Abstract

In my doctoral thesis, I undertook mathematical modelling for the design, development as well as for characterization of processes in microreactor systems. The aim of this work was the development of an enzymatic microreactor with surface-immobilized ω-transaminases, intended for study and determination of surface kinetics of enzyme catalyzed transamination in a microreactor.

The first part of my research work comprises fluid flow analysis in microchannel and the development of a mathematical model for diffusion coefficient determination using a microfluidic device. The initially developed mathematical model was later simplified. Solutions of the simplified model correlated well with solutions of initially developed model, which justified the introduction of selected simplifications and the use of numerically less demanding techniques. I continued by focusing on the development of enzymatic microreactors with surface-immobilized ω-transaminases. For ω-transaminase immobilization, I exploited the covalent binding and for the first time performed an ω-transaminase attachment based on ionic interactions between the surfaces of the Z_{basic2}-tag appended to the enzyme and silica-glass microreactor. The developed enzymatic microreactors were then compared and the optimal system was selected and in turn used in the surface enzyme kinetics study. Mathematical models describing processes in batch reactor with free enzymes and continuously operated microreactor with surface-immobilized enzymes were developed. The determination of kinetic parameter values was based on experimental data obtained in batch processes and the same values were then used for the modelling of a microreactor system with immobilized ω-transaminases. A time-scale analysis was applied and the initial model was simplified. It was revealed that the selected microreactor bioprocess is reaction-limited and that the simplified model was adequate for accurate surface enzyme kinetics determination and enzyme concentration estimation. Additionally, model validation was performed by conducting continuous enzymatic transamination in two consecutively-connected microreactors with surface-immobilized ω-transaminases.

Key words: microreactor, modelling, enzyme catalysed transamination, ω-transaminase, surface enzyme kinetics.