Heat and Mass Transfer Modeling in Lyophilization Using COMSOL Multiphysics®

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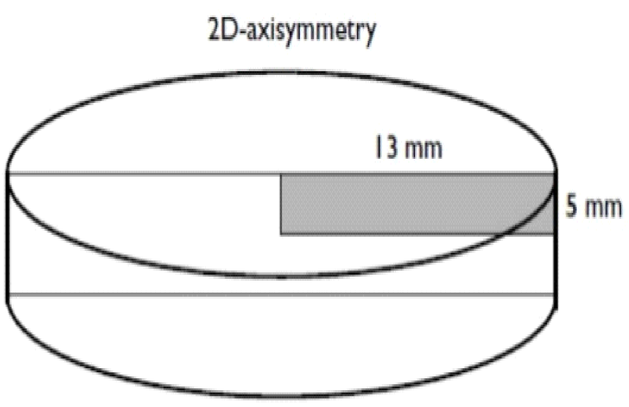
INTRODUCTION: Lyophilization is a dehydration process used to preserve perishable material like food. It depends on many parameters like temperature, pressure, rate of drying, type of heating for sublimation, chamber size etc. Therefore, optimization of multiple parameters is required for design and development of a lyophilizer. In the present work, COMSOL Multiphysics® 5.3a was used to model the governing equations for simulating the lyophilization of a fruit slice with the objective of designing a lyophilizer for preserving food for later use.

Figure 1. Lyophilization process of apple

COMPUTATIONAL METHODS: Simulation of drying of an apple slice was performed in COMSOL Multiphysics® 5.3a using Finite element analysis which compute the drying behaviour of an apple slice. The nonlinear partial differential equations, together with the described set of initial and boundary conditions, has been solved by FEM. The governing equations has been solved in heat transfer in solids and transport of dilute species interfaces of COMSOL Multiphysics® 5.3a. Newton's method was used to solve each non-linear system of equations. A slice of an apple was assumed to be circular disc having dimensions 10 mm thickness and 26 mm of diameter. A 2-D axisymmetric geometry was created in the software as shown in the Figure 2. The figure shows quarterly part of the geometry which helps the software to reduce the computational time.

Figure 2. Geometry of an apple slice



RESULTS: Results were obtained in terms of temperature and moisture content of the apple slice with respect to time. The hardware used was HP Z840 workstation having RAM 256 GB.

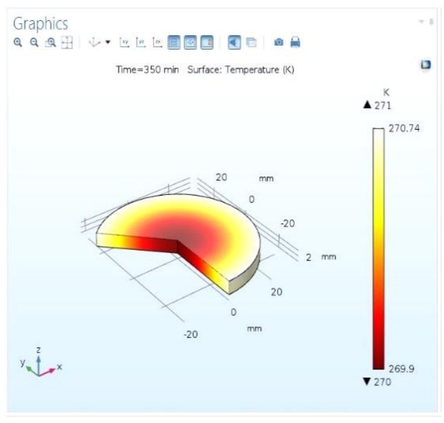


Figure 3. Simulation of Temperature In an apple slice.

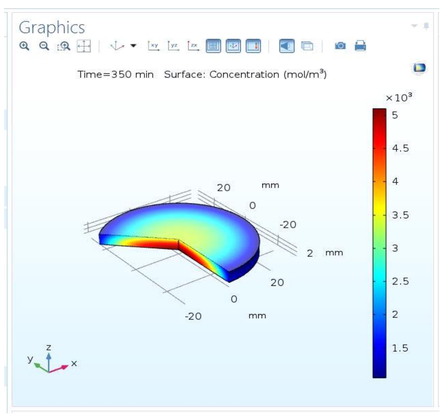


Figure 4. Simulation of moisture Content in an apple slice.

Variable	Value	Units
Density	788	Kg/m3
Initial Moisture	87.3	Dry basis
Diffusion Coefficient	3.3*E-9	m2/s

Table 1. Parameters and their values

CONCLUSIONS: A model of an apple slice was developed in COMSOL Multiphysics® 5.3a in order to predict the temperature and moisture content in an apple slice. The various input parameters and boundary conditions were given to the model. The COMSOL software couples the heat and mass transfer equations simultaneously. Some of the variable thermal properties were taken from the literature review of freeze drying process. The Heat Transfer and Chemical Reaction Engineering modules were used to predict the temperature profile inside the material under the time domain for complete process. The transport of dilute species interface was used to predict the moisture content in an apple slices under the time domain. This results helps in the fabrication of a lyophilizer and also helps to the experimental time.

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