Multiphysics Approach of the Performance of a Domestic Oven

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Abstract

Introduction
A deep knowledge of the heat and mass transfer processes occurring in a domestic oven is decisive in order to reach a high final quality of the cooked food. The objective of the present study is to perform thermal analyses to improve the energy efficiency of the domestic ovens, and compare it to the experimental results in order to adjust the model. The standard test for energy consumption of the European Union (EN 50304:2001), also called "Brick test", is selected as the reference case to be studied. In this test a wet brick representing the food matrix is inserted in the geometric center of a domestic oven and it is heated until it reaches a determined temperature jump. The weight of the brick decreases as it loses a certain amount of water during the heating process.

Use of COMSOL Multiphysics®
The modeling of the simultaneous heat and mass transfer occurring in an oven when heating a wet and cold food sample is performed by COMSOL Multiphysics®. A Finite element 3D model of the heating and evaporation processes is developed using "Heat and Mass Transfer" and "Transport of Dilute Species" Interfaces in a transient simulation. The main elements of oven system are simulated resulting in a system of non-linear unsteady-state partial differential equations to be solved.

As inputs, the initial conditions of each element, the oven function selected (static with a certain temperature set), the geometrical characteristics of the "food" matrix and the oven elements and the expressions of physical and transport properties (of both air and brick), formulated as functions of the local values of temperature and moisture content, are included. The heat transfer between each element is defined by conduction, convection and radiation.

Results
The developed model predicts the transient evolution of the quantity of water evaporated from the brick and the temperature profiles inside the brick, both in the longitudinal and traversal sections. The predicted results correlate well with the experimental data obtained from the standard test for evaluating the energy consumption of a domestic oven.

Conclusions
Therefore, the experimental validation of the proposed model represents then a general and

predictive tool capable to describe the real ovens behavior over a wide range of process and fluid-dynamic conditions. Thanks to the validation of this model with the experimental data it will be possible to further study different strategies to reduce the energy consumption of an oven without decreasing the final quality of the cooked product.

Keywords
Heat and mass transfer, Domestic Oven, Finite Elements Method, COMSOL Multiphysics®.

Reference

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