COUNTER-CURRENT CHROMATOGRAPHY (CCC)

BIOPROCESSING SEPARATIONS CONSORTIUM

SEPARATION CHALLENGES FOR LIGNIN VALORIZATION

In biochemical conversion processes, the valorization of lignin, a plant biopolymer, has been shown to be critical for both economics and biorefinery sustainability. However, separations processes to this end have received little attention to date. Accordingly, there is an urgent need to develop low-energy separation processes to separate lignin-derived chemicals to produce target co-products and to reduce overall biorefinery costs. Lignin streams are often a complex mixture of oligomers, dimers, and monomers, requiring multiple filtration and purification processes. A novel approach for this application is counter-current chromatography (CCC), which can separate lignin monomers from lignin oils. CCC is a promising process to recover bioproducts from these complex streams because it employs two liquid phases for both the mobile and stationary phases and, therefore, does not require a solid-liquid separation. Thus, the goals of this project were to develop an energy-efficient separation process with CCC to recover lignin-derived chemicals, to demonstrate the process at scale, and to evaluate the economic feasibility of the downstream process.

Individual lignin monomers can be separated using CCC.

The CCC process is more energy-efficient and economical than Simulated Moving Bed (SMB).

CCC IS CHROMATOGRAPHY THAT USES A LIQUID STATIONARY PHASE

CCC is a dynamic liquid-liquid chromatography process where the upper or lower phases of a biphasic solvent system can be used as the stationary phase of CCC. With the unique planetary motion of CCC, hundreds to thousands of mixing and settling events can occur in a small column. As a result, lignin-derived compounds can be separated based on their different polarities and solubilities in biphasic solvent systems. CCC can handle high feed loadings and solids in the feed, enables full product recovery with various elution modes, uses inexpensive solvents for the stationary phase, and avoids resin fouling issues.

LIGNIN-DERIVED MONOMERS FROM THE LIGNIN OIL USING CCC

With CCC, lignin-derived compounds were separated from lignin oil produced from reductive catalytic fractionation (RCF). Phenolic monomers were separated from oligomers using biphasic solvent systems in CCC, with yields and purities of individual aromatic monomers, both up to 99%. Tuning the polarity of the solvent can also separate dimers from higher molecular weight compounds.

MATHEMATICAL MODEL FOR CCC OPTIMIZATION

The Cell Utilized Partition (CUP) model was developed by NREL and PNNL from basic separation (LLE) measurements. The CUP model can predict the chromatograms for various elution modes of CCC or for a general liquid-liquid chromatography process. Accordingly, the model can be used to narrow down the most viable feedstocks to target with the technology and to optimize the process for high purity, yield, and productivity. The details of the model can be found in Choi *et al.* (2022). The CUP model source codes are publicly available on GitHub.

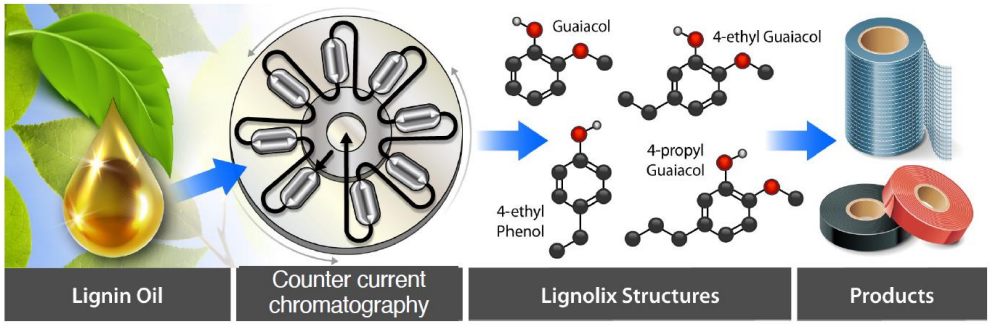

Figure 1. Overview of the downstream process using CCC. Lignin-derived chemicals are separated from lignin oil using CCC. The purified phenolic monomers can be used for high-value products.

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