Climate Informed Engineering

TUHH

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Project B3: Climate-informed optimization of solid lignin-based products

Lignin, one of the most underutilized natural polymers, has noteworthy potential for functional and environmentally friendly material applications. This project focuses on investigating the influence of climate conditions on lignin properties and, consequently, on its advanced applications.

Lignin is an aromatic biopolymer and one of the main components of wood. It acts as a natural glue that binds wood cells together, enhancing mechanical strength and rigidity while also contributing to barrier properties. Owing to its chemical composition and properties, lignin is an interesting material for a wide range of applications, including the reduction of wettability in hydrophilic materials.

Lignin is the second most abundant biopolymer on Earth. Every year, 50–70 million tons of technical lignin (a by-product of biomass separation processes) are produced, yet only about 2% is used commercially. Technical lignin differs from native lignin not only in its botanical origin, but also as a result of extraction processes and possible chemical modifications [1].

Within the Climate-Informed Engineering Research Training Group funded by the DFG, we aim to apply machine learning algorithms to identify and quantify the relationships between process parameters and the physicochemical properties of lignin. Particular emphasis is placed on colour and surface characteristics, which may be influenced by climatic conditions, and on how these factors affect lignin applications—for example, its use as a natural hydrophobizing agent for biopolymeric particles.

Given lignin's complex and highly variable structure, it is essential to characterize lignins derived not only from different feedstocks and extraction processes, but also from different climatic regions. To achieve this, climate data provided by the Max Planck Institute are combined with comprehensive lignin characterization, enabling a deeper understanding of lignin variability. This knowledge is required to investigate lignin applications under varying climate conditions, with a particular focus on lignin-based coatings for biopolymer aerogels. For this particular application, it is crucial to understand lignin self-organization mechanisms on bioparticle surfaces and their impact on coating performance.

Ultimately, we aim to develop a model that links climate information, lignin properties, and coating performance in novel applications. This work will be carried out in cooperation with areas A2 and B2, and in collaboration with B1 and A1 for analytics and data structuring.

[1] J. Ruwoldt, F. H. Blindheim, and G. Chinga-Carrasco, 'Functional surfaces, films, and coatings with lignin – a critical review', *RSC Adv.*, vol. 13, no. 18, pp. 12529–12553, 2023, doi: 10.1039/D2RA08179B

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