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Intensified Biphasic Reactors for Furfural Production

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Highlights

- Process intensification for continuous biphasic furfural production: milireactor and Spinning Disc Reactor
- Optimization of reaction conditions in terms of residence time, temperature and acid catalyst
- Increase of furfural selectivity under intensified process conditions

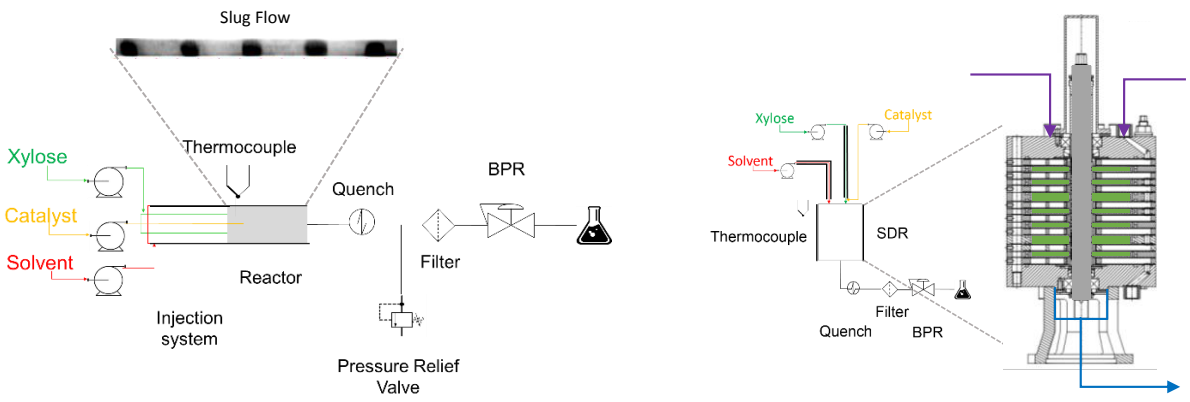
1. Introduction

Nowadays, lignocellulosic biomass is a very attractive feedstock that can replace the rapidly depleting fossil resources for the production of chemicals and fuels [1],[2]. An important biomass-derived C5 sugar is xylose, the most abundant pentose in the hemicellulose fraction, which accounts for 25-30% of the total biomass [3]. The most common chemical process of xylose is its dehydration under acidic environment. The main and desired product is furfural, an important building block in the production of bio-based plastics. However, when furfural remains in the reaction solution, it degrades leading to selectivity decrease. Hence, a continuous reaction system seems beneficial by better controlling the residence time and improving the mass and heat transfer. Furthermore, the presence of a hydrophobic solvent extracting furfural as soon as it is formed contributes to the intensification of furfural production leading to selectivity increase.

In the present work, two intensified technologies have been evaluated to perform the biphasic furfural production from xylose: (a) Milireactor and (b) Spinning Disc Reactor (SDR). In these reactors, various parameters such as temperature, extractant-to-feed ratio and catalyst concentration have been assessed. Finally, validation of the experimental data has been performed in terms of modelling and investigating the mechanism of furfural production in the systems mentioned above using MATLAB® software.

2. Methods

The experimental configurations are presented in Scheme 1.



Scheme 1 Experimental Configurations of milireactor (left) and SDR (right)

3. Results and discussion

The experimental configuration of milireactor was used for kinetics experiments. The comparison of extraction performance is evaluated based on furfural yield with F_{org}/F_{aq}=2:1 and F_{org}/F_{aq}=1:1 under the same reaction temperature and catalyst concentration. Figure 1A shows that furfural yield is remarkably higher when the ratio of organic to aqueous flow rates is set at 2:1 than that in the case of 1:1. In the first case, the furfural mass transfer is enhanced by increasing the driving force (i.e., by diluting the produced furfural in toluene). Hence, these results confirm that an increase in the extraction rate has a beneficial effect on furfural yield.

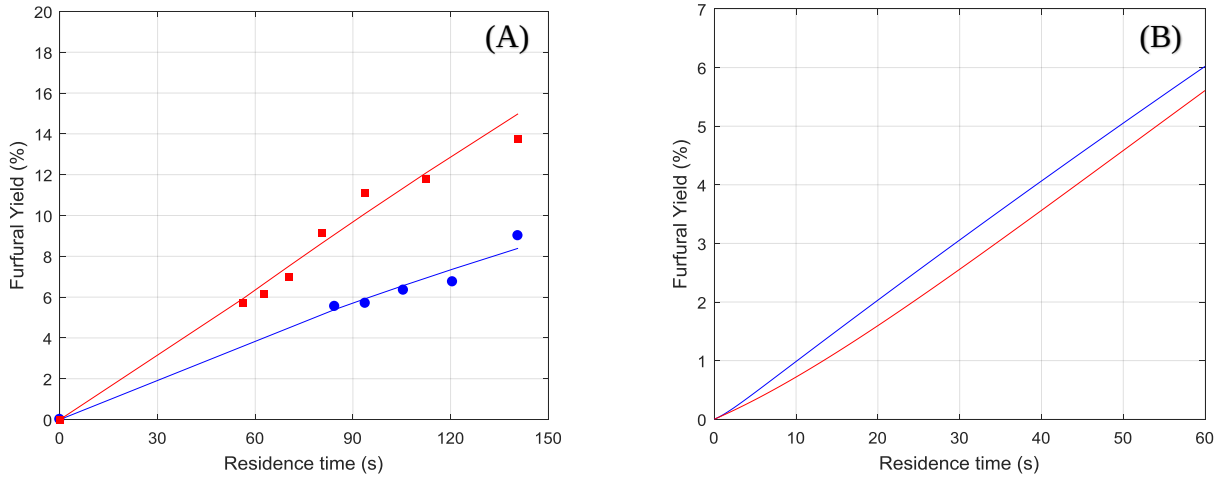


Figure 1. (A) Furfural yield with residence time; experimental data (points) and model (line) for F_{org}/F_{aq}=2:1 (red) and F_{org}/F_{aq}=1:1 (blue); (B) Furfural yield with residence time for milireactor (red) and SDR (blue) for F_{org}/F_{aq}=2:1; both T=170°C, C_{xyl}^0=4wt%, 0.1M H_2SO_4 and toluene as solvent (both)

A more elegant alternative to improve furfural yield is to increase the furfural extraction rate by intensifying the overall mass transfer coefficient while the amount of extracting medium remains the same. This can be achieved by optimizing the reactor configuration. In Figure 1B, the furfural yield is plotted for the two intensified reactors. We can clearly observe that performing the reaction in the SDR results in an increase of the furfural yield with respect to that in the milireactor. This is due to an intensification of the mass transfer properties of the SDR.

4. Conclusions

Two continuous reactors have been developed to perform the biphasic production of furfural from xylose. The in situ extraction of furfural in the milireactor has been proved successful even in short residence time and various temperatures. Intensification of the mass transfer properties of the SDR lead to superior furfural yields.

References

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Keywords

"Biomass", furfural", "intensification", "selectivity"