Pickering or not Pickering? Deformation of lignin nanoparticles at the air-water and oil-water interfaces

Felix Abik [1], Lin Chen [1], Paavo Penttilä [2], Kirsi S. Mikkonen [1]

[1] Department of Food and Nutrition, University of Helsinki, Finland, [2] Department of Physics, University of Jyväskylä, Finland

felix.abik@helsinki.fi

Lignin has long enjoyed plenty of attention in the development of new sustainable materials due to its high abundance, phenolic structure, and versatile applications. While lignin generally has a low solubility in water, converting it into nanoparticles (LNP) allowed its dispersion into water, enabling its use in water-based applications such as in oil-in-water emulsions. Given lignin's low solubility in water, LNPs have long been considered to behave like solid particles, effectively acting as Pickering emulsifiers whose emulsifying performance relies on their surface properties[1]. For this reason, we attempted to improve the emulsifying property of LNPs by coating them with hemicelluloses, which halted their aggregation in acidic pH[2, 3].

However, we found that unlike regular Pickering emulsions, the size of LNP had little influence on emulsion stability. Coating the LNPs also did not allow a stable emulsion to be formed at acidic pH; instead, the coated LNPs behaved similarly to unmodified LNPs, suggesting that the core lignin material was more important than the surface. Using a combination of X-ray and neutron scattering methods, we observed that despite being clearly solid and compact in water, the LNPs may deform upon adsorption. The extent of such deformation was dependent on the type of lignin (where softwood LignoBoost® lignin-based LNP was more resistant to deformation compared to BLN™-extracted hardwood lignin) and oil used in the emulsion (with isooctane emulsions having a thicker interfacial layer compared to hexadecane emulsions). Based on these results, we propose that as emulsifiers, LNPs should be treated more as polymeric microgels than solid particles, and call for further investigation into correlating the polymeric properties of lignin from different sources and extraction methods towards the functionalities of LNPs. Such knowledge will allow a more precise use of various types of lignin to tailor emulsion properties, hopefully facilitating a more widespread adaptation of lignin as future sustainable emulsifiers.

Keywords:
Lignin nanoparticles, Pickering emulsions, lignocellulose, lignin

References:

[1] Österberg, M., et al., Green Chemistry, 2020. **22** (9): p. 2712–2733 DOI: 10.1039/D0GC00096E.
[2] Figueiredo, P., et al., ChemSusChem, 2025. **18** (14): p. e202500668 DOI: https://doi.org/10.1002/cssc.202500668 .
[3] de Carvalho, D.M., et al., Macromolecular Rapid Communications, 2025. **46** (23): p. 2500120 DOI: https://doi.org/10.1002/marc.202500120 .