To break or not to break? Spectroscopic fingerprints for rapid screening of lignin's potential as a raw material to produce chemicals or materials

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Valorisation of lignin, a key component of plant biomass, is essential for advancing the bio-based economy. Unfortunately, the valuable native structural features of lignin are often compromised during traditional extraction processes such as Organosolv and Kraft pulping [1,2]. To maintain lignin's structural integrity and reactivity—crucial for converting it into high-value chemicals, biofuels, and materials—there is a need for more precise control over the chemical processes used in lignin extraction [1,2]. Supported by advanced HSQC NMR spectral data, this talk examines UV-Vis spectroscopy as an effective technique to identify and analyse significant structural and molecular differences in lignin according to various extraction methods. Our discussion is divided into three main parts. First, we discuss the rationale and strategic approaches to lignin valorisation, in line with the principles of Green Chemistry and Green Engineering. Second, we highlight the importance of fractionating lignin by molar mass to explore its molecular diversity. Third, we evaluate the valorisation potential based on molecular structures, emphasising how spectroscopic data can illuminate opportunities for valorisation. In this context, methods such as H-transfer reductive catalytic fractionation (HT-RCF) that preserve lignin's native structural architecture are proven to effectively maintain its inherent reactivity. The stabilisation of high molar mass lignin species through selective reductive processes in HT-RCF ensures that they remain close to their natural structural architecture [3]. This evolution of the RCF concept, which aims at producing lignin polymers with controlled properties, represents a significant development in the lignin-first strategy. It introduces a strategic pathway for creating sustainable materials directly from lignin extraction, circumventing the resource- and energy-intensive traditional processes that depend on post-depolymerisation, functionalisation, and (re)polymerisation as routes for lignin utilisation.

References

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BIO

Dr. Roberto Rinaldi, FRSC is a naturalised British academic distinguished for his catalysis-driven innovations in biomass conversion, notably the "lignin-first" biorefining approach. He obtained his PhD in Inorganic Chemistry from the Institute of Chemistry at the University of Campinas in São Paulo, Brazil, in 2006. Moving to Germany in 2007, he quickly ascended from a postdoctoral role to Junior Research Group Leader at the Max-Planck-Institut für Kohlenforschung by 2009. In 2010, Dr. Rinaldi was promoted to Independent Research Group Leader (W2 professor), backed by a prestigious Sofja-Kovalevskaja Award from the Alexander von Humboldt Foundation (1.54 M€, 2010-2015) to pioneer methods for lignin valorisation. In 2015, Dr. Rinaldi joined Imperial College London as a Senior Lecturer in the Department of Chemical Engineering and was promoted to Reader in Applied Chemistry in 2018. He currently heads Tomorrow's Chemical Technologies Lab, bolstered by a highly competitive ERC Consolidator Grant "LIGNINFIRST" (2 M€, 2017-2022). Recognised for his significant contributions in the field of lignocellulosic biomass fractionation, Dr. Rinaldi received the Willi Keim Prize from ProcessNet/DECHEMA, Germany, in 2014. He was appointed a Fellow of the Royal Society of Chemistry (FRSC) in 2017. He has authored approximately 100 research papers and book chapters, including the reference book "Catalytic Hydrogenation for Biomass Valorisation" published in the RSC Energy and Environment Book Series in 2014. He filed 14 application patents in biomass conversion and catalysis. His scholarly work has attracted over 12,000 citations (h-index 47). He has supervised 17 PhD and 21 MSc students and mentored 20 postdoctoral research fellows. Dr. Rinaldi also serves as an associate editor for npj Materials Sustainability and on the advisory boards of ChemCatChem and Green Chemistry.