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Towards understanding the mechanism of fibrous texture formation during high-moisture extrusion of meat substitutes

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Abstract

This paper investigates the physical mechanisms of structure formation during high-moisture extrusion of vegetable proteins. Our model starts from the observation that extrudates with fibrous, meat-like structures exhibit water-rich and protein-rich domains. The origin and structure of these domains is attributed to a spinodal phase-separation process which occurs upon cooling of the extrudate. We investigate the process using continuum-mechanics simulations, considering the combined effects of viscous flow, thermal diffusivity, and the mixing thermodynamics of water and protein. This multi-physics problem is numerically solved using an unconventional mesh-free approach, the material point method (MPM), combined with the Cahn- Hilliard model of phase separation. The method incorporates both Eulerian and Lagrangian aspects, and is well suited to model multicomponent flows of history-dependent materials. Our simulations show that fiber-like structures are obtained when the ratio of phase separation rate, heat conduction rate, and flow rate are matched within a narrow window. Our results predict that the shape of the temperature profile within the cooling channel determines the structure of the the phase-separated state. These findings suggest that the physical mechanism which causes fibrous structure formation is given by

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