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Catalytic Conversion of Ionic Liquid-Based Biorefinery Lignin

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Abstract

Lignin, an aromatic-based natural polymer accounting for one-third of the organic carbon in the biosphere, is underutilized when compared to holocellulosic fraction of lignocellulosic biomass – mostly due to the randomness and heterogeneity in the chemical structure. Additionally, conventional delignification processes (Kraft, sulfite, etc.) employed in pulp and paper industries causes condensation of lignin units through the formation of stable C-C bonds rendering depolymerization highly challenging. In contrast, ionic liquid (IL)-based processes, among various delignification processes, have attracted much attention because of high sugar yields, bio-compatible processes, and sulfur-free lignin with minimum structural changes.

In this poster, we will discuss the generation of IL-based biorefinery lignin from bioenergy crops including sorghum and poplar. The structure, composition, and purity of lignin will be discussed. Furthermore, two distinct catalytic conversion pathways i.e., hydrogenolytic and oxidative fractionation of such IL-based biorefinery lignin to value-added products will be included here.

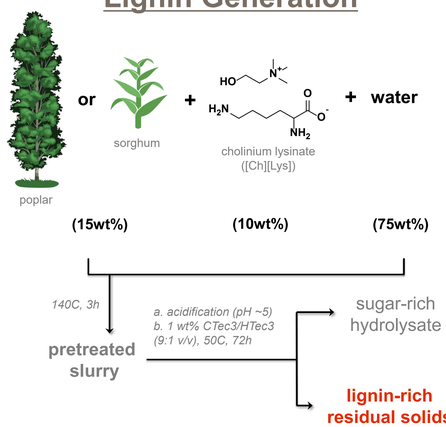
Objective

To develop and demonstrate integrated, feedstock agnostic, and efficient chemical deconstruction technologies using biocompatible ionic liquids (such as cholinium lysinate, [Ch][Lys]) for

- non-technical grade lignin stream for facile depolymerization into monomers
- high yields and selectivity of intermediates compatible with downstream processing
- catalytic depolymerization of lignin to afford minimum char formation over reusable and robust catalysts
- processing of various biomass sources including mixed biomass feedstock

Results

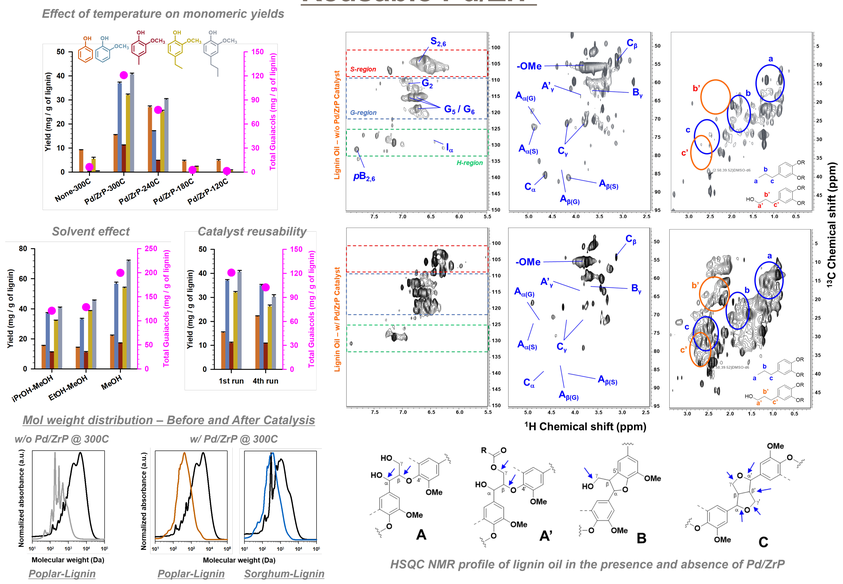
[Ch][Lys]-Based Biorefinery Lignin Generation



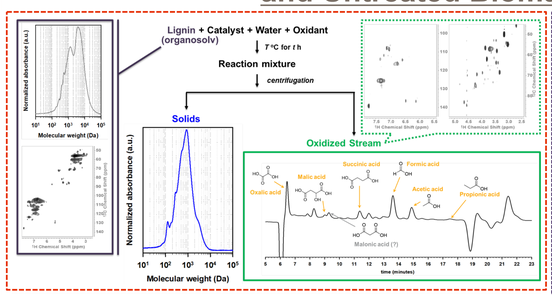
Compositional analysis of the residual solids after [Ch][Lys] pretreatment and enzymatic saccharification (%)

residual solids from	glucan	xylan	lignin
sorghum	4.9	2.0	51.6
poplar	19.3	3.8	42.3

Hydrogenolysis of [Ch][Lys]-Based Biorefinery Lignin over Reusable Pd/ZrP

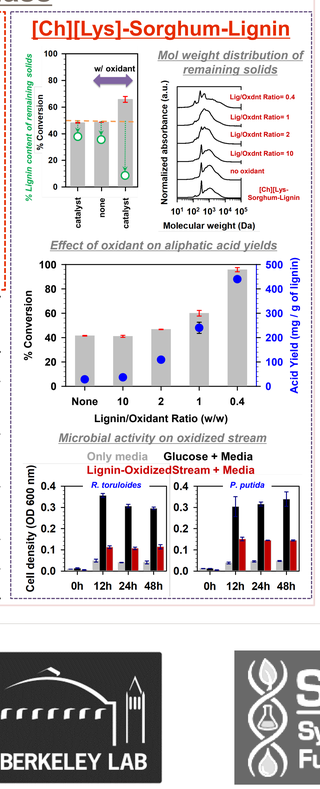


Catalytic Oxidation of [Ch][Lys]-Based Biorefinery Lignin and Untreated Biomass

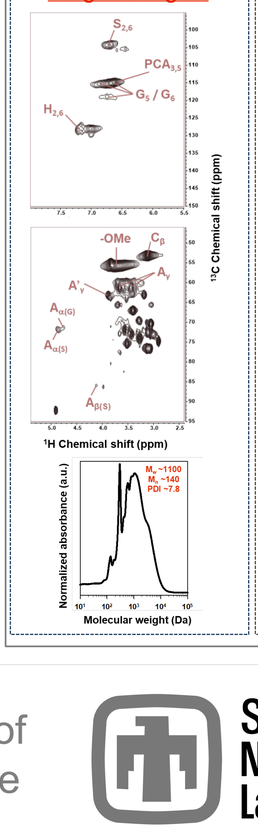


Lignin Source	Aliphatic acids (mg/g of lignin)	Aromatic acids (μM)	Composition Glucan / Xylan (%)	Sugar Release Glucose / Xylose (%)
organosolv	~85	~1180	-	-
[Ch][Lys]-Sorghum-Lignin	~450	~70	-	-
Untreated Sorghum	~800	~150	49.2 / 2.3	43.9 / 59.2
Untreated Switchgrass	~1150	~170	45.2 / 1.6	60.5 / 40.0
Untreated Poplar	~1250	~65	51.9 / 1.3	53.8 / 37.7
Untreated Pine	~1100	~95	50.9 / 1.6	51.0 / 54.4

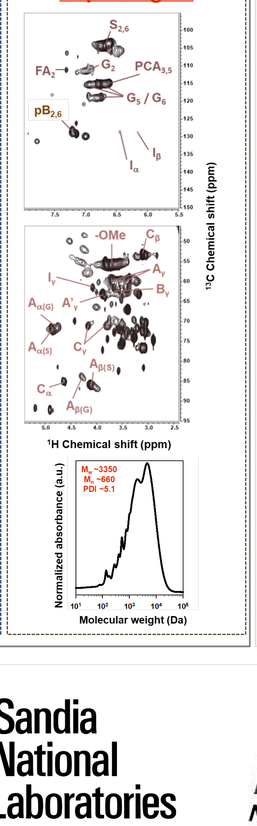
[Ch][Lys]-Sorghum-Lignin



Sorghum-Lignin



Poplar-Lignin



Conclusions

Commercial biorefineries must be able to convert the majority of components present in lignocellulosic biomass, including lignin, into biofuels and bioproducts. IL-based processes, as a function of the ions involved, influenced the structure, composition, and purity of the generated lignin as established by the analysis using HSQC NMR and GPC, among others. Furthermore, the hydrogenolytic conversion of [Ch][Lys]-based biorefinery lignin into guaiacols (upto 20wt%) over reusable Pd/ZrP catalyst was also demonstrated. The viability of oxidative depolymerization of [Ch][Lys]-based biorefinery lignin into aliphatic acids over heterogeneous W-ILs was also exhibited, producing ~450 mg aliphatic acids per g of lignin. Furthermore, lignin-first oxidative catalytic fractionation was employed to boost aliphatic acid yields to ~1250 mg per g of lignin. We acknowledge that rigorous models to understand the reaction pathways, catalytic sites, and environmental and economic impacts are required to enable overall sustainability and economic viability.

Acknowledgments

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