Scouting Structural Features that Contribute to Components Stability in 3D Printed Food Matrices

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Understanding the role of food structure in food deterioration has been hindered by the difficulty of fabricating structures with high reproducibility at several length scales. 3D printing can be used for matrix rational design and prototyping, allowing for the systematic study of the role of structural components on food quality deterioration.

Zein (in 70% 2-propanol) and a lipid blend (trilinolein/tristearin) were the components of all matrices. A coextruded protein/lipid mat and protein scaffolds with either a lipid blend or an oleogel (molecular vs. polymeric) deposited in the interstices were produced using a 3D bioprinter (100?m resolution) under different printing conditions. The selected conditions allowed for obtaining matrices with “fused” or “interrupted” structures (i.e., with continuous vs. shorter threads 250?m thick. Structural features of the matrices and lipid distribution were assessed using atomic force microscopy (AFM) and micro-computed tomography (?CT). Lipid oxidation, protein structure, scaffold rigidity, and formation of disulfide bonds were monitored using optical tools (Raman (micro)spectroscopy, FTIRS, and luminescence spectroscopy) at selected intervals.

Surface smoothness, number and depth of the pores and channels significantly differed among the samples. The fused structures were smoother, with shallower pores providing less lipid compartmentalization. BODIPY-C11 emission intensity in the interrupted and fused co-extruded structures increased by 2.3±0.3, and 3.6±0.4 fold, respectively, by the end of the study. Similarly, matrices with sequential addition of components showed less lipid oxidation when the protein scaffold was interrupted rather than fused (4.1±0.3 vs. 6.3±0.5). Less lipid oxidation in the interrupted matrices was attributed to better lipid compartmentalization, as confirmed by ?CT. Structuring the oil using gelators resulted in less and delayed lipid oxidation when a polymeric gelator was used (polymeric gel 1.3 fold < molecular gel?unstructured oil).

3D printing can be used to develop food prototypes with identical composition but subtle structural differences, allowing for the systematic study of the role of structural components on deteriorative phenomena. Structures designed with tailored separations between deposited layers and lipid structuring within the matrix allowed for less lipid oxidation, demonstrating the potential use of structural design to extend food freshness.