Title: Lignin Fractionation and Valorization: Focusing on both Value and Quality

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Topic Area 6: Lignin Valorization

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By exploiting the novel liquid–liquid equilibrium that exists between lignin and hot, one-phase solutions of aqueous renewable solvents, crude bulk lignins can be simultaneously fractionated, cleaned, and solvated for conversion to high-value, high-quality bioproducts. This unusual phase behavior forms the basis for a fractionation process that we refer to as Aqueous Lignin Purification with Hot Agents, or ALPHA. With this recently patented technology of PI Thies, control of both the purity and molecular weight of lignin becomes possible. Furthermore, the technology has also been developed for continuous operation, so it can be commercially scaled. Finally, ALPHA has the added advantage of using renewable solvents that are produced within the biorefinery, including hot aqueous solutions of acetic acid or ethanol.

Lignin is like any other polymer in that the molecular weight can have a dramatic impact on its suitability for a given application. Furthermore, polymer purity can be an equally important factor if the desired materials properties are to be achieved. Two large and growing markets have been identified for "ALPHA" lignin use: (1) high-performance carbon fibers for automotive applications and (2) rigid polyurethane foams for spray insulation for buildings. In both cases, we hypothesize that today's commercial lignins have too broad a molecular weight (MW) distribution and are too low in purity to give acceptable performance. Preliminary results with lignins of controlled MW and high purity are encouraging. For example, very clean, high-MW lignins isolated via ALPHA were converted by co-PI Ogale into carbon fibers almost 40% stronger than any previously reported from lignin. For rigid polyurethane foams, preliminary data by co-PI Nejad [5] suggest that very clean lignins of low molecular weight and polydispersity with high hydroxyl content would be ideal as a replacement for polyols.

Yet another lignin-containing stream from the lignocellulosic biorefinery will also be converted into a high-value product. Astaxanthin is a secondary carotenoid from the same family as β-carotene; it is considered to be a "super antioxidant," with important nutraceutical and pharmaceutical applications. Recently, co-PI Zheng has shown that the marine protist *T. striatum* can ferment the black liquor by-product from alkaline pretreatment into astaxanthin. Although lignin consumption to produce the astaxanthin is small compared to the two uses cited above, this bioproduct has such a high value that its generation provides a nontrivial assist towards our goal of <$2/gal ethanol.