Simulation of chemo-mechanical coupled gastric digestion process of starch hydrogels

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Abstract

Starch, a naturally abundant and biocompatible material, is widely used in hydrogel form in the food and pharmaceutical industries. Its digestion involves a complex interplay of mechanical breakdown by peristaltic waves and chemical degradation through diffusion and enzymatic reactions in the gastric environment, posing challenges to its design and application.

This study investigates the mechanical behaviour of starch hydrogels under chemical loads in in vitro conditions mimicking the digestion environment, providing insight without the need for in vivo tests on humans. Compression tests were conducted on starch hydrogels subjected to varying levels of hydrolysis catalysed by α-amylase. A pseudoelastic-viscoelastic constitutive model was developed to describe the chemo-mechanical behaviour of starch gels. Material parameters related to diffusion, reaction, and mechanical deformation parameters were calibrated using experimental data. The calibrated model was implemented in finite element analysis, where gastric peristaltic waves were applied via displacement boundary conditions, and chemical degradation due to the gastric fluids was modelled via a mass field and its reaction kinetics.

This integrated approach provides insights into the breakdown mechanisms of starch hydrogels and informs its design for the food and pharmaceutical industries.

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