Aldehyde Free Bio-adhesive Prepared from Soy Protein Isolate and Depolymerized Lignin

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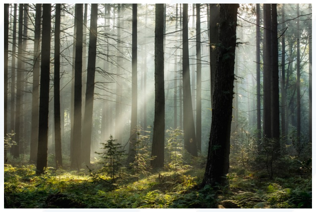
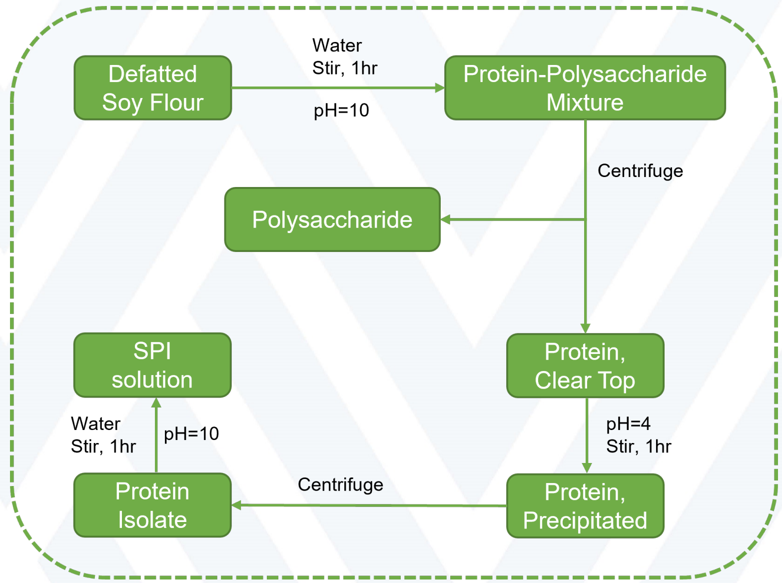
Research Background

- Concerns over formaldehyde release from aldehyde-based adhesives
- Renewable and degradable biobased adhesive from biomass
- Utilizing abundant lignin residue from forest product industry
- Challenges being improvements of dispersion, water resistance, and bonding strength



Soy Protein Isolate and Soy Protein Adhesive

- Defatted soy flour has ~51% soy protein
- Soy protein isolate (SPI) can be extracted using the pictured process
- SPI can be further dissolved to prepare SPI adhesive
- The adhesive system is water-based and formaldehyde-free

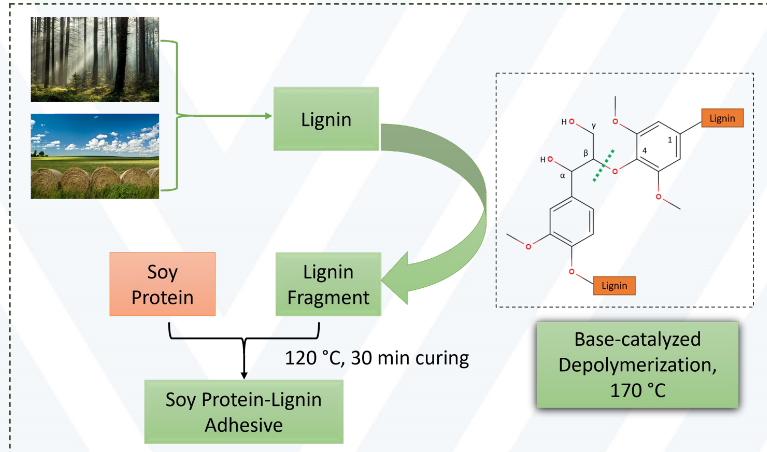


Extraction of SPI

SPI adhesive

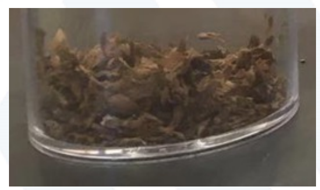
Lignin Fragments and Soy Protein-Lignin Adhesive

- Commercial kraft lignin was used to produce partially degraded lignin and resulted bio-adhesive.
- Mild base-catalyzed depolymerization at 140-200 °C were adopted [1].
- Lignin derived from biomass was also proven in lab as a similar candidate to prepare bio-adhesive

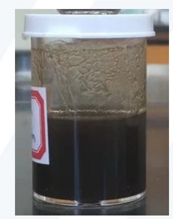


Autoclave reactor

SPI, Lignin fragment, Bio-adhesive


Lignin extraction for 2 hr at 140 °C

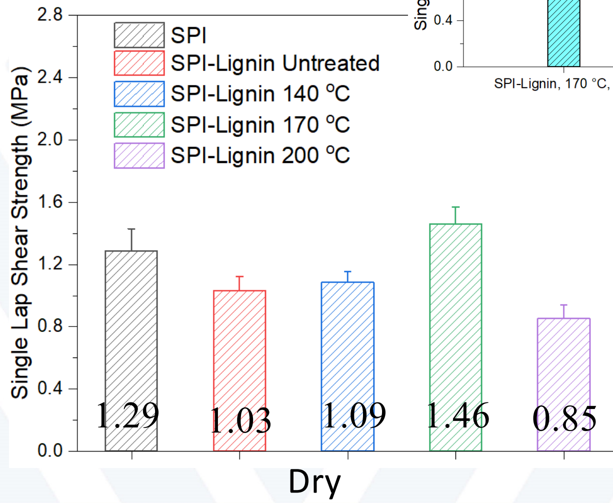

Lignin extraction for 18 hr at 140 °C

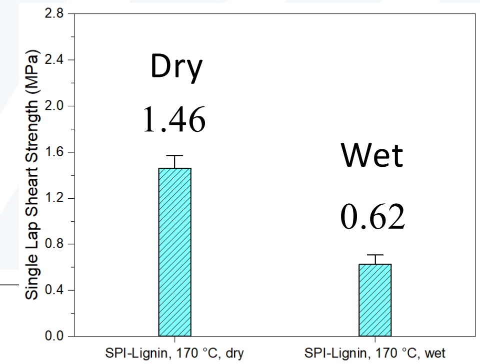

Bio-adhesive with lignin extracted from biomass

[1] Katahira, Rui, et al. "Base-catalyzed depolymerization of biorefinery lignins." *ACS Sustainable Chemistry & Engineering* 4.3 (2016): 1474-1486.

Bonding Strength: Single Lap Shear Test

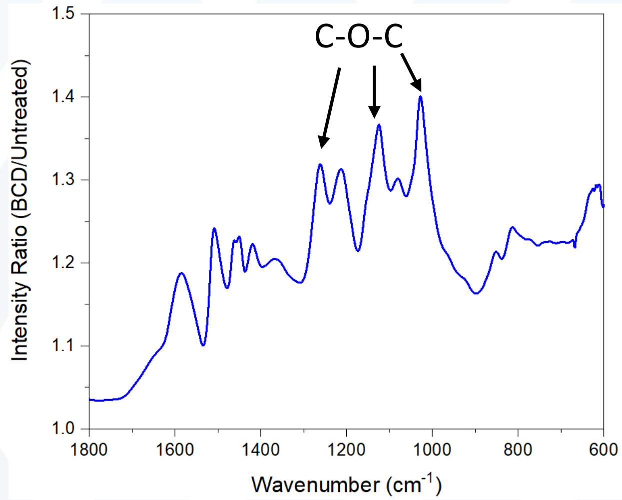
- High lignin loading, ~50 wt.%. Each adhesive was repeated five times for single lap shear strength
- It is speculated that lignin oligomers formed at 170 °C has the best crosslinking performance with soy protein isolate. The resultant adhesive SPI-D-Lignin has a higher strength than SPI adhesive.
- Lignin fragments resulted from higher temperatures might decrease the bonding strength
- Wet strength test: samples were soaked in water for 3 hr at room temperature before test.





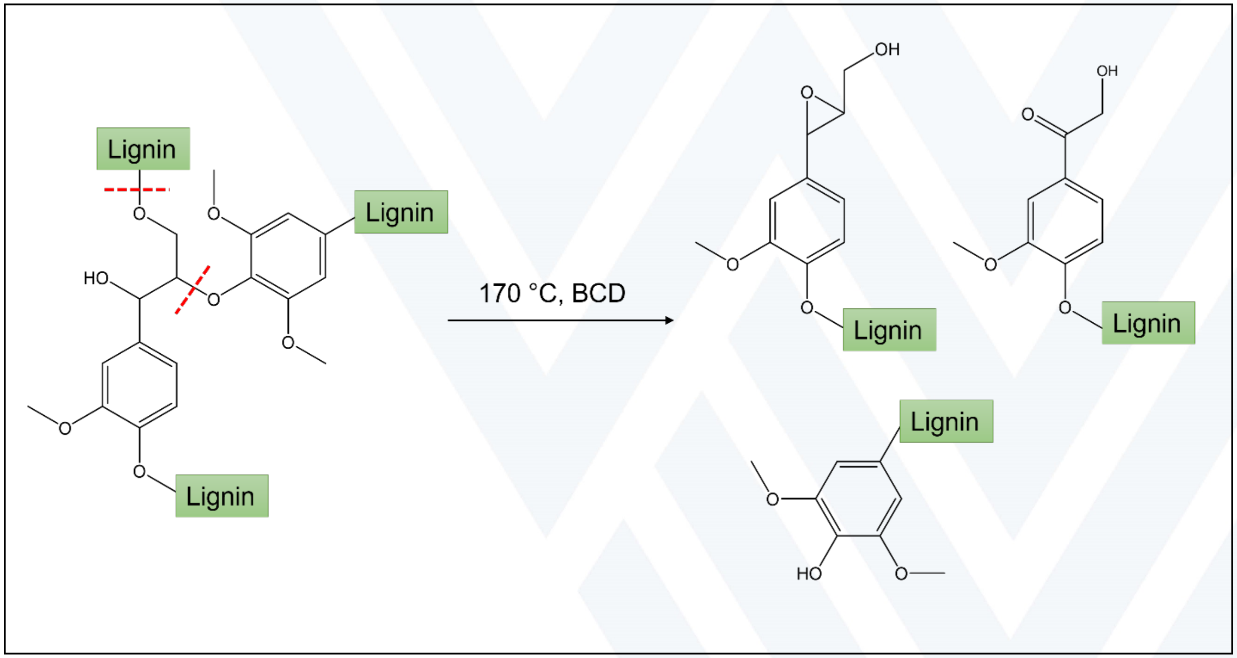
FTIR Characterization: Degraded Lignin vs Untreated Lignin

- Transmittance Intensity of C-O-C was visibly changed by observing peaks at 1028, 1214, and 1261 cm^{-1}
- Direct evidence of cleavage of β-O-4 ether taking place during depolymerization.



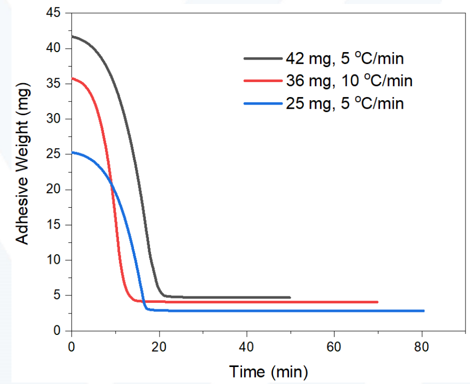
FTIR Transmittance Ratio:
D-lignin/untreated lignin

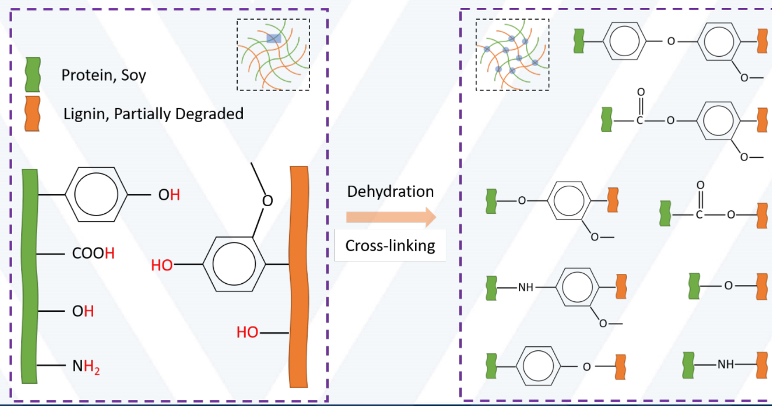
Possible Depolymerization Reactions



Curing of Adhesive and Possible Reactions

- Adhesive is observed to be cured within 25 mins.
- Measured solid contents is ~11.5%.
- Possible curing reactions of adhesive: dehydration (ether or ester) and secondary amine forming reactions.





Future Work

- ❖ LC-MS and NMR characterization of depolymerized lignin
- ❖ Correlation of viscosity to the bonding strength
- ❖ Transition metal catalyzed lignin deconstruction
- ❖ Selectivity of lignin depolymerization products