Computational Modeling of Drug Diffusion from Hydrogel Matrices for Transdermal Delivery Optimization

Claudia Geanina Watz
Department of Pharmaceutical Physics, Faculty of Pharmacy, "Victor Babes" University of Medicine and Pharmacy, Timisoara, Romania
Center for Drug Data Analysis, Cheminformatics and the Internet of Medical Things, "Victor Babes" University of Medicine and Pharmacy, Timisoara, Romania
Research Center for Pharmaco-Toxicological Evaluation, "Victor Babes" University of Medicine and Pharmacy, Timisoara, Romania

Lenuta Maria Suta
Pharmaceutical Technology, Faculty of Pharmacy, "Victor Babes" University of Medicine and Pharmacy, Timisoara, Romania

Mirela Nicolov
Department of Pharmaceutical Physics, Faculty of Pharmacy, "Victor Babes" University of Medicine and Pharmacy, Timisoara, Romania
Center for Drug Data Analysis, Cheminformatics and the Internet of Medical Things, "Victor Babes" University of Medicine and Pharmacy, Timisoara, Romania

Daria Unguras
Department of Pharmaceutical Physics, Faculty of Pharmacy, "Victor Babes" University of Medicine and Pharmacy, Timisoara, Romania

Ioan-Ovidiu Sirbu
Department of Biochemistry, Faculty of Medicine, "Victor Babes" University of Medicine and Pharmacy Timisoara, Timisoara, Romania
Complex Network Science Center,"Victor Babes" University of Medicine and Pharmacy Timisoara, Timisoara, Romania

Lucretia Udrescu
Research Center for Pharmaco-Toxicological Evaluation, "Victor Babes" University of Medicine and Pharmacy, Timisoara, Romania
Department of Drug Analysis,"Victor Babes" University of Medicine and Pharmacy, Timisoara, Romania

Abstract:

The optimization of transdermal drug delivery systems requires a precise understanding of drug diffusion behavior across polymeric matrices and skin layers. In the present study, we developed a computational algorithm that simulates the release kinetics of fisetin (used as a model drug) from

various hydrogel matrices into the skin. The computational model integrates Fick's second law of diffusion in a two-compartment system (hydrogel and skin), to closely reproduce the in vivo scenario. Simulations were performed for a range of commonly used polymers, such as: alginate, agar, acrylic acid, N-isopropylacrylamide (NIPAAm), poloxamer 407, and water-soluble chitosan derivatives. Results revealed polymer-dependent diffusion profiles, revealing the highest cumulative dose of fisetin into deeper skin layers when Poloxamer 407-based hydrogel matrix was used, whereas acrylic-based polymers exhibited high controlled release. The obtained data agrees with the ones reported in the literature. Also, our approach is complemented by in silico assessments of drug-polymer compatibility using tools, such as SwissADME, Pred-Skin and Endocrine Disruptome. Moreover, this algorithm can be adapted to simulate the release kinetics of other small molecules, offering a versatile tool for pre-formulation studies and reducing the experimental load in early-stage development.

Keywords:

computational analysis, drug release, hydrogel matrix.