INFLUENCE OF AIR VELOCITY IN DEHYDRATION OF POTATO CUBES

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Abstract: Air velocity is an important operating variable operation on hot air drying. For improving energy efficiency it is necessary to know its influence on the kinetics. The aim of this work was to establish the effect of air velocity on the drying kinetics of potato cubes. Potato cubes of 1 cm side were dehydrated at 60ºC and 0.5, 1.0, 1.5, 2.0, 3.0, 4.5, 7.0, 8.0 and 10.0 m/s. Experimental drying kinetics were modeled neglecting shrinkage and external resistance. It was observed that there is no interest to increase air velocity above 1.5 m/s, external resistance to mass transfer must be considered below this air velocity value.

Keywords: potato, modeling, external resistance, air velocity

INTRODUCTION

Dehydrated potatoes are an important source of carbohydrates for elaboration of food products such as soups or salads. Manufacturing of dried potatoes cubes should ensure a product of high quality (Iciek and Krysiak, 2009) and also an economic profitability when comparing drying with refrigeration.

Modeling of drying is very useful for design an optimization purposes. The most frequent models are the diffusion ones because of their formulation is relatively simple and the results obtained are usually reasonably good. Nevertheless some simplifications must be done and for that reason an effective diffusivity is considered. Effective diffusivity includes the effect of known hypothesis and unknown phenomena not included in the model (Mulet, 1994). Namely, the effect of air velocity will be included if external resistance is not negligible.

In most of the drying models shrinkage is not taken into account in order to simplify the model and facilitate its solution.

Another point that must be considered is the boundary conditions adopted on the material surface.

In order to facilitate the solution of the model, the most common assumption is that the material surface is in equilibrium with the drying air throughout the process, thus external resistance to mass transfer is neglected (Gou et al., 2004; Blasco et al., 2006). Nevertheless, sometimes this means that the model does not provide an accurate description of experimental conditions although interesting conclusions can be drawn.

The aim of this work was to establish the effect of air velocity on the drying kinetics and the relative importance of external resistance on hot air drying of potato cubes.

MATERIALS AND METHODS

Raw material

Monalisa potatoes (Solanum tuberosum) harvested in Spain were used as raw material. Until sample preparation potatoes were stored in a refrigerated chamber at 2 ± 0.1 ºC. For sample preparation, potatoes were left to stabilize at room temperature (around 24 ºC) for at least 15 hours. Then, they were peeled and cut, into cubes of 12 ± 0.2 mm side. In each experiment around 68.3 ± 2.1 g of the sample were used.
Drying experiments

Drying kinetics were determined in triplicate at 60°C and 0.5, 1.0, 1.5, 2.0, 3.0, 4.5, 7.0, 8.0 and 10.0 m/s. For that purpose a laboratory convective dryer, described in Sanjuán et al. (2003) was used.

The final moisture content of the samples was determined in triplicate by means of the AOAC method (AOAC, 1997).

Mathematical modeling

Modeling of the drying process was done considering that water transport from the centre of solid to the surface took place mainly by diffusion (Fick’s law). The model did not consider shrinkage and external resistance to mass transfer. The model include the governing equation (equation 1), the initial condition (equation 2), the symmetry conditions (equations 3, 4 and 5) and the surface boundary conditions (equations 6, 7 and 8).

\[
\frac{\partial X_1}{\partial t} = D_e \left( \frac{\partial^2 X_1}{\partial x^2} + \frac{\partial^2 X_1}{\partial y^2} + \frac{\partial^2 X_1}{\partial z^2} \right) \quad (1)
\]

\[
X_1(x,y,z,0) = X_0 \quad (2)
\]

\[
\frac{\partial X_1}{\partial x}(0,y,z,t) = 0 \quad (3)
\]

\[
\frac{\partial X_1}{\partial y}(x,0,z,t) = 0 \quad (4)
\]

\[
\frac{\partial X_1}{\partial z}(x,y,0,t) = 0 \quad (5)
\]

\[
X_1(L,y,z,t) = X_e \quad (6)
\]

\[
X_1(x,L,z,t) = X_e \quad (7)
\]

\[
X_1(x,y,L,t) = X_e \quad (8)
\]

Equilibrium moisture content (Xₑ) was obtained by modeling together different experimental potato sorption isotherms from literature (Wang y Brennan, 1991; McLaughlin y Magee, 1998; Chou et al., 2000; McMinn and Magee, 2003) by means of GAB model with effect of temperature.

The model was solved by means of Separation of Variables Method. The goodness of fit was evaluated considering the explained variance (%var).

RESULTS AND DISCUSSION

According to Mulet (1994), when the plot of \((\Psi d(ln\Psi)/dt)^2\) versus \(\Psi\) is a straight line, external resistance can be considered as non negligible on the mass transfer process. If external resistance can be neglected, the plot is a parabola. In Fig. 1, the plot of \((\Psi d(ln\Psi)/dt)^2\) versus \(\Psi\) is represented for all the air drying velocities considered.

As it can be observed in Fig. 1, for air velocities of 0.5, 1.0 and 1.5 m/s a straight line was obtained. It seems that for air velocities higher than 1.5 m/s external resistance to mass transfer can be neglected.

In Table 1 the values obtained for effective diffusivity are shown. These results are the average of the three replications. For all drying kinetics considered, an explained variance higher that 90% was obtained.

<table>
<thead>
<tr>
<th>Air velocity (m/s)</th>
<th>Dₑ ± sd * 10¹⁰ (m²/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>2.98 ± 0.11</td>
</tr>
<tr>
<td>1.0</td>
<td>4.35 ± 0.09</td>
</tr>
<tr>
<td>1.5</td>
<td>6.02 ± 0.17</td>
</tr>
<tr>
<td>2.0</td>
<td>8.21 ± 0.20</td>
</tr>
<tr>
<td>3.0</td>
<td>8.28 ± 0.32</td>
</tr>
<tr>
<td>4.5</td>
<td>8.74 ± 0.17</td>
</tr>
<tr>
<td>7.0</td>
<td>8.75 ± 0.11</td>
</tr>
<tr>
<td>8.0</td>
<td>8.72 ± 0.14</td>
</tr>
<tr>
<td>10.0</td>
<td>8.70 ± 0.11</td>
</tr>
</tbody>
</table>

For air velocity 0.5, 1.0 and 1.5 m/s the value of effective diffusivity is influenced by air velocity. Nevertheless, for air velocity of 2.0 m/s or higher, the value of effective diffusivity does not depend on air velocity. Effective diffusivity is a property which is linked to a particular product and must not be influenced by external conditions. If external resistance is not considered when it is important, effective diffusivity will be affected because it includes the effect of this hypothesis (Blasco et al. 2006).

The values in Table 1 are represented in Figure 2.
The results shown in Figure 2 and Table 1 are in agreement with those in Figure 1. For the experimental conditions in this study, it seems that external resistance does not influence mass transfer process for air velocity 2.0 m/s or higher. These results are in agreement with other authors in literature (Blasco et al., 2006; Clemente et al., 2011). These results show that the increase on air velocity above 2 m/s do not bring an improvement on the kinetics. As a consequence, 2 m/s seems to be a threshold from an energy point of view. For air velocity lower than 2 m/s an optimal air velocity should be determined considering all the costs involved.

CONCLUSIONS

During dehydration of potato cubes at 60ºC, external resistance to mass transfer can be neglected if air velocity is 2.0 m/s or higher. The results obtained show that air velocity during drying should be established to optimize the operation management increasing also the energy efficiency.

NOMENCLATURE

- $D_e$: effective diffusivity, $m^2s^{-1}$
- $L$: half-length of the cube, $m$
- $t$: time, $s$
- $X_e$: equilibrium moisture content, $db$
- $X_i$: local moisture content, $db$
- $x$, $y$, $z$: length co-ordinate, $m$
- $\Psi$: dimensionless moisture content

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REFERENCES


