Applications of Cellulose Nanowhiskers and Lignin In Preparation Of Rigid Polyurethane Nanocomposite Foams

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Lignin is the second most abundant biopolymer on Earth, right after cellulose, with a highly complex chemical structure that hinders its possible utilizations. As a consequence, it is mostly burned as an inexpensive resource, generating green electricity or heat that in turn can be used for the deconstruction of biomass itself. Applications that utilize lignin in different manners are of great interest, due to its inexpensive nature and promising return in case an efficient conversion process is discovered with possibly a high value end-product. The integrated biorefinery concept formulates that all biomass components should be used to their maximal potential to minimize emissions and generate a renewable biopolymer-based industry.

Present work is based on a more modest notion of converting lignin into different biofuels that have only a few, however important, advantages over lignin as a direct energy source. Pyrolysis, for instance, results a bio-oil that has a higher (in some cases 20 times) energy density than the starting lignin. Another possibility is bioconversion, through oleaginous microorganisms that can live off lignin as a sole carbon source, producing biodiesel precursor lipids. This latter path is more ambitious by aiming for the simplification of lignin's structure, through intermediate materials that have a uniform structure, facilitating various applications. These mentioned lignin modification methods represent the core of this dissertation.

The first part of current work (Chapter 4) details the analysis of lignin from a relatively new lignin isolation process called LignoBoost. It is obtained from the pulp and paper industry as a residual product of Kraft pulping, via CO2 precipitation of lignin from black liquor (BL). This method is environment friendly (CO2 is consumed), results a good quality lignin (detailed below), eliminates the main bottleneck of the Kraft cycle (recovery boiler capacity), and yet leaves enough lignin within the "weak" BL to recover pulping chemicals and generate energy for the pulp mill. Pyrolysis directly converts this lignin into biofuel with several advantageous properties.

The second part of this dissertation (Chapters 5-6) seeks proof for the theory that lignin degradation and lipid accumulation metabolic pathways can be interconnected to gain lipids while utilizing lignin. First, to prove the core concept, pure model compounds, such as vanillic acid, are used in nitrogen-limited fermentations with Gram-positive Rhodococcus opacus species, DSM 1069 and PD630. Subsequently, the same strains are used to evaluate lignin to lipid bioconversion, starting with ethanol organosolv and Kraft lignin. This conversion is a first step in a multistep process towards biodiesel production, which includes transesterification, after lipids are extracted from the cells.