pH-dependent Degradation Kinetics of Polylactic Acid

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Abstract

Polylactic acid (PLA) is a biodegradable and biocompatible polymer. Due to its properties it raised significant interest in the biomedical field, where it is often employed in drug delivery applications. The knowledge of the degradation kinetics of PLA has a key role when designing such drug releasing devices, as it allows modulating their release profiles. Among the different parameters affecting the PLA degradation kinetics, pH is one of the most relevant ones. While previous studies clarified the pH-dependent degradation mechanisms occurring (acid-, base- and non-catalyzed), the values of the corresponding kinetic constants were actually provided only at specific pH values.[1-3]

In this frame, the aim of this work is to study the degradation of lactic acid oligomers as a function of pH in a wide range of values of interest for biomedical applications. In particular, the degradation of oligomers with chain length varying from 2 to 8 repeating units was followed at 37°C for pH values equal to 1, 3.5, 5.7 and 7.4. These experimental data, along with those previously reported at pH = 2[1], are used to develop a detailed kinetic scheme and evaluate the corresponding kinetic constants. The resulting deterministic, pH-dependent model is able to describe the experimental data with reasonable accuracy and an average error of about 5%. The following values of the kinetic constants have been estimated: $k_D^{\alpha} = 4.44 \times 10^{-3}$ $L^2 mol^{-2} h^{-1}$, $k_D^{\beta} = 9.29 \times 10^{-4}$ $L^2 mol^{-2} h^{-1}$ (acid-catalyzed), $k_{RH} = 1.56 \times 10^{3}$ $L^2 mol^{-2} h^{-1}$, $k_{BB} = 2.88 \times 10^{6}$ $L mol^{-1} h^{-1}$ (base-catalyzed) and $k_W = 2.49 \times 10^{-5}$ $L mol^{-1} h^{-1}$ (non-catalyzed). Notably, these kinetic constants can be used to study also the degradation of PLA polymer chains, as the values have been found to be chain-length independent from the tetramer on. Taking advantage of the results of this kinetic analysis and accounting for the diffusion limitations typical of PLA biomedical devices (e.g. nano- and microparticles), a predictive modeling of the degradation behavior becomes possible for a wide range of pH conditions.

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