Numerical Simulation of the Heat, Mass, and Momentum Transfer During the Microwave Drying of Osmodehydrated Porous Material

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Abstract

Introduction: In recent years microwaves have been used in the food processing industry as a result of the advantages with respect to conventional treatments: less environmental impact related to the use of clean energy and low energy consumption and short processing time, and saving in location space. The above mentioned advantages are due to the microwaves have the ability to penetrate and heat within the materials. Microwaves are propagated in the form of an electromagnetic field that interact with the polar molecules (mainly water molecules) of the irradiated material and generates initially its heating. When the microwave heating progresses, promotes the water vaporization and the removing of inner water is enhanced by increasing water-vapor pressure and forcing the liquid-water and water-vapor toward the surface (Datta, 2007). Microwave drying could be combined with other techniques such as convective air drying or osmotic dehydration to obtain a variety of high quality foods. When osmotic dehydration is used as a pretreatment, it leads to a better final quality of dried products. The osmotic dehydration consists in food immersion in a hypertonic solution that produces a partial water removal. With the purpose to gain a better understanding about the complex phenomena involved in the osmotic-microwave drying process a complete mathematical model was developed and the process was simulated under various conditions, evaluating the influence of the food composition on the final drying step.

Use of COMSOL Multiphysics® software: A complete 2D model was developed in COMSOL considering: Transport of Dilute Species for liquid-water concentration, Maxwell-Stefan Diffusion for concentration of water-vapor, Darcy's Law for gas phase pressure and Heat Transfer in Fluids for temperature.

Results: The heat, mass and momentum balances were numerically solved to obtain the temperature, liquid-water concentration, water-vapor concentration and pressure profiles during the microwave drying of osmodehydrated products. The osmotic pretreatment produces changes in food composition. Those changes consist meanly in the decreasing of the liquid-water concentration and increasing the soluble solids concentration. As the microwave drying depends of the dielectric properties of food materials and the heat transfer is coupled with the mass and

momentum balances, the changes in the material composition affect the evolution of moisture content (water concentration), temperature and pressure.
As can be seen from the results the increasing in the concentration of osmotic solution from 20ºBx to 40ºBx produces an increase in the dehydration and heating rates, however an increase in the concentration of hypertonic solution from 40ºBx to 60ºBx leads to a diminishing in the water removal capability. From the results can be observed that the dielectric properties increase with the soluble solids concentration in the food up to a threshold at which they begin to decrease despite further increase in the soluble solids concentration of the material.

Conclusion: A complete mathematical model was developed in COMSOL Multiphysics® to simulate the evolution of temperature, moisture content, vapor production and inner pressure during the microwave drying process that consider the changes in composition of the food due to the osmotic dehydration pretreatment.

Reference

A.K. Datta, Porous media approaches to studying simultaneous heat and mass transfer in food processes. I: Problem formulations, Journal of Food Engineering, 80(1), 80-95 (2007).