Process intensification of hemicelluloses recovery from biorefinery process streams by precipitation and membrane separation

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Introduction

Hemicellulose (HMC) can account for 20-40% of the total dry weight of lignocellulosic materials and is underutilized in industry. HMC can be sourced from lignocellulosic biomass, via fractionation into cellulose, lignin and HMC. Typically, fractionation involves pulping, lignin precipitation from black liquor, and HMC treatment for further valorization. The EU-funded project BioSPRINT aims to achieve significant improvement of resource efficiency by valorization of HCM streams into high value products.

The main objective in this project is to establish a hybrid precipitation and membrane purification system for the removal of lignin and impurities from the HMC containing solutions, and concentration of HMCs recovering at least 80-90% of the HMCs weight. The spinning disc reactor (SDR) offers promising potential for efficient lignin precipitation by solvent evaporation due to its thin film enabling high rates of heat and mass transfer across very short diffusional lengths. The pressure driven membrane processes of nanofiltration (NF) and reverse osmosis (RO) are to be tested with diafiltration to achieve high product purity.

Experimental/methodology

A black liquor stream was obtained by an Organosolv treatment of beech wood. Lignin was precipitated from a thin film of black liquor flowing across a heated rotating disc (Figure 1) by evaporating ethanol and creating a supersaturated lignin solution. The effects of disc rotational speed, disc temperature, surface texture, black liquor

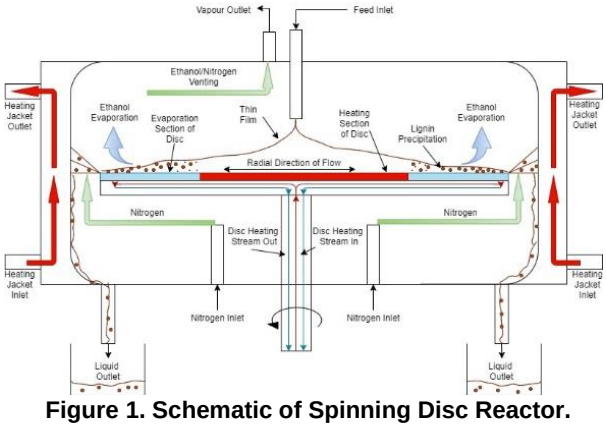

Figure 1. Schematic of Spinning Disc Reactor.

flowrate and nitrogen purge rate are being investigated to maximize lignin recovery. The process is benchmarked against conventional vacuum distillation as implemented by Fraunhofer CBP[1] (Schulze et al., 2019).

The concentration of HMC sugars was studied with a laboratory-scale crossflow membrane filtration unit (P-28 CM-Celfa Membrantechnik AG). A circular flat sheet membrane with an effective surface area of 28 cm^2 was used and the apparatus was pressurized by feeding nitrogen gas. First, screening experiments were carried out to identify the most promising membrane to recover HMCs from a synthetic stream mimicking a HMC filtrate after conventional lignin precipitation and solvent recovery in an Organosolv process. Different types of NF and RO membranes obtained from Alfa Laval and Dupont (Dow) FilmTec were investigated at constant operating conditions. Subsequently, the effects of feed pH, permeate flux, temperature, and feed concentrations will be investigated with the best membrane identified in the screening experiments.

Results/conclusion

The initial results for the SDR precipitation by solvent evaporation indicate that lignin precipitation is obtained after 26% of the ethanol originally present in the black liquor is removed at a disc residence time of under 5 seconds. Tests to quantify lignin recovery and characteristics are underway. A screening design of experiments is also on-going to determine the range of disc operating conditions conducive to high rates of lignin precipitation.

Results also show that certain NF membranes can be used to separate HMC sugars from the stream. More than 80% of xylose and glucose can be recovered even though a large portion of sulfates stay with them in the retentate. To achieve high purity of HMCs, the retentate can be further purified by diafiltration. Further work will investigate coupling the precipitation and membrane separation processes to effectively purify the HMC sugars for the conversion stages to valuable chemicals.

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[1] Schulze, P., Leschinsky, M., Seidel-Morgenstern, A. and Lorenz, H., 2019. Continuous separation of lignin from organosolv pulping liquors: combined lignin particle formation and solvent recovery. Industrial & Engineering Chemistry Research, 58(9), pp.3797-3810.