Multicomponent Diffusion Applied to Osmotic Dehydration

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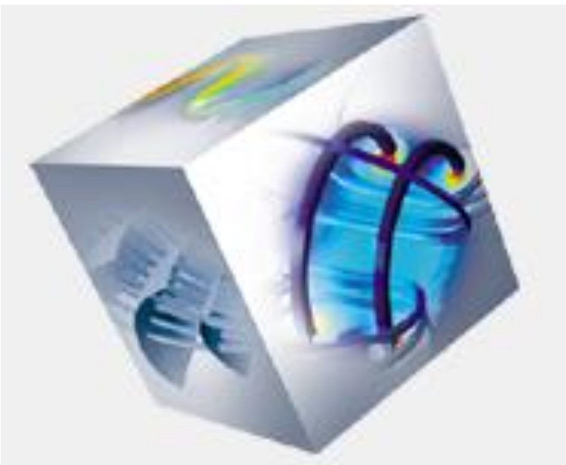
Introduction: The application of osmotic dehydration of fruits, has received attention in recent years as a technique for the production of intermediate moisture foods.

$$\frac{\partial C}{\partial t} = \frac{\partial}{\partial x}\left(D\frac{\partial C}{\partial x}\right)$$

2º Fick's law in non-stationary regime.

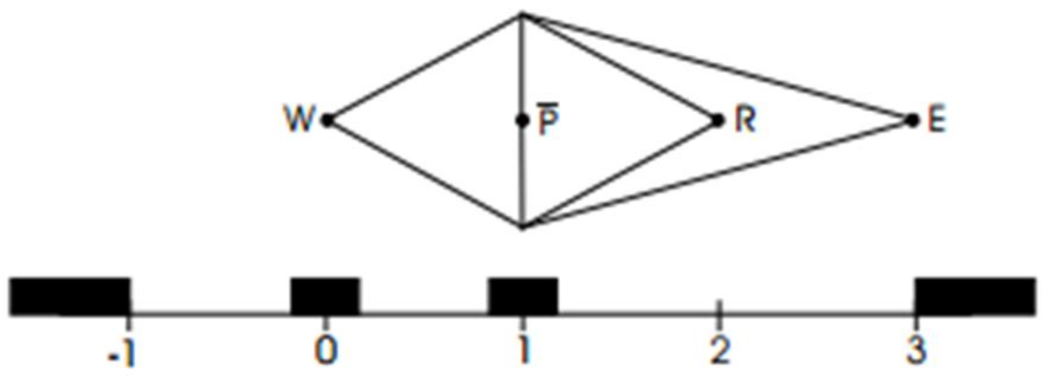


Finite element method.

$$\begin{pmatrix} D_{11} & D_{12} & D_{13} \\ D_{21} & D_{22} & D_{23} \\ D_{31} & D_{32} & D_{33} \end{pmatrix}$$

Components
1: Sucrose
2: Water
3: FOS

$$Biot = \frac{Internal\ Resistance}{External\ Resistance}$$



Super Modified Simplex

Computational Methods:

$$\frac{\partial C_1}{\partial t} = D_{11}\nabla^2 C_1 + D_{12}\nabla^2 C_2 + D_{13}\nabla^2 C_3$$

$$\frac{\partial C_2}{\partial t} = D_{21}\nabla^2 C_1 + D_{22}\nabla^2 C_2 + D_{23}\nabla^2 C_3$$

$$\frac{\partial C_3}{\partial t} = D_{31}\nabla^2 C_1 + D_{32}\nabla^2 C_2 + D_{33}\nabla^2 C_3$$

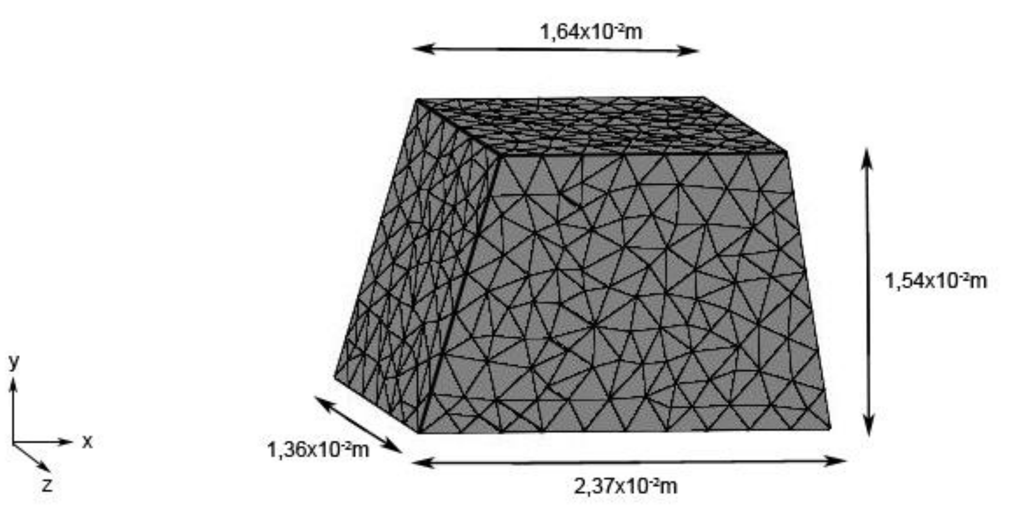
Onsager Equations

Subdomain Conditions

C_1= 10.66%, C_2= 87.44%
C_3= 1.9%

Boundary Conditions

C_1= 42%, C_2= 40%
C_3= 18%



5440 elements with 24.948 degrees of freedom

Figue 1. Tetrahedral mesh with average dimensions and spatial orientation used.

$$\%Error = 100\sum_{i=1}^{N}\left[\frac{\left|\overline{C}_{calc} - \overline{C}_{exp}\right|}{\overline{C}_{calc}}\right]\frac{1}{N}$$

Results:

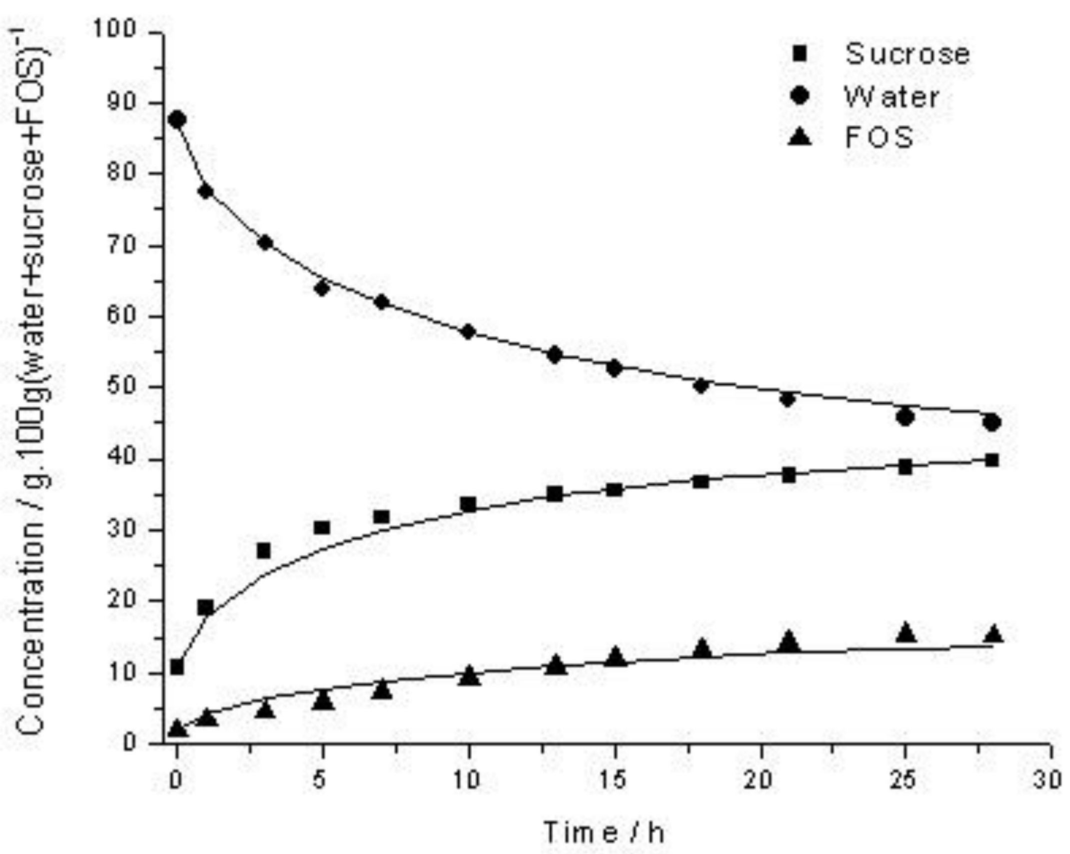


Figure 2. Distribution profile of the sucrose, water and FOS concentrations during the osmotic dehydration of melon pieces. The markers represent experimental data and the lines represent the simulation.

Table 1. Diffusion coefficients, obtained deviation. coefficient of mass transfer Biot number and adjusted to the process of osmotic dehydration of melon pieces.

	Sucrose	Water	FOS
Main Coefficients	21.07×10^{-11}	15.60×10^{-11}	8.96×10^{-11}
(m^2s^{-1})	(D_{11})	(D_{-22})	(D_{-33})
Cross Coefficients	1.62×10^{-11}	2.71×10^{-11}	1.52×10^{-11}
(m^2s^{-1})	(D_{12})	(D_{21})	(D_{31})
	4.74×10^{-11}	2.57×10^{-11}	1.48×10^{-11}
	(D_{13})	(D_{23})	(D_{32})
Errors	3.50%	1.17%	11.24%
h_m ($m.s^{-1}$)*	4.62×10^{-7}	3.42×10^{-7}	1.96×10^{-7}
Biot*		14.87	

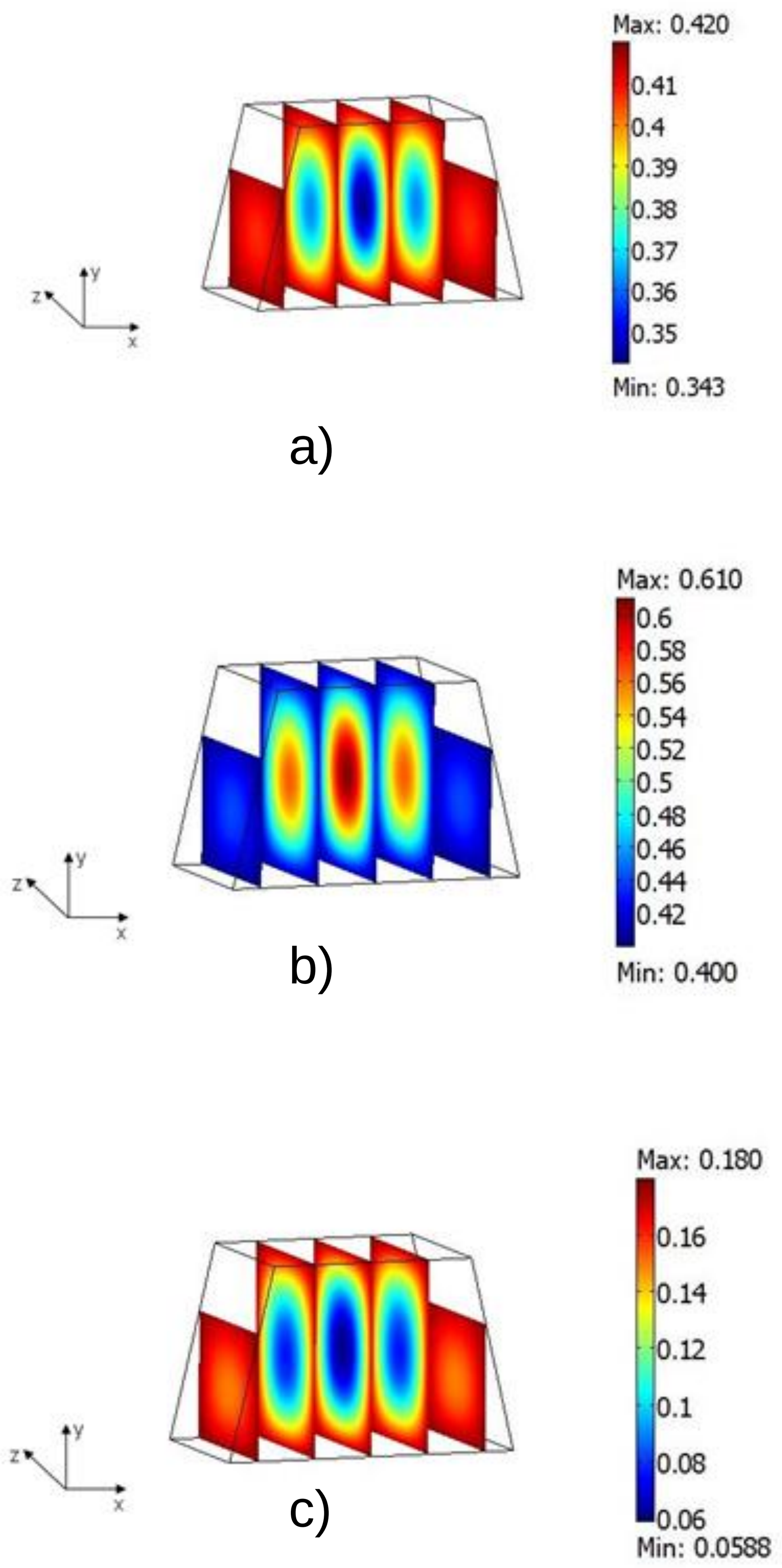


Figure 3. Concentration profile of a) sucrose, b) water and c) fructooligosaccheride (FOS) in melon after 28 hours of immersion.

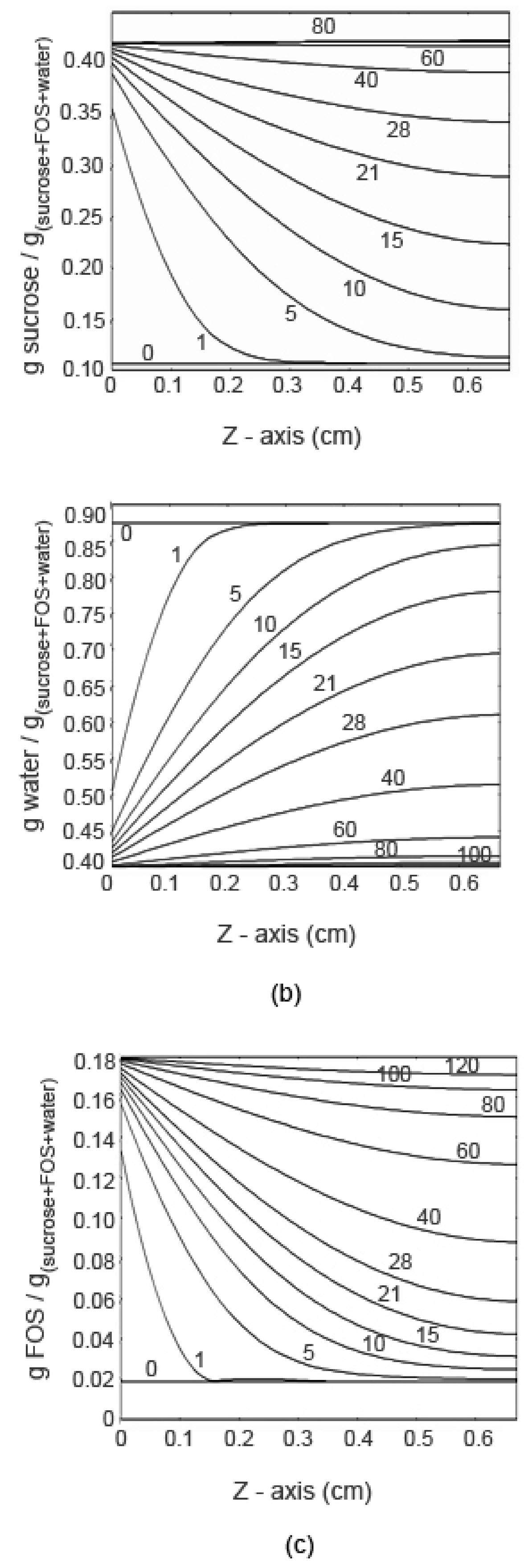


Figure 4. Distribution profile of concentration of (a) sucrose (b) water and (c) FOS in melon during 120 hours of simulating the osmotic diffusion process.

Conclusions: The values of concentration obtained by the simulation proved to be convergent and consistent with the experimental results, which validates the application of FEM to model the osmotic dehydration process. The simplex optimization method, coupled with the functions of desirability, proved to be an effective tool in the search of the primary parameters involved in the diffusion process during the osmotic dehydration of melon pieces.

References:

1. Schwartzberg HG, Chao RY. Solute diffusivities in leaching process. Food Technol 36(2):73-86. 1982.

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