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Computational Modeling of Curcumin Release from 3D-printed Food Mimics

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Abstract: Controlling the release of bioactive compounds in foods is essential to preserve their health benefits. Food 3D printing offers a promising approach to precisely localize bioactive compounds within matrices and achieve specific release profiles. This study presents a computational model predicting the in vitro digestion release of curcumin—a representative bioactive compound—encapsulated in yeast microcarriers and patterned into cubes via 3D printing. This approach enables rapid screening of different configurations to design foods with targeted release profiles. Curcumin release was modeled as a mass transfer process coupled with reaction kinetics during intestinal digestion. Two reaction-diffusion equations described bile salt transport into the cube and diffusion of the curcumin–bile salt complex out of it. First-order kinetics were used to describe interactions of bile salts with curcumin and other yeast components. The system was solved using finite element methods, with curcumin concentration as the output. To validate the model, a bioink composed of curcumin-loaded yeast and pectin was 3D-printed into cubes with either core-shell or uniform curcumin distribution. Experimental results showed strong agreement with the model for both configurations. This model can simulate bioactive release under varying geometries, concentrations, and spatial distributions, offering a powerful tool for designing functional foods with controlled health effects.

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