Catalytic sugar oxidation in continuous packed bed reactor: effect of liquid flow rate

Mouad Hachhach[1*], Vincenzo Russo[1,2], Irina Simakova[1], Kari Eränen[1], Dmitry Yu. Murzin[1], Tapio Salmi[1*]

1 Laboratory of Industrial Chemistry and Reaction Engineering (TKR), Johan Gadolin Process Chemistry Centre, Åbo Akademi University, Turku-Åbo FI-20500, Finland; 2 Università di Napoli Federico II, Chemical Sciences, Complesso Universitario Monte S. Angelo, Napoli IT-80126, Italy

** Corresponding authors: mouad.hachhach@abo.fi (M. Hachhach); tapio.salmi@abo.fi (T. Salmi).*

Highlights

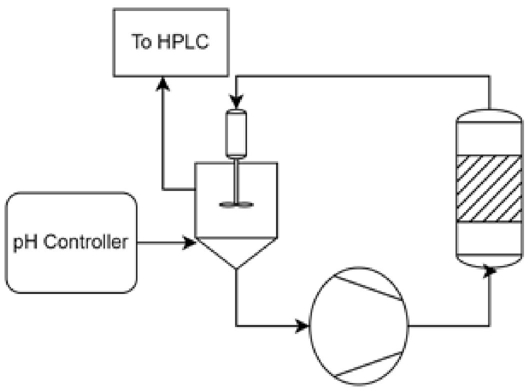
- A dynamic three-phase dynamic packed bed reactor model was developed.
- Liquid flow effect was studied on sugar oxidation both experimentally and numerically.
- Higher flow rates resulted in a higher sugar conversion to sugar acid.

1. Introduction

The catalytic oxidation of the monomeric sugars extracted from hemicellulose biomass (e.g. arabinose), is seen as an attractive way to valorise wood-based biomass by producing bio-based chemicals with a high value and low environmental impact. From this perspective, the catalytic oxidation of the arabinose sugar, which is present in large amounts in hemicellulose,was investigated in this work, with a focus on the impact of the effect of liquid flow rate on the arabinose conversion. The obtained results will also be used to ameliorate the developed continuous packed bed reactor model by improving the accuracy of mass transfer modelling.

2. Methods

The experiments were performed in a continuous system under a constant volumetric flow rate of oxygen, which ensured a constant concentration of dissolved oxygen in the system. The experimental setup is shown in reality and schematically in Figure 1. The catalyst used was a gold on alumina 3% , the temperature was kept constant at 70°C and the pH 8. The liquid flow rate was 150-250 ml/min.



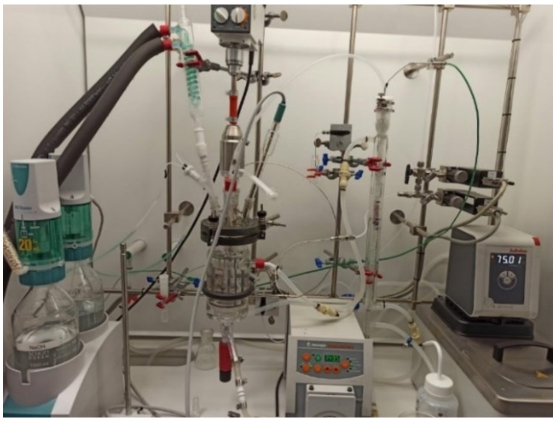


Figure 1. Photograph and simplified flowsheet of the experimental setup

The development of the model was based strictly on the mass and energy balances and well-established correlations for the reaction kinetics and flow-related phenomena [1,2]. The resulted model was used to estimate the correction parameter of the mass transfer coefficient.

3. Results and discussion

The experimental results revealed that complete conversion of arabinose to arabinonic acid was obtained in all cases, however it was achieved faster in case of higher liquid flows, which agrees well with our experimental findings, and this can be because the high flow suppresses the external mass transfer limitation in this case. Similarly, the simulation results confirmed that a complete arabinose conversion is obtained in all the cases, however, it was achieved faster in case of a higher liquid flow rate.

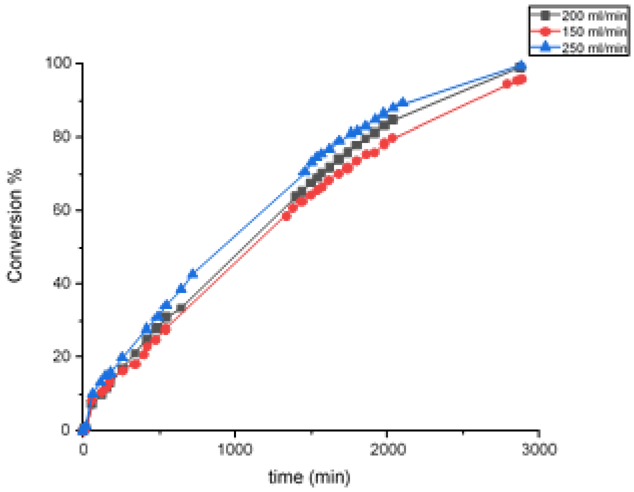


Figure 2. Experimental conversion of arabinose for various liquid flow rates.

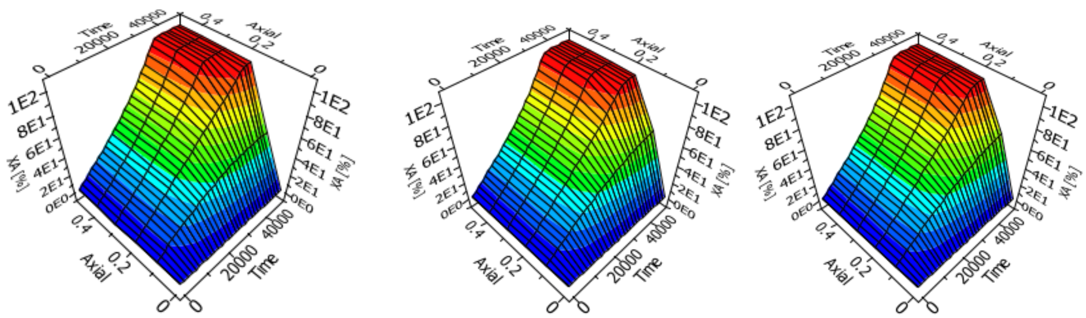


Figure 3. Simulation results for the conversion rate of arabinose at various liquid flow rates (250 ml/min in the left, 200 ml/min in the middle and 150 ml/min in the right).

4. Conclusions

The main objective of this work was to develop a general and dynamic model for three-phase packed bed reactors. Experimental data from arabinose oxidation were used for the validation of the model and for the estimation of the gas-liquid mass transfer coefficient, which increased the accuracy and reliability of the developed model. The profound effect of the liquid flow rate on the conversion rate was discovered experimentally and confirmed by extensive numerical simulations.

Acknowledgments

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References

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Keywords

gProms; packed bed reactor; arabinose; oxidation