

Fractionation of Lignocellulosic Biomass using biomass derived γ -valerolactone as solvent

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<https://www.glbrc.org/research/deconstruction>

Project Goals: Achieve carbon efficient fractionation of lignocellulosic biomass through solvent systems tailored for production of separate aqueous carbohydrate and lignin streams for downstream biological conversion.

Lignocellulosic biomass is a bountiful resource of renewable carbon and has the potential for the production of fuels and chemicals derived currently from fossil resources¹⁻². Lignocellulosic biomass can be grown on marginal land with limited resources, thus competing minimally with the food chain. However, compared to traditional carbon sources, like coal and petroleum, biomass is an expensive resource, and the atom-efficient utilization of this resource is pivotal for the economic success of a biomass-based industry. Biomass-derived sugars have been proposed to be versatile platform intermediates for production of fuels (through fermentation) and chemicals (through biological upgrading). Fractionation of biomass using γ -valerolactone (GVL) as solvent is unique in that GVL can be produced from the by-products of lignocellulosic biomass depolymerization, thereby leading to a self-sustainable biorefinery.

GVL-based fractionation process is potentially feedstock agnostic, allows virtually complete solubilization of the biomass, and leads to polysaccharide recovery at 70-85% yield.³ Moreover, two separate carbohydrate streams comprising mainly C₅ or C₆ sugars can be obtained, thus the GVL-based process provides significant flexibility by allowing either co-utilization of these streams or unique processing strategies for each component (Figure 1). Biological upgrading of carbohydrates to biofuels or bio-based chemicals requires that the carbohydrates be separated from GVL. We have developed a solvent system consisting of GVL, water and an organic co-solvent which is mono-phasic at the fractionation temperatures (e.g., 160°C) and is bi-phasic at lower temperatures (e.g., 25°C).⁴ This phase transition leads to a spontaneous partitioning of carbohydrates from the organic solvent components into an aqueous hydrolysate stream, thereby avoiding the need for expensive and potentially hazardous separation processes.

Finally, we have demonstrated that the solvent system comprised of GVL, water and co-solvent is also advantageous with respect to the recovery of lignin, as it renders a substantial portion of lignin (45 weight. %) insoluble in the solvent system upon cooling. Precipitating a portion of lignin present in the initial feed simplifies post-reaction processing.⁴ Moreover, the lignin obtained using GVL as a solvent has a native-like structure with little evidence of lignin degradation other than some β -ether cleavage and concomitant molecular weight reduction.³

In summary, the GVL-based deconstruction method can enable conversion of all three biomass fractions (hemicellulose, cellulose, and lignin) in a carbon-efficient, renewable manner. When integrated into a biorefinery process, the GVL/co-solvent method is predicted to render significant cost savings as it bypasses the need for cellulolytic enzymes, thus making this a highly attractive alternative to traditional deconstruction methods.

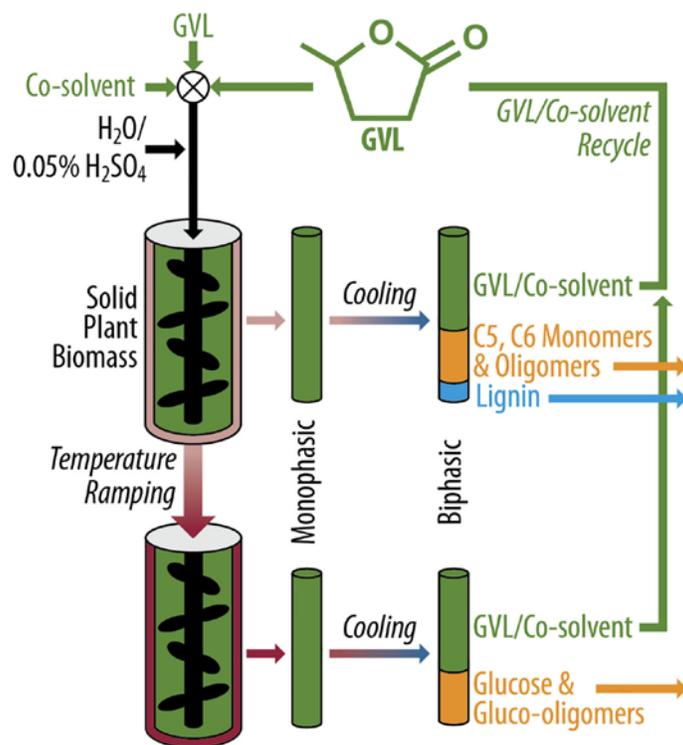


Figure 1. GVL-mediated biomass deconstruction. Conceptual diagram showing the fractionation of lignocellulosic biomass (~20 wt %) using GVL, water and a co-solvent and subsequent phase separation and product recovery.

References

1. J. C. Serrano-Ruiz, R. M. West and J. A. Dumesic, *Annu. Rev. Chem. Biomol. Eng.*, 2010, 1, 79–100.
2. G. W. Huber, I. Sara and A. Corma, *Chem Rev.*, 2006, 106, 4044–4098.
3. J. S. Luterbacher, J. M. Rand, D. M. Alonso, J. Han, J. T. Youngquist, C. T. Maravelias, B. F. Pfleger and J. A. Dumesic, *Science*, 2014, 343, 277–280
4. A. H. Motagamwala, W. Won, C. T. Maravelias, J. A. Dumesic, *Green Chem.*, 2016, 18, 5756.

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