ABSTRACT

A biorefinery aims at converting plant biomass into fuels, power, and value-added chemicals. It is analogous to today's petroleum refinery, which produces multiple fuels and products from crude oil, but it has a lower carbon footprint and enables a circular economy. Typical feedstocks include lignocellulosic biomass, food waste, algae, vegetable oils, sugars, etc. While significant developments have been made in the field, the poor economic viability of biorefineries has limited their widespread commercialization. The largest fraction of the cost is associated with the cost of the feedstock. To improve the economic potential of biorefineries, there is a need for cheaper and more diverse feedstocks and energy and material efficient conversion processes to produce a slate of high value-added chemicals. To this end, the objective of this thesis is to investigate the conversion of unconventional biomass feedstocks into platform chemicals as well as upgrading the intermediate chemicals into high value products towards a viable biorefinery.

In this thesis, we begin by studying the hydrolysis of food waste derived starch towards producing renewable chemicals and fuels. The kinetics of glycosidic bond scission of malto-oligosaccharides in lithium bromide acidified molten salt hydrate (AMSH) medium is investigated and modeled. The developed model is extended to simulate the hydrolysis of linear and cyclic saccharides of varying degree of polymerization and of potato starch.

Next, cheap and abundant waste from bioethanol and agricultural processing are depolymerized, over Ru/C powder and Ru/Al₂O₃ pellets into phenolic monomers with high yields, leaving behind a carbohydrate pulp residue. Batch reaction experiments, reaction kinetics
analysis, machine learning, and catalyst characterization are employed to provide fundamental insights toward the reductive depolymerization of herbaceous biomass lignin, which is structurally distinct from woody biomass lignin. Principal component analysis indicates that the monomer yields from herbaceous biomass depend on the content of lignin crosslinker – ferulate, explaining the unexpected low monomer yields of high β-O-4 herbaceous biomass.

Finally, we developed a strategy to synthesize branched benzene lubricant (BBL) and branched cyclic lubricants (BCL) lubricant base oils from lignin-derived monomers and aldehyde to replace current petroleum-derived lubricants. The reaction pathway involves carbon-carbon coupling through Brønsted acid-catalyzed hydroxyalkylation/alkylation (HAA) followed by hydrodeoxygenation (HDO). Quantification of properties indicates that the biobased lubricant base oils are comparable to commercial petroleum-derived poly α-olefin Group III, IV, and refrigerant base oils. This approach provides a sustainable pathway for upgrading lignin-derived monomers into replacements of petroleum-derived base oils.