Modeling of Pound Cake Baking Behavior in Continuous Flow

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Abstract

Cake batters are complex fat-in-water emulsions with four bulk phases (aqueous, fat, gas, and solid starch granules). The process of cake baking is very complex since a change in thermo-physical properties of batter take place during this process. The aim of this project is to develop an original concept to inject a cake dough through a nozzle by implementing ohmic heating (OH), to pre-bake the batter, which is dedicated to additive manufacturing (3D printers head).
Using continuous ohmic heating for baking cereal products such as cake dough is very challenging and innovative. During the baking process, all the physical and structural changes determining the quality of the final product, such as starch gelatinization, volume expansion, etc., are related to the internal heat and mass transfer phenomena and the temperature of the product. The objective is to control the voltage applied between the electrodes, or the geometry of the nozzle to control the temperature at its output. This temperature should be lower than the gelatinization temperature of starch in the cake dough.
A model was developed to study the temperature, the velocity and the viscosity profile of pound batter in a continuous flow using ohmic heating. Different modules were used in our work. The first one is Joule heating, which is applicable between two electrodes to heat the cake dough passing through the nozzle. It is coupled with heat transfer in solids and laminar flow modules.
The thermo-physical properties of the cake dough were determined experimentally, such as density, heat capacity, thermal conductivity, viscosity… Among the physical properties of interest, viscosity and electrical conductivity appear to be particularly important, because they undergo large changes during the baking process. By experiments we found that the rheological model for cake dough is the Power law, so we use it and couple it with the shear rate calculated in COMSOL Multiphysics®. By introducing the equation of Power law, we can see how it varies with the process parameters.
A rectangular geometry was chosen for the nozzle, with a distance between the electrodes of 0.5cm, as shown in the figure 1. Their width is 4cm, the length of the nozzle (i.e. length of the electrodes) is 10cm, and the electrodes thickness is 1mm.
The first numerical simulations make it possible to study the temperature distribution in the product during the baking and injection process. Hot and cold points are especially

highlighted. Moreover, close results are obtained when 2D and 3D models are compared. With the simulations, it will be possible to study how all the parameters of the model such as the thickness of the electrodes, the voltage applied, and other nozzle dimensions (length, width, electrodes distance), affect product parameters (temperature, viscosity, etc.) during the injection process. We will focus on the temperature gradients and how they vary during baking in order to control the solidification process. The final goal aims at injecting a foam based on starchy matrix in the printer head and to partly solidify the material by ohmic heating allowing additive manufacturing.

Figures used in the abstract

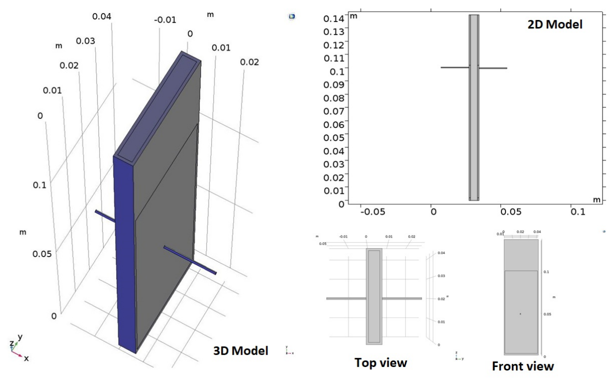

Figure 1: In this image, at the left we can see the 3D model, consisting of two electrodes of Titanium-21S, surrounded by an isolation of Silica glass, between the two electrodes we can see the flow of the cake dough which is made of virgin material. And from both sides, there are two electrical Copper wire to supply electricity. On the right top of the image, we can see the 2D model which is similar to the 3D one. On the top view we can see the distance between the two electrodes, and on the front view, the length of the electrodes and the total length of the nozzle (electrodes length + 4[cm]).