Lattice Boltzmann model of the flow of meat analogs through extruder die

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Given the growing demand for plant-protein based meat replacers, there is continued research towards their manufacturing by means of high moisture extrusion for several decades now. Due to the complexity of the extrusion process, and the rheology of the plant protein dough, there is still little understanding of which physical processes underly the anisotropic structuring of meat replacers. To advance this understanding we have developed a flow model describing the flow of a yield stress fluid through the cooling die, attached to a twin screw extruder.

Our rheological measurements [1] has shown that the protein dough is behaving as a Herschel-Bulkley fluid, exhibiting a yield stress and shear thinning. Furthermore, it is shown that the variations of yield stress and critical shear rate follows a scaling with Tg/T, the ratio with the moisture dependent glass transition temperature and the actual temperature (in Kelvin). The shear-thinning exponent is independent of material conditions.

To describe the flow in the extruder die, we have developed a Lattice Boltzmann model, solving simultaneously the flow field and the temperature field. Furthermore, we have incorporated wall slip in the model, which is shown crucial for the process – as the material exits the die as a single plug – with shear-flow only in a lubrication layer along the wall. The choice of Lattice Boltzmann is done, because the future extension of the model towards the mesoscale structuring, as observed by Wittek [2]. We view this process akin to syneresis, which can be modelled similar to viscoelastic phase separation [3].

In this contribution, we give a detailed description of the model, and show results of a parameter study – showing how flow profiles and pressure drops depend on rheological properties of the protein dough.

[1] van der Sman, RGM, Chakraborty P, Hua N.P., Kollmann N. Food Hydrocolloids (in press)
[2] Wittek, Patrick, et al. Foods 10.8 (2021): 1753.
[3] Tanaka, Hajime. Faraday discussions 158.1 (2012): 371-406.