ESTIMATION OF POTATOES MOISTURE DIFFUSION COEFFICIENT BY MEANS OF A NON-LINEAR ESTIMATOR

Casa abierta al tiempo

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OBJECTIVE

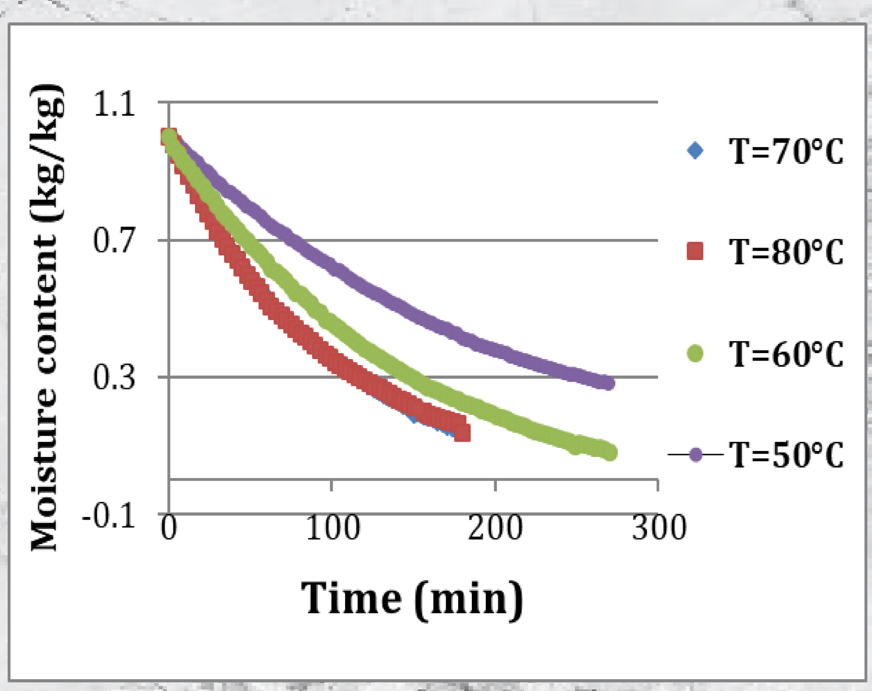
Analyze the importance of taking in to account the shrinking associated with the drying process during the determination of moisture diffusion coefficients (D). Two different approaches were followed:

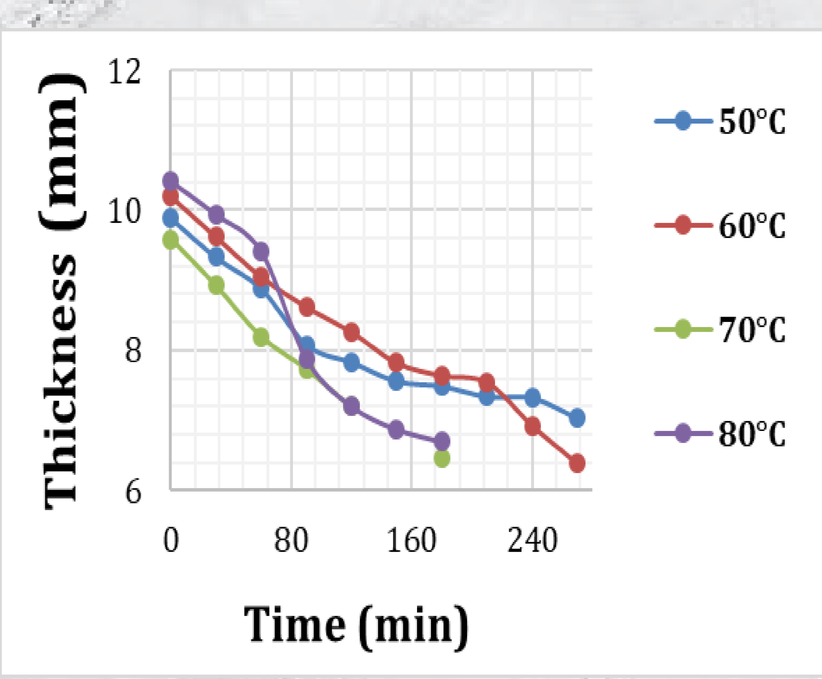
1) Neglecting the shrinking of the sample: D is calculated from the solution to the diffusion equation when the sample size, D and geometry remain constant.
2) Taking in to account the sample's shrinking: a non-linear estimator is constructed based on a solution to a model of the drying-shrinking process.

METHODOLOGY

1) Experimental procedure

Potatoes were cut in small rectangles of height L, four of their faces were sealed with Teflon tape and were put over an aluminum dish in a thermo-balance and only one of its faces was in contact with air. The experiments were carried on at four temperature levels. The weight loss and the size reduction were recorded.





2A) Diffusion coefficient estimation neglecting the sample's shrinking

The diffusion equation for a non-shrinking spherical porous solid is

$$\frac{\partial c}{\partial t}=\frac{D}{L^2}\frac{\partial}{\partial x}\left(\frac{\partial c}{\partial x}\right) \quad (1)$$

Whose approximate solution is:

$$\frac{c-c_0}{c_{eq}-c_0}=1-\frac{8}{\pi^2}\exp\left(-\frac{\pi^2 D\,t}{4\,L^2}\right) \quad (2)$$

D is obtained from Eq. (2). D-T data are fitted to an Arrhenius model for determining the activation energy Ea

$$\mathrm{Ln}[D]=D_0\mathrm{Ln}\left[-{}^{Ea}/_{(R\,T)}\right] \quad (3)$$

2B) Diffusion coefficient estimation taking in to account the sample's shrinking

A moving boundary problem ⟶ a fixed boundary problem by $z=x/L$.

The drying problem is modelled by:

$$\frac{dy}{dt}=\frac{1}{(z\cdot L)^2}\frac{\partial}{\partial z}\left(z^2\cdot D\frac{\partial y}{\partial z}\right)+\frac{1}{L}\frac{\partial y}{\partial z}z\frac{dL}{dt} \quad (4)$$

($y=c/c(t=0)$). The average moisture concentration is

$$\bar{y}(t)=\frac{1}{L}\int_0^L y(z,t)dz \quad (5)$$

Eq. (4) is solved by the collocation method with the test function:

$$y(z_c,t)=(1-z_c^2)\cdot\tau(t)+y_{eq} \quad (6)$$

(z_c denotes the collocation point). The substitution of Eq. (6) in Eq. (4) leads to the next equation for the time function τ at the collocation point z_c:

$$\frac{d\tau}{dt}=-\left(\frac{\frac{6\,D}{L^2}+\left(\frac{2\,z^2}{L}\right)\cdot\frac{dL}{dt}}{(1-z^2)}\right)\cdot\tau \quad (7)$$

The structure of the observer ($\hat{\tau}$ denotes the estimated value of the function τ (t) and $\hat{D}$ the estimated D value) is:

$$\frac{d\hat{\tau}}{dt}=-\left(\frac{\frac{6\,D}{L^2}+\left(\frac{2\,z^2}{L}\right)\cdot\frac{dL}{dt}}{(1-z^2)}\right)\cdot\hat{\tau}+\omega_1(y-\hat{y}) \quad (8)$$

$$\frac{d\hat{D}}{dt}=\omega_2\,(y-\hat{y}) \quad (9)$$

The function of the terms $\omega_i(y-\hat{y})$ is to drive the estimation error to zero. D can be considered constant if its dynamic is slower than the estimator dynamics determined by the filter gains, ω_i, which should be big enough.

RESULTS

Eqs. (8) and (9) $\rightarrow \hat{\tau}$ and $\hat{D} \rightarrow y(z_c,t) \rightarrow \bar{y}(t)$. $\hat{D}$'s are shown in Fig. 1, $\bar{y}'s$ (experimental and estimated) in Fig. 2. In one Table are reported the D values obtained neglecting and considering the sample's shrinking. The anomalous behavior of the diffusion coefficient at the higher temperature could be due to the formation of holes in the potato structure caused by the sudden breaking of the crust formed. In Fig. 3 is shown a photograph of the top of the potato surface after drying at T=80° C.

Fig. 1.

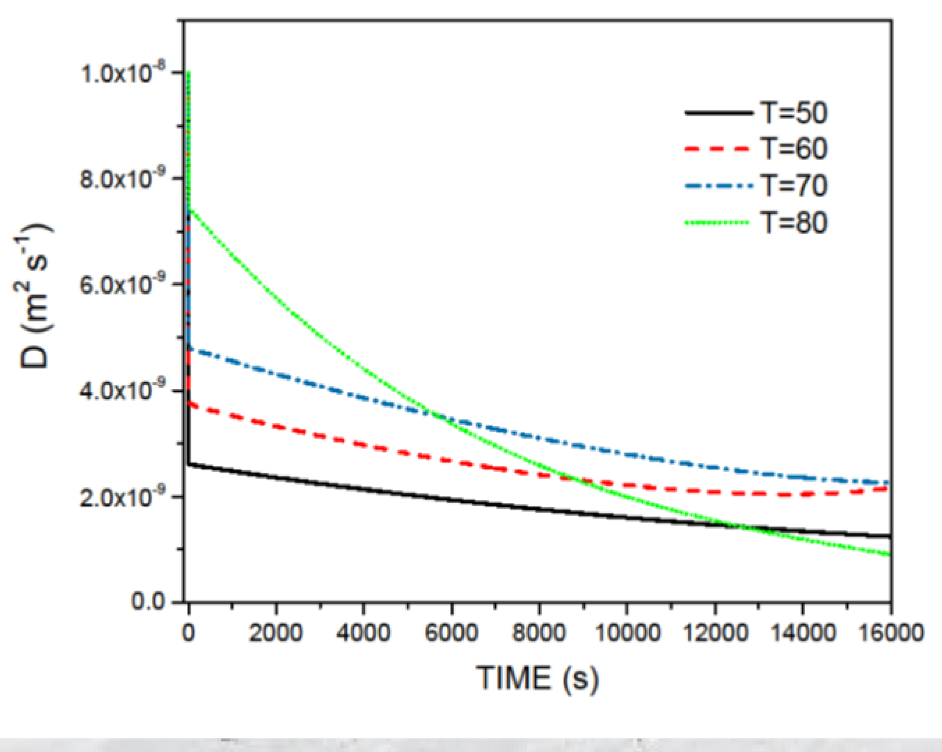
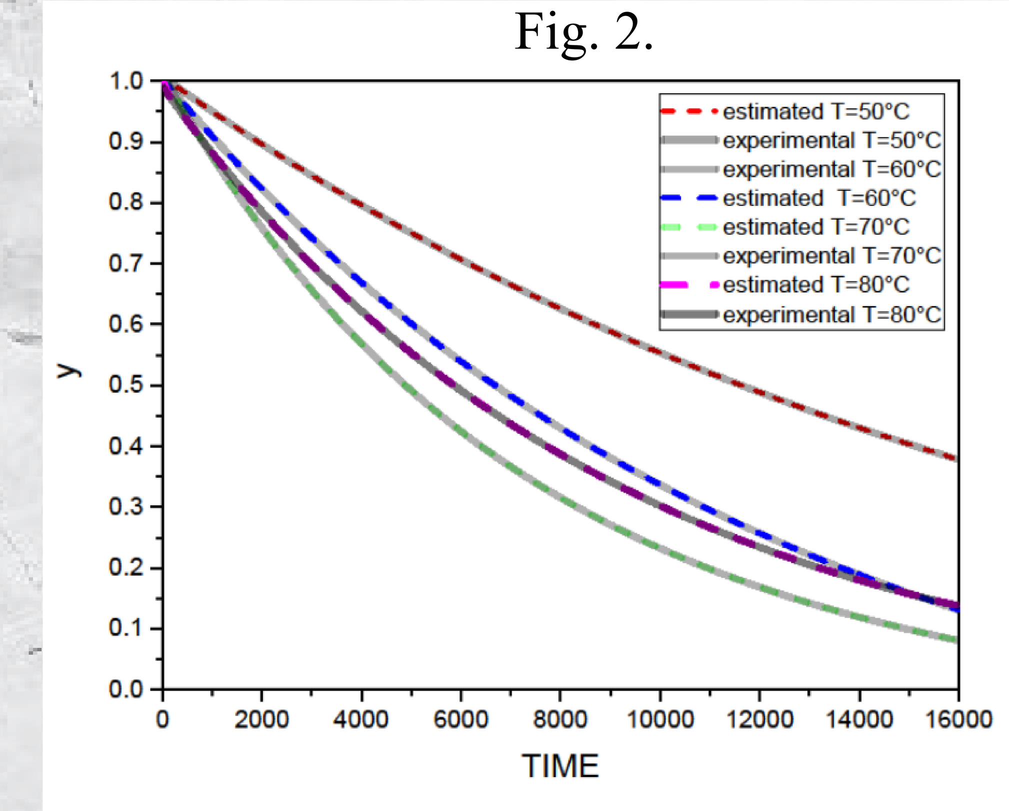


Fig. 2.



T [K]	D [m^2/seg] Neglecting shrinkage	D [m^2/seg] Considering shrinkage
323	3.40×10^{-9}	1.81×10^{-9}
333	6.28×10^{-9}	2.57×10^{-9}
343	7.34×10^{-9}	3.24×10^{-9}
353	8.40×10^{-9}	3.11×10^{-9}

Ea [kJ/mol]	
Neglecting shrinkage	27.448
Considering shrinkage	27.618

CONCLUSIONS

- The estimated concentrations by the observer match the experimental concentrations.
- When shrinkage is neglected, the diffusion coefficients obtained are overestimated by about a factor of 2.
- Ea obtained when the volume reduction associated to the drying process is neglected is slightly lower that the one estimated when shrinkage is considered.