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

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Introduction: The objective of this research is to develop a complete mathematical model to simulate the heat, mass and momentum transfer during the microwave drying process (MWD) considering the change in dielectric properties due to the osmotic dehydration pre-treatment.

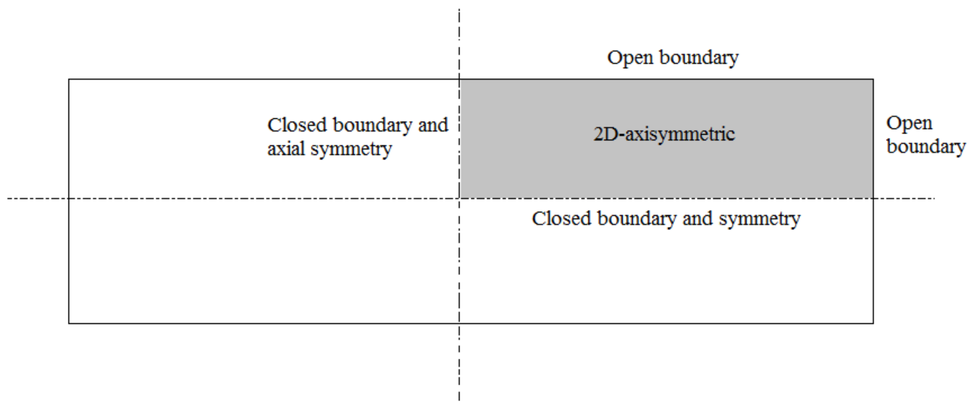

Figure 1. Simplified 2D-geometry of cylindrical sample.

Computational Methods: The following equations have to be solved to obtain the temperature, liquid and vapor water concentration and pressure profiles.

Mass transfer

1) $$\frac{\partial C_w}{\partial t} + u_{w,me}\nabla C_w + C_w \nabla u_{w,me} = \nabla\left(D_{w,eff}\nabla C_w\right) - I$$

2) $$\frac{\partial C_v}{\partial t} + u_{g,me}\nabla C_v + C_v \nabla u_{g,me} = I + \nabla\left(S_g \varepsilon \frac{C^2}{\rho_g} M_w M_a D_{g,eff}\nabla x_v\right)$$

3) $$\frac{\partial C_g}{\partial t} + \nabla\left(\rho_g u_g\right) = I$$

Momentum transfer

$$u_i = -\frac{k_{in,i}\,k_{r,i}}{\eta_i}\nabla P$$

Heat transfer

4) $$\rho_{eff} Cp_{eff}\frac{\partial T}{\partial t} + \sum_{i=w,v,a}\nabla\left(C_i u_{i,me} Cp_i T\right) - Cp_w T\nabla\left(D_{w,eff}\nabla C_w\right) = \nabla\left(k_{eff}\nabla T\right) - \lambda I + Q_{micro}$$

Absorbed microwave power

Considering the Lambert's Law and the dielectric properties as function of individual constituent of food and temperature.

$$\varepsilon'_{eff} = (1-\varepsilon)\,\varepsilon'_s + \varepsilon S_w \varepsilon'_{w/sol} + \varepsilon S_g \varepsilon'_g$$

$$\varepsilon''_{eff} = (1-\varepsilon)\,\varepsilon''_s + \varepsilon S_w \varepsilon''_{w/sol} + \varepsilon S_g \varepsilon''_g$$

Results: The simulated profiles show the non-uniformity of the distribution of microwave power producing a high temperature zone in the upper-right corner side (Fig. 2a).

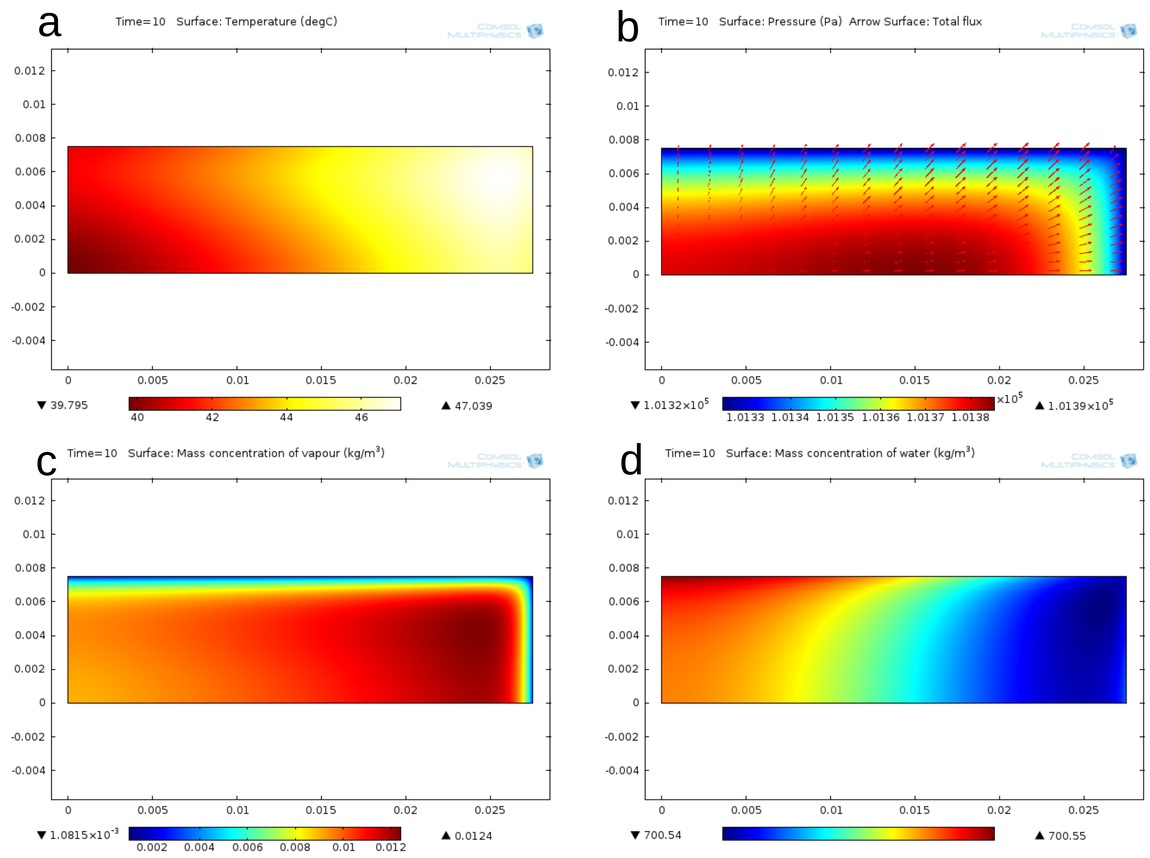

Figure 2. Profiles of (a) temperature, (b) pressure, (c) vapor and (d) liquid water concentration.

From Fig. 3 can be observed that as higher the concentration of osmotic solution in the pretreatment is, higher the increase of temperature rate. Higher dehydration rates (Fig. 4) were obtained for samples pretreated in 40ºBrix and 20ºBrix sucrose solution.

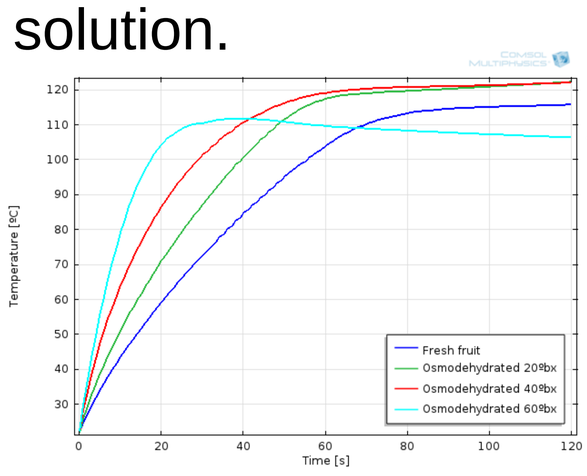

Figure 3. Temperatures.

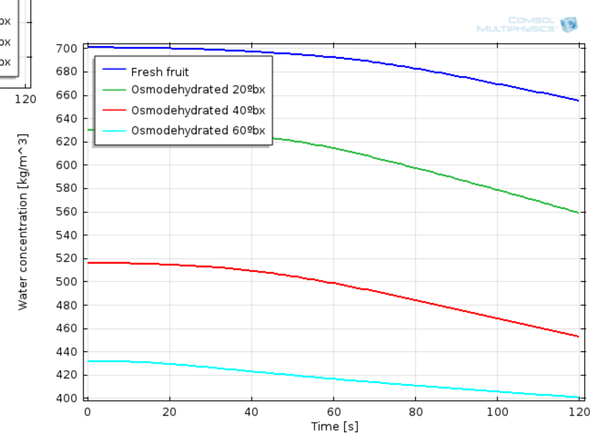

Figure 4. Moisture Content.

Conclusions: A complete mathematical model was obtained to simulate the MWD of osmodehydrated material that considers the change in food composition.