Microstructure evolution during deep frying and its impact on material properties

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During deep frying several multiphysical processes take place simultaneously. Therefore, a coupled model involving heat and mass transfer with mechanical deformation is necessary to understand and optimize the process. It has previously been observed that the porous microstructure plays an important role in oil uptake, however, few studies have investigated the influence of deforming microstructure on critical material properties necessary for the model. The purpose of this study was to explore the relationship between structure parameters (porosity, tortuosity) and material properties (permeability, young’s modulus) relevant to the deep frying process.
Native starch (potato and wheat) and wheat gluten samples with varying hydration levels were fried in perforated teflon tubes. High resolution in situ synchrotron X-ray ?CT was used to characterize the change in 3D porous microstructure with time. The different phases (starch/protein, oil, and air) were segmented to separate the pore space from the solid microstructure. Multiple regions of interest (ROI) in the pore space were selected to build a pore network model (PNM) and using Darcy’s law in fully saturated porous media, intrinsic permeability was evaluated. Directional open porosity of the ROIs was used to establish a structural relationship for permeability based on the Kozeny?Carmen equation. The solid microstructure of the same ROIs was converted to faceted geometry to evaluate the bulk modulus using FEM.
The initial moisture content greatly affected the changes in microstructure over the course of the process, with noticeable deformation in higher hydration samples. On comparing the intrinsic permeability from the PNM on various ROIs, it was found that that the correlation between absolute permeability and open porosity was greatly influenced by heterogeneous structure of the porous matrix. From the deformation analysis it was revealed that the structure thickness and pore morphology are crucial parameters affecting young’s modulus.
The results further support the importance of accounting for microstructural changes and the associated impact material property. The information from this study will be used as the basis for evaluation of fluid specific relative permeability to model the fluid flow as compared with in situ imaging of during the deep frying process.