

Computer Simulation of Microwave Heating of Initially Frozen Sandwiches Using COMSOL Multiphysics® Application Builder

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Abstract

Customers typically prepare sandwiches using a microwave oven to heat a frozen sandwich. This causes huge temperature variations and quality issues due to multicomponent with different dielectric and physical properties and with phase changes at different freezing points in the heating process. To better understand the heating process of the sandwich, a computer simulator with a graphic user interface (GUI) was created on the COMSOL Multiphysics® software for use by a broad group of development scientists who do not have a background in simulation. The simulator can be used as a powerful computational tool to enhance the understanding of the microwave heating process of frozen sandwiches and improve the product formulation and design of microwavable sandwiches. The microwave heating system consists of the four components: waveguide, oven cavity, turntable and sandwich (five layers: bottom bread, burger, egg, cheese and top bread). The simulation was carried out according to the procedure as shown in Figure 1. A mathematical model was developed to describe system geometries, physical and dielectric properties, electromagnetic transfer, heat transfer and mass transfer. Three studies were conducted to solve the electromagnetic, heat transfer and mass transfer sub-models, respectively. A graphic user interface (GUI) was created using the Application Builder of the COMSOL Multiphysics software as shown in Figure 2 for users to provide the specifications of the microwave oven, sandwiches and process control and visualize the simulation results. Experimental were conducted to investigate the effects of compositions of bread, cheese, egg and burger and temperature from -20oC to 110oC on their dielectric and physical properties. The experimental data were used to generate regression equations to determine temperature and composition-dependent physical and dielectric properties used in the model. Application methods were developed to determine the temperature and composition-dependent properties of individual components of sandwiches using the regression equations. The physical unit of the microwave oven and sandwich were created and meshed according to the dimensions specified by users through the GUI interface as shown in Figure 3. Research was conducted to optimize the mesh size and time step in order to save computational time. The temperature and moisture of a food item at each node and time segment were calculated using the mathematical model and corresponding software solvers. A report can be generated at the end of the simulation and emailed to users.

Reference

1. Wang, L. J. and Weller, C. L. 2011. Chapter 5 Thermophysical Properties of Frozen Foods, In: Sun, D. W. (editor), Handbook of Frozen Food Processing and Packaging (2 ed.). Boca Raton, FL: CRC Press, Taylor & Francis, pp.101-127.
2. Wang, L. J. and Singh, R. P. 2004. Finite element modeling and sensitivity analysis of double-sided contact-cooking process for initially frozen hamburger patties. Transaction of the ASAE. 47(1), 147-157.
3. Wang, L. J. and Sun, D.W. 2012. Chapter 2 Heat and Mass Transfer in Thermal Food Processing, In: Sun, D. W. (editor), Thermal Food Processing: New Technologies and Quality Issues (2 ed.). Boca Raton, FL: CRC Press, Taylor & Francis, pp. 33-69.

Figures used in the abstract

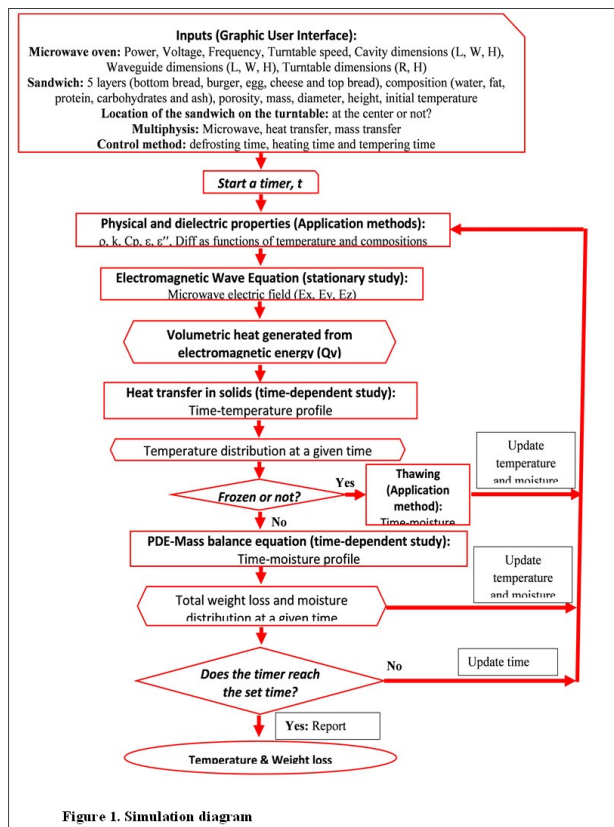


Figure 1: Simulation diagram

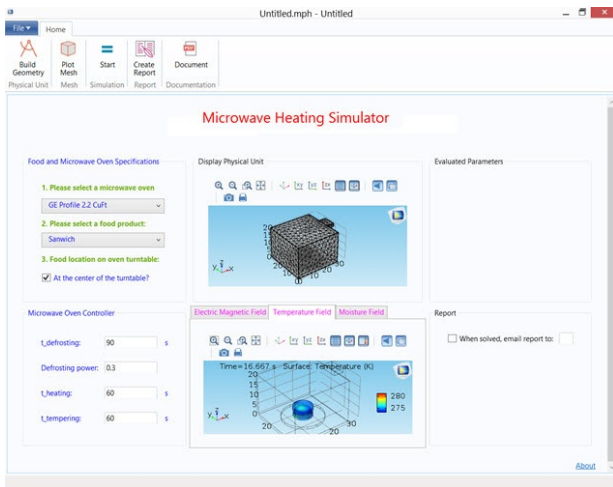
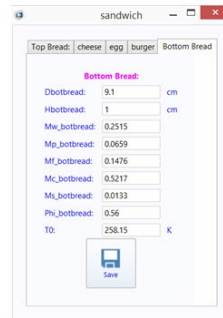


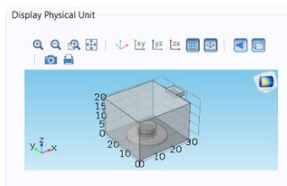
Figure 2: Graphic user interface of the microwave heating simulator



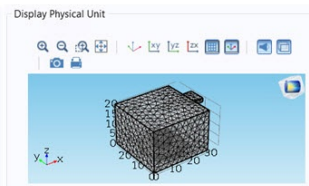
(1) Dialog form for inputting the specifications of the microwave oven



(2) Dialog form for inputting the specifications of the sandwich



(3) Physical unit for simulation



(4) Meshing the physical unit

Figure 3: Creation and meshing of the physical unit