Modelling and Simulation of Hydration Operation of Date Palm Fruits Using COMSOL Multiphysics

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A. Lakoud [1], S. Curet [2], M. Hassouna [1]

1. Ecole Supérieure des Industries Alimentaires de Tunis, 58 Alain Savary, 1003 Tunis El Khadra, Tunisie;
2. L'UNAM Université, ONIRIS, CNRS, GEPEA, UMR 6144, site de la Géraudière, Nantes, F-44322, France

Introduction:

Hydration is the key unit operation in the industrial thermal process of dates. This study focuses on modelling and simulation of this operation. The work is divided into two parts:

➢ An experimental investigation in which dry Tunisian Deglet Nour dates were hydrated by saturated air at laboratory scale.

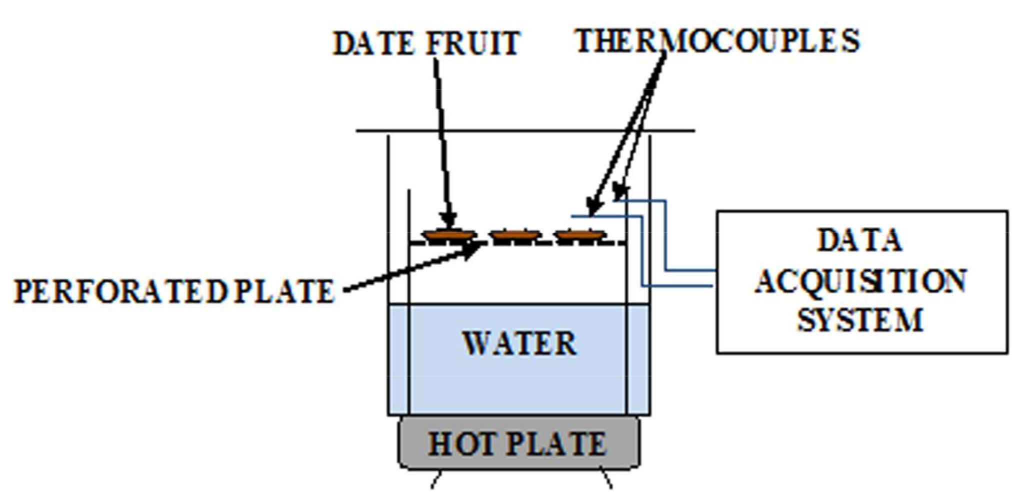

Figure 1 Experimental set-up

➢A numerical modelling with COMSOL Multiphysics release 5.1 in which both moisture diffusivity and convective mass transfer coefficient were estimated. The simulations based on estimated coefficients can be used to predict and optimize the hydration of dates.

Computational Methods:

➢Geometry

- A 2D axisymmetric domain

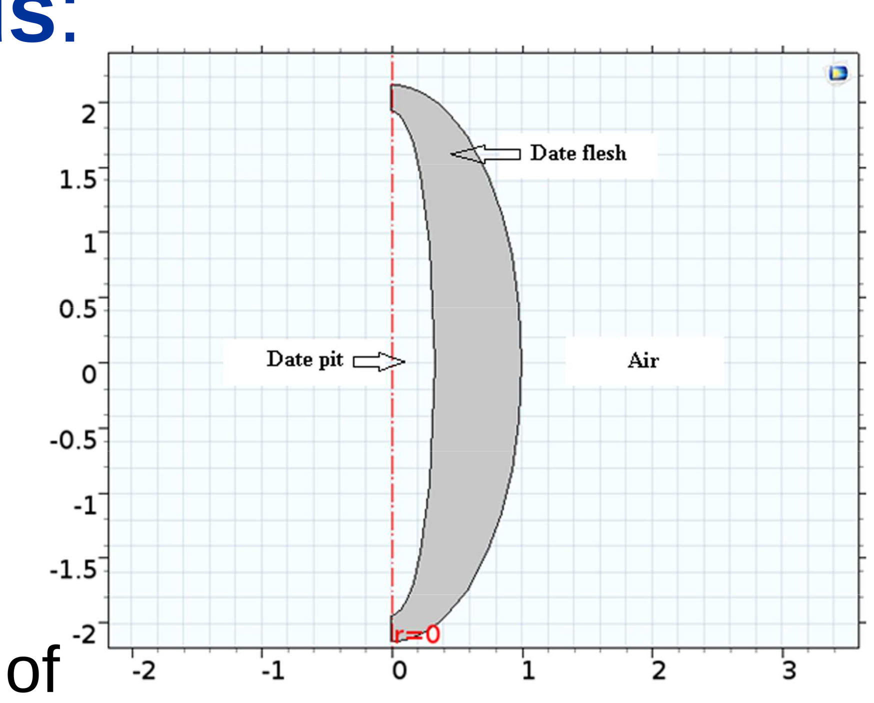

Figure 2. geometry

➢Equations

- Moisture diffusion in date flesh:

Fick's Law: $\frac{\partial C}{\partial t} = \nabla.(D\nabla C)$

- Uniform initial concentration of moisture in date flesh:

$$C_0 = \frac{X_0.\rho_0}{M_w}$$

- Null flux at the interior surface in contact with the date pit
- Natural convection at the outer surface in contact with saturated air:

$$N = k_c(C_b - C_s) \quad with \quad Cs = \frac{Pvs}{RT} aw$$

- By neglecting hysteresis phenomenon, *aw* is defined using the GAB model proposed by Kechaou and Mâalej [1].

➢Modelling approach

Using the "Transport of diluted species" physic and "optimization module", the modelling procedure is as follows:

- Computation of moisture distribution in date flesh
- Calculation of average moisture concentration with the average coupling operator
- Estimation of moisture diffusivity and convective coefficient using Levenberg-Marquardt optimization solver by minimizing the least-square objective function calculated from experimental and numerical mean moisture contents.

Results:

Only results for two dates of one type of Deglet Nour dates which are slightly harder and drier than labeled Extra category dates are presented.

Table 1. Estimated moisture diffusivities and mass transfer coefficients

Date Number	Date1	Date2
***D*(m²/s)**	5.54E-11	5.54E-11
k_c (m/s)	0.00123	0.00126

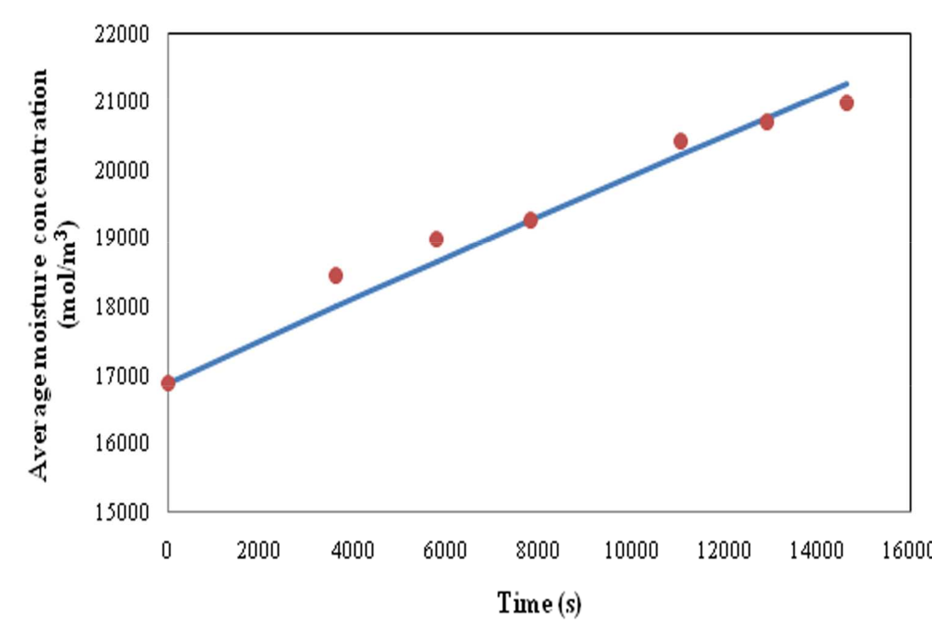

Figure 3. Experimental vs calculated average moisture concentration of Date1

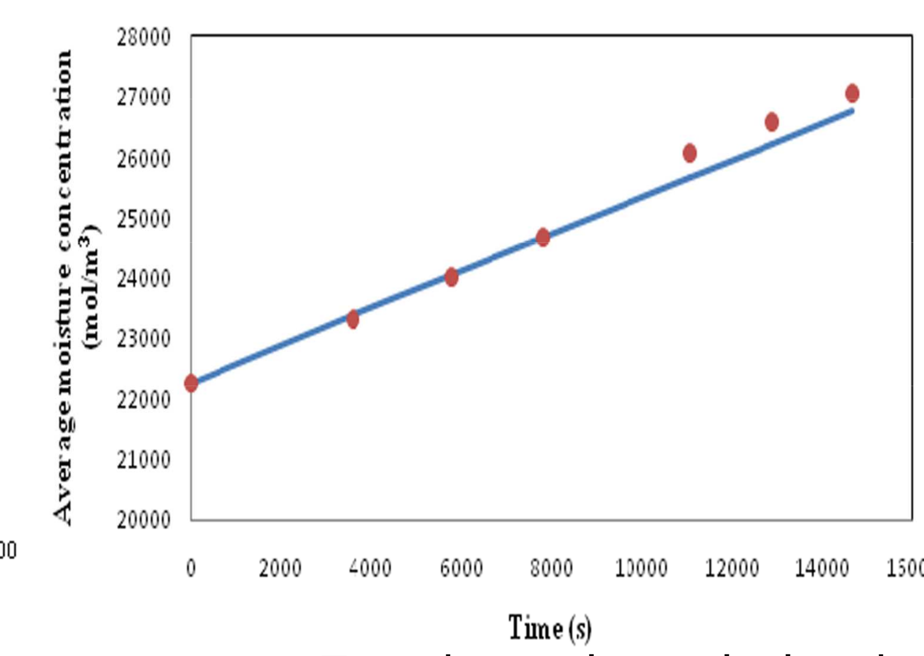

Figure 4. Experimental vs calculated average moisture concentration of Date2

- The root mean square difference (RMS) values are shown in the following table:

$$RMS = \sqrt{\frac{\sum_i \left(\frac{Cav_{i,exp} - Cav_{i,cal}}{Cav_{i,exp}}\right)^2}{n-1}}.100 \quad [1]$$

Table 2. RMS differences between experimental and calculated data

Date Number	Date1	Date2
RMS (%)	1.39	0.97

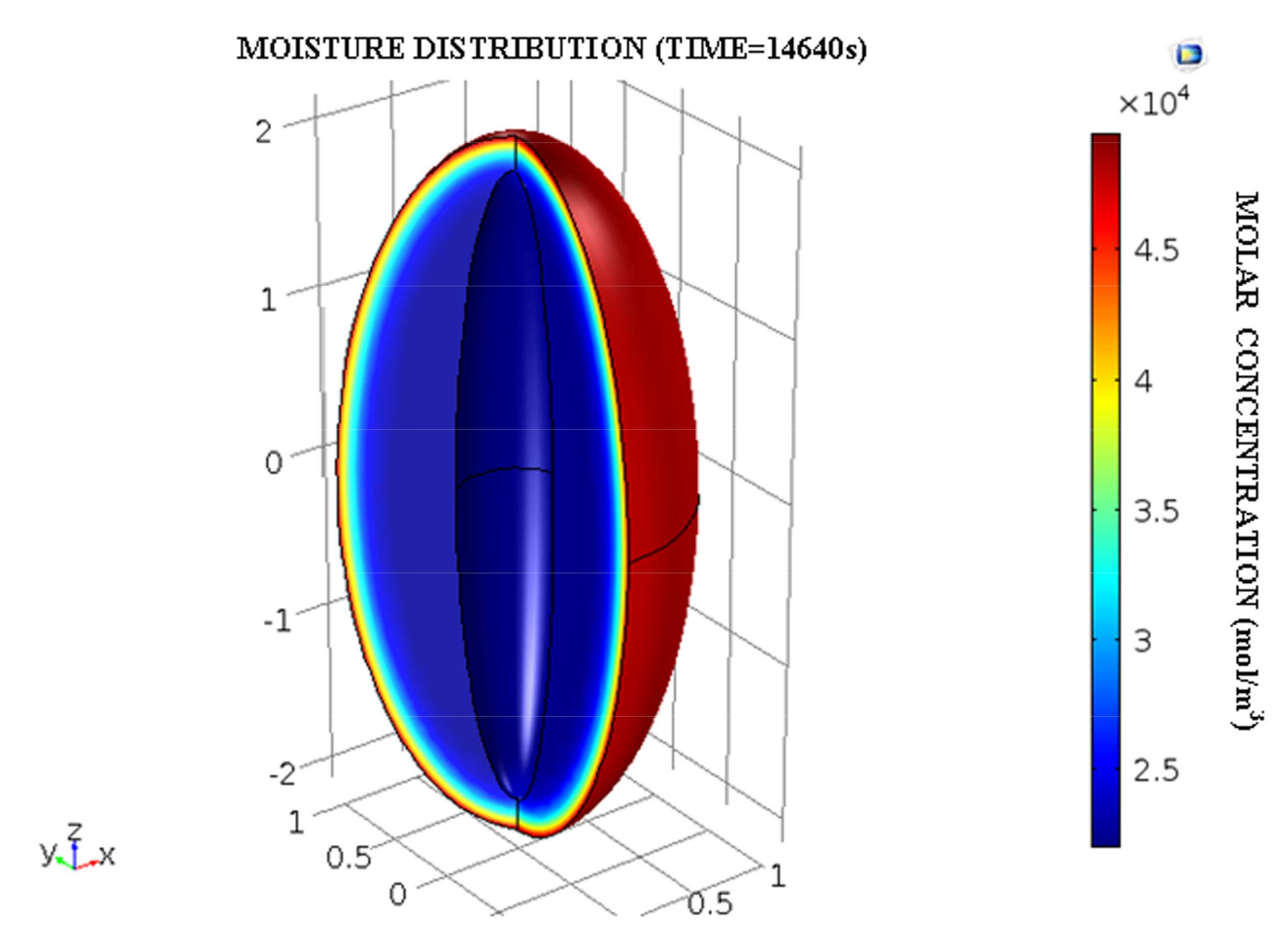

Figure 5. Simulated moisture concentration distribution within a date flesh after 4h

Conclusions:

- There is a good agreement between experimental and computed data
- Estimated coefficients vary little with initial concentration
- Moisture diffusion mainly occurs near the outer surface for the considered range of hydration times
- The proposed modelling approach can be employed to simulate hydration of dates in order to improve the quality of final product and reducing processing time.

Reference:

1. N. Kechaou and M. Mâalej. A simplified model for determination of moisture diffusivity of date from experimental drying curves. Drying Technology, 18, 1109-1125 (2000).