Modeling Maillard Reaction and Thermal Transformations During Bread Baking

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Abstract

Introduction
In the recent years, several research groups are focusing their attention to the modeling of foods and food cooking. With this aim, a lot of different phenomena can be considered in order to get models pertinent to the real properties and behavior of foods. Multi-physical modeling can help to face the problem of coupling these phenomena in a single simulation, making possible to better understand, control, design and predict certain real processes.

Bread baking represents a complex problem since it involves simultaneous heat and mass transfer. Crust formation, water evaporation, browning, changes in structure and volume, thermal properties and flavor formation are just some of the phenomena occurring during bread baking. One of the ultimate challenges for the food industry is to predict and optimize flavors. The so-called Maillard reaction comprises a wide number of elementary reactions and occurs in food matrices containing carbohydrates and proteins under specific operating conditions. In fact, the resulting products and intermediates depend, among other things, on the thermal heating, the water activity, and the pH of the matrices.

Use of COMSOL Multiphysics®
The presented research wants to show a first application of a coupled thermal and kinetic modeling to the bread baking process, which is the ideal field to study this very complex set of reactions with a key-role in the development of bread flavors (and more generally of cooked food flavors). The thermal model has been developed considering a forced convection oven environment and variable thermal properties for the bread material, taking into account for the dough to crumb and crust transition, as suggested by the work of Purlis and his group (Purlis et Salvadori, 2009). The kinetics of the Maillard-driven flavor formation is a simplification of the work of (Jousse et al., 2002). The COMSOL Multiphysics® (COMSOL, 2012) is used to solve the inherent coupled problem. Experimental measurements have been used for the model validation.

The preliminary results reproduce the oven and bread thermal behavior, and show a prediction of the flavor compounds development. As an assumption, only the thermal aspects for the bread baking kinetics are considered.

This multi-physics approach is going to be extended to the study of volume variations, composition changes, water content and water activity.

Figure 1 shows the temperature inside the bread and the oven after 20 minutes of baking. Figure 2 shows the production of Maillard compounds in the crust versus the baking time according to the kinetic scheme.

Reference

Purlis, E., Salvadori, V., 2009, Bread baking as a moving boundary problem. Part 2: Model validation and numerical simulation, Journal of Food Engineering , 91 (3), 434–442
Jousse, F., Jongen, T., Agterof, W., Russell, S., Braat, P., 2002. Simplified kinetic scheme of flavor formation by the Maillard reaction. Journal of Food Science, 67, 2534-2542.
COMSOL, 2012. COMSOL Multiphysics Reference Guide, Version 4.3. COMSOL AB.

Figures used in the abstract

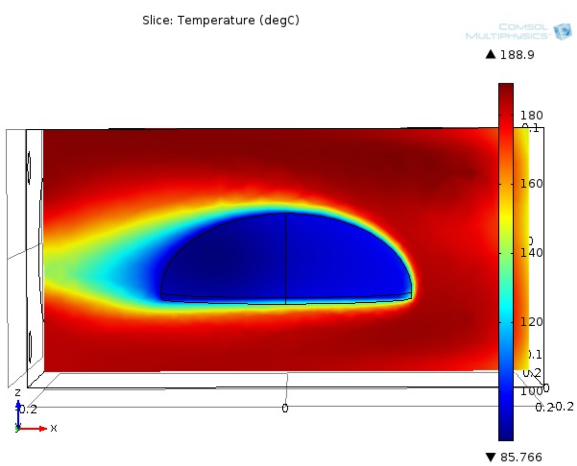

Figure 1: Temperature profile of Bread and Oven after 20 minutes of Baking

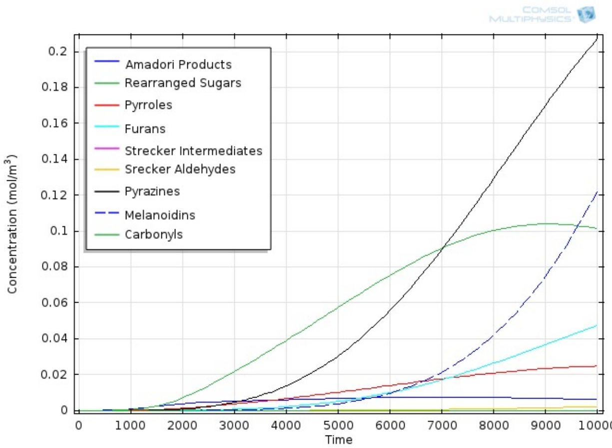

Figure 2: Maillard Products production