Numerical modeling of heat and mass transfer during cake baking process

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This article deals with the development of a numerical multiphysic model to study heat and mass transfer phenomena as well as the swelling during the baking of a cake contained in mold. The aim of this study is to provide an effective numerical tool, experimentally validated, for a better understanding of mechanisms leading to the desired end product. In this approach, the medium is assumed to be a deformable porous medium containing three phases: solid (dough), liquid (water) and gas. Gas phase includes two species, water and CO2 (released by the leavening agent). Based on the governing equations for heat and mass transport and under few assumptions (homogenous medium, local thermodynamic equilibrium, gas phase assumed to be an ideal gas mixture…), the problem consists in solving a system of five coupled partial derivative equations. The state variables are the temperature, the moisture content, the total gas pressure, the porosity and the displacement. The swelling of dough caused by the increase of total gas pressure is predicted by a viscoelastic model. This thermo-hydro-mechanical model is implemented in finite elements code.
At the same time as numerical approach, experimental tests are carried out on a laboratory oven. In this context, an experimental laboratory set-up was developed in order to continually acquire temperatures, water losses and to correctly apprehend the boundaries conditions. The cake deformation is also tracked by camera. The numerical results are next compared with experimental data and analysed. Various operating conditions are tested to check the robustness of predictions.
Moreover, a sensitivity analysis is performed to understand the impact of material properties and model parameters on the behaviour of cake during baking process.