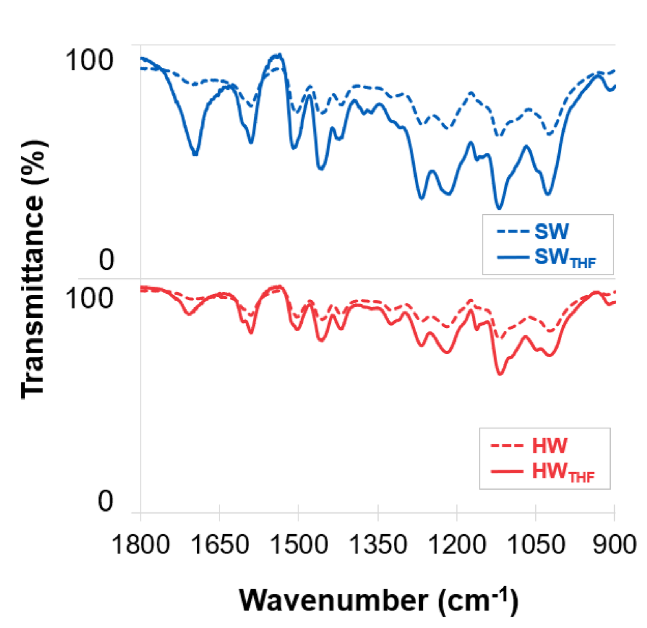
Technical lignins from acid hydrolysis in a biorefining plant

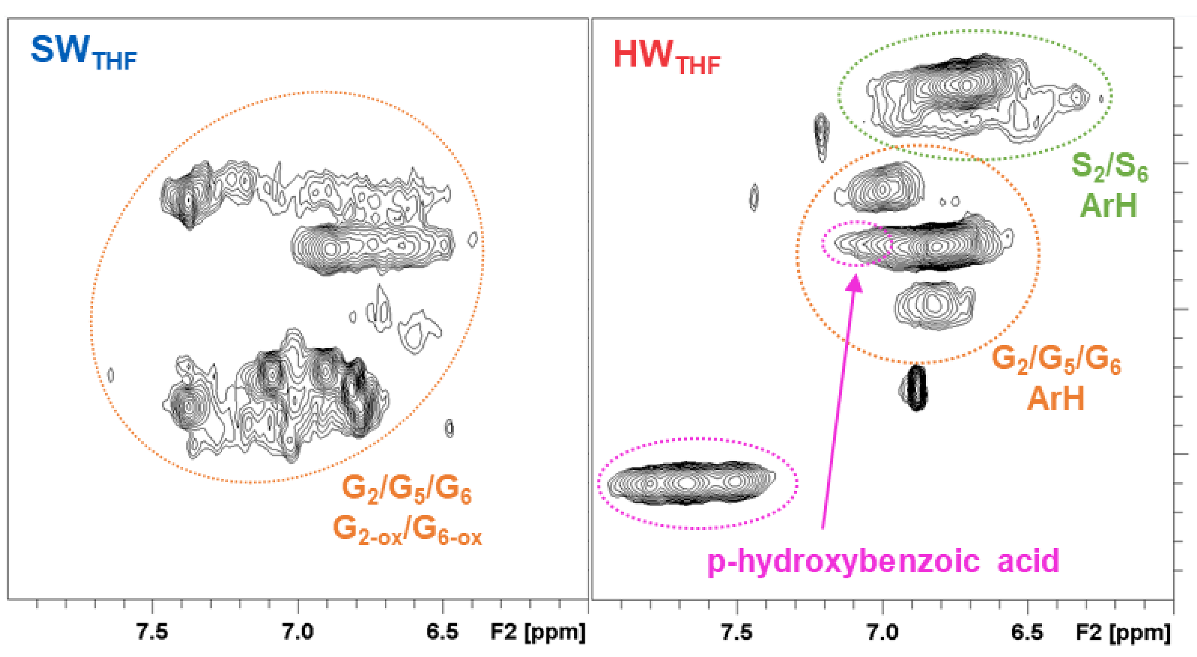
Softwood (pine) Hardwood (aspen)



Results

Structural characterization of biorefinery lignins





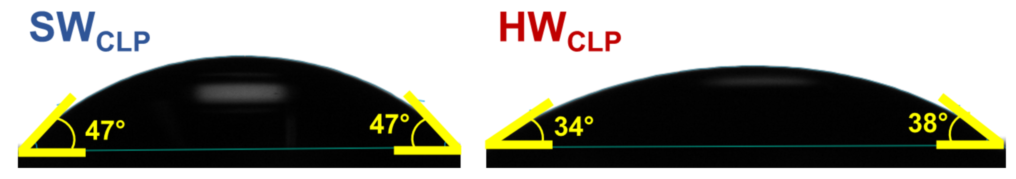
SW lignin has modified structures in comparison to HW lignin

Production and characterization of colloidal lignin nanoparticles (CLP)

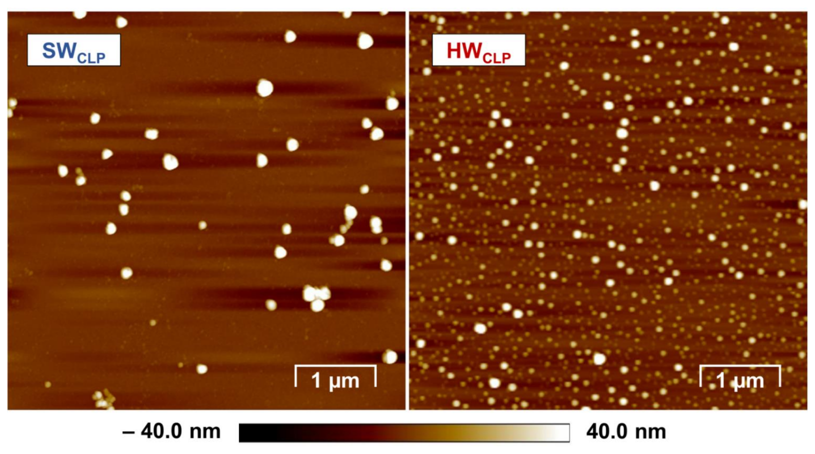
Particle morphology

Parameter	SW_{CLP}	HW_{CLP}
Average particle size (nm)	97	69
PDI	0.2	0.2
Zeta potential (mV)	– 25	– 34

Water contact angle

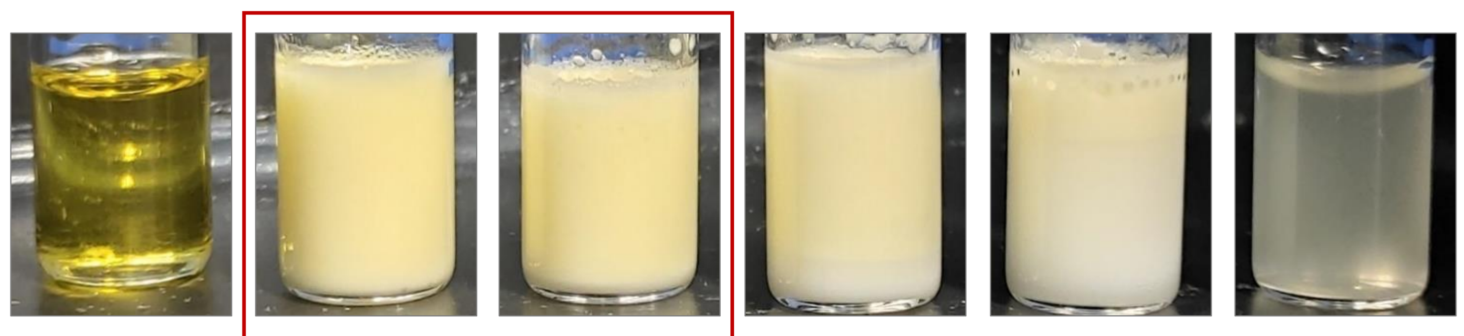


AFM imaging



Application of CLPs for stabilization of Pickering emulsions

Pickering emulsions with modified lignin (d-HW_{CLP}), immediately after sonication



CLP / olive oil ratio (v/v): 0.0 / 2.0; 0.4 / 1.6; 0.8 / 1.2; 1.2 / 0.8; 1.6 / 0.4; 2.0 / 0.0

Stable emulsions formed at lower CLP concentrations

Conclusion

- Acid hydrolysis lignins from biorefineries can be efficiently converted into nanoparticles with tailored properties;
- Derivatization of lignin improves capacity of CLPs of stabilizing Pickering emulsions with olive oil;
- CLPs with tunable properties allows the development of new materials with targeted applications that can efficiently respond to specific needs for biobased materials.

References

1. Österberg, M.; Sipponen, M. H.; Mattos, B. D.; Rojas, O. J. Spherical lignin particles: A review on their sustainability and applications. *Green Chem*, 2020, 22(9), 2712-2733.
2. Sipponen, M. H.; Smyth, M.; Leskinen, T.; Johansson, L.-S.; Österberg, M. All-lignin approach to prepare cationic colloidal lignin particles: stabilization of durable Pickering emulsions. *Green Chem*, 2017, 19, 5831–5840.
3. Zou, T.; Sipponen, M. H.; Österberg, M. Natural shape-retaining microcapsules with shells made of chitosan-coated colloidal lignin particles. 2019, *Front Chem*, 7, 370.
4. Rivière, G. N.; Pion, F.; Farooq, M.; Sipponen, M. H.; Koivula, H.; Jayabalan, T.; Pandard, P.; Marlair, G.; Liao, X.; Baumberger, S; Österberg, M. Toward waste valorization by converting bioethanol production residues into nanoparticles and nanocomposite films. *Sust Mat Tech*, 2021, 28, e00269.

Acknowledgments

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