ABSTRACT

2, 3-butanediol (BDO) is an important bio-based platform chemical produced through microbial fermentation in dilute aqueous fermentation broth. Due to its industrial importance, a lot of work is carried out to develop a sustainable technology for production and of BDO and its recovery from dilute fermentation broth. Being produced at low concentration levels and exhibiting extreme solubility in water, the separation of BDO from fermentation broth is perhaps the most challenging step and contributes significantly to its production cost. Thus there is strong need to develop an efficient technology for separating BDO from fermentation broth which would be scalable and also economically attractive. Although Liquid-liquid extraction (solvent extraction) is considered as a potential method for separation of BDO, the unusually high solvents ratios coupled with the huge CAPEX and OPEX numbers are major deterrents to scale this technology to industrial scale. Intensification of this technique, by means of enhancing mass transfer could therefore potentially give a good value proposition. The focus of this thesis is to develop an efficient downstream separation method for recovery of BDO from the molasses based fermentation broth.

The first aim of this thesis is to screen potential solvents using thermodynamic solvent screening strategy for the extraction of BDO. The second aim of the thesis is to screen various inorganic salts that provide higher distribution of BDO in selected solvents using repulsive extraction strategy i.e. salting out extraction method. The third aim of the thesis is to develop an alternative intensified extraction method for the extraction of BDO in selected solvent using Colloidal Liquid Aphron (CLA) technology, commonly referred as predispersed solvent extraction (PDSE) method.

In the thermodynamic solvent screening strategy, use of molecular-thermodynamic tools provided prediction of activity coefficients and distribution coefficients of BDO in various solvents. The experimental validation of theoretical predictions enabled the choice of appropriate thermodynamic model to represent liquid-liquid extraction of BDO. The benefits of salt addition during BDO extraction is verified with repulsive extraction strategy (salting out extraction method). Further design and scale up of BDO extraction using continuous countercurrent mode of operation in a
simple bubble column apparatus provided continuous extraction of BDO in selected solvent and salt. The continuous countercurrent extraction is demonstrated for synthetic as well as fermented BDO solutions. Various mass transfer characteristics of BDO in selected solvent are evaluated to verify the performance and benefits of the two solvent extraction systems: salting out extraction method and PDSE method.

In PDSE method, the use of CLAs during continuous extraction of BDO enabled higher mass transfer in selected solvent. For the first time, the use of centrifugal contactor is established for the formation of stable CLAs. The system parameters required for the CLAs formation using centrifugal contactor method are optimized: 0.25 wt% sodium dodecyl sulfate is used as ionic surfactant in aqueous phase and 0.5 wt% Tween 80 is used as non-ionic surfactant in organic solvent phase. Compared to the traditional liquid–liquid extraction process, the use of new CLAs method provided increase in mass transfer coefficient up to 85% and about 30% reduction in overall solvent loading. Predispersed solvent extraction method provided advantages over reduced number of theoretical stages with higher extraction and lowered solvent loading.

The thermodynamic modeling tools and experimental results provided in this thesis show enormous promise with the regard to their use for the further design and scale up of liquid-liquid extraction of BDO. Finally, the results of this thesis open up the scope of PDSE technology using CLAs for the downstream processing of other bio-based products.