

Protect and serve: acetal formation during biomass fractionation as a toolkit for reducing degradation and introducing new reactivity

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The production of various fuels and chemicals from biomass usually involves the depolymerization of biomass's three constituent polymers: cellulose, hemicellulose, and lignin. These three types of complex molecules are broken down into their constituent monomers, which include sugars and phenyl propane derivatives. These platform molecules can then be upgraded, either chemically or biologically to direct or indirect substitutes for petrochemicals. During depolymerization, the biggest challenge is usually not achieving the desired reaction, but rather avoiding being outcompeted by other, detrimental reactions. Specifically, depolymerization reactions of the major biomass constituents – polysaccharides and lignin – are often outpaced by subsequent degradation reactions of sugars and lignin intermediates. I will present how we can use acetal formation, both during lignin extraction and polysaccharide depolymerization, to reversibly “trap” stabilized intermediate molecules, reducing degradation and increasing product yields. Using this method, lignin can be extracted during pretreatment and still retain its ability to be upgraded at near-theoretical yields (1–3). Polysaccharides can be depolymerized using dilute acids at previously highly unfavorable conditions and be converted to simple sugars at unprecedented yields and concentrations (4). Furthermore, acetal protected sugars and acetal protected lignin oligomers can be produced almost quantitatively from their respective polymers, and, depending on the aldehyde used for functionalization, can have very different properties. Therefore, we are beginning to explore the unique properties and reactivity of these protected molecules to develop new biomass upgrading routes.

References

1. L. Shuai et al., Formaldehyde stabilization facilitates lignin monomer production during biomass depolymerization. *Science*. **354**, 329–333 (2016).
2. W. Lan, M. T. Amiri, C. M. Hunston, J. S. Luterbacher, Protection Group Effects During α,γ -Diol Lignin Stabilization Promote High-Selectivity Monomer Production. *Angew. Chem. Int. Ed.* **57**, 1356–1360 (2018).
3. W. Lan, J. B. de Bueren, J. Luterbacher, Highly Selective Oxidation and Depolymerization of α,γ -Diol Protected Lignin. *Angew. Chem. Int. Ed.*, doi:10.1002/anie.201811630 (2019).
4. Y. M. Questell-Santiago, R. Zambrano-Varela, M. T. Amiri, J. S. Luterbacher, Carbohydrate stabilization extends the kinetic limits of chemical polysaccharide depolymerization. *Nature Chem.*, 1222–1228 (2018).